CONTENTS

Preface xxix
  Audience xxix
  Purpose xxix
  Conventions xxx
  Related Publications xxx
  Obtaining Documentation, Obtaining Support, and Security Guidelines xxxi

CHAPTER 1

Overview 1-1
  Features 1-1
    Ease-of-Deployment and Ease-of-Use Features 1-2
    Performance Features 1-3
    Management Options 1-4
    Manageability Features 1-4
    Availability and Redundancy Features 1-5
    VLAN Features 1-6
    Security Features 1-7
    QoS and CoS Features 1-8
    Monitoring Features 1-9
  Default Settings After Initial Switch Configuration 1-9
  Design Concepts for Using the Switch 1-12
  Where to Go Next 1-14

CHAPTER 2

Using the Command-Line Interface 2-1
  Understanding Command Modes 2-1
  Understanding the Help System 2-3
  Understanding Abbreviated Commands 2-4
  Understanding no and default Forms of Commands 2-4
  Understanding CLI Error Messages 2-5
  Using Configuration Logging 2-5
  Using Command History 2-6
    Changing the Command History Buffer Size 2-6
    Recalling Commands 2-6
    Disabling the Command History Feature 2-7
Contents

Using Editing Features  2-7
   Enabling and Disabling Editing Features  2-7
   Editing Commands through Keystrokes  2-7
   Editing Command Lines that Wrap  2-9
Searching and Filtering Output of show and more Commands  2-10
Accessing the CLI  2-10
   Accessing the CLI through a Console Connection or through Telnet  2-10

CHAPTER 3

Assigning the Switch IP Address and Default Gateway  3-1
   Understanding the Bootup Process  3-1
Assigning Switch Information  3-2
   Default Switch Information  3-3
   Understanding DHCP-Based Autoconfiguration  3-3
      DHCP Client Request Process  3-4
   Configuring DHCP-Based Autoconfiguration  3-5
      DHCP Server Configuration Guidelines  3-5
   Configuring the TFTP Server  3-6
   Configuring the DNS  3-6
   Configuring the Relay Device  3-6
   Obtaining Configuration Files  3-7
   Example Configuration  3-8
   Manually Assigning IP Information  3-10
Checking and Saving the Running Configuration  3-11
Modifying the Startup Configuration  3-12
   Default Bootup Configuration  3-12
   Automatically Downloading a Configuration File  3-13
   Specifying the Filename to Read and Write the System Configuration  3-13
   Booting Up Manually  3-13
   Booting Up a Specific Software Image  3-14
   Controlling Environment Variables  3-15
Scheduling a Reload of the Software Image  3-16
   Configuring a Scheduled Reload  3-17
   Displaying Scheduled Reload Information  3-18

CHAPTER 4

Administering the Switch  4-1
   Managing the System Time and Date  4-1
      Understanding the System Clock  4-1
      Understanding Network Time Protocol  4-2
      Configuring NTP  4-3
Default NTP Configuration  4-4
Configuring NTP Authentication  4-4
Configuring NTP Associations  4-5
Configuring NTP Broadcast Service  4-6
Configuring NTP Access Restrictions  4-8
Configuring the Source IP Address for NTP Packets  4-10
Displaying the NTP Configuration  4-11
Configuring Time and Date Manually  4-11
  Setting the System Clock  4-11
  Displaying the Time and Date Configuration  4-12
  Configuring the Time Zone  4-12
  Configuring Summer Time (Daylight Saving Time)  4-13
Configuring a System Name and Prompt  4-14
  Default System Name and Prompt Configuration  4-15
  Configuring a System Name  4-15
  Understanding DNS  4-15
    Default DNS Configuration  4-16
    Setting Up DNS  4-16
    Displaying the DNS Configuration  4-17
Creating a Banner  4-17
  Default Banner Configuration  4-17
  Configuring a Message-of-the-Day Login Banner  4-18
  Configuring a Login Banner  4-19
Managing the MAC Address Table  4-19
  Building the Address Table  4-20
  MAC Addresses and VLANs  4-20
  Default MAC Address Table Configuration  4-21
  Changing the Address Aging Time  4-21
  Removing Dynamic Address Entries  4-22
  Configuring MAC Address Notification Traps  4-22
  Adding and Removing Static Address Entries  4-24
  Configuring Unicast MAC Address Filtering  4-25
  Displaying Address Table Entries  4-26
Managing the ARP Table  4-26

CHAPTER  5
Configuring Switch-Based Authentication  5-1
Preventing Unauthorized Access to Your Switch  5-1
Protecting Access to Privileged EXEC Commands  5-2
Default Password and Privilege Level Configuration  5-2
Setting or Changing a Static Enable Password  5-3
Protecting Enable and Enable Secret Passwords with Encryption  5-3
Disabling Password Recovery  5-5
Setting a Telnet Password for a Terminal Line  5-6
Configuring Username and Password Pairs  5-6
Configuring Multiple Privilege Levels  5-7
  Setting the Privilege Level for a Command  5-8
  Changing the Default Privilege Level for Lines  5-9
  Logging into and Exiting a Privilege Level  5-9
Controlling Switch Access with TACACS+  5-10
  Understanding TACACS+  5-10
  TACACS+ Operation  5-12
Configuring TACACS+  5-12
  Default TACACS+ Configuration  5-13
  Identifying the TACACS+ Server Host and Setting the Authentication Key  5-13
  Configuring TACACS+ Login Authentication  5-14
  Configuring TACACS+ Authorization for Privileged EXEC Access and Network Services  5-16
  Starting TACACS+ Accounting  5-17
  Displaying the TACACS+ Configuration  5-17
Controlling Switch Access with RADIUS  5-17
  Understanding RADIUS  5-18
  RADIUS Operation  5-19
Configuring RADIUS  5-19
  Default RADIUS Configuration  5-20
  Identifying the RADIUS Server Host  5-20
  Configuring RADIUS Login Authentication  5-23
  Defining AAA Server Groups  5-25
  Configuring RADIUS Authorization for User Privileged Access and Network Services  5-27
  Starting RADIUS Accounting  5-28
  Configuring Settings for All RADIUS Servers  5-29
  Configuring the Switch to Use Vendor-Specific RADIUS Attributes  5-29
  Configuring the Switch for Vendor-Proprietary RADIUS Server Communication  5-31
  Displaying the RADIUS Configuration  5-31
Controlling Switch Access with Kerberos  5-32
  Understanding Kerberos  5-32
  Kerberos Operation  5-34
    Authenticating to a Boundary Switch  5-34
    Obtaining a TGT from a KDC  5-35
    Authenticating to Network Services  5-35
Chapter 6
Configuring IEEE 802.1x Port-Based Authentication 6-1
Understanding IEEE 802.1x Port-Based Authentication 6-1
Device Roles 6-2
Authentication Process 6-3
Authentication Initiation and Message Exchange 6-5
Ports in Authorized and Unauthorized States 6-7
IEEE 802.1x Host Mode 6-8
IEEE 802.1x Accounting 6-9
IEEE 802.1x Accounting Attribute-Value Pairs 6-9
Using IEEE 802.1x Authentication with VLAN Assignment 6-10
Using IEEE 802.1x Authentication with Per-User ACLs 6-11
Using IEEE 802.1x Authentication with Guest VLAN 6-12
Using IEEE 802.1x Authentication with Restricted VLAN 6-13
Using IEEE 802.1x Authentication with Inaccessible Authentication Bypass 6-14
Using IEEE 802.1x Authentication with Voice VLAN Ports 6-15
Using IEEE 802.1x Authentication with Port Security 6-16
Using IEEE 802.1x Authentication with Wake-on-LAN 6-16
Using IEEE 802.1x Authentication with MAC Authentication Bypass 6-17
Using Web Authentication 6-18
Configuring IEEE 802.1x Authentication 6-19
Default IEEE 802.1x Authentication Configuration 6-19
IEEE 802.1x Authentication Configuration Guidelines 6-21
IEEE 802.1x Authentication 6-21
VLAN Assignment, Guest VLAN, Restricted VLAN, and Inaccessible Authentication Bypass 6-22
MAC Authentication Bypass 6-22
Upgrading from a Previous Software Release 6-23
Configuring IEEE 802.1x Authentication 6-23
Configuring the Switch-to-RADIUS-Server Communication 6-24
Configuring the Host Mode 6-26
Configuring Periodic Re-Authentication 6-26
Manually Re-Authenticating a Client Connected to a Port 6-27
Changing the Quiet Period 6-27
Changing the Switch-to-Client Retransmission Time 6-28
Setting the Switch-to-Client Frame-Retransmission Number 6-29
Setting the Re-Authentication Number 6-29
Configuring IEEE 802.1x Accounting 6-30
Configuring a Guest VLAN 6-31
Configuring a Restricted VLAN 6-32
Configuring the Inaccessible Authentication Bypass Feature 6-33
Configuring IEEE 802.1x Authentication with WoL 6-36
Configuring MAC Authentication Bypass 6-37
Configuring IEEE 802.1x Authentication Using a RADIUS Server 6-38
Configuring Web Authentication 6-38
Disabling IEEE 802.1x Authentication on the Port 6-41
Resetting the IEEE 802.1x Authentication Configuration to the Default Values 6-42
Displaying IEEE 802.1x Statistics and Status 6-42

CHAPTER 7

Configuring Interface Characteristics 7-1
Understanding Interface Types 7-1
Port-Based VLANs 7-1
Switch Ports 7-2
Access Ports 7-2
Contents

Trunk Ports 7-3
EtherChannel Port Groups 7-3
Connecting Interfaces 7-4
Using Interface Configuration Mode 7-4
Procedures for Configuring Interfaces 7-5
Configuring a Range of Interfaces 7-6
Configuring and Using Interface Range Macros 7-7
Configuring Ethernet Interfaces 7-9
Default Ethernet Interface Configuration 7-9
Interface Speed and Duplex Mode 7-10
   Speed and Duplex Configuration Guidelines 7-10
   Setting the Interface Speed and Duplex Parameters 7-11
Configuring IEEE 802.3x Flow Control 7-12
Configuring Auto-MDIX on an Interface 7-13
Adding a Description for an Interface 7-14
Configuring the System MTU 7-14
Monitoring and Maintaining the Interfaces 7-16
   Monitoring Interface Status 7-16
   Clearing and Resetting Interfaces and Counters 7-17
   Shutting Down and Restarting the Interface 7-17

CHAPTER 8
Configuring Smartports Macros 8-1
Understanding Smartports Macros 8-1
Configuring Smartports Macros 8-2
   Default Smartports Macro Configuration 8-2
   Smartports Macro Configuration Guidelines 8-3
   Creating Smartports Macros 8-4
   Applying Smartports Macros 8-5
   Applying Cisco-Default Smartports Macros 8-6
Displaying Smartports Macros 8-8

CHAPTER 9
Configuring VLANs 9-1
Understanding VLANs 9-1
   Supported VLANs 9-2
   VLAN Port Membership Modes 9-3
Configuring Normal-Range VLANs 9-4
   Token Ring VLANs 9-5
   Normal-Range VLAN Configuration Guidelines 9-5
VLAN Configuration Mode Options  9-6
  VLAN Configuration in config-vlan Mode  9-6
  VLAN Configuration in VLAN Database Configuration Mode  9-6

Saving VLAN Configuration  9-7
Default Ethernet VLAN Configuration  9-7
Creating or Modifying an Ethernet VLAN  9-8
Deleting a VLAN  9-10
Assigning Static-Access Ports to a VLAN  9-10

Configuring Extended-Range VLANs  9-11
  Default VLAN Configuration  9-12
  Extended-Range VLAN Configuration Guidelines  9-12
  Creating an Extended-Range VLAN  9-12

Displaying VLANs  9-14

Configuring VLAN Trunks  9-14
  Trunking Overview  9-14
    Encapsulation Types  9-16
    IEEE 802.1Q Configuration Considerations  9-16
  Default Layer 2 Ethernet Interface VLAN Configuration  9-17
  Configuring an Ethernet Interface as a Trunk Port  9-17
    Interaction with Other Features  9-18
  Configuring a Trunk Port  9-18
  Defining the Allowed VLANs on a Trunk  9-19
  Changing the Pruning-Eligible List  9-20
  Configuring the Native VLAN for Untagged Traffic  9-21
  Configuring Trunk Ports for Load Sharing  9-22
    Load Sharing Using STP Port Priorities  9-22
    Load Sharing Using STP Path Cost  9-24

Configuring VMPS  9-25
  Understanding VMPS  9-25
    Dynamic-Access Port VLAN Membership  9-26
  Default VMPS Client Configuration  9-26
  VMPS Configuration Guidelines  9-27
  Configuring the VMPS Client  9-27
    Entering the IP Address of the VMPS  9-27
    Configuring Dynamic-Access Ports on VMPS Clients  9-28
    Reconfirming VLAN Memberships  9-29
    Changing the Reconfirmation Interval  9-29
    Changing the Retry Count  9-29
  Monitoring the VMPS  9-30
CHAPTER 10 Configuring VTP 10-1

Understanding VTP 10-1
- The VTP Domain 10-2
- VTP Modes 10-3
- VTP Advertisements 10-3
- VTP Version 2 10-4
- VTP Pruning 10-4

Configuring VTP 10-6
- Default VTP Configuration 10-6
- VTP Configuration Options 10-7
  - VTP Configuration in Global Configuration Mode 10-7
  - VTP Configuration in VLAN Database Configuration Mode 10-7

VTP Configuration Guidelines 10-8
- Domain Names 10-8
- Passwords 10-8
- VTP Version 10-8
- Configuration Requirements 10-9

Configuring a VTP Server 10-9
Configuring a VTP Client 10-11
Disabling VTP (VTP Transparent Mode) 10-12
Enabling VTP Version 2 10-13
Enabling VTP Pruning 10-14
Adding a VTP Client Switch to a VTP Domain 10-14

Monitoring VTP 10-16

CHAPTER 11 Configuring Voice VLAN 11-1

Understanding Voice VLAN 11-1
- Cisco IP Phone Voice Traffic 11-2
- Cisco IP Phone Data Traffic 11-2

Configuring Voice VLAN 11-3
- Default Voice VLAN Configuration 11-3
- Voice VLAN Configuration Guidelines 11-3
- Configuring a Port Connected to a Cisco 7960 IP Phone 11-4
  - Configuring Cisco IP Phone Voice Traffic 11-5
  - Configuring the Priority of Incoming Data Frames 11-6

Displaying Voice VLAN 11-6
CHAPTER 12

Configuring STP 12-1

Understanding Spanning-Tree Features 12-1

STP Overview 12-2
Spanning-Tree Topology and BPDUs 12-3
Bridge ID, Switch Priority, and Extended System ID 12-4

Spanning-Tree Interface States 12-4

Blocking State 12-6
Listening State 12-6
Learning State 12-6
Forwarding State 12-6
Disabled State 12-7

How a Switch or Port Becomes the Root Switch or Root Port 12-7

Spanning Tree and Redundant Connectivity 12-8
Spanning-Tree Address Management 12-8
Accelerated Aging to Retain Connectivity 12-8
Spanning-Tree Modes and Protocols 12-9
Supported Spanning-Tree Instances 12-9
Spanning-Tree Interoperability and Backward Compatibility 12-10

STP and IEEE 802.1Q Trunks 12-10

Configuring Spanning-Tree Features 12-10

Default Spanning-Tree Configuration 12-11
Spanning-Tree Configuration Guidelines 12-12
Changing the Spanning-Tree Mode 12-13
Disabling Spanning Tree 12-14
Configuring the Root Switch 12-14
Configuring a Secondary Root Switch 12-16
Configuring Port Priority 12-16
Configuring Path Cost 12-18
Configuring the Switch Priority of a VLAN 12-19
Configuring Spanning-Tree Timers 12-20

Configuring the Hello Time 12-20
Configuring the Forwarding-Delay Time for a VLAN 12-21
Configuring the Maximum-Aging Time for a VLAN 12-21
Configuring the Transmit Hold-Count 12-22

Displaying the Spanning-Tree Status 12-22
CHAPTER 14

Configuring Optional Spanning-Tree Features 14-1
Understanding Optional Spanning-Tree Features 14-1
  Understanding Port Fast 14-2
  Understanding BPDU Guard 14-2
  Understanding BPDU Filtering 14-3
  Understanding UplinkFast 14-3
  Understanding BackboneFast 14-5
  Understanding EtherChannel Guard 14-7
  Understanding Root Guard 14-8
  Understanding Loop Guard 14-9

Configuring Optional Spanning-Tree Features 14-9
  Default Optional Spanning-Tree Configuration 14-9
  Optional Spanning-Tree Configuration Guidelines 14-10
  Enabling Port Fast 14-10
  Enabling BPDU Guard 14-11
  Enabling BPDU Filtering 14-12
  Enabling UplinkFast for Use with Redundant Links 14-13
  Enabling BackboneFast 14-13
  Enabling EtherChannel Guard 14-14
  Enabling Root Guard 14-15
  Enabling Loop Guard 14-15

Displaying the Spanning-Tree Status 14-16

CHAPTER 15

Configuring Flex Links and the MAC Address-Table Move Update Feature 15-1
Understanding Flex Links and the MAC Address-Table Move Update 15-1
  Flex Links 15-1
  VLAN Flex Link Load Balancing and Support 15-2
  MAC Address-Table Move Update 15-3

Configuring Flex Links and MAC Address-Table Move Update 15-5
  Configuration Guidelines 15-5
  Default Configuration 15-5

Configuring Flex Links and MAC Address-Table Move Update 15-6
  Configuring Flex Links 15-6
  Configuring VLAN Load Balancing on Flex Links 15-8
  Configuring the MAC Address-Table Move Update Feature 15-9
  Monitoring Flex Links and the MAC Address-Table Move Update 15-11
CHAPTER 16
Configuring DHCP Features 16-1
Understanding DHCP Features 16-1
  DHCP Server 16-2
  DHCP Relay Agent 16-2
  DHCP Snooping 16-2
  Option-82 Data Insertion 16-3
Configuring DHCP Features 16-5
  Default DHCP Configuration 16-5
  DHCP Snooping Configuration Guidelines 16-6
  Configuring the DHCP Relay Agent 16-7
  Enabling DHCP Snooping and Option 82 16-7
  Enabling the Cisco IOS DHCP Server Database 16-9
Displaying DHCP Snooping Information 16-9

CHAPTER 17
Configuring IGMP Snooping and MVR 17-1
Understanding IGMP Snooping 17-1
  IGMP Versions 17-2
  Joining a Multicast Group 17-3
  Leaving a Multicast Group 17-5
  Immediate Leave 17-5
  IGMP Configurable-Leave Timer 17-5
  IGMP Report Suppression 17-6
Configuring IGMP Snooping 17-6
  Default IGMP Snooping Configuration 17-6
  Enabling or Disabling IGMP Snooping 17-7
  Setting the Snooping Method 17-8
  Configuring a Multicast Router Port 17-9
  Configuring a Blade Server Statically to Join a Group 17-9
  Enabling IGMP Immediate Leave 17-10
  Configuring the IGMP Leave Timer 17-11
  Configuring TCN-Related Commands 17-11
    Controlling the Multicast Flooding Time After a TCN Event 17-12
    Recovering from Flood Mode 17-12
    Disabling Multicast Flooding During a TCN Event 17-13
    Configuring the IGMP Snooping Querier 17-13
    Disabling IGMP Report Suppression 17-15
Displaying IGMP Snooping Information 17-15
Understanding Multicast VLAN Registration 17-17
  Using MVR in a Multicast Television Application 17-18
Configuring MVR  17-19
  Default MVR Configuration  17-19
  MVR Configuration Guidelines and Limitations  17-20
  Configuring MVR Global Parameters  17-20
  Configuring MVR Interfaces  17-21

Displaying MVR Information  17-23

Configuring IGMP Filtering and Throttling  17-23
  Default IGMP Filtering and Throttling Configuration  17-24
  Configuring IGMP Profiles  17-24
  Applying IGMP Profiles  17-25
  Setting the Maximum Number of IGMP Groups  17-26
  Configuring the IGMP Throttling Action  17-27

Displaying IGMP Filtering and Throttling Configuration  17-28

CHAPTER 18
Configuring Port-Based Traffic Control  18-1

Configuring Storm Control  18-1
  Understanding Storm Control  18-1
  Default Storm Control Configuration  18-3
  Configuring Storm Control and Threshold Levels  18-3

Configuring Protected Ports  18-5
  Default Protected Port Configuration  18-6
  Protected Port Configuration Guidelines  18-6
  Configuring a Protected Port  18-6

Configuring Port Blocking  18-6
  Default Port Blocking Configuration  18-7
  Blocking Flooded Traffic on an Interface  18-7

Configuring Port Security  18-7
  Understanding Port Security  18-8
    Secure MAC Addresses  18-8
    Security Violations  18-9
  Default Port Security Configuration  18-10
  Port Security Configuration Guidelines  18-10
  Enabling and Configuring Port Security  18-11
  Enabling and Configuring Port Security Aging  18-16

Displaying Port-Based Traffic Control Settings  18-17
CHAPTER 19 Configuring CDP 19-1
Understanding CDP 19-1
Configuring CDP 19-2
Default CDP Configuration 19-2
Configuring the CDP Characteristics 19-2
Disabling and Enabling CDP 19-3
Disabling and Enabling CDP on an Interface 19-4
Monitoring and Maintaining CDP 19-5

CHAPTER 20 Configuring LLDP and LLDP-MED 20-1
Understanding LLDP and LLDP-MED 20-1
Understanding LLDP 20-1
Understanding LLDP-MED 20-2
Configuring LLDP and LLDP-MED 20-3
Default LLDP Configuration 20-3
Configuring LLDP Characteristics 20-3
Disabling and Enabling LLDP Globally 20-4
Disabling and Enabling LLDP on an Interface 20-5
Configuring LLDP-MED TLVs 20-6
Monitoring and Maintaining LLDP and LLDP-MED 20-7

CHAPTER 21 Configuring UDLD 21-1
Understanding UDLD 21-1
Modes of Operation 21-1
Methods to Detect Unidirectional Links 21-2
Configuring UDLD 21-3
Default UDLD Configuration 21-4
Configuration Guidelines 21-4
Enabling UDLD Globally 21-5
Enabling UDLD on an Interface 21-5
Resetting an Interface Disabled by UDLD 21-6
Displaying UDLD Status 21-6

CHAPTER 22 Configuring SPAN and RSPAN 22-1
Understanding SPAN and RSPAN 22-1
Local SPAN 22-2
Remote SPAN 22-2
SPAN and RSPAN Concepts and Terminology 22-3
Contents

SPAN Sessions 22-3
Monitored Traffic 22-4
Source Ports 22-5
Source VLANs 22-6
VLAN Filtering 22-6
Destination Port 22-6
RSPAN VLAN 22-7

SPAN and RSPAN Interaction with Other Features 22-8

Configuring SPAN and RSPAN 22-9
Default SPAN and RSPAN Configuration 22-9

Configuring Local SPAN 22-9
SPAN Configuration Guidelines 22-10
Creating a Local SPAN Session 22-10
Creating a Local SPAN Session and Configuring Incoming Traffic 22-13
Specifying VLANs to Filter 22-14

Configuring RSPAN 22-15
RSPAN Configuration Guidelines 22-15
Configuring a VLAN as an RSPAN VLAN 22-16
Creating an RSPAN Source Session 22-17
Creating an RSPAN Destination Session 22-19
Creating an RSPAN Destination Session and Configuring Incoming Traffic 22-20
Specifying VLANs to Filter 22-22

Displaying SPAN and RSPAN Status 22-23

CHAPTER 23

Configuring RMON 23-1
Understanding RMON 23-1

Configuring RMON 23-2
Default RMON Configuration 23-3
Configuring RMON Alarms and Events 23-3
Collecting Group History Statistics on an Interface 23-5
Collecting Group Ethernet Statistics on an Interface 23-5

Displaying RMON Status 23-6

CHAPTER 24

Configuring System Message Logging 24-1
Understanding System Message Logging 24-1

Configuring System Message Logging 24-2
System Log Message Format 24-2
Default System Message Logging Configuration 24-3
Disabling Message Logging 24-3
CHAPTER 25
Configuring SNMP 25-1

Understanding SNMP 25-1
SNMP Versions 25-2
SNMP Manager Functions 25-3
SNMP Agent Functions 25-4
SNMP Community Strings 25-4
Using SNMP to Access MIB Variables 25-4
SNMP Notifications 25-5
SNMP ifIndex MIB Object Values 25-6

Configuring SNMP 25-6
Default SNMP Configuration 25-7
SNMP Configuration Guidelines 25-7
Disabling the SNMP Agent 25-8
Configuring Community Strings 25-8
Configuring SNMP Groups and Users 25-10
Configuring SNMP Notifications 25-12
Setting the Agent Contact and Location Information 25-15
Limiting TFTP Servers Used Through SNMP 25-16
SNMP Examples 25-16
Displaying SNMP Status 25-17

CHAPTER 26
Configuring Network Security with ACLs 26-1

Understanding ACLs 26-1
Supported ACLs 26-2
Port ACLs 26-2
VLAN Maps 26-3
Handling Fragmented and Unfragmented Traffic 26-4
Configuring IPv4 ACLs 26-5

Setting the Message Display Destination Device 24-4
Synchronizing Log Messages 24-5
Enabling and Disabling Time Stamps on Log Messages 24-7
Enabling and Disabling Sequence Numbers in Log Messages 24-7
Defining the Message Severity Level 24-8
Limiting Syslog Messages Sent to the History Table and to SNMP 24-9
Configuring UNIX Syslog Servers 24-10
Logging Messages to a UNIX Syslog Daemon 24-10
Configuring the UNIX System Logging Facility 24-11
Displaying the Logging Configuration 24-12
Creating Standard and Extended IPv4 ACLs 26-6
  Access List Numbers 26-6
  Creating a Numbered Standard ACL 26-7
  Creating a Numbered Extended ACL 26-8
  Resequencing ACEs in an ACL 26-12
  Creating Named Standard and Extended ACLs 26-12
  Using Time Ranges with ACLs 26-14
  Including Comments in ACLs 26-16
Applying an IPv4 ACL to a Terminal Line 26-16
Applying an IPv4 ACL to an Interface 26-17
Hardware and Software Treatment of IP ACLs 26-18
IPv4 ACL Configuration Examples 26-18
  Numbered ACLs 26-18
  Extended ACLs 26-18
  Named ACLs 26-19
  Time Range Applied to an IP ACL 26-19
  Commented IP ACL Entries 26-19
Creating Named MAC Extended ACLs 26-20
Applying a MAC ACL to a Layer 2 Interface 26-21
Configuring VLAN Maps 26-22
  VLAN Map Configuration Guidelines 26-23
Creating a VLAN Map 26-24
  Examples of ACLs and VLAN Maps 26-24
Applying a VLAN Map to a VLAN 26-26
Using VLAN Maps in Your Network 26-27
  Wiring Closet Configuration 26-27
  Denying Access to a Server on a VLAN 26-28
Displaying IPv4 ACL Configuration 26-29

CHAPTER 27

Configuring QoS 27-1

Understanding QoS 27-1
  Basic QoS Model 27-3
Classification 27-5
  Classification Based on QoS ACLs 27-7
  Classification Based on Class Maps and Policy Maps 27-7
Policing and Marking 27-8
  Policing on Physical Ports 27-9
  Policing on SVIs 27-10
Mapping Tables 27-12
Contents

Queueing and Scheduling Overview 27-13
  Weighted Tail Drop 27-13
  SRR Shaping and Sharing 27-14
  Queueing and Scheduling on Ingress Queues 27-15
  Queueing and Scheduling on Egress Queues 27-17
Packet Modification 27-19
Configuring Auto-QoS 27-20
  Generated Auto-QoS Configuration 27-21
  Effects of Auto-QoS on the Configuration 27-25
  Auto-QoS Configuration Guidelines 27-25
  Enabling Auto-QoS for VoIP 27-26
  Auto-QoS Configuration Example 27-27
Displaying Auto-QoS Information 27-29
Configuring Standard QoS 27-29
  Default Standard QoS Configuration 27-30
    Default Ingress Queue Configuration 27-30
    Default Egress Queue Configuration 27-31
    Default Mapping Table Configuration 27-32
  Standard QoS Configuration Guidelines 27-32
    QoS ACL Guidelines 27-32
    Applying QoS on Interfaces 27-32
    Policing Guidelines 27-33
    General QoS Guidelines 27-33
Enabling QoS Globally 27-34
Enabling VLAN-Based QoS on Physical Ports 27-34
Configuring Classification Using Port Trust States 27-35
  Configuring the Trust State on Ports within the QoS Domain 27-35
  Configuring the CoS Value for an Interface 27-37
  Configuring a Trusted Boundary to Ensure Port Security 27-37
  Enabling DSCP Transparency Mode 27-39
  Configuring the DSCP Trust State on a Port Bordering Another QoS Domain 27-39
Configuring a QoS Policy 27-41
  Classifying Traffic by Using ACLs 27-42
  Classifying Traffic by Using Class Maps 27-45
  Classifying, Policing, and Marking Traffic on Physical Ports by Using Policy Maps 27-47
  Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps 27-50
  Classifying, Policing, and Marking Traffic by Using Aggregate Policers 27-55
Configuring DSCP Maps 27-57
  Configuring the CoS-to-DSCP Map 27-58
Configuring the IP-Precedence-to-DSCP Map 27-59
Configuring the Policed-DSCP Map 27-60
Configuring the DSCP-to-CoS Map 27-61
Configuring the DSCP-to-DSCP-Mutation Map 27-62
Configuring Ingress Queue Characteristics 27-63
Mapping DSCP or CoS Values to an Ingress Queue and Setting WTD Thresholds 27-64
Allocating Buffer Space Between the Ingress Queues 27-65
Allocating Bandwidth Between the Ingress Queues 27-65
Configuring the Ingress Priority Queue 27-66
Configuring Egress Queue Characteristics 27-67
Configuration Guidelines 27-68
Allocating Buffer Space to and Setting WTD Thresholds for an Egress Queue-Set 27-68
Mapping DSCP or CoS Values to an Egress Queue and to a Threshold ID 27-70
Configuring SRR Shaped Weights on Egress Queues 27-72
Configuring SRR Shared Weights on Egress Queues 27-73
Configuring the Egress Expedite Queue 27-74
Limiting the Bandwidth on an Egress Interface 27-74
Displaying Standard QoS Information 27-75

CHAPTER 28 Configuring EtherChannels and Layer 2 Trunk Failover 28-1
Understanding EtherChannels 28-1
EtherChannel Overview 28-2
Port-Channel Interfaces 28-3
Port Aggregation Protocol 28-4
PAgP Modes 28-4
PAgP Interaction with Other Features 28-5
Link Aggregation Control Protocol 28-5
LACP Modes 28-5
LACP Interaction with Other Features 28-6
EtherChannel On Mode 28-6
Load Balancing and Forwarding Methods 28-6
Configuring EtherChannels 28-8
Default EtherChannel Configuration 28-9
EtherChannel Configuration Guidelines 28-9
Configuring Layer 2 EtherChannels 28-10
Configuring EtherChannel Load Balancing 28-12
Configuring the PAgP Learn Method and Priority 28-13
Configuring LACP Hot-Standby Ports 28-14
Configuring the LACP System Priority 28-15
Configuring the LACP Port Priority 28-16
Displaying EtherChannel, PAgP, and LACP Status 28-17
Understanding Layer 2 Trunk Failover 28-17
Configuring Layer 2 Trunk Failover 28-18
  Default Layer 2 Trunk Failover Configuration 28-18
  Layer 2 Trunk Failover Configuration Guidelines 28-19
  Configuring Layer 2 Trunk Failover 28-19
  Displaying Layer 2 Trunk Failover Status 28-20

CHAPTER 29 Troubleshooting 29-1
Recovering from a Software Failure 29-2
Recovering from a Lost or Forgotten Password 29-3
  Procedure with Password Recovery Enabled 29-4
  Procedure with Password Recovery Disabled 29-6
Recovering from a Command Switch Failure 29-8
  Replacing a Failed Command Switch with a Cluster Member 29-8
  Replacing a Failed Command Switch with Another Switch 29-10
Recovering from Lost Cluster Member Connectivity 29-11
Preventing Autonegotiation Mismatches 29-11
SFP Module Security and Identification 29-12
Monitoring SFP Module Status 29-12
Using Ping 29-13
  Understanding Ping 29-13
  Executing Ping 29-13
Using Layer 2 Traceroute 29-14
  Understanding Layer 2 Traceroute 29-14
  Usage Guidelines 29-15
  Displaying the Physical Path 29-16
Using IP Traceroute 29-16
  Understanding IP Traceroute 29-16
  Executing IP Traceroute 29-17
Using TDR 29-18
  Understanding TDR 29-18
  Running TDR and Displaying the Results 29-18
Using Debug Commands 29-18
  Enabling Debugging on a Specific Feature 29-19
  Enabling All-System Diagnostics 29-19
  Redirecting Debug and Error Message Output 29-20
Using the show platform forward Command 29-20
Using the crashinfo Files 29-22
Basic crashinfo Files 29-22
Extended crashinfo Files 29-22

[APPENDIX A]

Supported MIBs  A-1
MIB List  A-1
Using FTP to Access the MIB Files  A-3

[APPENDIX B]

Working with the Cisco IOS File System, Configuration Files, and Software Images  B-1
Working with the Flash File System  B-1
Displaying Available File Systems  B-2
Setting the Default File System  B-3
Displaying Information about Files on a File System  B-3
Changing Directories and Displaying the Working Directory  B-3
Creating and Removing Directories  B-4
Copying Files  B-4
Deleting Files  B-5
Creating, Displaying, and Extracting tar Files  B-5
Creating a tar File  B-6
Displaying the Contents of a tar File  B-6
Extracting a tar File  B-8
Displaying the Contents of a File  B-8
Working with Configuration Files  B-8
Guidelines for Creating and Using Configuration Files  B-10
Configuration File Types and Location  B-10
Creating a Configuration File By Using a Text Editor  B-11
Copying Configuration Files By Using TFTP  B-11
Preparing to Download or Upload a Configuration File By Using TFTP  B-11
Downloading the Configuration File By Using TFTP  B-12
Uploading the Configuration File By Using TFTP  B-12
Copying Configuration Files By Using FTP  B-13
Preparing to Download or Upload a Configuration File By Using FTP  B-13
Downloading a Configuration File By Using FTP  B-14
Uploading a Configuration File By Using FTP  B-15
Copying Configuration Files By Using RCP  B-17
Preparing to Download or Upload a Configuration File By Using RCP  B-17
Downloading a Configuration File By Using RCP  B-18
Uploading a Configuration File By Using RCP  B-19
Clearing Configuration Information  B-20
Clearing the Startup Configuration File  B-20
Deleting a Stored Configuration File  B-20

Working with Software Images  B-20
Image Location on the Switch  B-21
tar File Format of Images on a Server or Cisco.com  B-21

Copying Image Files By Using TFTP  B-22
Preparing to Download or Upload an Image File By Using TFTP  B-23
Downloading an Image File By Using TFTP  B-23
Uploading an Image File By Using TFTP  B-25

Copying Image Files By Using FTP  B-25
Preparing to Download or Upload an Image File By Using FTP  B-26
Downloading an Image File By Using FTP  B-27
Uploading an Image File By Using FTP  B-28

Copying Image Files By Using RCP  B-29
Preparing to Download or Upload an Image File By Using RCP  B-30
Downloading an Image File By Using RCP  B-31
Uploading an Image File By Using RCP  B-33

Unsupported Commands in Cisco IOS Release 12.2(37)SE  C-1

Access Control Lists  C-1
Unsupported Privileged EXEC Commands  C-1
Unsupported Global Configuration Commands  C-1
Unsupported Route-Map Configuration Command  C-1

Bootloader Commands  C-2
Unsupported Global Configuration Command  C-2

Debug Commands  C-2
Unsupported Privileged EXEC Commands  C-2

IGMP Snooping Commands  C-2
Unsupported Global Configuration Command  C-2

Interface Commands  C-2
Unsupported Privileged EXEC Command  C-2
Unsupported Global Configuration Command  C-2
Unsupported Interface Configuration Command  C-2

MAC Address Commands  C-3
Unsupported Privileged EXEC Commands  C-3
Unsupported Global Configuration Commands  C-3

Miscellaneous  C-3
Unsupported Privileged EXEC Commands  C-3
Unsupported Global Configuration Commands  C-3
Network Address Translation (NAT) Commands  C-4
  Unsupported Privileged EXEC Commands  C-4
QoS  C-4
  Unsupported Global Configuration Command  C-4
  Unsupported Interface Configuration Commands  C-4
  Unsupported Policy-Map Configuration Command  C-4
RADIUS  C-4
  Unsupported Global Configuration Commands  C-4
SNMP  C-5
  Unsupported Global Configuration Commands  C-5
Spanning Tree  C-5
  Unsupported Global Configuration Command  C-5
  Unsupported Interface Configuration Command  C-5
VLAN  C-5
  Unsupported Global Configuration Command  C-5
  Unsupported vlan-config Command  C-5
  Unsupported User EXEC Commands  C-5
VTP  C-6
  Unsupported Privileged EXEC Command  C-6
Preface

Audience

This guide is for the networking professional managing the Cisco Gigabit Ethernet Switch Module (CGESM), referred to as the switch. Before using this guide, you should have experience working with the Cisco IOS software and be familiar with the concepts and terminology of Ethernet and local area networking.

Purpose

This guide provides the information that you need to configure Cisco IOS software features on your switch. The Cisco Catalyst Blade Switch software provides enterprise-class intelligent services such as access control lists (ACLs) and quality of service (QoS) features.

This guide provides procedures for using the commands that have been created or changed for use with the Cisco Catalyst Blade Switch switch. It does not provide detailed information about these commands. For detailed information about these commands, see the Cisco Catalyst Blade Switch Command Reference for this release. For information about the standard Cisco IOS Release 12.2 commands, see the Cisco IOS documentation set available from the Cisco.com home page at Technical Support & Documentation > Cisco IOS Software.

This guide does not provide detailed information on the graphical user interfaces (GUIs) for the embedded device manager or for Cisco Network Assistant (hereafter referred to as Network Assistant) that you can use to manage the switch. However, the concepts in this guide are applicable to the GUI user. For information about the device manager, see the switch online help. For information about Network Assistant, see Getting Started with Cisco Network Assistant, available on Cisco.com.

This guide does not describe system messages you might encounter or how to install your switch. For more information, see the Cisco Catalyst Blade Switch System Message Guide for this release and the Cisco Catalyst Blade Switch Hardware Installation Guide.

For documentation updates, see the release notes for this release.
Conventions

This publication uses these conventions to convey instructions and information:

Command descriptions use these conventions:
- Commands and keywords are in **boldface** text.
- Arguments for which you supply values are in *italic*.
- Square brackets ([ ]) mean optional elements.
- Braces ({ }) group required choices, and vertical bars ( | ) separate the alternative elements.
- Braces and vertical bars within square brackets ([{ | }]) mean a required choice within an optional element.

Interactive examples use these conventions:
- Terminal sessions and system displays are in `screen` font.
- Information you enter is in **boldface screen** font.
- Nonprinting characters, such as passwords or tabs, are in angle brackets (< >).

Notes, cautions, and timesavers use these conventions and symbols:

---

**Note**

Means reader take note. Notes contain helpful suggestions or references to materials not contained in this manual.

**Caution**

Means reader be careful. In this situation, you might do something that could result in equipment damage or loss of data.

---

Related Publications

These documents provide complete information about the switch and are available from this Cisco.com site:

---

**Note**

Before installing, configuring, or upgrading the switch, see these documents:
- For initial configuration information, see the blade switch configuration and installation instructions in the getting started guide or the “Configuring the Switch with the CLI-Based Setup Program” appendix in the hardware installation guide.
- For device manager requirements, see the “System Requirements” section in the release notes (not orderable but available on Cisco.com).
- For Network Assistant requirements, see the *Getting Started with Cisco Network Assistant* (not orderable but available on Cisco.com).
- For cluster requirements, see the *Release Notes for Cisco Network Assistant* (not orderable but available on Cisco.com).
- For upgrading information, see the “Downloading Software” section in the release notes.
You can order printed copies of documents with a DOC-xxxxxx= number from the Cisco.com sites and from the telephone numbers listed in the “Obtaining Documentation, Obtaining Support, and Security Guidelines” section on page xxxi.

- Cisco Small Form-Factor Pluggable Modules Installation Notes (order number DOC-781160=)
- These compatibility matrix documents are available from this Cisco.com site:
  - Cisco Gigabit Ethernet Transceiver Modules Compatibility Matrix (not orderable but available on Cisco.com)
  - Cisco Small Form-Factor Pluggable Modules Compatibility Matrix (not orderable but available on Cisco.com)
  - Compatibility Matrix for 1000BASE-T Small Form-Factor Pluggable Modules (not orderable but available on Cisco.com)
- Getting Started with Cisco Network Assistant (not orderable but available on Cisco.com)
- Release Notes for Cisco Network Assistant (not orderable but available on Cisco.com)
- Cisco RPS 300 Redundant Power System Hardware Installation Guide (order number DOC-7810372=)
- Cisco RPS 675 Redundant Power System Hardware Installation Guide (order number DOC-7815201=)

Obtaining Documentation, Obtaining Support, and Security Guidelines

For information on obtaining documentation, obtaining support, providing documentation feedback, security guidelines, and also recommended aliases and general Cisco documents, see the monthly What’s New in Cisco Product Documentation, which also lists all new and revised Cisco technical documentation, at:

Overview

This chapter provides these topics about the switch software:

- Features, page 1-1
- Default Settings After Initial Switch Configuration, page 1-9
- Design Concepts for Using the Switch, page 1-12
- Where to Go Next, page 1-14

In this document, IP refers to IP Version 4 (IPv4).

Features

Some features described in this chapter are available only on the cryptographic (supports encryption) version of the software. You must obtain authorization to use this feature and to download the cryptographic version of the software from Cisco.com. For more information, see the release notes for this release.

The switch has these features:

- Ease-of-Deployment and Ease-of-Use Features, page 1-2
- Performance Features, page 1-3
- Management Options, page 1-4
- Manageability Features, page 1-4 (includes a feature requiring the cryptographic version of the software)
- Availability and Redundancy Features, page 1-5
- VLAN Features, page 1-6
- Security Features, page 1-7 (includes a feature requiring the cryptographic version of the software)
- QoS and CoS Features, page 1-8
- Monitoring Features, page 1-9
Ease-of-Deployment and Ease-of-Use Features

The switch ships with these features to make the deployment and the use easier:

- **Express Setup** for quickly configuring a switch for the first time with basic IP information, contact information, switch and Telnet passwords, and Simple Network Management Protocol (SNMP) information through a browser-based program. For more information about Express Setup, see the getting started guide.

- **User-defined and Cisco-default Smartports macros** for creating custom switch configurations for simplified deployment across the network.

- **Cisco Network Assistant** (hereafter referred to as *Network Assistant*) for
  - Managing communities, which are device groups like clusters, except that they can contain routers and access points and can be made more secure.
  - Simplifying and minimizing switch and switch cluster management from anywhere in your intranet.
  - Accomplishing multiple configuration tasks from a single graphical interface without needing to remember command-line interface (CLI) commands to accomplish specific tasks.
  - Interactive guide mode that guides you in configuring complex features such as VLANs, ACLs, and quality of service (QoS).
  - Configuration wizards that prompt you to provide only the minimum required information to configure complex features such as QoS priorities for video traffic, priority levels for data applications, and security.
  - Downloading an image to a switch.
  - Applying actions to multiple ports and multiple switches at the same time, such as VLAN and QoS settings, inventory and statistic reports, link- and switch-level monitoring and troubleshooting, and multiple switch software upgrades.
  - Viewing a topology of interconnected devices to identify existing switch clusters and eligible switches that can join a cluster and to identify link information between switches.
  - Monitoring real-time status of a switch or multiple switches from the LEDs on the front-panel images. The system, redundant power system (RPS), and port LED colors on the images are similar to those used on the physical LEDs.

- **Switch clustering technology** for
  - Unified configuration, monitoring, authentication, and software upgrade of multiple, cluster-capable switches, regardless of their geographic proximity and interconnection media, including Ethernet, Fast Ethernet, Fast EtherChannel, small form-factor pluggable (SFP) modules, Gigabit Ethernet, and Gigabit EtherChannel connections. For a list of cluster-capable switches, see the release notes.
  - Automatic discovery of candidate switches and creation of clusters of up to 16 switches that can be managed through a single IP address.
  - Extended discovery of cluster candidates that are not directly connected to the command switch.
Performance Features

The switch ships with these performance features:

- Autosensing of port speed and autonegotiation of duplex mode on all switch ports for optimizing bandwidth
- Automatic-medium-dependent interface crossover (auto-MDI(X)) capability on 10/100 and 10/100/1000 Mb/s interfaces that enables the interface to automatically detect the required cable connection type (straight-through or crossover) and to configure the connection appropriately
- Support for up to 9000 bytes for frames that are bridged in hardware and up to 2000 bytes for frames that are bridged by software
- IEEE 802.3x flow control on all ports (the switch does not send pause frames)
- EtherChannel for enhanced fault tolerance and for providing up to 8 Gb/s (Gigabit EtherChannel) full-duplex bandwidth among switches, routers, and servers
- Port Aggregation Protocol (PAgP) and Link Aggregation Control Protocol (LACP) for automatic creation of EtherChannel links
- Forwarding of Layer 2 packets at Gigabit line rate
- Per-port storm control for preventing broadcast, multicast, and unicast storms
- Port blocking on forwarding unknown Layer 2 unknown unicast, multicast, and bridged broadcast traffic
- Internet Group Management Protocol (IGMP) snooping for IGMP Versions 1, 2, and 3 for efficiently forwarding multimedia and multicast traffic
- IGMP report suppression for sending only one IGMP report per multicast router query to the multicast devices (supported only for IGMPv1 or IGMPv2 queries)
- IGMP snooping querier support to configure switch to generate periodic IGMP General Query messages
- Multicast VLAN registration (MVR) to continuously send multicast streams in a multicast VLAN while isolating the streams from subscriber VLANs for bandwidth and security reasons
- IGMP filtering for controlling the set of multicast groups to which hosts on a switch port can belong
- IGMP throttling for configuring the action when the maximum number of entries is in the IGMP forwarding table
- IGMP leave timer for configuring the leave latency for the network
Management Options

These are the options for configuring and managing the switch:

- An embedded device manager—The device manager is a GUI that is integrated in the software image. You use it to configure and to monitor a single switch. For information about launching the device manager, see the getting started guide. For more information about the device manager, see the switch online help.

- Network Assistant—Network Assistant is a network management application that can be downloaded from Cisco.com. You use it to manage a single switch, a cluster of switches, or a community of devices. For more information about Network Assistant, see Getting Started with Cisco Network Assistant, available on Cisco.com.

- CLI—The Cisco IOS software supports desktop- and multilayer-switching features. You can access the CLI either by connecting your management station directly to the switch console port or by using Telnet from a remote management station. For more information about the CLI, see Chapter 2, “Using the Command-Line Interface.”

- SNMP—SNMP management applications such as CiscoWorks2000 LAN Management Suite (LMS) and HP OpenView. You can manage from an SNMP-compatible management station that is running platforms such as HP OpenView or SunNet Manager. The switch supports a comprehensive set of MIB extensions and four remote monitoring (RMON) groups. For more information about using SNMP, see Chapter 25, “Configuring SNMP.”

- IE2100—Cisco Intelligence Engine 2100 Series Configuration Registrar is a network management device that works with embedded Cisco Networking Services (CNS) agents in the switch software. You can automate initial configurations and configuration updates by generating switch-specific configuration changes, sending them to the switch, executing the configuration change, and logging the results.

   For more information about IE2100, see Chapter 4, “Configuring Cisco IOS CNS Agents.”

Manageability Features

These are the manageability features:

- Cisco IE2100 Series CNS embedded agents for automating switch management, configuration storage, and delivery

- DHCP for automating configuration of switch information (such as IP address, default gateway, hostname, and Domain Name System [DNS] and TFTP server names)

- DHCP relay for forwarding User Datagram Protocol (UDP) broadcasts, including IP address requests, from DHCP clients

- DHCP server for automatic assignment of IP addresses and other DHCP options to IP hosts

- Directed unicast requests to a DNS server for identifying a switch through its IP address and its corresponding hostname and to a TFTP server for administering software upgrades from a TFTP server

- Address Resolution Protocol (ARP) for identifying a switch through its IP address and its corresponding MAC address

- Unicast MAC address filtering to drop packets with specific source or destination MAC addresses

- Cisco Discovery Protocol (CDP) Versions 1 and 2 for network topology discovery and mapping between the switch and other Cisco devices on the network
• Link Layer Discovery Protocol (LLDP) and LLDP Media Endpoint Discovery (LLDP-MED) for interoperability with third-party IP phones
• Network Time Protocol (NTP) for providing a consistent time stamp to all switches from an external source
• Cisco IOS File System (IFS) for providing a single interface to all file systems that the switch uses
• Configuration logging to log and to view changes to the switch configuration
• Unique device identifier to provide product identification information through a `show inventory` user EXEC command display
• In-band management access through the device manager over a Netscape Navigator or Microsoft Internet Explorer browser session
• In-band management access for up to 16 simultaneous Telnet connections for multiple CLI-based sessions over the network
• In-band management access for up to five simultaneous, encrypted Secure Shell (SSH) connections for multiple CLI-based sessions over the network (requires the cryptographic version of the software)
• In-band management access through SNMP Versions 1, 2c, and 3 get and set requests
• Out-of-band management access through the switch console port to a directly attached terminal or to a remote terminal through a serial connection or a modem
• Secure Copy Protocol (SCP) feature to provide a secure and authenticated method for copying switch configuration or switch image files (requires the cryptographic versions of the software IP base and IP services images)(requires the cryptographic version of the software)

Note
For additional descriptions of the management interfaces, see the “Design Concepts for Using the Switch” section on page 1-12.

Availability and Redundancy Features

These are the availability and redundancy features:
• UniDirectional Link Detection (UDLD) and aggressive UDLD for detecting and disabling unidirectional links on fiber-optic interfaces caused by incorrect fiber-optic wiring or port faults
• IEEE 802.1D Spanning Tree Protocol (STP) for redundant backbone connections and loop-free networks. STP has these features:
  - Up to 128 spanning-tree instances supported
  - Per-VLAN spanning-tree plus (PVST+) for load balancing across VLANs
  - Rapid PVST+ for load balancing across VLANs and providing rapid convergence of spanning-tree instances
  - UplinkFast and BackboneFast for fast convergence after a spanning-tree topology change and for achieving load balancing between redundant uplinks, including Gigabit uplinks
• IEEE 802.1s Multiple Spanning Tree Protocol (MSTP) for grouping VLANs into a spanning-tree instance and for providing multiple forwarding paths for data traffic and load balancing and rapid per-VLAN Spanning-Tree plus (rapid-PVST+) based on the IEEE 802.1w Rapid Spanning Tree Protocol (RSTP) for rapid convergence of the spanning tree by immediately changing root and designated ports to the forwarding state
Chapter 1  Overview

Features

• Optional spanning-tree features available in PVST+, rapid-PVST+, and MSTP mode:
  – Port Fast for eliminating the forwarding delay by enabling a port to immediately change from the blocking state to the forwarding state
  – BPDU guard for shutting down Port Fast-enabled ports that receive bridge protocol data units (BPDUs)
  – BPDU filtering for preventing a Port Fast-enabled port from sending or receiving BPDUs
  – Root guard for preventing switches outside the network core from becoming the spanning-tree root
  – Loop guard for preventing alternate or root ports from becoming designated ports because of a failure that leads to a unidirectional link

• Flex Link Layer 2 interfaces to back up one another as an alternative to STP for basic link redundancy

• Link state tracking (Layer 2 trunk failover) to mirror the state of the external Ethernet links and to allow the failover of the processor blade traffic to an operational external link on a separate Cisco Ethernet switch

• RPS support through the Cisco RPS 300 and Cisco RPS 675 for enhancing power reliability

**Note**  The switch supports up to 64 spanning-tree instances.

VLAN Features

These are the VLAN features:

• Support for up to 1005 VLANs for assigning users to VLANs associated with appropriate network resources, traffic patterns, and bandwidth

• Support for VLAN IDs in the 1 to 4094 range as allowed by the IEEE 802.1Q standard

• VLAN Query Protocol (VQP) for dynamic VLAN membership

• IEEE 802.1Q trunking encapsulation on all ports for network moves, adds, and changes; management and control of broadcast and multicast traffic; and network security by establishing VLAN groups for high-security users and network resources

• Dynamic Trunking Protocol (DTP) for negotiating trunking on a link between two devices and for negotiating the type of trunking encapsulation (IEEE 802.1Q) to be used

• VLAN Trunking Protocol (VTP) and VTP pruning for reducing network traffic by restricting flooded traffic to links destined for stations receiving the traffic

• Voice VLAN for creating subnets for voice traffic from Cisco IP Phones

• VLAN 1 minimization for reducing the risk of spanning-tree loops or storms by allowing VLAN 1 to be disabled on any individual VLAN trunk link. With this feature enabled, no user traffic is sent or received on the trunk. The switch CPU continues to send and receive control protocol frames.

• VLAN Flex Link Load Balancing to provide Layer 2 redundancy without requiring Spanning Tree Protocol (STP). A pair of interfaces configured as primary and backup links can load balance traffic based on VLAN.
Security Features

The switch ships with these security features:

- Password-protected access (read-only and read-write access) to management interfaces (device manager, Network Assistant, and the CLI for protection against unauthorized configuration changes
- Multilevel security for a choice of security level, notification, and resulting actions
- Static MAC addressing for ensuring security
- Protected port option for restricting the forwarding of traffic to designated ports on the same switch
- Port security option for limiting and identifying MAC addresses of the stations allowed to access the port
- VLAN aware port security option shut down the VLAN on the port when a violation occurs, instead of shutting down the entire port.
- Port security aging to set the aging time for secure addresses on a port
- BPDU guard for shutting down a Port Fast-configured port when an invalid configuration occurs
- Standard and extended IP access control lists (ACLs) for defining security policies in both directions on VLANs and inbound on Layer 2 interfaces (port ACLs)
- Extended MAC access control lists for defining security policies in the inbound direction on Layer 2 interfaces
- VLAN ACLs (VLAN maps) for providing intra-VLAN security by filtering traffic based on information in the MAC, IP, and TCP/UDP headers
- Source and destination MAC-based ACLs for filtering non-IP traffic
- DHCP snooping to filter untrusted DHCP messages between untrusted hosts and DHCP servers
- IEEE 802.1x port-based authentication to prevent unauthorized devices (clients) from gaining access to the network. These features are supported:
  - VLAN assignment for restricting IEEE 802.1x-authenticated users to a specified VLAN
  - Port security for controlling access to IEEE 802.1x ports
  - Voice VLAN to permit a Cisco IP Phone to access the voice VLAN regardless of the authorized or unauthorized state of the port
  - Guest VLAN to provide limited services to non-IEEE 802.1x-compliant users
  - Restricted VLAN to provide limited services to users who are IEEE 802.1x compliant, but do not have the credentials to authenticate via the standard IEEE 802.1x processes
  - IEEE 802.1x accounting to track network usage
  - IEEE 802.1x with wake-on-LAN to allow dormant PCs to be powered on based on the receipt of a specific Ethernet frame
- MAC authentication bypass to authorize clients based on the client MAC address
- Network Admission Control (NAC) Layer 2 IEEE 802.1x validation of the antivirus condition or posture of endpoint systems or clients before granting the devices network access.
- TACACS+, a proprietary feature for managing network security through a TACACS server
- RADIUS for verifying the identity of, granting access to, and tracking the actions of remote users through authentication, authorization, and accounting (AAA) services
• Kerberos security system to authenticate requests for network resources by using a trusted third party (requires the cryptographic version of the software)
• Secure Socket Layer (SSL) Version 3.0 support for the HTTP 1.1 server authentication, encryption, and message integrity and HTTP client authentication to allow secure HTTP communications (requires the cryptographic version of the software)

QoS and CoS Features

These are the QoS and CoS features:
• Automatic QoS (auto-QoS) to simplify the deployment of existing QoS features by classifying traffic and configuring egress queues
• Classification
  – IP type-of-service/Differentiated Services Code Point (IP ToS/DSCP) and IEEE 802.1p CoS marking priorities on a per-port basis for protecting the performance of mission-critical applications
  – IP ToS/DSCP and IEEE 802.1p CoS marking based on flow-based packet classification (classification based on information in the MAC, IP, and TCP/UDP headers) for high-performance quality of service at the network edge, allowing for differentiated service levels for different types of network traffic and for prioritizing mission-critical traffic in the network
  – Trusted port states (CoS, DSCP, and IP precedence) within a QoS domain and with a port bordering another QoS domain
  – Trusted boundary for detecting the presence of a Cisco IP Phone, trusting the CoS value received, and ensuring port security
• Policing
  – Traffic-policing policies on the switch port for managing how much of the port bandwidth should be allocated to a specific traffic flow
  – In Cisco IOS Release 12.2(25)SED and later, if you configure multiple class maps for a hierarchical policy map, each class map can be associated with its own port-level (second-level) policy map. Each second-level policy map can have a different policer.
  – Aggregate policing for policing traffic flows in aggregate to restrict specific applications or traffic flows to metered, predefined rates
• Out-of-Profile
  – Out-of-profile markdown for packets that exceed bandwidth utilization limits
• Ingress queueing and scheduling
  – Two configurable ingress queues for user traffic (one queue can be the priority queue)
  – Weighted tail drop (WTD) as the congestion-avoidance mechanism for managing the queue lengths and providing drop precedences for different traffic classifications
  – Shaped round robin (SRR) as the scheduling service for specifying the rate at which packets are sent to the ring (sharing is the only supported mode on ingress queues)
• Egress queues and scheduling
  – Four egress queues per port
  – WTD as the congestion-avoidance mechanism for managing the queue lengths and providing drop precedences for different traffic classifications
  – SRR as the scheduling service for specifying the rate at which packets are dequeued to the egress interface (shaping or sharing is supported on egress queues). Shaped egress queues are guaranteed but limited to using a share of port bandwidth. Shared egress queues are also guaranteed a configured share of bandwidth, but can use more than the guarantee if other queues become empty and do not use their share of the bandwidth.

Monitoring Features

These are the monitoring features:
• Switch LEDs that provide status
• MAC address notification traps and RADIUS accounting for tracking users on a network by storing the MAC addresses that the switch has learned or removed
• Switched Port Analyzer (SPAN) and Remote SPAN (RSPAN) for traffic monitoring on any port or VLAN
• SPAN and RSPAN support of Intrusion Detection Systems (IDS) to monitor, repel, and report network security violations
• Four groups (history, statistics, alarms, and events) of embedded RMON agents for network monitoring and traffic analysis
• Syslog facility for logging system messages about authentication or authorization errors, resource issues, and time-out events
• Layer 2 traceroute to identify the physical path that a packet takes from a source device to a destination device
• Time Domain Reflector (TDR) to diagnose and resolve cabling problems on 10/100/1000 copper Ethernet ports
• SFP module diagnostic management interface to monitor physical or operational status of an SFP module

Default Settings After Initial Switch Configuration

The switch is designed for plug-and-play operation, requiring only that you assign basic IP information to the switch and connect it to the other devices in your network. If you have specific network needs, you can change the interface-specific and system-wide settings.

Note For information about assigning an IP address by using the browser-based Express Setup program, see the getting started guide. For information about assigning an IP address by using the CLI-based setup program, see the hardware installation guide.
If you do not configure the switch at all, the switch operates with these default settings:

- Default switch IP address, subnet mask, and default gateway is 0.0.0.0. For more information, see Chapter 3, “Assigning the Switch IP Address and Default Gateway,” and Chapter 16, “Configuring DHCP Features.”

- Default domain name is not configured. For more information, see Chapter 3, “Assigning the Switch IP Address and Default Gateway.”

- DHCP client is enabled, the DHCP server is enabled (only if the device acting as a DHCP server is configured and is enabled), and the DHCP relay agent is enabled (only if the device is acting as a DHCP relay agent is configured and is enabled). For more information, see Chapter 3, “Assigning the Switch IP Address and Default Gateway,” and Chapter 16, “Configuring DHCP Features.”

- Switch cluster is disabled. For more information about switch clusters, see Chapter 6, “Clustering Switches,” and the Getting Started with Cisco Network Assistant, available on Cisco.com.

- No passwords are defined. For more information, see Chapter 4, “Administering the Switch.”

- System name and prompt is Switch. For more information, see Chapter 4, “Administering the Switch.”

- NTP is enabled. For more information, see Chapter 4, “Administering the Switch.”

- DNS is enabled. For more information, see Chapter 4, “Administering the Switch.”

- TACACS+ is disabled. For more information, see Chapter 5, “Configuring Switch-Based Authentication.”

- RADIUS is disabled. For more information, see Chapter 5, “Configuring Switch-Based Authentication.”

- The standard HTTP server and Secure Socket Layer (SSL) HTTPS server are both enabled. For more information, see Chapter 5, “Configuring Switch-Based Authentication.”

- IEEE 802.1x is disabled. For more information, see Chapter 6, “Configuring IEEE 802.1x Port-Based Authentication.”

- Port parameters
  - Interface speed and duplex mode is autonegotiate. For more information, see Chapter 7, “Configuring Interface Characteristics.”
  - Auto-MDIX is enabled. For more information, see Chapter 7, “Configuring Interface Characteristics.”
  - Flow control is off. For more information, see Chapter 7, “Configuring Interface Characteristics.”
  - PortFast is enabled on the internal Gigabit Ethernet ports. For more information, see Chapter 14, “Configuring Optional Spanning-Tree Features.”

- No Smartports macros are defined. For more information, see Chapter 8, “Configuring Smartports Macros.”
VLANs
- Default VLAN is VLAN 1. For more information, see Chapter 9, “Configuring VLANs.”
- VLAN trunking setting is dynamic auto (DTP). For more information, see Chapter 9, “Configuring VLANs.”
- Trunk encapsulation is negotiate. For more information, see Chapter 9, “Configuring VLANs.”
- VTP mode is server. For more information, see Chapter 10, “Configuring VTP.”
- VTP version is Version 1. For more information, see Chapter 10, “Configuring VTP.”
- Voice VLAN is disabled. For more information, see Chapter 11, “Configuring Voice VLAN.”

STP, PVST+ is enabled on VLAN 1. For more information, see Chapter 12, “Configuring STP.”

MSTP is disabled. For more information, see Chapter 13, “Configuring MSTP.”

Optional spanning-tree features are disabled. For more information, see Chapter 14, “Configuring Optional Spanning-Tree Features.”

Flex Links are not configured. For more information, see Chapter 15, “Configuring Flex Links and the MAC Address-Table Move Update Feature.”

DHCP snooping is disabled. The DHCP snooping information option is enabled. For more information, see Chapter 16, “Configuring DHCP Features.”

IGMP snooping is enabled. No IGMP filters are applied. For more information, see Chapter 17, “Configuring IGMP Snooping and MVR.”

IGMP throttling setting is deny. For more information, see Chapter 17, “Configuring IGMP Snooping and MVR.”

The IGMP snooping querier feature is disabled. For more information, see Chapter 17, “Configuring IGMP Snooping and MVR.”

MVR is disabled. For more information, see Chapter 17, “Configuring IGMP Snooping and MVR.”

Port-based traffic
- Broadcast, multicast, and unicast storm control is disabled. For more information, see Chapter 18, “Configuring Port-Based Traffic Control.”
- No protected ports are defined. For more information, see Chapter 18, “Configuring Port-Based Traffic Control.”
- Unicast and multicast traffic flooding is not blocked. For more information, see Chapter 18, “Configuring Port-Based Traffic Control.”
- No secure ports are configured. For more information, see Chapter 18, “Configuring Port-Based Traffic Control.”

CDP is enabled. For more information, see Chapter 19, “Configuring CDP.”

UDLD is disabled. For more information, see Chapter 21, “Configuring UDLD.”

SPAN and RSPAN are disabled. For more information, see Chapter 22, “Configuring SPAN and RSPAN.”

RMON is disabled. For more information, see Chapter 23, “Configuring RMON.”

Syslog messages are enabled and appear on the console. For more information, see Chapter 24, “Configuring System Message Logging.”

SNMP is enabled (Version 1). For more information, see Chapter 25, “Configuring SNMP.”

No ACLs are configured. For more information, see Chapter 26, “Configuring Network Security with ACLs.”
QoS is disabled. For more information, see Chapter 27, “Configuring QoS.”

No EtherChannels are configured. For more information, see Chapter 28, “Configuring EtherChannels and Layer 2 Trunk Failover.”

**Design Concepts for Using the Switch**

As your network users compete for network bandwidth, it takes longer to send and receive data. When you configure your network, consider the bandwidth required by your network users and the relative priority of the network applications that they use.

Table 1-1 describes what can cause network performance to degrade and how you can configure your network to increase the bandwidth available to your network users.

### Table 1-1 Increasing Network Performance

<table>
<thead>
<tr>
<th>Network Demands</th>
<th>Suggested Design Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too many users on a single network segment and a growing number of users</td>
<td>• Create smaller network segments so that fewer users share the bandwidth, and use VLANs and IP subnets to place the network resources in the same logical network as the users who access those resources most.</td>
</tr>
<tr>
<td>and a growing number of users accessing the Internet</td>
<td>• Use full-duplex operation between the switch and its connected workstations.</td>
</tr>
<tr>
<td>• Increased power of new PCs, workstations, and servers</td>
<td>• Connect global resources—such as servers and routers to which the network users require equal access—directly to the high-speed switch ports so that they have their own high-speed segment.</td>
</tr>
<tr>
<td>• High bandwidth demand from networked applications (such as e-mail with large attached files) and from bandwidth-intensive applications (such as multimedia)</td>
<td>• Use the EtherChannel feature between the switch and its connected servers and routers.</td>
</tr>
</tbody>
</table>

Bandwidth alone is not the only consideration when designing your network. As your network traffic profiles evolve, consider providing network services that can support applications for voice and data integration, multimedia integration, application prioritization, and security. Table 1-2 describes some network demands and how you can meet them.

### Table 1-2 Providing Network Services

<table>
<thead>
<tr>
<th>Network Demands</th>
<th>Suggested Design Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient bandwidth usage for multimedia applications and guaranteed bandwidth for critical applications</td>
<td>• Use IGMP snooping to efficiently forward multimedia and multicast traffic.</td>
</tr>
<tr>
<td></td>
<td>• Use other QoS mechanisms such as packet classification, marking, scheduling, and congestion avoidance to classify traffic with the appropriate priority level, thereby providing maximum flexibility and support for mission-critical, unicast, and multicast and multimedia applications.</td>
</tr>
<tr>
<td></td>
<td>• Use MVR to continuously send multicast streams in a multicast VLAN but to isolate the streams from subscriber VLANs for bandwidth and security reasons.</td>
</tr>
<tr>
<td>High demand on network redundancy and availability to provide always on mission-critical applications</td>
<td>• Use VLAN trunks and BackboneFast for traffic-load balancing on the uplink ports so that the uplink port with a lower relative port cost is selected to carry the VLAN traffic.</td>
</tr>
</tbody>
</table>
You can use the switches to create the following:

- Cost-effective Gigabit-to-the-blade server for high-performance workgroups (Figure 1-1)—For high-speed access to network resources, you can use the blade switches in the access layer to provide Gigabit Ethernet to the blade servers. To prevent congestion, use QoS DSCP marking priorities on these switches. For high-speed IP forwarding at the distribution layer, connect the switches in the access layer to a Gigabit multilayer switch with routing capability, such as a Catalyst 3750 switch, or to a router.

  The first illustration is of an isolated high-performance workgroup, where the blade switches are connected to Catalyst 3750 switches in the distribution layer.

  Each blade switch in this configuration provides users with a dedicated 1-Gb/s connection to network resources. Using SFP modules also provides flexibility in media and distance options through fiber-optic connections.

Table 1-2  Providing Network Services (continued)

<table>
<thead>
<tr>
<th>Network Demands</th>
<th>Suggested Design Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>An evolving demand for IP telephony</td>
<td>• Use QoS to prioritize applications such as IP telephony during congestion and to help control both delay and jitter within the network.</td>
</tr>
<tr>
<td></td>
<td>• Use switches that support at least two queues per port to prioritize voice and data traffic as either high- or low-priority, based on IEEE 802.1p/Q. The switch supports at least four queues per port.</td>
</tr>
<tr>
<td></td>
<td>• Use voice VLAN IDs (VVIDs) to provide separate VLANs for voice traffic.</td>
</tr>
<tr>
<td>A growing demand for using existing infrastructure to transport data and voice from a home or office to the Internet or an intranet at higher speeds</td>
<td>Use the Catalyst Long-Reach Ethernet (LRE) switches to provide up to 15 Mb of IP connectivity over existing infrastructure, such as existing telephone lines.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong>  LRE is the technology used in the Catalyst 2900 LRE XL and Catalyst 2950 LRE switches. See the documentation sets specific to these switches for LRE information.</td>
</tr>
</tbody>
</table>
Server aggregation (Figure 1-2)—You can use the switches to interconnect groups of servers, centralizing physical security and administration of your network. For high-speed IP forwarding at the distribution layer, connect the switches in the access layer to multilayer switches with routing capability. The Gigabit interconnections minimize latency in the data flow.

QoS and policing on the blade switches provide preferential treatment for certain data streams. They segment traffic streams into different paths for processing. Security features on the blade switch ensure rapid handling of packets.

Fault tolerance from the server racks to the core is achieved through dual homing of servers connected to the blade switches, which have redundant Gigabit EtherChannels.

Using dual SFP module uplinks from the blade switches provides redundant uplinks to the network core. Using SFP modules provides flexibility in media and distance options through fiber-optic connections.

Figure 1-2 Server Aggregation

Where to Go Next

Before configuring the switch, review these sections for startup information:

- Chapter 2, “Using the Command-Line Interface”
- Chapter 3, “Assigning the Switch IP Address and Default Gateway”
Using the Command-Line Interface

This chapter describes the Cisco IOS command-line interface (CLI) and how to use it to configure your switch. It contains these sections:

- Understanding Command Modes, page 2-1
- Understanding the Help System, page 2-3
- Understanding Abbreviated Commands, page 2-4
- Understanding no and default Forms of Commands, page 2-4
- Understanding CLI Error Messages, page 2-5
- Using Configuration Logging, page 2-5
- Using Command History, page 2-6
- Using Editing Features, page 2-7
- Searching and Filtering Output of show and more Commands, page 2-10
- Accessing the CLI, page 2-10

Understanding Command Modes

The Cisco IOS user interface is divided into many different modes. The commands available to you depend on which mode you are currently in. Enter a question mark (?) at the system prompt to obtain a list of commands available for each command mode.

When you start a session on the switch, you begin in user mode, often called user EXEC mode. Only a limited subset of the commands are available in user EXEC mode. For example, most of the user EXEC commands are one-time commands, such as `show` commands, which show the current configuration status, and `clear` commands, which clear counters or interfaces. The user EXEC commands are not saved when the switch reboots.

To have access to all commands, you must enter privileged EXEC mode. Normally, you must enter a password to enter privileged EXEC mode. From this mode, you can enter any privileged EXEC command or enter global configuration mode.

Using the configuration modes (global, interface, and line), you can make changes to the running configuration. If you save the configuration, these commands are stored and used when the switch reboots. To access the various configuration modes, you must start at global configuration mode. From global configuration mode, you can enter interface configuration mode and line configuration mode.
Table 2-1 describes the main command modes, how to access each one, the prompt you see in that mode, and how to exit the mode. The examples in the table use the hostname *Switch.*

### Table 2-1  Command Mode Summary

<table>
<thead>
<tr>
<th>Mode</th>
<th>Access Method</th>
<th>Prompt</th>
<th>Exit Method</th>
<th>About This Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>User EXEC</td>
<td>Begin a session with your switch.</td>
<td>Switch&gt;</td>
<td>Enter <strong>logout</strong> or <strong>quit</strong>.</td>
<td>Use this mode to&lt;br&gt;Change terminal settings.&lt;br&gt;Perform basic tests.&lt;br&gt;Display system information.</td>
</tr>
<tr>
<td>Privileged EXEC</td>
<td>While in user EXEC mode, enter the <strong>enable</strong> command.</td>
<td>Switch#</td>
<td>Enter <strong>disable</strong> to exit.</td>
<td>Use this mode to verify commands that you have entered. Use a password to protect access to this mode.</td>
</tr>
<tr>
<td>Global configuration</td>
<td>While in privileged EXEC mode, enter the <strong>configure</strong> command.</td>
<td>Switch(config)#</td>
<td>To exit to privileged EXEC mode, enter <strong>exit</strong> or <strong>end</strong>, or press <strong>Ctrl-Z</strong>.</td>
<td>Use this mode to configure parameters that apply to the entire switch.</td>
</tr>
<tr>
<td>Config-vlan</td>
<td>While in global configuration mode, enter the <strong>vlan vlan-id</strong> command.</td>
<td>Switch(config-vlan)#</td>
<td>To exit to global configuration mode, enter the <strong>exit</strong> command.&lt;br&gt;To return to privileged EXEC mode, press <strong>Ctrl-Z</strong> or enter <strong>end</strong>.</td>
<td>Use this mode to configure VLAN parameters. When VTP mode is transparent, you can create extended-range VLANs (VLAN IDs greater than 1005) and save configurations in the switch startup configuration file.</td>
</tr>
<tr>
<td>VLAN configuration</td>
<td>While in privileged EXEC mode, enter the <strong>vlan database</strong> command.</td>
<td>Switch(vlan)#</td>
<td>To exit to privileged EXEC mode, enter <strong>exit</strong>.</td>
<td>Use this mode to configure VLAN parameters for VLANs 1 to 1005 in the VLAN database.</td>
</tr>
</tbody>
</table>
Chapter 2  Using the Command-Line Interface

Understanding the Help System

You can enter a question mark (?) at the system prompt to display a list of commands available for each command mode. You can also obtain a list of associated keywords and arguments for any command, as shown in Table 2-2.

Table 2-2  Help Summary

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>help</td>
<td>Obtain a brief description of the help system in any command mode.</td>
</tr>
<tr>
<td>abbreviated-command-entry?</td>
<td>Obtain a list of commands that begin with a particular character string.</td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>Switch# di?</td>
<td></td>
</tr>
<tr>
<td>dir disable disconnect</td>
<td></td>
</tr>
<tr>
<td>abbreviated-command-entry&lt;Tab&gt;</td>
<td>Complete a partial command name.</td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>Switch# sh conf&lt;Tab&gt;</td>
<td></td>
</tr>
<tr>
<td>Switch# show configuration</td>
<td></td>
</tr>
</tbody>
</table>
### Understanding Abbreviated Commands

You need to enter only enough characters for the switch to recognize the command as unique.

This example shows how to enter the `show configuration` privileged EXEC command in an abbreviated form:

```
Switch# show conf
```

### Understanding no and default Forms of Commands

Almost every configuration command also has a `no` form. In general, use the `no` form to disable a feature or function or reverse the action of a command. For example, the `no shutdown` interface configuration command reverses the shutdown of an interface. Use the command without the keyword `no` to re-enable a disabled feature or to enable a feature that is disabled by default.

Configuration commands can also have a `default` form. The `default` form of a command returns the command setting to its default. Most commands are disabled by default, so the `default` form is the same as the `no` form. However, some commands are enabled by default and have variables set to certain default values. In these cases, the `default` command enables the command and sets variables to their default values.

---

**Table 2-2 Help Summary (continued)**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>List all commands available for a particular command mode. For example: <code>Switch&gt; ?</code></td>
</tr>
<tr>
<td><code>command ?</code></td>
<td>List the associated keywords for a command. For example: <code>Switch&gt; show ?</code></td>
</tr>
</tbody>
</table>
| `command keyword ?` | List the associated arguments for a keyword. For example: `Switch(config)# cdp holdtime ?`  
<10-255> Length of time (in sec) that receiver must keep this packet
Understanding CLI Error Messages

Table 2-3 lists some error messages that you might encounter while using the CLI to configure your switch.

Table 2-3 Common CLI Error Messages

<table>
<thead>
<tr>
<th>Error Message</th>
<th>Meaning</th>
<th>How to Get Help</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Ambiguous command: &quot;show con&quot;</td>
<td>You did not enter enough characters for your switch to recognize the command.</td>
<td>Re-enter the command followed by a question mark (?) with a space between the command and the question mark. The possible keywords that you can enter with the command appear.</td>
</tr>
<tr>
<td>% Incomplete command.</td>
<td>You did not enter all the keywords or values required by this command.</td>
<td>Re-enter the command followed by a question mark (?) with a space between the command and the question mark. The possible keywords that you can enter with the command appear.</td>
</tr>
<tr>
<td>% Invalid input detected at '^' marker.</td>
<td>You entered the command incorrectly. The caret (^) marks the point of the error.</td>
<td>Enter a question mark (?) to display all the commands that are available in this command mode. The possible keywords that you can enter with the command appear.</td>
</tr>
</tbody>
</table>

Using Configuration Logging

You can log and view changes to the switch configuration. You can use the Configuration Change Logging and Notification feature to track changes on a per-session and per-user basis. The logger tracks each configuration command that is applied, the user who entered the command, the time that the command was entered, and the parser return code for the command. This feature includes a mechanism for asynchronous notification to registered applications whenever the configuration changes. You can choose to have the notifications sent to the syslog.

For more information, see the Configuration Change Notification and Logging feature module at this URL:


Note

Only CLI or HTTP changes are logged.
Using Command History

The software provides a history or record of commands that you have entered. The command history feature is particularly useful for recalling long or complex commands or entries, including access lists. You can customize this feature to suit your needs as described in these sections:

- Changing the Command History Buffer Size, page 2-6 (optional)
- Recalling Commands, page 2-6 (optional)
- Disabling the Command History Feature, page 2-7 (optional)

Changing the Command History Buffer Size

By default, the switch records ten command lines in its history buffer. You can alter this number for a current terminal session or for all sessions on a particular line. These procedures are optional.

Beginning in privileged EXEC mode, enter this command to change the number of command lines that the switch records during the current terminal session:

```
Switch# terminal history [size number-of-lines]
```

The range is from 0 to 256.

Beginning in line configuration mode, enter this command to configure the number of command lines the switch records for all sessions on a particular line:

```
Switch(config-line)# history [size number-of-lines]
```

The range is from 0 to 256.

Recalling Commands

To recall commands from the history buffer, perform one of the actions listed in Table 2-4. These actions are optional.

<table>
<thead>
<tr>
<th>Action</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press Ctrl-P or the up arrow key.</td>
<td>Recall commands in the history buffer, beginning with the most recent command. Repeat the key sequence to recall successively older commands.</td>
</tr>
<tr>
<td>Press Ctrl-N or the down arrow key.</td>
<td>Return to more recent commands in the history buffer after recalling commands with Ctrl-P or the up arrow key. Repeat the key sequence to recall successively more recent commands.</td>
</tr>
<tr>
<td>show history</td>
<td>While in privileged EXEC mode, list the last several commands that you just entered. The number of commands that appear is controlled by the setting of the terminal history global configuration command and the history line configuration command.</td>
</tr>
</tbody>
</table>

1. The arrow keys function only on ANSI-compatible terminals such as VT100s.
Disabling the Command History Feature

The command history feature is automatically enabled. You can disable it for the current terminal session or for the command line. These procedures are optional.

To disable the feature during the current terminal session, enter the `terminal no history` privileged EXEC command.

To disable command history for the line, enter the `no history` line configuration command.

Using Editing Features

This section describes the editing features that can help you manipulate the command line. It contains these sections:

- Enabling and Disabling Editing Features, page 2-7 (optional)
- Editing Commands through Keystrokes, page 2-7 (optional)
- Editing Command Lines that Wrap, page 2-9 (optional)

Enabling and Disabling Editing Features

Although enhanced editing mode is automatically enabled, you can disable it, re-enable it, or configure a specific line to have enhanced editing. These procedures are optional.

To globally disable enhanced editing mode, enter this command in line configuration mode:

```
Switch (config-line)# no editing
```

To re-enable the enhanced editing mode for the current terminal session, enter this command in privileged EXEC mode:

```
Switch# terminal editing
```

To reconfigure a specific line to have enhanced editing mode, enter this command in line configuration mode:

```
Switch(config-line)# editing
```

Editing Commands through Keystrokes

Table 2-5 shows the keystrokes that you need to edit command lines. These keystrokes are optional.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move around the command line to make changes or corrections.</td>
<td>Press Ctrl-B, or press the left arrow key.</td>
<td>Move the cursor back one character.</td>
</tr>
</tbody>
</table>
### Using Editing Features

**Recall commands from the buffer and paste them in the command line.** The switch provides a buffer with the last ten items that you deleted.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press Ctrl-F, or press the right arrow key.</td>
<td>Move the cursor forward one character.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-A.</td>
<td>Move the cursor to the beginning of the command line.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-E.</td>
<td>Move the cursor to the end of the command line.</td>
<td></td>
</tr>
<tr>
<td>Press Esc B.</td>
<td>Move the cursor back one word.</td>
<td></td>
</tr>
<tr>
<td>Press Esc F.</td>
<td>Move the cursor forward one word.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-T.</td>
<td>Transpose the character to the left of the cursor with the character located at the cursor.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-Y.</td>
<td>Recall the most recent entry in the buffer.</td>
<td></td>
</tr>
<tr>
<td>Press Esc Y.</td>
<td>Recall the next buffer entry. The buffer contains only the last 10 items that you have deleted or cut. If you press Esc Y more than ten times, you cycle to the first buffer entry.</td>
<td></td>
</tr>
</tbody>
</table>

**Delete entries if you make a mistake or change your mind.**

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press Ctrl-D.</td>
<td>Delete the character at the cursor.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-K.</td>
<td>Delete all characters from the cursor to the end of the command line.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-U or Ctrl-X.</td>
<td>Delete all characters from the cursor to the beginning of the command line.</td>
<td></td>
</tr>
<tr>
<td>Press Ctrl-W.</td>
<td>Delete the word to the left of the cursor.</td>
<td></td>
</tr>
<tr>
<td>Press Esc D.</td>
<td>Delete from the cursor to the end of the word.</td>
<td></td>
</tr>
</tbody>
</table>

**Capitalize or lowercase words or capitalize a set of letters.**

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press Esc C.</td>
<td>Capitalize at the cursor.</td>
<td></td>
</tr>
<tr>
<td>Press Esc L.</td>
<td>Change the word at the cursor to lowercase.</td>
<td></td>
</tr>
<tr>
<td>Press Esc U.</td>
<td>Capitalize letters from the cursor to the end of the word.</td>
<td></td>
</tr>
</tbody>
</table>

**Designate a particular keystroke as an executable command, perhaps as a shortcut.**

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press Ctrl-V or Esc Q.</td>
<td>Capitalize letters from the cursor to the end of the word.</td>
<td></td>
</tr>
</tbody>
</table>

---

1. Use Esc Q to copy the buffer entry to the command line.
Using Editing Features

Chapter 2      Using the Command-Line Interface

Editing Command Lines that Wrap

You can use a wraparound feature for commands that extend beyond a single line on the screen. When the cursor reaches the right margin, the command line shifts ten spaces to the left. You cannot see the first ten characters of the line, but you can scroll back and check the syntax at the beginning of the command. The keystroke actions are optional.

To scroll back to the beginning of the command entry, press Ctrl-B or the left arrow key repeatedly. You can also press Ctrl-A to immediately move to the beginning of the line.

The arrow keys function only on ANSI-compatible terminals such as VT100s.

In this example, the access-list global configuration command entry extends beyond one line. When the cursor first reaches the end of the line, the line is shifted ten spaces to the left and redisplayed. The dollar sign ($) shows that the line has been scrolled to the left. Each time the cursor reaches the end of the line, the line is again shifted ten spaces to the left.

Switch(config)# access-list 101 permit tcp 131.108.2.5 255.255.255.0 131.108.1$
Switch(config)# $ 101 permit tcp 131.108.2.5 255.255.255.0 131.108.1.20 255.255.255.0 eq
Switch(config)# $t tcp 131.108.2.5 255.255.255.0 131.108.1.20 255.255.255.0 eq 45

After you complete the entry, press Ctrl-A to check the complete syntax before pressing the Return key to execute the command. The dollar sign ($) appears at the end of the line to show that the line has been scrolled to the right:

Switch(config)# access-list 101 permit tcp 131.108.2.5 255.255.255.0 131.108.1$

The software assumes you have a terminal screen that is 80 columns wide. If you have a width other than that, use the terminal width privileged EXEC command to set the width of your terminal.

Use line wrapping with the command history feature to recall and modify previous complex command entries. For information about recalling previous command entries, see the “Editing Commands through Keystrokes” section on page 2-7.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Keystroke¹</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scroll down a line or screen on displays that are longer than the terminal screen can display.</td>
<td>Press the Return key.</td>
<td>Scroll down one line.</td>
</tr>
<tr>
<td>Note</td>
<td>The More prompt is used for any output that has more lines than can be displayed on the terminal screen, including show command output. You can use the Return and Space bar keystrokes whenever you see the More prompt.</td>
<td>Press the Space bar.</td>
</tr>
<tr>
<td>Redisplay the current command line if the switch suddenly sends a message to your screen.</td>
<td>Press Ctrl-L or Ctrl-R.</td>
<td>Redisplay the current command line.</td>
</tr>
</tbody>
</table>

¹. The arrow keys function only on ANSI-compatible terminals such as VT100s.
Searching and Filtering Output of show and more Commands

You can search and filter the output for show and more commands. This is useful when you need to sort through large amounts of output or if you want to exclude output that you do not need to see. Using these commands is optional.

To use this functionality, enter a show or more command followed by the pipe character (|), one of the keywords \begin, \include, or \exclude, and an expression that you want to search for or filter out:

\texttt{command} \texttt{| \begin | \include | \exclude} \texttt{regular-expression}

Expressions are case sensitive. For example, if you enter \texttt{| exclude output}, the lines that contain \texttt{output} are not displayed, but the lines that contain \texttt{Output} appear.

This example shows how to include in the output display only lines where the expression \texttt{protocol} appears:

\begin{verbatim}
Switch# show interfaces | include protocol
Vlan1 is up, line protocol is up
Vlan10 is up, line protocol is down
GigabitEthernet0/1 is up, line protocol is down
GigabitEthernet0/2 is up, line protocol is up
\end{verbatim}

Accessing the CLI

You can access the CLI through a console connection, through Telnet, or by using the browser.

Accessing the CLI through a Console Connection or through Telnet

Before you can access the CLI, you must connect a terminal or PC to the switch console port and power on the switch, as described in the hardware installation guide that shipped with your switch. Then, to understand the boot up process and the options available for assigning IP information, see Chapter 3, “Assigning the Switch IP Address and Default Gateway.”

If your switch is already configured, you can access the CLI through a local console connection or through a remote Telnet session, but your switch must first be configured for this type of access. For more information, see the “Setting a Telnet Password for a Terminal Line” section on page 5-6.

You can use one of these methods to establish a connection with the switch:

- Connect the switch console port to a management station or dial-up modem. For information about connecting to the console port, see the switch hardware installation guide.
- Use any Telnet TCP/IP or encrypted Secure Shell (SSH) package from a remote management station. The switch must have network connectivity with the Telnet or SSH client, and the switch must have an enable secret password configured.

For information about configuring the switch for Telnet access, see the “Setting a Telnet Password for a Terminal Line” section on page 5-6. The switch supports up to 16 simultaneous Telnet sessions. Changes made by one Telnet user are reflected in all other Telnet sessions.

For information about configuring the switch for SSH, see the “Configuring the Switch for Secure Shell” section on page 5-37. The switch supports up to five simultaneous secure SSH sessions.

After you connect through the console port, through a Telnet session or through an SSH session, the user EXEC prompt appears on the management station.
Assigning the Switch IP Address and Default Gateway

This chapter describes how to create the initial switch configuration (for example, assigning the IP address and default gateway information) by using a variety of automatic and manual methods. It also describes how to modify the switch startup configuration.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release and the Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services, Release 12.2.

This chapter consists of these sections:
- Understanding the Bootup Process, page 3-1
- Assigning Switch Information, page 3-2
- Checking and Saving the Running Configuration, page 3-11
- Modifying the Startup Configuration, page 3-12
- Scheduling a Reload of the Software Image, page 3-16

Understanding the Bootup Process

To start your switch, you need to follow the procedures in the getting started guide or the hardware installation guide for installing and powering on the switch and setting up the initial switch configuration (IP address, subnet mask, default gateway, secret and Telnet passwords, and so forth).

The normal bootup process involves the operation of the bootloader software, which performs these activities:
- Performs low-level CPU initialization. It initializes the CPU registers, which control where physical memory is mapped, its quantity, its speed, and so forth.
- Performs power-on self-test (POST) for the CPU subsystem. It tests the CPU DRAM and the portion of the flash device that makes up the flash file system.
- Initializes the flash file system on the system board.
- Loads a default operating system software image into memory and boots the switch.
The bootloader provides access to the flash file system before the operating system is loaded. Normally, the bootloader is used only to load, uncompress, and launch the operating system. After the bootloader gives the operating system control of the CPU, the bootloader is not active until the next system reset or power-on.

The bootloader also provides trap-door access into the system if the operating system has problems serious enough that it cannot be used. The trap-door mechanism provides enough access to the system so that if it is necessary, you can format the flash file system, reinstall the operating system software image by using the Xmodem Protocol, recover from a lost or forgotten password, and finally restart the operating system. For more information, see the “Recovering from a Software Failure” section on page 29-2 and the “Recovering from a Lost or Forgotten Password” section on page 29-3.

Note
You can disable password recovery. For more information, see the “Disabling Password Recovery” section on page 5-5.

Before you can assign switch information, make sure you have connected a PC or terminal to the console port, and configured the PC or terminal-emulation software baud rate and character format to match these of the switch console port:

- Baud rate default is 9600.
- Data bits default is 8.

Note
If the data bits option is set to 8, set the parity option to none.

- Stop bits default is 1.
- Parity settings default is none.

Assigning Switch Information

You can assign IP information through the switch setup program, through a DHCP server, or manually. Use the switch setup program if you want to be prompted for specific IP information. With this program, you can also configure a hostname and an enable secret password. It gives you the option of assigning a Telnet password (to provide security during remote management) and configuring your switch as a command or member switch of a cluster or as a standalone switch. For more information about the setup program, see the hardware installation guide.

Use a DHCP server for centralized control and automatic assignment of IP information after the server is configured.

Note
If you are using DHCP, do not respond to any of the questions in the setup program until the switch receives the dynamically assigned IP address and reads the configuration file.
Assigning Switch Information

If you are an experienced user familiar with the switch configuration steps, manually configure the switch. Otherwise, use the setup program described previously.

These sections contain this configuration information:

- Default Switch Information, page 3-3
- Understanding DHCP-Based Autoconfiguration, page 3-3
- Manually Assigning IP Information, page 3-10

Default Switch Information

Table 3-1 shows the default switch information.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCHP client</td>
<td>Enabled.</td>
</tr>
<tr>
<td>IP address and subnet mask</td>
<td>No specific IP address or subnet mask are defined.</td>
</tr>
<tr>
<td>Default gateway</td>
<td>No specific default gateway is defined.</td>
</tr>
<tr>
<td>Enable secret password</td>
<td>No specific password is defined.</td>
</tr>
<tr>
<td>Hostname</td>
<td>The factory-assigned default hostname is Switch.</td>
</tr>
<tr>
<td>Telnet password</td>
<td>No specific password is defined.</td>
</tr>
<tr>
<td>Cluster command switch function</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Cluster name</td>
<td>No specific cluster name is defined.</td>
</tr>
</tbody>
</table>

Understanding DHCP-Based Autoconfiguration

DHCP provides configuration information to Internet hosts and internetworking devices. This protocol consists of two components: one for delivering configuration parameters from a DHCP server to a device and a mechanism for allocating network addresses to devices. DHCP is built on a client-server model, in which designated DHCP servers allocate network addresses and deliver configuration parameters to dynamically configured devices. The switch can act as both a DHCP client and a DHCP server.

During DHCP-based autoconfiguration, your switch (DHCP client) is automatically configured at startup with IP address information and a configuration file.

With DHCP-based autoconfiguration, no DHCP client-side configuration is needed on your switch. However, you need to configure the DHCP server for various lease options associated with IP addresses. If you are using DHCP to relay the configuration file location on the network, you might also need to configure a Trivial File Transfer Protocol (TFTP) server and a Domain Name System (DNS) server.

The DHCP server for your switch can be on the same LAN or on a different LAN than the switch. If the DHCP server is running on a different LAN, you should configure a DHCP relay device between your switch and the DHCP server. A relay device forwards broadcast traffic between two directly connected LANs. A router does not forward broadcast packets, but it forwards packets based on the destination IP address in the received packet.

DHCP-based autoconfiguration replaces the BOOTP client functionality on your switch.
**DHCP Client Request Process**

When you boot up your switch, the DHCP client is invoked and requests configuration information from a DHCP server when the configuration file is not present on the switch. If the configuration file is present and the configuration includes the `ip address dhcp` interface configuration command on specific routed interfaces, the DHCP client is invoked and requests the IP address information for those interfaces.

**Figure 3-1** shows the sequence of messages that are exchanged between the DHCP client and the DHCP server.

**Figure 3-1  DHCP Client and Server Message Exchange**

The client, Switch A, broadcasts a DHCPDISCOVER message to locate a DHCP server. The DHCP server offers configuration parameters (such as an IP address, subnet mask, gateway IP address, DNS IP address, a lease for the IP address, and so forth) to the client in a DHCPOFFER unicast message.

In a DHCPREQUEST broadcast message, the client returns a formal request for the offered configuration information to the DHCP server. The formal request is broadcast so that all other DHCP servers that received the DHCPDISCOVER broadcast message from the client can reclaim the IP addresses that they offered to the client.

The DHCP server confirms that the IP address has been allocated to the client by returning a DHCPACK unicast message to the client. With this message, the client and server are bound, and the client uses configuration information received from the server. The amount of information the switch receives depends on how you configure the DHCP server. For more information, see the “Configuring the TFTP Server” section on page 3-6.

If the configuration parameters sent to the client in the DHCPOFFER unicast message are invalid (a configuration error exists), the client returns a DHCPDECLINE broadcast message to the DHCP server.

The DHCP server sends the client a DHCPNAK denial broadcast message, which means that the offered configuration parameters have not been assigned, that an error has occurred during the negotiation of the parameters, or that the client has been slow in responding to the DHCPOFFER message (the DHCP server assigned the parameters to another client).

A DHCP client might receive offers from multiple DHCP or BOOTP servers and can accept any of the offers; however, the client usually accepts the first offer it receives. The offer from the DHCP server is not a guarantee that the IP address is allocated to the client; however, the server usually reserves the address until the client has had a chance to formally request the address. If the switch accepts replies from a BOOTP server and configures itself, the switch broadcasts, instead of unicasts, TFTP requests to obtain the switch configuration file.
Configuring DHCP-Based Autoconfiguration

These sections contain this configuration information:

- DHCP Server Configuration Guidelines, page 3-5
- Configuring the TFTP Server, page 3-6
- Configuring the DNS, page 3-6
- Configuring the Relay Device, page 3-6
- Obtaining Configuration Files, page 3-7
- Example Configuration, page 3-8

If your DHCP server is a Cisco device, see the “Configuring DHCP” section of the “IP Addressing and Services” section of the Cisco IOS IP Configuration Guide, Release 12.2 for additional information about configuring DHCP.

DHCP Server Configuration Guidelines

Follow these guidelines if you are configuring a device as a DHCP server:

You should configure the DHCP server with reserved leases that are bound to each switch by the switch hardware address.

If you want the switch to receive IP address information, you must configure the DHCP server with these lease options:

- IP address of the client (required)
- Subnet mask of the client (required)
- DNS server IP address (optional)
- Router IP address (default gateway address to be used by the switch) (required)

If you want the switch to receive the configuration file from a TFTP server, you must configure the DHCP server with these lease options:

- TFTP server name (required)
- Boot filename (the name of the configuration file that the client needs) (recommended)
- Hostname (optional)

Depending on the settings of the DHCP server, the switch can receive IP address information, the configuration file, or both.

If you do not configure the DHCP server with the lease options described previously, it replies to client requests with only those parameters that are configured. If the IP address and the subnet mask are not in the reply, the switch is not configured. If the router IP address or the TFTP server name are not found, the switch might send broadcast, instead of unicast, TFTP requests. Unavailability of other lease options does not affect autoconfiguration.
Configuring the TFTP Server

Based on the DHCP server configuration, the switch attempts to download one or more configuration files from the TFTP server. If you configured the DHCP server to respond to the switch with all the options required for IP connectivity to the TFTP server, and if you configured the DHCP server with a TFTP server name, address, and configuration filename, the switch attempts to download the specified configuration file from the specified TFTP server.

If you did not specify the configuration filename, the TFTP server, or if the configuration file could not be downloaded, the switch attempts to download a configuration file by using various combinations of filenames and TFTP server addresses. The files include the specified configuration filename (if any) and these files: network-config, cisconet.cfg, hostname.config, or hostname.cfg, where hostname is the switch’s current hostname. The TFTP server addresses used include the specified TFTP server address (if any) and the broadcast address (255.255.255.255).

For the switch to successfully download a configuration file, the TFTP server must contain one or more configuration files in its base directory. The files can include these files:

- The configuration file named in the DHCP reply (the actual switch configuration file).
- The network-config or the cisconet.cfg file (known as the default configuration files).
- The router-config or the ciscortr.cfg file (These files contain commands common to all switches. Normally, if the DHCP and TFTP servers are properly configured, these files are not accessed.)

If you specify the TFTP server name in the DHCP server-lease database, you must also configure the TFTP server name-to-IP-address mapping in the DNS-server database.

If the TFTP server to be used is on a different LAN from the switch, or if it is to be accessed by the switch through the broadcast address (which occurs if the DHCP server response does not contain all the required information described previously), a relay must be configured to forward the TFTP packets to the TFTP server. For more information, see the “Configuring the Relay Device” section on page 3-6. The preferred solution is to configure the DHCP server with all the required information.

Configuring the DNS

The DHCP server uses the DNS server to resolve the TFTP server name to an IP address. You must configure the TFTP server name-to-IP address map on the DNS server. The TFTP server contains the configuration files for the switch.

You can configure the IP addresses of the DNS servers in the lease database of the DHCP server from where the DHCP replies will retrieve them. You can enter up to two DNS server IP addresses in the lease database.

The DNS server can be on the same or on a different LAN as the switch. If it is on a different LAN, the switch must be able to access it through a router.

Configuring the Relay Device

You must configure a relay device, also referred to as a relay agent, when a switch sends broadcast packets that require a response from a host on a different LAN. Examples of broadcast packets that the switch might send are DHCP, DNS, and in some cases, TFTP packets. You must configure this relay device to forward received broadcast packets on an interface to the destination host.

If the relay device is a Cisco router, enable IP routing (ip routing global configuration command), and configure helper addresses by using the ip helper-address interface configuration command.
For example, in Figure 3-2, configure the router interfaces as follows:

On interface 10.0.0.2:
```
router(config-if)# ip helper-address 20.0.0.2
router(config-if)# ip helper-address 20.0.0.3
router(config-if)# ip helper-address 20.0.0.4
```

On interface 20.0.0.1
```
router(config-if)# ip helper-address 10.0.0.1
```

**Figure 3-2 Relay Device Used in Autoconfiguration**

Obtaining Configuration Files

Depending on the availability of the IP address and the configuration filename in the DHCP reserved lease, the switch obtains its configuration information in these ways:

- The IP address and the configuration filename is reserved for the switch and provided in the DHCP reply (one-file read method).
  
  The switch receives its IP address, subnet mask, TFTP server address, and the configuration filename from the DHCP server. The switch sends a unicast message to the TFTP server to retrieve the named configuration file from the base directory of the server and upon receipt, it completes its bootup process.

- The IP address and the configuration filename is reserved for the switch, but the TFTP server address is not provided in the DHCP reply (one-file read method).
  
  The switch receives its IP address, subnet mask, and the configuration filename from the DHCP server. The switch sends a broadcast message to a TFTP server to retrieve the named configuration file from the base directory of the server, and upon receipt, it completes its bootup process.

- Only the IP address is reserved for the switch and provided in the DHCP reply. The configuration filename is not provided (two-file read method).
  
  The switch receives its IP address, subnet mask, and the TFTP server address from the DHCP server. The switch sends a unicast message to the TFTP server to retrieve the network-config or cisconet.cfg default configuration file. (If the network-config file cannot be read, the switch reads the cisconet.cfg file.)
Assigning Switch Information

The default configuration file contains the hostnames-to-IP-address mapping for the switch. The switch fills its host table with the information in the file and obtains its hostname. If the hostname is not found in the file, the switch uses the hostname in the DHCP reply. If the hostname is not specified in the DHCP reply, the switch uses the default Switch as its hostname.

After obtaining its hostname from the default configuration file or the DHCP reply, the switch reads the configuration file that has the same name as its hostname (hostname-config or hostname.cfg, depending on whether network-config or cisconet.cfg was read earlier) from the TFTP server. If the cisconet.cfg file is read, the filename of the host is truncated to eight characters.

If the switch cannot read the network-config, cisconet.cfg, or the hostname file, it reads the router-config file. If the switch cannot read the router-config file, it reads the ciscortr.cfg file.

Note
The switch broadcasts TFTP server requests if the TFTP server is not obtained from the DHCP replies, if all attempts to read the configuration file through unicast transmissions fail, or if the TFTP server name cannot be resolved to an IP address.

Example Configuration

Figure 3-3 shows a sample network for retrieving IP information by using DHCP-based autoconfiguration.

![Figure 3-3: DHCP-Based Autoconfiguration Network Example](image)

Table 3-2 shows the configuration of the reserved leases on the DHCP server.

<table>
<thead>
<tr>
<th>Table 3-2: DHCP Server Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Switch A</strong></td>
</tr>
<tr>
<td>Binding key (hardware address)</td>
</tr>
<tr>
<td>IP address</td>
</tr>
<tr>
<td>Subnet mask</td>
</tr>
<tr>
<td>Router address</td>
</tr>
<tr>
<td>DNS server address</td>
</tr>
<tr>
<td>TFTP server name</td>
</tr>
</tbody>
</table>
Assigning Switch Information

DNS Server Configuration

The DNS server maps the TFTP server name tftpserver to IP address 10.0.0.3.

TFTP Server Configuration (on UNIX)

The TFTP server base directory is set to /tftpserver/work/. This directory contains the network-confg file used in the two-file read method. This file contains the hostname to be assigned to the switch based on its IP address. The base directory also contains a configuration file for each switch (switcha-confg, switchb-confg, and so forth) as shown in this display:

```
prompt> cd /tftpserver/work/
prompt> ls
network-confg
switcha-confg
switchb-confg
switchc-confg
switchd-confg
prompt> cat network-confg
ip host switcha 10.0.0.21
ip host switchb 10.0.0.22
ip host switchc 10.0.0.23
ip host switchd 10.0.0.24
```

DHCP Client Configuration

No configuration file is present on Switch A through Switch D.

Configuration Explanation

In Figure 3-3, Switch A reads its configuration file as follows:

- It obtains its IP address 10.0.0.21 from the DHCP server.
- If no configuration filename is given in the DHCP server reply, Switch A reads the network-confg file from the base directory of the TFTP server.
- It adds the contents of the network-confg file to its host table.
- It reads its host table by indexing its IP address 10.0.0.21 to its hostname (switcha).
- It reads the configuration file that corresponds to its hostname; for example, it reads switch1-confg from the TFTP server.

Switches B through D retrieve their configuration files and IP addresses in the same way.

### Table 3-2 DHCP Server Configuration (continued)

<table>
<thead>
<tr>
<th></th>
<th>Switch A</th>
<th>Switch B</th>
<th>Switch C</th>
<th>Switch D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boot filename</td>
<td>switcha-confg</td>
<td>switchb-confg</td>
<td>switchc-confg</td>
<td>switchd-confg</td>
</tr>
<tr>
<td>(configuration file)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(optional)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hostname</td>
<td>switcha</td>
<td>switchb</td>
<td>switchc</td>
<td>switchd</td>
</tr>
<tr>
<td>(optional)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Manually Assigning IP Information

Beginning in privileged EXEC mode, follow these steps to manually assign IP information to multiple switched virtual interfaces (SVIs):

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface vlan vlan-id Enter interface configuration mode, and enter the VLAN to which the IP information is assigned. The VLAN range is 1 to 4094.</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip address ip-address subnet-mask Enter the IP address and subnet mask.</td>
</tr>
<tr>
<td>Step 4</td>
<td>exit Return to global configuration mode.</td>
</tr>
<tr>
<td>Step 5</td>
<td>ip default-gateway ip-address Enter the IP address of the next-hop router interface that is directly connected to the switch where a default gateway is being configured. The default gateway receives IP packets with unresolved destination IP addresses from the switch. Once the default gateway is configured, the switch has connectivity to the remote networks with which a host needs to communicate. <strong>Note</strong> When your switch is configured to route with IP, it does not need to have a default gateway set.</td>
</tr>
<tr>
<td>Step 6</td>
<td>end Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7</td>
<td>show interfaces vlan vlan-id Verify the configured IP address.</td>
</tr>
<tr>
<td>Step 8</td>
<td>show ip redirects Verify the configured default gateway.</td>
</tr>
<tr>
<td>Step 9</td>
<td>copy running-config startup-config (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove the switch IP address, use the **no ip address** interface configuration command. If you are removing the address through a Telnet session, your connection to the switch will be lost. To remove the default gateway address, use the **no ip default-gateway** global configuration command.

All VLAN interfaces have assigned MAC addresses that are derived from the base MAC address. The base MAC address is the hardware address that is on the switch label. It also appears when you enter the **show version** privileged EXEC command.

On the first VLAN interface (VLAN 1), the MAC address is the base MAC address + 0 x 40. On the next VLAN interface that you configure, the MAC address is the base MAC address + 0 x 40 +1, and so on for other VLAN interfaces.

You can enter the **show interfaces vlan vlan-id** privileged EXEC command to show the MAC and IP addresses. The MAC addresses that appear in the **show interfaces vlan vlan-id** command output are not the same as the MAC address that is printed on the switch label (the base MAC address).

By default, VLAN 1 is the interface that connects to the management network. When the switch boots up, the DHCP client (switch) requests an IP address from a DHCP server by using the MAC address of VLAN 1.

For information on setting the switch system name, protecting access to privileged EXEC commands, and setting time and calendar services, see Chapter 4, “Administering the Switch.”
Checking and Saving the Running Configuration

You can check the configuration settings that you entered or changes that you made by entering this privileged EXEC command:

```
Switch# show running-config
Building configuration...
Current configuration : 1833 bytes
!
version 12.2
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
no aaa new-model
ip subnet-zero
!
no file verify auto
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
interface GigabitEthernet0/1
  switchport trunk encapsulation dot1q
  switchport mode trunk
  speed 1000
  spanning-tree portfast
!
interface GigabitEthernet0/2
  switchport access vlan 2
  speed 1000
  storm-control unicast level 50.00
  storm-control action shutdown
  spanning-tree portfast
!
<output truncated>
!
interface Vlan1
  ip address 192.168.100.21 255.255.255.0
  no ip route-cache
!
ip http server
ip http secure-server
!
control-plane
!
!
line con 0
  exec-timeout 0 0
line vty 0 4
  no login
line vty 5 15
  no login
!
end
```
To store the configuration or changes you have made to your startup configuration in flash memory, enter this privileged EXEC command:

```
Switch# copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
```

This command saves the configuration settings that you made. If you fail to do this, your configuration will be lost the next time you reload the system. To display information stored in the NVRAM section of flash memory, use the `show startup-config` or `more startup-config` privileged EXEC command.

For more information about alternative locations from which to copy the configuration file, see Appendix B, “Working with the Cisco IOS File System, Configuration Files, and Software Images.”

## Modifying the Startup Configuration

These sections describe how to modify the switch startup configuration:

- Default Bootup Configuration, page 3-12
- Automatically Downloading a Configuration File, page 3-13
- Booting Up Manually, page 3-13
- Booting Up a Specific Software Image, page 3-14
- Controlling Environment Variables, page 3-15

See also Appendix B, “Working with the Cisco IOS File System, Configuration Files, and Software Images,” for information about switch configuration files.

## Default Bootup Configuration

Table 3-3 shows the default bootup configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating system software image</td>
<td>The switch attempts to automatically boot up the system using information in the BOOT environment variable. If the variable is not set, the switch attempts to load and execute the first executable image it can by performing a recursive, depth-first search throughout the flash file system. The Cisco IOS image is stored in a directory that has the same name as the image file (excluding the .bin extension). In a depth-first search of a directory, each encountered subdirectory is completely searched before continuing the search in the original directory.</td>
</tr>
<tr>
<td>Configuration file</td>
<td>Configured switches use the <code>config.text</code> file stored on the system board in flash memory. A new switch has no configuration file.</td>
</tr>
</tbody>
</table>
Automatically Downloading a Configuration File

You can automatically download a configuration file to your switch by using the DHCP-based autoconfiguration feature. For more information, see the “Understanding DHCP-Based Autoconfiguration” section on page 3-3.

Specifying the Filename to Read and Write the System Configuration

By default, the Cisco IOS software uses the file `config.text` to read and write a nonvolatile copy of the system configuration. However, you can specify a different filename, which will be loaded during the next bootup cycle.

Beginning in privileged EXEC mode, follow these steps to specify a different configuration filename:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>boot config-file flash:/file-url</td>
<td>Specify the configuration file to load during the next bootup cycle. For <code>file-url</code>, specify the path (directory) and the configuration filename. Filenames and directory names are case sensitive.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>4</td>
<td>show boot</td>
<td>Verify your entries. The <code>boot config-file</code> global configuration command changes the setting of the CONFIG_FILE environment variable.</td>
</tr>
<tr>
<td>5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no boot config-file` global configuration command.

Booting Up Manually

By default, the switch automatically boots up; however, you can configure it to manually boot up.

Beginning in privileged EXEC mode, follow these steps to configure the switch to manually boot up during the next bootup cycle:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>boot manual</td>
<td>Enable the switch to manually boot up during the next bootup cycle.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
### Step 4

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| `show boot`      | Verify your entries. The **boot manual** global command changes the setting of the MANUAL_BOOT environment variable. The next time you reboot the system, the switch is in bootloader mode, shown by the `switch:` prompt. To boot up the system, use the **boot filesystem:file-url** bootloader command.  
- For `filesystem:`, use **flash:** for the system board flash device.  
- For `file-url`, specify the path (directory) and the name of the bootable image. Filenames and directory names are case sensitive. |

### Step 5

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable manual booting up, use the **no boot manual** global configuration command.

---

## Booting Up a Specific Software Image

By default, the switch attempts to automatically boot up the system using information in the BOOT environment variable. If this variable is not set, the switch attempts to load and execute the first executable image it can by performing a recursive, depth-first search throughout the flash file system. In a depth-first search of a directory, each encountered subdirectory is completely searched before continuing the search in the original directory. However, you can specify a specific image with which to boot up the switch.

Beginning in privileged EXEC mode, follow these steps to configure the switch to boot up a specific image during the next bootup cycle:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>configure terminal</code></td>
<td></td>
</tr>
</tbody>
</table>
| **Step 2**        | Configure the switch to boot up a specific image in flash memory during the next bootup cycle.  
- For `filesystem:`, use **flash:** for the system board flash device.  
- For `file-url`, specify the path (directory) and the name of the bootable image. Filenames and directory names are case sensitive. |
| `boot system filesystem:file-url` |                                                                 |
| **Step 3**        | Return to privileged EXEC mode.                                          |
| `end`             |                                                                         |
| **Step 4**        | Verify your entries. The **boot system** global command changes the setting of the BOOT environment variable. During the next bootup cycle, the switch attempts to automatically boot up the system using information in the BOOT environment variable. |
| `show boot`       |                                                                         |
| **Step 5**        | (Optional) Save your entries in the configuration file.                 |
| `copy running-config startup-config` |                                                                         |

To return to the default setting, use the **no boot system** global configuration command.
Controlling Environment Variables

With a normally operating switch, you enter the boot loader mode only through a switch console connection configured for 9600 bps. Unplug the switch power cord, and press the switch Mode button while reconnecting the power cord. You can release the Mode button a second or two after the LED above port 1 turns off. Then the boot loader switch: prompt appears.

The switch bootloader software provides support for nonvolatile environment variables, which can be used to control how the bootloader, or any other software running on the system, behaves. bootloader environment variables are similar to environment variables that can be set on UNIX or DOS systems.

Environment variables that have values are stored in flash memory outside of the flash file system.

Each line in these files contains an environment variable name and an equal sign followed by the value of the variable. A variable has no value if it is not listed in this file; it has a value if it is listed in the file even if the value is a null string. A variable that is set to a null string (for example, “” ) is a variable with a value. Many environment variables are predefined and have default values.

Environment variables store two kinds of data:

- Data that controls code, which does not read the Cisco IOS configuration file. For example, the name of a bootloader helper file, which extends or patches the functionality of the bootloader can be stored as an environment variable.

- Data that controls code, which is responsible for reading the Cisco IOS configuration file. For example, the name of the Cisco IOS configuration file can be stored as an environment variable.

You can change the settings of the environment variables by accessing the bootloader or by using Cisco IOS commands. Under normal circumstances, it is not necessary to alter the setting of the environment variables.

Note

For complete syntax and usage information for the bootloader commands and environment variables, see the command reference for this release.
Table 3-4 describes the function of the most common environment variables.

### Table 3-4   Environment Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bootloader Command</th>
<th>Cisco IOS Global Configuration Command</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOOT</strong></td>
<td>set BOOT filesystem:/file-url ...</td>
<td>boot system filesystem:/file-url ...</td>
</tr>
<tr>
<td></td>
<td>A semicolon-separated list of executable files to try to load and execute when automatically booting up the switch. If the BOOT environment variable is not set, the system attempts to load and execute the first executable image it can find by using a recursive, depth-first search through the flash file system. If the BOOT variable is set but the specified images cannot be loaded, the system attempts to boot up the first bootable file that it can find in the flash file system.</td>
<td>Specifies the Cisco IOS image to load during the next bootup cycle. This command changes the setting of the BOOT environment variable.</td>
</tr>
<tr>
<td><strong>MANUAL_BOOT</strong></td>
<td>set MANUAL_BOOT yes</td>
<td>boot manual</td>
</tr>
<tr>
<td></td>
<td>Decides whether the switch automatically or manually boots up. Valid values are 1, yes, 0, and no. If it is set to no or 0, the bootloader attempts to automatically boot up the system. If it is set to anything else, you must manually boot up the switch from the bootloader mode.</td>
<td>Enables manually booting up the switch during the next bootup cycle and changes the setting of the MANUAL_BOOT environment variable. The next time you reboot the system, the switch is in bootloader mode. To boot up the system, use the boot flash:filesystem:/file-url bootloader command, and specify the name of the bootable image.</td>
</tr>
<tr>
<td><strong>CONFIG_FILE</strong></td>
<td>set CONFIG_FILE flash:/file-url</td>
<td>boot config-file flash:/file-url</td>
</tr>
<tr>
<td></td>
<td>Changes the filename that Cisco IOS uses to read and write a nonvolatile copy of the system configuration.</td>
<td>Specifies the filename that Cisco IOS uses to read and write a nonvolatile copy of the system configuration. This command changes the CONFIG_FILE environment variable.</td>
</tr>
</tbody>
</table>

### Scheduling a Reload of the Software Image

You can schedule a reload of the software image to occur on the switch at a later time (for example, late at night or during the weekend when the switch is used less), or you can synchronize a reload network-wide (for example, to perform a software upgrade on all switches in the network).

**Note**

A scheduled reload must take place within approximately 24 days.
Configuring a Scheduled Reload

To configure your switch to reload the software image at a later time, use one of these commands in privileged EXEC mode:

- **reload in [hh:mm] [text]**
  
  This command schedules a reload of the software to take effect in the specified minutes or hours and minutes. The reload must take place within approximately 24 days. You can specify the reason for the reload in a string up to 255 characters in length.

- **reload at hh:mm [month day | day month] [text]**
  
  This command schedules a reload of the software to take place at the specified time (using a 24-hour clock). If you specify the month and day, the reload is scheduled to take place at the specified time and date. If you do not specify the month and day, the reload takes place at the specified time on the current day (if the specified time is later than the current time) or on the next day (if the specified time is earlier than the current time). Specifying 00:00 schedules the reload for midnight.

  **Note** Use the *at* keyword only if the switch system clock has been set (through Network Time Protocol (NTP), the hardware calendar, or manually). The time is relative to the configured time zone on the switch. To schedule reloads across several switches to occur simultaneously, the time on each switch must be synchronized with NTP.

The **reload** command halts the system. If the system is not set to manually boot up, it reboots itself. Use the **reload** command after you save the switch configuration information to the startup configuration (**copy running-config startup-config**).

If your switch is configured for manual booting up, do not reload it from a virtual terminal. This restriction prevents the switch from entering the bootloader mode and thereby taking it from the remote user’s control.

If you modify your configuration file, the switch prompts you to save the configuration before reloading. During the save operation, the system requests whether you want to proceed with the save if the CONFIG_FILE environment variable points to a startup configuration file that no longer exists. If you proceed in this situation, the system enters setup mode upon reload.

This example shows how to reload the software on the switch on the current day at 7:30 p.m:

```
Switch# reload at 19:30
Reload scheduled for 19:30:00 UTC Wed Jun 5 1996 (in 2 hours and 25 minutes)
Proceed with reload? [confirm]
```

This example shows how to reload the software on the switch at a future time:

```
Switch# reload at 02:00 jun 20
Reload scheduled for 02:00:00 UTC Thu Jun 20 1996 (in 344 hours and 53 minutes)
Proceed with reload? [confirm]
```

To cancel a previously scheduled reload, use the **reload cancel** privileged EXEC command.
Displaying Scheduled Reload Information

To display information about a previously scheduled reload or to find out if a reload has been scheduled on the switch, use the `show reload` privileged EXEC command.

It displays reload information including the time the reload is scheduled to occur and the reason for the reload (if it was specified when the reload was scheduled).
Administering the Switch

This chapter describes how to perform one-time operations to administer the switch.

This chapter consists of these sections:
- Managing the System Time and Date, page 4-1
- Configuring a System Name and Prompt, page 4-14
- Creating a Banner, page 4-17
- Managing the MAC Address Table, page 4-19
- Managing the ARP Table, page 4-26

Managing the System Time and Date

You can manage the system time and date on your switch using automatic configuration, such as the Network Time Protocol (NTP), or manual configuration methods.

Note

For complete syntax and usage information for the commands used in this section, see the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

These sections contain this configuration information:
- Understanding the System Clock, page 4-1
- Understanding Network Time Protocol, page 4-2
- Configuring NTP, page 4-3
- Configuring Time and Date Manually, page 4-11

Understanding the System Clock

The heart of the time service is the system clock. This clock runs from the moment the system starts up and keeps track of the date and time.

The system clock can then be set from these sources:
- NTP
- Manual configuration
The system clock can provide time to these services:

- User `show` commands
- Logging and debugging messages

The system clock keeps track of time internally based on Universal Time Coordinated (UTC), also known as Greenwich Mean Time (GMT). You can configure information about the local time zone and summer time (daylight saving time) so that the time appears correctly for the local time zone.

The system clock keeps track of whether the time is authoritative or not (that is, whether it has been set by a time source considered to be authoritative). If it is not authoritative, the time is available only for display purposes and is not redistributed. For configuration information, see the “Configuring Time and Date Manually” section on page 4-11.

**Understanding Network Time Protocol**

The NTP is designed to time-synchronize a network of devices. NTP runs over User Datagram Protocol (UDP), which runs over IP. NTP is documented in RFC 1305.

An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the network. NTP is extremely efficient; no more than one packet per minute is necessary to synchronize two devices to within a millisecond of one another.

NTP uses the concept of a *stratum* to describe how many NTP hops away a device is from an authoritative time source. A stratum 1 time server has a radio or atomic clock directly attached, a stratum 2 time server receives its time through NTP from a stratum 1 time server, and so on. A device running NTP automatically chooses as its time source the device with the lowest stratum number with which it communicates through NTP. This strategy effectively builds a self-organizing tree of NTP speakers.

NTP avoids synchronizing to a device whose time might not be accurate by never synchronizing to a device that is not synchronized. NTP also compares the time reported by several devices and does not synchronize to a device whose time is significantly different than the others, even if its stratum is lower.

The communications between devices running NTP (known as *associations*) are usually statically configured; each device is given the IP address of all devices with which it should form associations. Accurate timekeeping is possible by exchanging NTP messages between each pair of devices with an association. However, in a LAN environment, NTP can be configured to use IP broadcast messages instead. This alternative reduces configuration complexity because each device can simply be configured to send or receive broadcast messages. However, in that case, information flow is one-way only.

The time kept on a device is a critical resource; you should use the security features of NTP to avoid the accidental or malicious setting of an incorrect time. Two mechanisms are available: an access list-based restriction scheme and an encrypted authentication mechanism.

Cisco’s implementation of NTP does not support stratum 1 service; it is not possible to connect to a radio or atomic clock. We recommend that the time service for your network be derived from the public NTP servers available on the IP Internet.
Figure 4-1 shows a typical network example using NTP. Switch A is the NTP master, with Switches B, C, and D configured in NTP server mode, in server association with Switch A. Switch E is configured as an NTP peer to the upstream and downstream switches, Switch B and Switch F.

Figure 4-1  Typical NTP Network Configuration

If the network is isolated from the Internet, Cisco’s implementation of NTP allows a device to act as if it is synchronized through NTP, when in fact it has learned the time by using other means. Other devices then synchronize to that device through NTP.

When multiple sources of time are available, NTP is always considered to be more authoritative. NTP time overrides the time set by any other method.

Several manufacturers include NTP software for their host systems, and a publicly available version for systems running UNIX and its various derivatives is also available. This software allows host systems to be time-synchronized as well.

Configuring NTP

The switch does not have a hardware-supported clock and cannot function as an NTP master clock to which peers synchronize themselves when an external NTP source is not available. The switch also has no hardware support for a calendar. As a result, the ntp update-calendar and the ntp master global configuration commands are not available.
Managing the System Time and Date

Chapter 4  Administering the Switch

These sections contain this configuration information:

- Default NTP Configuration, page 4-4
- Configuring NTP Authentication, page 4-4
- Configuring NTP Associations, page 4-5
- Configuring NTP Broadcast Service, page 4-6
- Configuring NTP Access Restrictions, page 4-8
- Configuring the Source IP Address for NTP Packets, page 4-10
- Displaying the NTP Configuration, page 4-11

Default NTP Configuration

Table 4-1 shows the default NTP configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTP authentication</td>
<td>Disabled. No authentication key is specified.</td>
</tr>
<tr>
<td>NTP peer or server associations</td>
<td>None configured.</td>
</tr>
<tr>
<td>NTP broadcast service</td>
<td>Disabled; no interface sends or receives NTP broadcast packets.</td>
</tr>
<tr>
<td>NTP access restrictions</td>
<td>No access control is specified.</td>
</tr>
<tr>
<td>NTP packet source IP address</td>
<td>The source address is set by the outgoing interface.</td>
</tr>
</tbody>
</table>

NTP is enabled on all interfaces by default. All interfaces receive NTP packets.

Configuring NTP Authentication

This procedure must be coordinated with the administrator of the NTP server; the information you configure in this procedure must be matched by the servers used by the switch to synchronize its time to the NTP server.

Beginning in privileged EXEC mode, follow these steps to authenticate the associations (communications between devices running NTP that provide for accurate timekeeping) with other devices for security purposes:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>ntp authenticate</td>
<td>Enable the NTP authentication feature, which is disabled by default.</td>
</tr>
</tbody>
</table>
Managing the System Time and Date

To disable NTP authentication, use the `no ntp authenticate` global configuration command. To remove an authentication key, use the `no ntp authentication-key number md5` global configuration command. To disable authentication of the identity of a device, use the `no ntp trusted-key key-number` global configuration command.

This example shows how to configure the switch to synchronize only to devices providing authentication key 42 in the device’s NTP packets:

```
Switch(config)# ntp authenticate
Switch(config)# ntp authentication-key 42 md5 aNiceKey
Switch(config)# ntp trusted-key 42
```

Configuring NTP Associations

An NTP association can be a peer association (this switch can either synchronize to the other device or allow the other device to synchronize to it), or it can be a server association (meaning that only this switch synchronizes to the other device, and not the other way around).
Beginning in privileged EXEC mode, follow these steps to form an NTP association with another device:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>ntp peer ip-address [version number] [key keyid] [source interface] [prefer]</td>
<td>Configure the switch system clock to synchronize a peer or to be</td>
</tr>
<tr>
<td></td>
<td>synchronized by a peer (peer association).</td>
</tr>
<tr>
<td>or ntp server ip-address [version number] [key keyid] [source interface] [prefer]</td>
<td>Configure the switch system clock to be synchronized by a time server</td>
</tr>
<tr>
<td></td>
<td>(server association).</td>
</tr>
<tr>
<td></td>
<td>No peer or server associations are defined by default.</td>
</tr>
<tr>
<td></td>
<td>• For ip-address in a peer association, specify either the IP address of</td>
</tr>
<tr>
<td></td>
<td>the peer providing, or being provided, the clock synchronization. For</td>
</tr>
<tr>
<td></td>
<td>a server association, specify the IP address of the time server</td>
</tr>
<tr>
<td></td>
<td>providing the clock synchronization.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For number, specify the NTP version number. The range</td>
</tr>
<tr>
<td></td>
<td>is 1 to 3. By default, Version 3 is selected.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For keyid, enter the authentication key defined with the</td>
</tr>
<tr>
<td></td>
<td>ntp authentication-key global configuration command.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For interface, specify the interface from which to pick</td>
</tr>
<tr>
<td></td>
<td>the IP source address. By default, the source IP address is taken from</td>
</tr>
<tr>
<td></td>
<td>the outgoing interface.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) Enter the prefer keyword to make this peer or server the</td>
</tr>
<tr>
<td></td>
<td>preferred one that provides synchronization. This keyword reduces</td>
</tr>
<tr>
<td></td>
<td>switching back and forth between peers and servers.</td>
</tr>
<tr>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

You need to configure only one end of an association; the other device can automatically establish the association. If you are using the default NTP version (Version 3) and NTP synchronization does not occur, try using NTP Version 2. Many NTP servers on the Internet run Version 2.

To remove a peer or server association, use the no ntp peer ip-address or the no ntp server ip-address global configuration command.

This example shows how to configure the switch to synchronize its system clock with the clock of the peer at IP address 172.16.22.44 using NTP Version 2:

Switch(config)# ntp server 172.16.22.44 version 2

### Configuring NTP Broadcast Service

The communications between devices running NTP (known as associations) are usually statically configured; each device is given the IP addresses of all devices with which it should form associations. Accurate timekeeping is possible by exchanging NTP messages between each pair of devices with an association. However, in a LAN environment, NTP can be configured to use IP broadcast messages instead. This alternative reduces configuration complexity because each device can simply be configured to send or receive broadcast messages. However, the information flow is one-way only.
The switch can send or receive NTP broadcast packets on an interface-by-interface basis if there is an NTP broadcast server, such as a router, broadcasting time information on the network. The switch can send NTP broadcast packets to a peer so that the peer can synchronize to it. The switch can also receive NTP broadcast packets to synchronize its own clock. This section provides procedures for both sending and receiving NTP broadcast packets.

Beginning in privileged EXEC mode, follow these steps to configure the switch to send NTP broadcast packets to peers so that they can synchronize their clock to the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>ntp broadcast [version number] [key keyid] [destination-address]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td>Step 7</td>
<td></td>
</tr>
</tbody>
</table>

To disable the interface from sending NTP broadcast packets, use the no ntp broadcast interface configuration command.

This example shows how to configure a port to send NTP Version 2 packets:

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ntp broadcast version 2
```

Beginning in privileged EXEC mode, follow these steps to configure the switch to receive NTP broadcast packets from connected peers:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>ntp broadcast client</td>
</tr>
<tr>
<td>Step 4</td>
<td>exit</td>
</tr>
</tbody>
</table>
Managing the System Time and Date

To disable an interface from receiving NTP broadcast packets, use the `no ntp broadcast client` interface configuration command. To change the estimated round-trip delay to the default, use the `no ntp broadcastdelay` global configuration command.

This example shows how to configure a port to receive NTP broadcast packets:

```plaintext
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ntp broadcast client
```

### Configuring NTP Access Restrictions

You can control NTP access on two levels as described in these sections:

- Creating an Access Group and Assigning a Basic IP Access List, page 4-8
- Disabling NTP Services on a Specific Interface, page 4-10

#### Creating an Access Group and Assigning a Basic IP Access List

Beginning in privileged EXEC mode, follow these steps to control access to NTP services by using access lists:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>ntp access-group { query-only</td>
</tr>
</tbody>
</table>

Create an access group, and apply a basic IP access list. The keywords have these meanings:

- `query-only`—Allows only NTP control queries.
- `serve-only`—Allows only time requests.
- `serve`—Allows time requests and NTP control queries, but does not allow the switch to synchronize to the remote device.
- `peer`—Allows time requests and NTP control queries and allows the switch to synchronize to the remote device.

For `access-list-number`, enter a standard IP access list number from 1 to 99.
Managing the System Time and Date

The access group keywords are scanned in this order, from least restrictive to most restrictive:

1. **peer**—Allows time requests and NTP control queries and allows the switch to synchronize itself to a device whose address passes the access list criteria.
2. **serve**—Allows time requests and NTP control queries, but does not allow the switch to synchronize itself to a device whose address passes the access list criteria.
3. **serve-only**—Allows only time requests from a device whose address passes the access list criteria.
4. **query-only**—Allows only NTP control queries from a device whose address passes the access list criteria.

If the source IP address matches the access lists for more than one access type, the first type is granted. If no access groups are specified, all access types are granted to all devices. If any access groups are specified, only the specified access types are granted.

To remove access control to the switch NTP services, use the `no ntp access-group {query-only | serve-only | serve | peer}` global configuration command.

This example shows how to configure the switch to allow itself to synchronize to a peer from access list 99. However, the switch restricts access to allow only time requests from access list 42:

```bash
Switch# configure terminal
Switch(config)# ntp access-group peer 99
Switch(config)# ntp access-group serve-only 42
Switch(config)# access-list 99 permit 172.20.130.5
Switch(config)# access list 42 permit 172.20.130.6
```
Disabling NTP Services on a Specific Interface

NTP services are enabled on all interfaces by default.

Beginning in privileged EXEC mode, follow these steps to disable NTP packets from being received on an interface:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>interface interface-id</td>
<td>Enter interface configuration mode, and specify the interface to disable.</td>
</tr>
<tr>
<td>3</td>
<td>ntp disable</td>
<td>Disable NTP packets from being received on the interface. By default, all interfaces receive NTP packets.</td>
</tr>
<tr>
<td>4</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>5</td>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>6</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To re-enable receipt of NTP packets on an interface, use the no ntp disable interface configuration command.

Configuring the Source IP Address for NTP Packets

When the switch sends an NTP packet, the source IP address is normally set to the address of the interface through which the NTP packet is sent. Use the ntp source global configuration command when you want to use a particular source IP address for all NTP packets. The address is taken from the specified interface. This command is useful if the address on an interface cannot be used as the destination for reply packets.

Beginning in privileged EXEC mode, follow these steps to configure a specific interface from which the IP source address is to be taken:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>ntp source type number</td>
<td>Specify the interface type and number from which the IP source address is taken. By default, the source address is set by the outgoing interface.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>4</td>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

The specified interface is used for the source address for all packets sent to all destinations. If a source address is to be used for a specific association, use the source keyword in the ntp peer or ntp server global configuration command as described in the “Configuring NTP Associations” section on page 4-5.
Displaying the NTP Configuration

You can use two privileged EXEC commands to display NTP information:

- `show ntp associations [detail]`
- `show ntp status`

For detailed information about the fields in these displays, see the *Cisco IOS Configuration Fundamentals Command Reference, Release 12.2*.

Configuring Time and Date Manually

If no other source of time is available, you can manually configure the time and date after the system is restarted. The time remains accurate until the next system restart. We recommend that you use manual configuration only as a last resort. If you have an outside source to which the switch can synchronize, you do not need to manually set the system clock.

These sections contain this configuration information:

- Setting the System Clock, page 4-11
- Displaying the Time and Date Configuration, page 4-12
- Configuring the Time Zone, page 4-12
- Configuring Summer Time (Daylight Saving Time), page 4-13

Setting the System Clock

If you have an outside source on the network that provides time services, such as an NTP server, you do not need to manually set the system clock.

Beginning in privileged EXEC mode, follow these steps to set the system clock:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><code>clock set hh:mm:ss day month year</code> or <code>clock set hh:mm:ss month day year</code></td>
<td>Manually set the system clock using one of these formats.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For <code>hh:mm:ss</code>, specify the time in hours (24-hour format), minutes, and seconds. The time specified is relative to the configured time zone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For <code>day</code>, specify the day by date in the month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For <code>month</code>, specify the month by name.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For <code>year</code>, specify the year (no abbreviation).</td>
</tr>
</tbody>
</table>

This example shows how to manually set the system clock to 1:32 p.m. on July 23, 2001:

```
Switch# clock set 13:32:00 23 July 2001
```
Displaying the Time and Date Configuration

To display the time and date configuration, use the `show clock [detail]` privileged EXEC command.

The system clock keeps an authoritative flag that shows whether the time is authoritative (believed to be accurate). If the system clock has been set by a timing source such as NTP, the flag is set. If the time is not authoritative, it is used only for display purposes. Until the clock is authoritative and the authoritative flag is set, the flag prevents peers from synchronizing to the clock when the peers’ time is invalid.

The symbol that precedes the `show clock` display has this meaning:

- *—Time is not authoritative.
- (blank)—Time is authoritative.
- .—Time is authoritative, but NTP is not synchronized.

Configuring the Time Zone

Beginning in privileged EXEC mode, follow these steps to manually configure the time zone:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 clock timezone zone hours-offset</td>
<td>Set the time zone. The switch keeps internal time in universal time coordinated (UTC), so this command is used only for display purposes and when the time is manually set.</td>
</tr>
<tr>
<td>minutes-offset</td>
<td></td>
</tr>
<tr>
<td>For zone, enter the name of the time zone to be displayed when standard time is in effect. The default is UTC.</td>
<td></td>
</tr>
<tr>
<td>For hours-offset, enter the hours offset from UTC.</td>
<td></td>
</tr>
<tr>
<td>(Optional) For minutes-offset, enter the minutes offset from UTC.</td>
<td></td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

The minutes-offset variable in the `clock timezone` global configuration command is available for those cases where a local time zone is a percentage of an hour different from UTC. For example, the time zone for some sections of Atlantic Canada (AST) is UTC-3.5, where the 3 means 3 hours and .5 means 50 percent. In this case, the necessary command is `clock timezone AST -3 30`.

To set the time to UTC, use the `no clock timezone` global configuration command.
Configuring Summer Time (Daylight Saving Time)

Beginning in privileged EXEC mode, follow these steps to configure summer time (daylight saving time) in areas where it starts and ends on a particular day of the week each year:

### Command Purpose

<table>
<thead>
<tr>
<th>Step 1</th>
<th>configure terminal</th>
<th>Enter global configuration mode.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>clock summer-time zone recurring [week day month hh:mm week day month hh:mm [offset]]</td>
<td>Configure summer time to start and end on the specified days every year. Summer time is disabled by default. If you specify clock summer-time zone recurring without parameters, the summer time rules default to the United States rules.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• For zone, specify the name of the time zone (for example, PDT) to be displayed when summer time is in effect.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For week, specify the week of the month (1 to 5 or last).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For day, specify the day of the week (Sunday, Monday...).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For month, specify the month (January, February...).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For hh:mm, specify the time (24-hour format) in hours and minutes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For offset, specify the number of minutes to add during summer time. The default is 60.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4</td>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

The first part of the `clock summer-time` global configuration command specifies when summer time begins, and the second part specifies when it ends. All times are relative to the local time zone. The start time is relative to standard time. The end time is relative to summer time. If the starting month is after the ending month, the system assumes that you are in the southern hemisphere.

This example shows how to specify that summer time starts on the first Sunday in April at 02:00 and ends on the last Sunday in October at 02:00:

```
Switch(config)# clock summer-time PDT recurring 1 Sunday April 2:00 last Sunday October 2:00
```
Beginning in privileged EXEC mode, follow these steps if summer time in your area does not follow a recurring pattern (configure the exact date and time of the next summer time events):

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>clock summer-time zone date [month date year hh:mm month date year hh:mm [offset]]</td>
</tr>
<tr>
<td></td>
<td>or clock summer-time zone date [date month year hh:mm date month year hh:mm [offset]]</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show running-config</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

The first part of the `clock summer-time` global configuration command specifies when summer time begins, and the second part specifies when it ends. All times are relative to the local time zone. The start time is relative to standard time. The end time is relative to summer time. If the starting month is after the ending month, the system assumes that you are in the southern hemisphere.

To disable summer time, use the `no clock summer-time` global configuration command.

This example shows how to set summer time to start on October 12, 2000, at 02:00, and end on April 26, 2001, at 02:00:

```
Switch(config)# clock summer-time pdt date 12 October 2000 2:00 26 April 2001 2:00
```

## Configuring a System Name and Prompt

You configure the system name on the switch to identify it. By default, the system name and prompt are `Switch`.

If you have not configured a system prompt, the first 20 characters of the system name are used as the system prompt. A greater-than symbol `>:` is appended. The prompt is updated whenever the system name changes.

For complete syntax and usage information for the commands used in this section, see the *Cisco IOS Configuration Fundamentals Command Reference, Release 12.2* and the *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols, Release 12.2*. 
These sections contain this configuration information:

- Default System Name and Prompt Configuration, page 4-15
- Configuring a System Name, page 4-15
- Understanding DNS, page 4-15

Default System Name and Prompt Configuration

The default switch system name and prompt is Switch.

Configuring a System Name

Beginning in privileged EXEC mode, follow these steps to manually configure a system name:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 hostname name</td>
<td>Manually configure a system name.</td>
</tr>
<tr>
<td></td>
<td>The default setting is switch.</td>
</tr>
<tr>
<td></td>
<td>The name must follow the rules for ARPANET hostnames. They must start</td>
</tr>
<tr>
<td></td>
<td>with a letter, end with a letter or digit, and have as interior</td>
</tr>
<tr>
<td></td>
<td>characters only letters, digits, and hyphens. Names can be up to 63</td>
</tr>
<tr>
<td></td>
<td>characters.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

When you set the system name, it is also used as the system prompt.

To return to the default hostname, use the no hostname global configuration command.

Understanding DNS

The DNS protocol controls the Domain Name System (DNS), a distributed database with which you can map hostnames to IP addresses. When you configure DNS on your switch, you can substitute the hostname for the IP address with all IP commands, such as ping, telnet, connect, and related Telnet support operations.

IP defines a hierarchical naming scheme that allows a device to be identified by its location or domain. Domain names are pieced together with periods (.) as the delimiting characters. For example, Cisco Systems is a commercial organization that IP identifies by a com domain name, so its domain name is cisco.com. A specific device in this domain, for example, the File Transfer Protocol (FTP) system is identified as ftp.cisco.com.

To keep track of domain names, IP has defined the concept of a domain name server, which holds a cache (or database) of names mapped to IP addresses. To map domain names to IP addresses, you must first identify the hostnames, specify the name server that is present on your network, and enable the DNS.
These sections contain this configuration information:

- Default DNS Configuration, page 4-16
- Setting Up DNS, page 4-16
- Displaying the DNS Configuration, page 4-17

Default DNS Configuration

Table 4-2 shows the default DNS configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNS enable state</td>
<td>Enabled.</td>
</tr>
<tr>
<td>DNS default domain name</td>
<td>None configured.</td>
</tr>
<tr>
<td>DNS servers</td>
<td>No name server addresses are configured.</td>
</tr>
</tbody>
</table>

Setting Up DNS

Beginning in privileged EXEC mode, follow these steps to set up your switch to use the DNS:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>ip domain-name name</td>
<td>Define a default domain name that the software uses to complete unqualified hostnames (names without a dotted-decimal domain name). Do not include the initial period that separates an unqualified name from the domain name. At bootup time, no domain name is configured; however, if the switch configuration comes from a BOOTP or Dynamic Host Configuration Protocol (DHCP) server, then the default domain name might be set by the BOOTP or DHCP server (if the servers were configured with this information).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 3</td>
<td>ip name-server server-address1 [server-address2 ... server-address6]</td>
<td>Specify the address of one or more name servers to use for name and address resolution. You can specify up to six name servers. Separate each server address with a space. The first server specified is the primary server. The switch sends DNS queries to the primary server first. If that query fails, the backup servers are queried.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 4</td>
<td>ip domain-lookup</td>
<td>(Optional) Enable DNS-based hostname-to-address translation on your switch. This feature is enabled by default. If your network devices require connectivity with devices in networks for which you do not control name assignment, you can dynamically assign device names that uniquely identify your devices by using the global Internet naming scheme (DNS).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 5</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 5</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
If you use the switch IP address as its hostname, the IP address is used and no DNS query occurs. If you configure a hostname that contains no periods (.), a period followed by the default domain name is appended to the hostname before the DNS query is made to map the name to an IP address. The default domain name is the value set by the `ip domain-name` global configuration command. If there is a period (.) in the hostname, the Cisco IOS software looks up the IP address without appending any default domain name to the hostname.

To remove a domain name, use the `no ip domain-name name` global configuration command. To remove a name server address, use the `no ip name-server server-address` global configuration command. To disable DNS on the switch, use the `no ip domain-lookup` global configuration command.

### Displaying the DNS Configuration

To display the DNS configuration information, use the `show running-config` privileged EXEC command.

### Creating a Banner

You can configure a message-of-the-day (MOTD) and a login banner. The MOTD banner displays on all connected terminals at login and is useful for sending messages that affect all network users (such as impending system shutdowns).

The login banner also displays on all connected terminals. It appears after the MOTD banner and before the login prompts.

#### Note

For complete syntax and usage information for the commands used in this section, see the *Cisco IOS Configuration Fundamentals Command Reference, Release 12.2*.

These sections contain this configuration information:

- Default Banner Configuration, page 4-17
- Configuring a Message-of-the-Day Login Banner, page 4-18
- Configuring a Login Banner, page 4-19

### Default Banner Configuration

The MOTD and login banners are not configured.
Configuring a Message-of-the-Day Login Banner

You can create a single or multiline message banner that appears on the screen when someone logs in to the switch.

Beginning in privileged EXEC mode, follow these steps to configure a MOTD login banner:

To delete the MOTD banner, use the `no banner motd` global configuration command.

This example shows how to configure a MOTD banner for the switch by using the pound sign (#) symbol as the beginning and ending delimiter:

```
Switch(config)# banner motd #
This is a secure site. Only authorized users are allowed.
For access, contact technical support.
#
Switch(config)#
```

This example shows the banner that appears from the previous configuration:

```
Unix> telnet 172.2.5.4
Trying 172.2.5.4...
Connected to 172.2.5.4.
Escape character is '^]'.

This is a secure site. Only authorized users are allowed.
For access, contact technical support.

User Access Verification

Password:
```
Configuring a Login Banner

You can configure a login banner to be displayed on all connected terminals. This banner appears after the MOTD banner and before the login prompt.

Beginning in privileged EXEC mode, follow these steps to configure a login banner:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1  configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2  banner login c message c</td>
<td>Specify the login message.</td>
</tr>
<tr>
<td></td>
<td>For c, enter the delimiting character of your choice, for example, a pound sign (#), and press the Return key. The delimiting character signifies the beginning and end of the banner text. Characters after the ending delimiter are discarded. For message, enter a login message up to 255 characters. You cannot use the delimiting character in the message.</td>
</tr>
<tr>
<td>Step 3  end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4  show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5  copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To delete the login banner, use the no banner login global configuration command.

This example shows how to configure a login banner for the switch by using the dollar sign ($) symbol as the beginning and ending delimiter:

```
Switch(config)# banner login $
Access for authorized users only. Please enter your username and password.
$
Switch(config)#
```

Managing the MAC Address Table

The MAC address table contains address information that the switch uses to forward traffic between ports. All MAC addresses in the address table are associated with one or more ports. The address table includes these types of addresses:

- Dynamic address: a source MAC address that the switch learns and then ages when it is not in use.
- Static address: a manually entered unicast address that does not age and that is not lost when the switch resets.

The address table lists the destination MAC address, the associated VLAN ID, and port number associated with the address and the type (static or dynamic).

Note

For complete syntax and usage information for the commands used in this section, see the command reference for this release.
Managing the MAC Address Table

These sections contain this configuration information:

- Building the Address Table, page 4-20
- MAC Addresses and VLANs, page 4-20
- Default MAC Address Table Configuration, page 4-21
- Changing the Address Aging Time, page 4-21
- Removing Dynamic Address Entries, page 4-22
- Configuring MAC Address Notification Traps, page 4-22
- Adding and Removing Static Address Entries, page 4-24
- Configuring Unicast MAC Address Filtering, page 4-25
- Displaying Address Table Entries, page 4-26

Building the Address Table

With multiple MAC addresses supported on all ports, you can connect any port on the switch to individual workstations, repeaters, switches, routers, or other network devices. The switch provides dynamic addressing by learning the source address of packets it receives on each port and adding the address and its associated port number to the address table. As stations are added or removed from the network, the switch updates the address table, adding new dynamic addresses and aging out those that are not in use.

The aging interval is globally configured. However, the switch maintains an address table for each VLAN, and STP can accelerate the aging interval on a per-VLAN basis.

The switch sends packets between any combination of ports, based on the destination address of the received packet. Using the MAC address table, the switch forwards the packet only to the port associated with the destination address. If the destination address is on the port that sent the packet, the packet is filtered and not forwarded. The switch always uses the store-and-forward method: complete packets are stored and checked for errors before transmission.

MAC Addresses and VLANs

All addresses are associated with a VLAN. An address can exist in more than one VLAN and have different destinations in each. Unicast addresses, for example, could be forwarded to port 1 in VLAN 1 and ports 9, 10, and 1 in VLAN 5.

Each VLAN maintains its own logical address table. A known address in one VLAN is unknown in another until it is learned or statically associated with a port in the other VLAN.
Default MAC Address Table Configuration

Table 4-3 shows the default MAC address table configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aging time</td>
<td>300 seconds</td>
</tr>
<tr>
<td>Dynamic addresses</td>
<td>Automatically learned</td>
</tr>
<tr>
<td>Static addresses</td>
<td>None configured</td>
</tr>
</tbody>
</table>

Changing the Address Aging Time

Dynamic addresses are source MAC addresses that the switch learns and then ages when they are not in use. You can change the aging time setting for all VLANs or for a specified VLAN.

Setting too short an aging time can cause addresses to be prematurely removed from the table. Then when the switch receives a packet for an unknown destination, it floods the packet to all ports in the same VLAN as the receiving port. This unnecessary flooding can impact performance. Setting too long an aging time can cause the address table to be filled with unused addresses, which prevents new addresses from being learned.Flooding results, which can impact switch performance.

Beginning in privileged EXEC mode, follow these steps to configure the dynamic address table aging time:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 mac address-table aging-time [0</td>
<td>10-1000000] [vlan vlan-id]</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show mac address-table aging-time</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default value, use the no mac address-table aging-time global configuration command.
Removing Dynamic Address Entries

To remove all dynamic entries, use the `clear mac address-table dynamic` command in privileged EXEC mode. You can also remove a specific MAC address (`clear mac address-table dynamic address mac-address`), remove all addresses on the specified physical port or port channel (`clear mac address-table dynamic interface interface-id`), or remove all addresses on a specified VLAN (`clear mac address-table dynamic vlan vlan-id`).

To verify that dynamic entries have been removed, use the `show mac address-table dynamic` privileged EXEC command.

Configuring MAC Address Notification Traps

MAC address notification enables you to track users on a network by storing the MAC address activity on the switch. Whenever the switch learns or removes a MAC address, an SNMP notification can be generated and sent to the NMS. If you have many users coming and going from the network, you can set a trap interval time to bundle the notification traps and reduce network traffic. The MAC notification history table stores the MAC address activity for each hardware port for which the trap is enabled. MAC address notifications are generated for dynamic and secure MAC addresses; events are not generated for self addresses, multicast addresses, or other static addresses.

Beginning in privileged EXEC mode, follow these steps to configure the switch to send MAC address notification traps to an NMS host:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>`snmp-server host host-addr {traps</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>snmp-server enable traps mac-notification</code></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>mac address-table notification</code></td>
</tr>
</tbody>
</table>
### Command: `mac_address-table_notification [interval value] | [history-size value]`

**Purpose:** Enter the trap interval time and the history table size.

- **(Optional)** For `interval value`, specify the notification trap interval in seconds between each set of traps that are generated to the NMS. The range is 0 to 2147483647 seconds; the default is 1 second.
- **(Optional)** For `history-size value`, specify the maximum number of entries in the MAC notification history table. The range is 0 to 500; the default is 1.

### Command: `interface interface-id`

**Purpose:** Enter interface configuration mode, and specify the interface on which to enable the SNMP MAC address notification trap.

### Command: `snmp trap mac-notification {added | removed}`

**Purpose:** Enable the MAC address notification trap.

- Enable the MAC notification trap whenever a MAC address is **added** on this interface.
- Enable the MAC notification trap whenever a MAC address is **removed** from this interface.

### Command: `end`

**Purpose:** Return to privileged EXEC mode.

### Command: `show mac address-table notification interface`

**Purpose:** Verify your entries.

### Command: `show running-config`

**Purpose:** (Optional) Save your entries in the configuration file.

---

To disable the switch from sending MAC address notification traps, use the `no snmp-server enable traps mac-notification` global configuration command. To disable the MAC address notification traps on a specific interface, use the `no snmp trap mac-notification {added | removed}` interface configuration command. To disable the MAC address notification feature, use the `no mac address-table notification` global configuration command.

This example shows how to specify 172.20.10.10 as the NMS, enable the switch to send MAC address notification traps to the NMS, enable the MAC address notification feature, set the interval time to 60 seconds, set the history-size to 100 entries, and enable traps whenever a MAC address is added on the specified port.

```bash
Switch(config)# snmp-server host 172.20.10.10 traps private
Switch(config)# snmp-server enable traps mac-notification
Switch(config)# mac address-table notification
Switch(config)# mac address-table notification interval 60
Switch(config)# mac address-table notification history-size 100
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# snmp trap mac-notification added
```

You can verify the previous commands by entering the `show mac address-table notification interface` and the `show mac address-table notification` privileged EXEC commands.
Adding and Removing Static Address Entries

A static address has these characteristics:

- It is manually entered in the address table and must be manually removed.
- It can be a unicast or multicast address.
- It does not age and is retained when the switch restarts.

You can add and remove static addresses and define the forwarding behavior for them. The forwarding behavior defines how a port receives a packet forwards it to another port for transmission. Because all ports are associated with at least one VLAN, the switch acquires the VLAN ID for the address from the ports that you specify. You can specify a different list of destination ports for each source port.

A packet with a static address that arrives on a VLAN where it has not been statically entered is flooded to all ports and not learned.

You add a static address to the address table by specifying the destination MAC unicast address and the VLAN from which it is received. Packets received with this destination address are forwarded to the interface specified with the `interface-id` option.

Beginning in privileged EXEC mode, follow these steps to add a static address:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>mac address-table static mac-addr vlan vlan-id interface interface-id</code></td>
</tr>
<tr>
<td></td>
<td>• For <code>mac-addr</code>, specify the destination MAC unicast address to add to the address table. Packets with this destination address received in the specified VLAN are forwarded to the specified interface.</td>
</tr>
<tr>
<td></td>
<td>• For <code>vlan-id</code>, specify the VLAN for which the packet with the specified MAC address is received. Valid VLAN IDs are 1 to 4094.</td>
</tr>
<tr>
<td></td>
<td>• For <code>interface-id</code>, specify the interface to which the received packet is forwarded. Valid interfaces include physical ports or port channels. For static multicast addresses, you can enter multiple interface IDs. For static unicast addresses, you can enter only one interface at a time, but you can enter the command multiple times with the same MAC address and VLAN ID.</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>end</code></td>
</tr>
<tr>
<td>Step 4</td>
<td><code>show mac address-table static</code></td>
</tr>
<tr>
<td>Step 5</td>
<td><code>copy running-config startup-config</code></td>
</tr>
</tbody>
</table>

To remove static entries from the address table, use the `no mac address-table static mac-addr vlan vlan-id [interface interface-id]` global configuration command.

This example shows how to add the static address c2f3.220a.12f4 to the MAC address table. When a packet is received in VLAN 4 with this MAC address as its destination address, the packet is forwarded to the specified port:

```
Switch(config)# mac address-table static c2f3.220a.12f4 vlan 4 interface gigabitethernet0/1
```
Configuring Unicast MAC Address Filtering

When unicast MAC address filtering is enabled, the switch drops packets with specific source or destination MAC addresses. This feature is disabled by default and only supports unicast static addresses.

Follow these guidelines when using this feature:

- Multicast MAC addresses, broadcast MAC addresses, and router MAC addresses are not supported. If you specify one of these addresses when entering the `mac address-table static mac-addr vlan vlan-id drop` global configuration command, one of these messages appears:

  % Only unicast addresses can be configured to be dropped

  % CPU destined address cannot be configured as drop address

- Packets that are forwarded to the CPU are also not supported.

- If you add a unicast MAC address as a static address and configure unicast MAC address filtering, the switch either adds the MAC address as a static address or drops packets with that MAC address, depending on which command was entered last. The second command that you entered overrides the first command.

  For example, if you enter the `mac address-table static mac-addr vlan vlan-id interface interface-id` global configuration command followed by the `mac address-table static mac-addr vlan vlan-id drop` command, the switch drops packets with the specified MAC address as a source or destination.

  If you enter the `mac address-table static mac-addr vlan vlan-id drop` global configuration command followed by the `mac address-table static mac-addr vlan vlan-id interface interface-id` command, the switch adds the MAC address as a static address.

You enable unicast MAC address filtering and configure the switch to drop packets with a specific address by specifying the source or destination unicast MAC address and the VLAN from which it is received.

Beginning in privileged EXEC mode, follow these steps to configure the switch to drop a source or destination unicast static address:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>mac address-table static mac-addr vlan vlan-id drop</code></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show mac address-table static</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable unicast MAC address filtering, use the `no mac address-table static mac-addr vlan vlan-id` global configuration command.
Managing the ARP Table

This example shows how to enable unicast MAC address filtering and to configure the switch to drop packets that have a source or destination address of c2f3.220a.12f4. When a packet is received in VLAN 4 with this MAC address as its source or destination, the packet is dropped:

Switch(config)# mac address-table static c2f3.220a.12f4 vlan 4 drop

Displaying Address Table Entries

You can display the MAC address table by using one or more of the privileged EXEC commands described in Table 4-4:

Table 4-4 Commands for Displaying the MAC Address Table

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>show ip igmp snooping groups</td>
<td>Displays the Layer 2 multicast entries for all VLANs or the specified VLAN.</td>
</tr>
<tr>
<td>show mac address-table address</td>
<td>Displays MAC address table information for the specified MAC address.</td>
</tr>
<tr>
<td>show mac address-table aging-time</td>
<td>Displays the aging time in all VLANs or the specified VLAN.</td>
</tr>
<tr>
<td>show mac address-table count</td>
<td>Displays the number of addresses present in all VLANs or the specified VLAN.</td>
</tr>
<tr>
<td>show mac address-table dynamic</td>
<td>Displays only dynamic MAC address table entries.</td>
</tr>
<tr>
<td>show mac address-table interface</td>
<td>Displays the MAC address table information for the specified interface.</td>
</tr>
<tr>
<td>show mac address-table notification</td>
<td>Displays the MAC notification parameters and history table.</td>
</tr>
<tr>
<td>show mac address-table static</td>
<td>Displays only static MAC address table entries.</td>
</tr>
<tr>
<td>show mac address-table vlan</td>
<td>Displays the MAC address table information for the specified VLAN.</td>
</tr>
</tbody>
</table>

Managing the ARP Table

To communicate with a device (over Ethernet, for example), the software first must learn the 48-bit MAC address or the local data link address of that device. The process of learning the local data link address from an IP address is called address resolution.

The Address Resolution Protocol (ARP) associates a host IP address with the corresponding media or MAC addresses and the VLAN ID. Using an IP address, ARP finds the associated MAC address. When a MAC address is found, the IP-MAC address association is stored in an ARP cache for rapid retrieval. Then the IP datagram is encapsulated in a link-layer frame and sent over the network. Encapsulation of IP datagrams and ARP requests and replies on IEEE 802 networks other than Ethernet is specified by the Subnetwork Access Protocol (SNAP). By default, standard Ethernet-style ARP encapsulation (represented by the arpa keyword) is enabled on the IP interface.

ARP entries added manually to the table do not age and must be manually removed.

For CLI procedures, see the Cisco IOS Release 12.2 documentation on Cisco.com.
CHAPTER

5

Configuring Switch-Based Authentication

This chapter describes how to configure switch-based authentication on the switch. It consists of these sections:

- Preventing Unauthorized Access to Your Switch, page 5-1
- Protecting Access to Privileged EXEC Commands, page 5-2
- Controlling Switch Access with TACACS+, page 5-10
- Controlling Switch Access with RADIUS, page 5-17
- Controlling Switch Access with Kerberos, page 5-32
- Configuring the Switch for Local Authentication and Authorization, page 5-36
- Configuring the Switch for Secure Shell, page 5-37
- Configuring the Switch for Secure Socket Layer HTTP, page 5-42
- Configuring the Switch for Secure Copy Protocol, page 5-48

Preventing Unauthorized Access to Your Switch

You can prevent unauthorized users from reconfiguring your switch and viewing configuration information. Typically, you want network administrators to have access to your switch while you restrict access to users who dial from outside the network through an asynchronous port, connect from outside the network through a serial port, or connect through a terminal or workstation from within the local network.

To prevent unauthorized access into your switch, you should configure one or more of these security features:

- At a minimum, you should configure passwords and privileges at each switch port. These passwords are locally stored on the switch. When users attempt to access the switch through a port or line, they must enter the password specified for the port or line before they can access the switch. For more information, see the “Protecting Access to Privileged EXEC Commands” section on page 5-2.

- For an additional layer of security, you can also configure username and password pairs, which are locally stored on the switch. These pairs are assigned to lines or ports and authenticate each user before that user can access the switch. If you have defined privilege levels, you can also assign a specific privilege level (with associated rights and privileges) to each username and password pair. For more information, see the “Configuring Username and Password Pairs” section on page 5-6.
If you want to use username and password pairs, but you want to store them centrally on a server instead of locally, you can store them in a database on a security server. Multiple networking devices can then use the same database to obtain user authentication (and, if necessary, authorization) information. For more information, see the “Controlling Switch Access with TACACS+” section on page 5-10.

Protecting Access to Privileged EXEC Commands

A simple way of providing terminal access control in your network is to use passwords and assign privilege levels. Password protection restricts access to a network or network device. Privilege levels define what commands users can enter after they have logged into a network device.

Note
For complete syntax and usage information for the commands used in this section, see the Cisco IOS Security Command Reference, Release 12.2.

These sections contain this configuration information:

- Default Password and Privilege Level Configuration, page 5-2
- Setting or Changing a Static Enable Password, page 5-3
- Protecting Enable and Enable Secret Passwords with Encryption, page 5-3
- Disabling Password Recovery, page 5-5
- Setting a Telnet Password for a Terminal Line, page 5-6
- Configuring Username and Password Pairs, page 5-6
- Configuring Multiple Privilege Levels, page 5-7

Default Password and Privilege Level Configuration

Table 5-1 shows the default password and privilege level configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable password and privilege level</td>
<td>No password is defined. The default is level 15 (privileged EXEC level). The password is not encrypted in the configuration file.</td>
</tr>
<tr>
<td>Enable secret password and privilege level</td>
<td>No password is defined. The default is level 15 (privileged EXEC level). The password is encrypted before it is written to the configuration file.</td>
</tr>
<tr>
<td>Line password</td>
<td>No password is defined.</td>
</tr>
</tbody>
</table>
Setting or Changing a Static Enable Password

The enable password controls access to the privileged EXEC mode. Beginning in privileged EXEC mode, follow these steps to set or change a static enable password:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 enable password password</td>
<td>Define a new password or change an existing password for access to privileged EXEC mode. By default, no password is defined. For password, specify a string from 1 to 25 alphanumeric characters. The string cannot start with a number, is case sensitive, and allows spaces but ignores leading spaces. It can contain the question mark (?) character if you precede the question mark with the key combination Ctrl-v when you create the password; for example, to create the password abc?123, do this: Enter abc. Enter Ctrl-v. Enter ?123. When the system prompts you to enter the enable password, you need not precede the question mark with the Ctrl-v; you can simply enter abc?123 at the password prompt.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file. The enable password is not encrypted and can be read in the switch configuration file.</td>
</tr>
</tbody>
</table>

To remove the password, use the no enable password global configuration command.

This example shows how to change the enable password to l1u2c3k4y5. The password is not encrypted and provides access to level 15 (traditional privileged EXEC mode access):

```
Switch(config)# enable password l1u2c3k4y5
```

Protecting Enable and Enable Secret Passwords with Encryption

To provide an additional layer of security, particularly for passwords that cross the network or that are stored on a Trivial File Transfer Protocol (TFTP) server, you can use either the enable password or enable secret global configuration commands. Both commands accomplish the same thing; that is, you can establish an encrypted password that users must enter to access privileged EXEC mode (the default) or any privilege level you specify.

We recommend that you use the enable secret command because it uses an improved encryption algorithm.

If you configure the enable secret command, it takes precedence over the enable password command; the two commands cannot be in effect simultaneously.
Beginning in privileged EXEC mode, follow these steps to configure encryption for enable and enable secret passwords:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>enable password [level level] {password</td>
</tr>
<tr>
<td>or</td>
<td>enable secret [level level] {password</td>
</tr>
<tr>
<td></td>
<td>(Optional) For level, the range is from 0 to 15. Level 1 is normal user EXEC mode privileges. The default level is 15 (privileged EXEC mode privileges).</td>
</tr>
<tr>
<td></td>
<td>(Optional) For password, specify a string from 1 to 25 alphanumeric characters. The string cannot start with a number, is case sensitive, and allows spaces but ignores leading spaces. By default, no password is defined.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For encryption-type, only type 5, a Cisco proprietary encryption algorithm, is available. If you specify an encryption type, you must provide an encrypted password—an encrypted password that you copy from another switch configuration.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>service password-encryption</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

If both the enable and enable secret passwords are defined, users must enter the enable secret password. Use the level keyword to define a password for a specific privilege level. After you specify the level and set a password, give the password only to users who need to have access at this level. Use the privilege level global configuration command to specify commands accessible at various levels. For more information, see the “Configuring Multiple Privilege Levels” section on page 5-7.

If you enable password encryption, it applies to all passwords including username passwords, authentication key passwords, the privileged command password, and console and virtual terminal line passwords.

To remove a password and level, use the no enable password [level level] or no enable secret [level level] global configuration command. To disable password encryption, use the no service password-encryption global configuration command.
This example shows how to configure the encrypted password $1$FaD0$Xyti5Rkls3LoyxzS8 for privilege level 2:

Switch(config)# enable secret level 2 5 $1$FaD0$Xyti5Rkls3LoyxzS8

Disabling Password Recovery

By default, any end user with physical access to the switch can recover from a lost password by interrupting the bootup process while the switch is powering on and then by entering a new password.

The password-recovery disable feature protects access to the switch password by disabling part of this functionality. When this feature is enabled, the end user can interrupt the bootup process only by agreeing to set the system back to the default configuration. With password recovery disabled, you can still interrupt the bootup process and change the password, but the configuration file (config.text) and the VLAN database file (vlan.dat) are deleted.

If you disable password recovery, we recommend that you keep a backup copy of the configuration file on a secure server in case the end user interrupts the bootup process and sets the system back to default values. Do not keep a backup copy of the configuration file on the switch. If the switch is operating in VTP transparent mode, we recommend that you also keep a backup copy of the VLAN database file on a secure server. When the switch is returned to the default system configuration, you can download the saved files to the switch by using the Xmodem protocol. For more information, see the “Recovering from a Lost or Forgotten Password” section on page 29-3.

Beginning in privileged EXEC mode, follow these steps to disable password recovery:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>no service password-recovery</td>
<td>Disable password recovery.</td>
</tr>
<tr>
<td></td>
<td>This setting is saved in an area of the flash memory that is accessible by the bootloader and the Cisco IOS image, but it is not part of the file system and is not accessible by any user.</td>
</tr>
<tr>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>show version</td>
<td>Verify the configuration by checking the last few lines of the command output.</td>
</tr>
</tbody>
</table>

To re-enable password recovery, use the **service password-recovery** global configuration command.

Disabling password recovery will not work if you have set the switch to boot up manually by using the **boot manual** global configuration command. This command produces the bootloader prompt (switch:) after the switch is power cycled.
**Chapter 5      Configuring Switch-Based Authentication**

## Setting a Telnet Password for a Terminal Line

When you power-up your switch for the first time, an automatic setup program runs to assign IP information and to create a default configuration for continued use. The setup program also prompts you to configure your switch for Telnet access through a password. If you did not configure this password during the setup program, you can configure it now through the command-line interface (CLI).

Beginning in privileged EXEC mode, follow these steps to configure your switch for Telnet access:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 1**               | Attach a PC or workstation with emulation software to the switch console port.  
                            | The default data characteristics of the console port are 9600, 8, 1, no parity. You might need to press the Return key several times to see the command-line prompt. |
| **Step 2**               | enter privileged EXEC mode.                                             |
| **Step 3**               | Enter global configuration mode.                                       |
| **Step 4**               | Configure the number of Telnet sessions (lines), and enter line configuration mode.  
                            | There are 16 possible sessions on a command-capable switch. The 0 and 15 mean that you are configuring all 16 possible Telnet sessions. |
| **Step 5**               | Enter a Telnet password for the line or lines.  
                            | For password, specify a string from 1 to 25 alphanumeric characters. The string cannot start with a number, is case sensitive, and allows spaces but ignores leading spaces. By default, no password is defined. |
| **Step 6**               | Return to privileged EXEC mode.                                         |
| **Step 7**               | Verify your entries.  
                            | The password is listed under the command line vty 0 15.                 |
| **Step 8**               | (Optional) Save your entries in the configuration file.                |

To remove the password, use the **no password** global configuration command.

This example shows how to set the Telnet password to `let45me67in89`:

```
Switch(config)# line vty 10
Switch(config-line)# password let45me67in89
```

### Configuring Username and Password Pairs

You can configure username and password pairs, which are locally stored on the switch. These pairs are assigned to lines or ports and authenticate each user before that user can access the switch. If you have defined privilege levels, you can also assign a specific privilege level (with associated rights and privileges) to each username and password pair.
Beginning in privileged EXEC mode, follow these steps to establish a username-based authentication system that requests a login username and a password:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2</th>
<th>username name [privilege level] { password encryption-type password}</th>
<th>Enter the username, privilege level, and password for each user.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• For name, specify the user ID as one word. Spaces and quotation marks are not allowed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• (Optional) For level, specify the privilege level the user has after gaining access. The range is 0 to 15. Level 15 gives privileged EXEC mode access. Level 1 gives user EXEC mode access.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• For encryption-type, enter 0 to specify that an unencrypted password will follow. Enter 7 to specify that a hidden password will follow.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• For password, specify the password the user must enter to gain access to the switch. The password must be from 1 to 25 characters, can contain embedded spaces, and must be the last option specified in the username command.</td>
<td></td>
</tr>
</tbody>
</table>

| Step 3     | line console 0 or line vty 0 15 | Enter line configuration mode, and configure the console port (line 0) or the VTY lines (line 0 to 15). |

| Step 4     | login local                  | Enable local password checking at login time. Authentication is based on the username specified in Step 2. |

| Step 5     | end                          | Return to privileged EXEC mode.               |

| Step 6     | show running-config          | Verify your entries.                          |

| Step 7     | copy running-config startup-config | (Optional) Save your entries in the configuration file. |

To disable username authentication for a specific user, use the no username name global configuration command. To disable password checking and allow connections without a password, use the no login line configuration command.

### Configuring Multiple Privilege Levels

By default, the Cisco IOS software has two modes of password security: user EXEC and privileged EXEC. You can configure up to 16 hierarchical levels of commands for each mode. By configuring multiple passwords, you can allow different sets of users to have access to specified commands.

For example, if you want many users to have access to the clear line command, you can assign it level 2 security and distribute the level 2 password fairly widely. But if you want more restricted access to the configure command, you can assign it level 3 security and distribute that password to a more restricted group of users.

These sections contain this configuration information:

- Setting the Privilege Level for a Command, page 5-8
- Changing the Default Privilege Level for Lines, page 5-9
- Logging into and Exiting a Privilege Level, page 5-9
Chapter 5  Configuring Switch-Based Authentication

Setting the Privilege Level for a Command

Beginning in privileged EXEC mode, follow these steps to set the privilege level for a command mode:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>privilege mode level level command</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>enable password level level password</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show running-config</td>
</tr>
<tr>
<td>or</td>
<td>show privilege</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

When you set a command to a privilege level, all commands whose syntax is a subset of that command are also set to that level. For example, if you set the show ip traffic command to level 15, the show commands and show ip commands are automatically set to privilege level 15 unless you set them individually to different levels.

To return to the default privilege for a given command, use the no privilege mode level level command global configuration command.

This example shows how to set the configure command to privilege level 14 and define SecretPs wd14 as the password users must enter to use level 14 commands:

```
Switch(config)# privilege exec level 14 configure
Switch(config)# enable password level 14 SecretPswd14
```
Changing the Default Privilege Level for Lines

Beginning in privileged EXEC mode, follow these steps to change the default privilege level for a line:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 line vty line</td>
<td>Select the virtual terminal line on which to restrict access.</td>
</tr>
<tr>
<td>Step 3 privilege level level</td>
<td>Change the default privilege level for the line.</td>
</tr>
<tr>
<td></td>
<td>For level, the range is from 0 to 15. Level 1 is for normal user EXEC mode privileges. Level 15 is the level of access permitted by the enable password.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td>The first command shows the password and access level configuration.</td>
</tr>
<tr>
<td></td>
<td>The second command shows the privilege level configuration.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Users can override the privilege level you set using the privilege level line configuration command by logging in to the line and enabling a different privilege level. They can lower the privilege level by using the disable command. If users know the password to a higher privilege level, they can use that password to enable the higher privilege level. You might specify a high level or privilege level for your console line to restrict line usage.

To return to the default line privilege level, use the no privilege level line configuration command.

Logging into and Exiting a Privilege Level

Beginning in privileged EXEC mode, follow these steps to log in to a specified privilege level and to exit to a specified privilege level:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 enable level</td>
<td>Log in to a specified privilege level.</td>
</tr>
<tr>
<td></td>
<td>For level, the range is 0 to 15.</td>
</tr>
<tr>
<td>Step 2 disable level</td>
<td>Exit to a specified privilege level.</td>
</tr>
<tr>
<td></td>
<td>For level, the range is 0 to 15.</td>
</tr>
</tbody>
</table>
Controlling Switch Access with TACACS+

This section describes how to enable and configure Terminal Access Controller Access Control System Plus (TACACS+), which provides detailed accounting information and flexible administrative control over authentication and authorization processes. TACACS+ is facilitated through authentication, authorization, accounting (AAA) and can be enabled only through AAA commands.

Note

For complete syntax and usage information for the commands used in this section, see the Cisco IOS Security Command Reference, Release 12.2.

These sections contain this configuration information:

- Understanding TACACS+, page 5-10
- TACACS+ Operation, page 5-12
- Configuring TACACS+, page 5-12
- Displaying the TACACS+ Configuration, page 5-17

Understanding TACACS+

TACACS+ is a security application that provides centralized validation of users attempting to gain access to your switch. TACACS+ services are maintained in a database on a TACACS+ daemon typically running on a UNIX or Windows NT workstation. You should have access to and should configure a TACACS+ server before the configuring TACACS+ features on your switch.

TACACS+ provides for separate and modular authentication, authorization, and accounting facilities. TACACS+ allows for a single access control server (the TACACS+ daemon) to provide each service—authentication, authorization, and accounting—independently. Each service can be tied into its own database to take advantage of other services available on that server or on the network, depending on the capabilities of the daemon.

The goal of TACACS+ is to provide a method for managing multiple network access points from a single management service. Your switch can be a network access server along with other Cisco routers and access servers. A network access server provides connections to a single user, to a network or subnetwork, and to interconnected networks as shown in Figure 5-1.
TACACS+, administered through the AAA security services, can provide these services:

- **Authentication**—Provides complete control of authentication through login and password dialog, challenge and response, and messaging support.

  The authentication facility can conduct a dialog with the user (for example, after a username and password are provided, to challenge a user with several questions, such as home address, mother’s maiden name, service type, and social security number). The TACACS+ authentication service can also send messages to user screens. For example, a message could notify users that their passwords must be changed because of the company’s password aging policy.

- **Authorization**—Provides fine-grained control over user capabilities for the duration of the user’s session, including but not limited to setting autocommands, access control, session duration, or protocol support. You can also enforce restrictions on what commands a user can execute with the TACACS+ authorization feature.

- **Accounting**—Collects and sends information used for billing, auditing, and reporting to the TACACS+ daemon. Network managers can use the accounting facility to track user activity for a security audit or to provide information for user billing. Accounting records include user identities, start and stop times, executed commands (such as PPP), number of packets, and number of bytes.

The TACACS+ protocol provides authentication between the switch and the TACACS+ daemon, and it ensures confidentiality because all protocol exchanges between the switch and the TACACS+ daemon are encrypted.

You need a system running the TACACS+ daemon software to use TACACS+ on your switch.
TACACS+ Operation

When a user attempts a simple ASCII login by authenticating to a switch using TACACS+, this process occurs:

1. When the connection is established, the switch contacts the TACACS+ daemon to obtain a username prompt to show to the user. The user enters a username, and the switch then contacts the TACACS+ daemon to obtain a password prompt. The switch displays the password prompt to the user, the user enters a password, and the password is then sent to the TACACS+ daemon.

   TACACS+ allows a dialog between the daemon and the user until the daemon receives enough information to authenticate the user. The daemon prompts for a username and password combination, but can include other items, such as the user’s mother’s maiden name.

2. The switch eventually receives one of these responses from the TACACS+ daemon:
   - ACCEPT—The user is authenticated and service can begin. If the switch is configured to require authorization, authorization begins at this time.
   - REJECT—The user is not authenticated. The user can be denied access or is prompted to retry the login sequence, depending on the TACACS+ daemon.
   - ERROR—An error occurred at some time during authentication with the daemon or in the network connection between the daemon and the switch. If an ERROR response is received, the switch typically tries to use an alternative method for authenticating the user.
   - CONTINUE—The user is prompted for additional authentication information.

   After authentication, the user undergoes an additional authorization phase if authorization has been enabled on the switch. Users must first successfully complete TACACS+ authentication before proceeding to TACACS+ authorization.

3. If TACACS+ authorization is required, the TACACS+ daemon is again contacted, and it returns an ACCEPT or REJECT authorization response. If an ACCEPT response is returned, the response contains data in the form of attributes that direct the EXEC or NETWORK session for that user and the services that the user can access:
   - Telnet, Secure Shell (SSH), rlogin, or privileged EXEC services
   - Connection parameters, including the host or client IP address, access list, and user timeouts

Configuring TACACS+

This section describes how to configure your switch to support TACACS+. At a minimum, you must identify the host or hosts maintaining the TACACS+ daemon and define the method lists for TACACS+ authentication. You can optionally define method lists for TACACS+ authorization and accounting. A method list defines the sequence and methods to be used to authenticate, to authorize, or to keep accounts on a user. You can use method lists to designate one or more security protocols to be used, thus ensuring a backup system if the initial method fails. The software uses the first method listed to authenticate, to
authorize, or to keep accounts on users; if that method does not respond, the software selects the next method in the list. This process continues until there is successful communication with a listed method or the method list is exhausted.

These sections contain this configuration information:

- Default TACACS+ Configuration, page 5-13
- Identifying the TACACS+ Server Host and Setting the Authentication Key, page 5-13
- Configuring TACACS+ Login Authentication, page 5-14
- Configuring TACACS+ Authorization for Privileged EXEC Access and Network Services, page 5-16
- Starting TACACS+ Accounting, page 5-17

**Default TACACS+ Configuration**

TACACS+ and AAA are disabled by default.

To prevent a lapse in security, you cannot configure TACACS+ through a network management application. When enabled, TACACS+ can authenticate users accessing the switch through the CLI.

**Note** Although TACACS+ configuration is performed through the CLI, the TACACS+ server authenticates HTTP connections that have been configured with a privilege level of 15.

**Identifying the TACACS+ Server Host and Setting the Authentication Key**

You can configure the switch to use a single server or AAA server groups to group existing server hosts for authentication. You can group servers to select a subset of the configured server hosts and use them for a particular service. The server group is used with a global server-host list and contains the list of IP addresses of the selected server hosts.

Beginning in privileged EXEC mode, follow these steps to identify the IP host or host maintaining TACACS+ server and optionally set the encryption key:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| tacacs-server host hostname [port integer] [timeout integer] [key string] | Identify the IP host or hosts maintaining a TACACS+ server. Enter this command multiple times to create a list of preferred hosts. The software searches for hosts in the order in which you specify them.  
  - For *hostname*, specify the name or IP address of the host.  
  - (Optional) For *port integer*, specify a server port number. The default is port 49. The range is 1 to 65535.  
  - (Optional) For *timeout integer*, specify a time in seconds the switch waits for a response from the daemon before it times out and declares an error. The default is 5 seconds. The range is 1 to 1000 seconds.  
  - (Optional) For *key string*, specify the encryption key for encrypting and decrypting all traffic between the switch and the TACACS+ daemon. You must configure the same key on the TACACS+ daemon for encryption to be successful. |
Controlling Switch Access with TACACS+

To remove the specified TACACS+ server name or address, use the `no tacacs-server host hostname` global configuration command. To remove a server group from the configuration list, use the `no aaa group server tacacs+ group-name` global configuration command. To remove the IP address of a TACACS+ server, use the `no server ip-address` server group subconfiguration command.

Configuring TACACS+ Login Authentication

To configure AAA authentication, you define a named list of authentication methods and then apply that list to various ports. The method list defines the types of authentication to be performed and the sequence in which they are performed; it must be applied to a specific port before any of the defined authentication methods are performed. The only exception is the default method list (which, by coincidence, is named `default`). The default method list is automatically applied to all ports except those that have a named method list explicitly defined. A defined method list overrides the default method list.

A method list describes the sequence and authentication methods to be queried to authenticate a user. You can designate one or more security protocols to be used for authentication, thus ensuring a backup system for authentication in case the initial method fails. The software uses the first method listed to authenticate users; if that method fails to respond, the software selects the next authentication method in the method list. This process continues until there is successful communication with a listed authentication method or until all defined methods are exhausted. If authentication fails at any point in this cycle—meaning that the security server or local username database responds by denying the user access—the authentication process stops, and no other authentication methods are attempted.

Beginning in privileged EXEC mode, follow these steps to configure login authentication:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 aaa new-model</td>
<td>Enable AAA.</td>
</tr>
</tbody>
</table>

To remove the specified TACACS+ server name or address, use the `no tacacs-server host hostname` global configuration command. To remove a server group from the configuration list, use the `no aaa group server tacacs+ group-name` global configuration command. To remove the IP address of a TACACS+ server, use the `no server ip-address` server group subconfiguration command.
### Chapter 5  Configuring Switch-Based Authentication

**Controlling Switch Access with TACACS+**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3</strong></td>
<td>**aaa authentication login {default</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>**line [console</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>**login authentication {default</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><strong>show running-config</strong></td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>
To disable AAA, use the `no aaa new-model` global configuration command. To disable AAA authentication, use the `no aaa authentication login {default | list-name} method1 [method2...` global configuration command. To either disable TACACS+ authentication for logins or to return to the default value, use the `no login authentication {default | list-name}` line configuration command.

**Note**
To secure the switch for HTTP access by using AAA methods, you must configure the switch with the `ip http authentication aaa` global configuration command. Configuring AAA authentication does not secure the switch for HTTP access by using AAA methods.

For more information about the `ip http authentication` command, see the Cisco IOS Security Command Reference, Release 12.2.

**Configuring TACACS+ Authorization for Privileged EXEC Access and Network Services**

AAA authorization limits the services available to a user. When AAA authorization is enabled, the switch uses information retrieved from the user’s profile, which is located either in the local user database or on the security server, to configure the user’s session. The user is granted access to a requested service only if the information in the user profile allows it.

You can use the `aaa authorization` global configuration command with the `tacacs+` keyword to set parameters that restrict a user’s network access to privileged EXEC mode.

The `aaa authorization exec tacacs+ local` command sets these authorization parameters:

- Use TACACS+ for privileged EXEC access authorization if authentication was performed by using TACACS+.
- Use the local database if authentication was not performed by using TACACS+.

**Note** Authorization is bypassed for authenticated users who log in through the CLI even if authorization has been configured.

Beginning in privileged EXEC mode, follow these steps to specify TACACS+ authorization for privileged EXEC access and network services:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>Step 2</strong></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 3</strong></td>
</tr>
<tr>
<td></td>
<td>aaa authorization network tacacs+</td>
</tr>
<tr>
<td></td>
<td>Configure the switch for user TACACS+ authorization for all network-related service requests.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 4</strong></td>
</tr>
<tr>
<td></td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 5</strong></td>
</tr>
<tr>
<td></td>
<td>show running-config</td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 6</strong></td>
</tr>
<tr>
<td></td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable authorization, use the `no aaa authorization {network | exec} method1` global configuration command.

---

**Command Purpose**

**Step 1**
configure terminal
Enter global configuration mode.

**Step 2**
aaa authorization network tacacs+
Configure the switch for user TACACS+ authorization for all network-related service requests.

**Step 3**
aaa authorization exec tacacs+
Configure the switch for user TACACS+ authorization if the user has privileged EXEC access.

The `exec` keyword might return user profile information (such as `autocommand` information).

**Step 4**
end
Return to privileged EXEC mode.

**Step 5**
show running-config
Verify your entries.

**Step 6**
copy running-config startup-config
(Optional) Save your entries in the configuration file.
Starting TACACS+ Accounting

The AAA accounting feature tracks the services that users are accessing and the amount of network resources that they are consuming. When AAA accounting is enabled, the switch reports user activity to the TACACS+ security server in the form of accounting records. Each accounting record contains accounting attribute-value (AV) pairs and is stored on the security server. This data can then be analyzed for network management, client billing, or auditing.

Beginning in privileged EXEC mode, follow these steps to enable TACACS+ accounting for each Cisco IOS privilege level and for network services:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>aaa accounting network start-stop tacacs+</td>
</tr>
<tr>
<td>Step 3</td>
<td>aaa accounting exec start-stop tacacs+</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable accounting, use the no aaa accounting { network | exec } { start-stop } method1... global configuration command.

Displaying the TACACS+ Configuration

To display TACACS+ server statistics, use the show tacacs privileged EXEC command.

Controlling Switch Access with RADIUS

This section describes how to enable and configure the RADIUS, which provides detailed accounting information and flexible administrative control over authentication and authorization processes. RADIUS is facilitated through AAA and can be enabled only through AAA commands.

Note

For complete syntax and usage information for the commands used in this section, see the *Cisco IOS Security Command Reference, Release 12.2*.

These sections contain this configuration information:
- Understanding RADIUS, page 5-18
- RADIUS Operation, page 5-19
- Configuring RADIUS, page 5-19
- Displaying the RADIUS Configuration, page 5-31
Understanding RADIUS

RADIUS is a distributed client/server system that secures networks against unauthorized access. RADIUS clients run on supported Cisco routers and switches. Clients send authentication requests to a central RADIUS server, which contains all user authentication and network service access information. The RADIUS host is normally a multiuser system running RADIUS server software from Cisco (Cisco Secure Access Control Server Version 3.0), Livingston, Merit, Microsoft, or another software provider. For more information, see the RADIUS server documentation.

Use RADIUS in these network environments that require access security:

- Networks with multiple-vendor access servers, each supporting RADIUS. For example, access servers from several vendors use a single RADIUS server-based security database. In an IP-based network with multiple vendors’ access servers, dial-in users are authenticated through a RADIUS server that has been customized to work with the Kerberos security system.

- Turnkey network security environments in which applications support the RADIUS protocol, such as in an access environment that uses a smart card access control system. In one case, RADIUS has been used with Enigma’s security cards to validate users and to grant access to network resources.

- Networks already using RADIUS. You can add a Cisco switch containing a RADIUS client to the network. This might be the first step when you make a transition to a TACACS+ server. See Figure 5-2 on page 5-19.

- Network in which the user must only access a single service. Using RADIUS, you can control user access to a single host, to a single utility such as Telnet, or to the network through a protocol such as IEEE 802.1x. For more information about this protocol, see Chapter 6, “Configuring IEEE 802.1x Port-Based Authentication.”

- Networks that require resource accounting. You can use RADIUS accounting independently of RADIUS authentication or authorization. The RADIUS accounting functions allow data to be sent at the start and end of services, showing the amount of resources (such as time, packets, bytes, and so forth) used during the session. An Internet service provider might use a freeware-based version of RADIUS access control and accounting software to meet special security and billing needs.

RADIUS is not suitable in these network security situations:

- Multiprotocol access environments. RADIUS does not support AppleTalk Remote Access (ARA), NetBIOS Frame Control Protocol (NBFCP), NetWare Asynchronous Services Interface (NASI), or X.25 PAD connections.

- Switch-to-switch or router-to-router situations. RADIUS does not provide two-way authentication. RADIUS can be used to authenticate from one device to a non-Cisco device if the non-Cisco device requires authentication.

- Networks using a variety of services. RADIUS generally binds a user to one service model.
RADIUS Operation

When a user attempts to log in and authenticate to a switch that is access controlled by a RADIUS server, these events occur:

1. The user is prompted to enter a username and password.
2. The username and encrypted password are sent over the network to the RADIUS server.
3. The user receives one of these responses from the RADIUS server:
   a. ACCEPT—The user is authenticated.
   b. REJECT—The user is either not authenticated and is prompted to re-enter the username and password, or access is denied.
   c. CHALLENGE—A challenge requires additional data from the user.
   d. CHALLENGE PASSWORD—A response requests the user to select a new password.

The ACCEPT or REJECT response is bundled with additional data that is used for privileged EXEC or network authorization. Users must first successfully complete RADIUS authentication before proceeding to RADIUS authorization, if it is enabled. The additional data included with the ACCEPT or REJECT packets includes these items:

- Telnet, SSH, rlogin, or privileged EXEC services
- Connection parameters, including the host or client IP address, access list, and user timeouts

Configuring RADIUS

This section describes how to configure your switch to support RADIUS. At a minimum, you must identify the host or hosts that run the RADIUS server software and define the method lists for RADIUS authentication. You can optionally define method lists for RADIUS authorization and accounting.

A method list defines the sequence and methods to be used to authenticate, to authorize, or to keep accounts on a user. You can use method lists to designate one or more security protocols to be used (such as TACACS+ or local username lookup), thus ensuring a backup system if the initial method fails.
software uses the first method listed to authenticate, to authorize, or to keep accounts on users; if that method does not respond, the software selects the next method in the list. This process continues until there is successful communication with a listed method or the method list is exhausted.

You should have access to and should configure a RADIUS server before configuring RADIUS features on your switch.

These sections contain this configuration information:

- Default RADIUS Configuration, page 5-20
- Identifying the RADIUS Server Host, page 5-20 (required)
- Configuring RADIUS Login Authentication, page 5-23 (required)
- Defining AAA Server Groups, page 5-25 (optional)
- Configuring RADIUS Authorization for User Privileged Access and Network Services, page 5-27 (optional)
- Starting RADIUS Accounting, page 5-28 (optional)
- Configuring Settings for All RADIUS Servers, page 5-29 (optional)
- Configuring the Switch to Use Vendor-Specific RADIUS Attributes, page 5-29 (optional)
- Configuring the Switch for Vendor-Proprietary RADIUS Server Communication, page 5-31 (optional)

Default RADIUS Configuration

RADIUS and AAA are disabled by default.

To prevent a lapse in security, you cannot configure RADIUS through a network management application. When enabled, RADIUS can authenticate users accessing the switch through the CLI.

Identifying the RADIUS Server Host

Switch-to-RADIUS-server communication involves several components:

- Hostname or IP address
- Authentication destination port
- Accounting destination port
- Key string
- Timeout period
- Retransmission value

You identify RADIUS security servers by their hostname or IP address, hostname and specific UDP port numbers, or their IP address and specific UDP port numbers. The combination of the IP address and the UDP port number creates a unique identifier, allowing different ports to be individually defined as RADIUS hosts providing a specific AAA service. This unique identifier enables RADIUS requests to be sent to multiple UDP ports on a server at the same IP address.

If two different host entries on the same RADIUS server are configured for the same service—for example, accounting—the second host entry configured acts as a fail-over backup to the first one. Using this example, if the first host entry fails to provide accounting services, the %RADIUS-4-RADIUS_DEAD message appears, and then the switch tries the second host entry configured on the same device for accounting services. (The RADIUS host entries are tried in the order that they are configured.)
A RADIUS server and the switch use a shared secret text string to encrypt passwords and exchange responses. To configure RADIUS to use the AAA security commands, you must specify the host running the RADIUS server daemon and a secret text (key) string that it shares with the switch.

The timeout, retransmission, and encryption key values can be configured globally for all RADIUS servers, on a per-server basis, or in some combination of global and per-server settings. To apply these settings globally to all RADIUS servers communicating with the switch, use the three unique global configuration commands: `radius-server timeout`, `radius-server retransmit`, and `radius-server key`. To apply these values on a specific RADIUS server, use the `radius-server host` global configuration command.

**Note**

If you configure both global and per-server functions (timeout, retransmission, and key commands) on the switch, the per-server timer, retransmission, and key value commands override global timer, retransmission, and key value commands. For information on configuring these settings on all RADIUS servers, see the “Configuring Settings for All RADIUS Servers” section on page 5-29.

You can configure the switch to use AAA server groups to group existing server hosts for authentication. For more information, see the “Defining AAA Server Groups” section on page 5-25.
Beginning in privileged EXEC mode, follow these steps to configure per-server RADIUS server communication. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>radius-server host {hostname</td>
</tr>
<tr>
<td></td>
<td>Specify the IP address or hostname of the remote RADIUS server host.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For auth-port port-number, specify the UDP destination port for authentication requests.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For acct-port port-number, specify the UDP destination port for accounting requests.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For timeout seconds, specify the time interval that the switch waits for the RADIUS server to reply before resending. The range is 1 to 1000. This setting overrides the radius-server timeout global configuration command setting. If no timeout is set with the radius-server host command, the setting of the radius-server timeout command is used.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For retransmit retries, specify the number of times a RADIUS request is resent to a server if that server is not responding or responding slowly. The range is 1 to 1000. If no retransmit value is set with the radius-server host command, the setting of the radius-server retransmit global configuration command is used.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For key string, specify the authentication and encryption key used between the switch and the RADIUS daemon running on the RADIUS server.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show running-config</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

Note: The key is a text string that must match the encryption key used on the RADIUS server. Always configure the key as the last item in the radius-server host command. Leading spaces are ignored, but spaces within and at the end of the key are used. If you use spaces in your key, do not enclose the key in quotation marks unless the quotation marks are part of the key.

To configure the switch to recognize more than one host entry associated with a single IP address, enter this command as many times as necessary, making sure that each UDP port number is different. The switch software searches for hosts in the order in which you specify them. Set the timeout, retransmit, and encryption key values to use with the specific RADIUS host.
To remove the specified RADIUS server, use the `no radius-server host hostname | ip-address` global configuration command.

This example shows how to configure one RADIUS server to be used for authentication and another to be used for accounting:

```
Switch(config)# radius-server host 172.29.36.49 auth-port 6403 key rad1
Switch(config)# radius-server host 172.20.36.50 acct-port 6403 key rad2
```

This example shows how to configure host1 as the RADIUS server and to use the default ports for both authentication and accounting:

```
Switch(config)# radius-server host host1
```

**Note**  You also need to configure some settings on the RADIUS server. These settings include the IP address of the switch and the key string to be shared by both the server and the switch. For more information, see the RADIUS server documentation.

---

**Configuring RADIUS Login Authentication**

To configure AAA authentication, you define a named list of authentication methods and then apply that list to various ports. The method list defines the types of authentication to be performed and the sequence in which they are performed; it must be applied to a specific port before any of the defined authentication methods are performed. The only exception is the default method list (which, by coincidence, is named `default`). The default method list is automatically applied to all ports except those that have a named method list explicitly defined.

A method list describes the sequence and authentication methods to be queried to authenticate a user. You can designate one or more security protocols to be used for authentication, thus ensuring a backup system for authentication in case the initial method fails. The software uses the first method listed to authenticate users; if that method fails to respond, the software selects the next authentication method in the method list. This process continues until there is successful communication with a listed authentication method or until all defined methods are exhausted. If authentication fails at any point in this cycle—meaning that the security server or local username database responds by denying the user access—the authentication process stops, and no other authentication methods are attempted.

Beginning in privileged EXEC mode, follow these steps to configure login authentication. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td>aaa new-model</td>
<td>Enable AAA.</td>
</tr>
</tbody>
</table>
### Command Purpose

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 3**  
**aaa authentication login** `{default | list-name} method1 [method2...]` | Create a login authentication method list.  
- To create a default list that is used when a named list is *not* specified in the `login authentication` command, use the **default** keyword followed by the methods that are to be used in default situations. The default method list is automatically applied to all ports.  
- For **list-name**, specify a character string to name the list you are creating.  
- For **method1...**, specify the actual method the authentication algorithm tries. The additional methods of authentication are used only if the previous method returns an error, not if it fails.  
  Select one of these methods:  
  - **enable**—Use the enable password for authentication. Before you can use this authentication method, you must define an enable password by using the **enable password** global configuration command.  
  - **group radius**—Use RADIUS authentication. Before you can use this authentication method, you must configure the RADIUS server. For more information, see the “Identifying the RADIUS Server Host” section on page 5-20.  
  - **line**—Use the line password for authentication. Before you can use this authentication method, you must define a line password. Use the **password password** line configuration command.  
  - **local**—Use the local username database for authentication. You must enter username information in the database. Use the **username name password** global configuration command.  
  - **local-case**—Use a case-sensitive local username database for authentication. You must enter username information in the database by using the **username password** global configuration command.  
  - **none**—Do not use any authentication for login. |
| **Step 4**  
**line** `{console | tty | vty} line-number [ending-line-number]` | Enter line configuration mode, and configure the lines to which you want to apply the authentication list. |
| **Step 5**  
**login authentication** `{default | list-name}` | Apply the authentication list to a line or set of lines.  
- If you specify **default**, use the default list created with the **aaa authentication login** command.  
- For **list-name**, specify the list created with the **aaa authentication login** command. |
| **Step 6**  
**end** | Return to privileged EXEC mode. |
| **Step 7**  
**show running-config** | Verify your entries. |
| **Step 8**  
**copy running-config startup-config** | (Optional) Save your entries in the configuration file. |
To disable AAA, use the `no aaa new-model` global configuration command. To disable AAA authentication, use the `no aaa authentication login {default | list-name} method1 [method2...]` global configuration command. To either disable RADIUS authentication for logins or to return to the default value, use the `no login authentication {default | list-name}` line configuration command.

**Note**

To secure the switch for HTTP access by using AAA methods, you must configure the switch with the `ip http authentication aaa` global configuration command. Configuring AAA authentication does not secure the switch for HTTP access by using AAA methods.

For more information about the `ip http authentication` command, see the *Cisco IOS Security Command Reference, Release 12.2*.

**Defining AAA Server Groups**

You can configure the switch to use AAA server groups to group existing server hosts for authentication. You select a subset of the configured server hosts and use them for a particular service. The server group is used with a global server-host list, which lists the IP addresses of the selected server hosts.

Server groups also can include multiple host entries for the same server if each entry has a unique identifier (the combination of the IP address and UDP port number), allowing different ports to be individually defined as RADIUS hosts providing a specific AAA service. If you configure two different host entries on the same RADIUS server for the same service, (for example, accounting), the second configured host entry acts as a fail-over backup to the first one.

You use the `server` group server configuration command to associate a particular server with a defined group server. You can either identify the server by its IP address or identify multiple host instances or entries by using the optional `auth-port` and `acct-port` keywords.
Beginning in privileged EXEC mode, follow these steps to define the AAA server group and associate a particular RADIUS server with it:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>radius-server host {hostname</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note</td>
</tr>
<tr>
<td>Step 3</td>
<td>aaa new-model</td>
</tr>
<tr>
<td>Step 4</td>
<td>aaa group server radius group-name</td>
</tr>
<tr>
<td>Step 5</td>
<td>server ip-address</td>
</tr>
<tr>
<td>Step 6</td>
<td>end</td>
</tr>
<tr>
<td>Step 7</td>
<td>show running-config</td>
</tr>
</tbody>
</table>
Controlling Switch Access with RADIUS

### Configuring Switch-Based Authentication

To remove the specified RADIUS server, use the `no radius-server host hostname | ip-address` global configuration command. To remove a server group from the configuration list, use the `no aaa group server radius group-name` global configuration command. To remove the IP address of a RADIUS server, use the `no server ip-address` server group configuration command.

In this example, the switch is configured to recognize two different RADIUS group servers (`group1` and `group2`). Group1 has two different host entries on the same RADIUS server configured for the same services. The second host entry acts as a fail-over backup to the first entry.

```
Switch(config)# radius-server host 172.20.0.1 auth-port 1000 acct-port 1001
Switch(config)# radius-server host 172.10.0.1 auth-port 1645 acct-port 1646
Switch(config)# aaa new-model
Switch(config)# aaa group server radius group1
Switch(config-sg-radius)# server 172.20.0.1 auth-port 1000 acct-port 1001
Switch(config-sg-radius)# exit
Switch(config)# aaa group server radius group2
Switch(config-sg-radius)# server 172.20.0.1 auth-port 2000 acct-port 2001
Switch(config-sg-radius)# exit
```

### Configuring RADIUS Authorization for User Privileged Access and Network Services

AAA authorization limits the services available to a user. When AAA authorization is enabled, the switch uses information retrieved from the user’s profile, which is in the local user database or on the security server, to configure the user’s session. The user is granted access to a requested service only if the information in the user profile allows it.

You can use the `aaa authorization` global configuration command with the `radius` keyword to set parameters that restrict a user’s network access to privileged EXEC mode.

The `aaa authorization exec radius local` command sets these authorization parameters:

- Use RADIUS for privileged EXEC access authorization if authentication was performed by using RADIUS.
- Use the local database if authentication was not performed by using RADIUS.

**Note**

Authorization is bypassed for authenticated users who log in through the CLI even if authorization has been configured.

Beginning in privileged EXEC mode, follow these steps to specify RADIUS authorization for privileged EXEC access and network services:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>aaa authorization network radius</code></td>
<td>Configure the switch for user RADIUS authorization for all network-related service requests.</td>
</tr>
</tbody>
</table>
Controlling Switch Access with RADIUS

Chapter 5 Configuring Switch-Based Authentication

Controlling Switch Access with RADIUS

To disable authorization, use the `no aaa authorization {network | exec} method1` global configuration command.

Starting RADIUS Accounting

The AAA accounting feature tracks the services that users are accessing and the amount of network resources that they are consuming. When AAA accounting is enabled, the switch reports user activity to the RADIUS security server in the form of accounting records. Each accounting record contains accounting attribute-value (AV) pairs and is stored on the security server. This data can then be analyzed for network management, client billing, or auditing.

Beginning in privileged EXEC mode, follow these steps to enable RADIUS accounting for each Cisco IOS privilege level and for network services:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 aaa accounting network start-stop radius</td>
<td>Enable RADIUS accounting for all network-related service requests.</td>
</tr>
<tr>
<td>Step 3 aaa accounting exec start-stop radius</td>
<td>Enable RADIUS accounting to send a start-record accounting notice at the beginning of a privileged EXEC process and a stop-record at the end.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable accounting, use the `no aaa accounting {network | exec} {start-stop} method1`... global configuration command.
Configuring Settings for All RADIUS Servers

Beginning in privileged EXEC mode, follow these steps to configure global communication settings between the switch and all RADIUS servers:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>radius-server key string</td>
</tr>
<tr>
<td>Step 3</td>
<td>radius-server retransmit retries</td>
</tr>
<tr>
<td>Step 4</td>
<td>radius-server timeout seconds</td>
</tr>
<tr>
<td>Step 5</td>
<td>radius-server deadtime minutes</td>
</tr>
<tr>
<td>Step 6</td>
<td>end</td>
</tr>
<tr>
<td>Step 7</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 8</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting for the retransmit, timeout, and deadtime, use the no forms of these commands.

Configuring the Switch to Use Vendor-Specific RADIUS Attributes

The Internet Engineering Task Force (IETF) draft standard specifies a method for communicating vendor-specific information between the switch and the RADIUS server by using the vendor-specific attribute (attribute 26). Vendor-specific attributes (VSAs) allow vendors to support their own extended attributes not suitable for general use. The Cisco RADIUS implementation supports one vendor-specific option by using the format recommended in the specification. Cisco’s vendor-ID is 9, and the supported option has vendor-type 1, which is named cisco-avpair. The value is a string with this format:

```
protocol : attribute sep value *
```

*Protocol* is a value of the Cisco protocol attribute for a particular type of authorization. *Attribute* and *value* are an appropriate attribute-value (AV) pair defined in the Cisco TACACS+ specification, and *sep* is = for mandatory attributes and is * for optional attributes. The full set of features available for TACACS+ authorization can then be used for RADIUS.

For example, this AV pair activates Cisco’s multiple named ip address pools feature during IP authorization (during PPP IPCP address assignment):

```
cisco-avpair= "ip:addr-pool=first"
```
This example shows how to provide a user logging in from a switch with immediate access to privileged EXEC commands:

cisco-avpair= "shell:priv-lvl=15"

This example shows how to specify an authorized VLAN in the RADIUS server database:

cisco-avpair= "tunnel-type(#64)=VLAN(13)"
cisco-avpair= "tunnel-medium-type(#65)=802 media(6)"
cisco-avpair= "tunnel-private-group-ID(#81)=vlanId"

This example shows how to apply an input ACL in ASCII format to an interface for the duration of this connection:

cisco-avpair= "ip:inacl#1=deny ip 10.10.10.10 0.0.255.255 20.20.20.20 255.255.0.0"
cisco-avpair= "ip:inacl#2=deny ip 10.10.10.10 0.0.255.255 any"
cisco-avpair= "mac:inacl#3=deny any any decnet-iv"

This example shows how to apply an output ACL in ASCII format to an interface for the duration of this connection:

cisco-avpair= "ip:outacl#2=deny ip 10.10.10.10 0.0.255.255 any"

Other vendors have their own unique vendor-IDs, options, and associated VSAs. For more information about vendor-IDs and VSAs, see RFC 2138, “Remote Authentication Dial-In User Service (RADIUS).”

Beginning in privileged EXEC mode, follow these steps to configure the switch to recognize and use VSAs:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 radius-server vsa send [accounting</td>
<td>Enable the switch to recognize and use VSAs as defined by RADIUS IETF</td>
</tr>
<tr>
<td></td>
<td>• (Optional) Use the accounting keyword to limit the set of recognized</td>
</tr>
<tr>
<td></td>
<td>vendor-specific attributes to only accounting attributes.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) Use the authentication keyword to limit the set of</td>
</tr>
<tr>
<td></td>
<td>recognized vendor-specific attributes to only authentication</td>
</tr>
<tr>
<td></td>
<td>attributes.</td>
</tr>
<tr>
<td></td>
<td>If you enter this command without keywords, both accounting and</td>
</tr>
<tr>
<td></td>
<td>authentication vendor-specific attributes are used.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your settings.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

For a complete list of RADIUS attributes or more information about vendor-specific attribute 26, see the “RADIUS Attributes” appendix in the Cisco IOS Security Configuration Guide, Release 12.2.
Configuring the Switch for Vendor-Proprietary RADIUS Server Communication

Although an IETF draft standard for RADIUS specifies a method for communicating vendor-proprietary information between the switch and the RADIUS server, some vendors have extended the RADIUS attribute set in a unique way. Cisco IOS software supports a subset of vendor-proprietary RADIUS attributes.

As mentioned earlier, to configure RADIUS (whether vendor-proprietary or IETF draft-compliant), you must specify the host running the RADIUS server daemon and the secret text string it shares with the switch. You specify the RADIUS host and secret text string by using the `radius-server` global configuration commands.

Beginning in privileged EXEC mode, follow these steps to specify a vendor-proprietary RADIUS server host and a shared secret text string:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>radius-server host <code>{hostname | ip-address}</code> non-standard</td>
</tr>
<tr>
<td>Step 3</td>
<td>radius-server key <code>string</code></td>
</tr>
<tr>
<td>Note</td>
<td>The key is a text string that must match the encryption key used on the RADIUS server. Leading spaces are ignored, but spaces within and at the end of the key are used. If you use spaces in your key, do not enclose the key in quotation marks unless the quotation marks are part of the key.</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To delete the vendor-proprietary RADIUS host, use the `no radius-server host `{hostname \| ip-address}` non-standard` global configuration command. To disable the key, use the `no radius-server key` global configuration command.

This example shows how to specify a vendor-proprietary RADIUS host and to use a secret key of `rad124` between the switch and the server:

```
Switch(config)# radius-server host 172.20.30.15 nonstandard
Switch(config)# radius-server key rad124
```

Displaying the RADIUS Configuration

To display the RADIUS configuration, use the `show running-config` privileged EXEC command.
Controlling Switch Access with Kerberos

This section describes how to enable and configure the Kerberos security system, which authenticates requests for network resources by using a trusted third party. To use this feature, the cryptographic (that is, supports encryption) versions of the switch software must be installed on your switch.

You must obtain authorization to use this feature and to download the cryptographic software files from Cisco.com. You can download the cryptographic software image from [www.hp.com/support](http://www.hp.com/support). For more information, see the release notes *Cisco Gigabit Ethernet Switch Module for HP BladeSystem p-Class Release Notes* for this release.

These sections contain this information:

- Understanding Kerberos, page 5-32
- Kerberos Operation, page 5-34
- Configuring Kerberos, page 5-35

For Kerberos configuration examples, see the “Kerberos Configuration Examples” section in the “Security Server Protocols” chapter of the *Cisco IOS Security Configuration Guide, Release 12.2*, at this URL:


For complete syntax and usage information for the commands used in this section, see the “Kerberos Commands” section in the “Security Server Protocols” chapter of the *Cisco IOS Security Command Reference, Release 12.2*, at this URL:


For Kerberos configuration examples and in the *Cisco IOS Security Command Reference, Release 12.2*, the trusted third party can be a switch that supports Kerberos, that is configured as a network security server, and that can authenticate users by using the Kerberos protocol.

Understanding Kerberos

Kerberos is a secret-key network authentication protocol, which was developed at the Massachusetts Institute of Technology (MIT). It uses the Data Encryption Standard (DES) cryptographic algorithm for encryption and authentication and authenticates requests for network resources. Kerberos uses the concept of a trusted third party to perform secure verification of users and services. This trusted third party is called the key distribution center (KDC).

Kerberos verifies that users are who they claim to be and the network services that they use are what the services claim to be. To do this, a KDC or trusted Kerberos server issues tickets to users. These tickets, which have a limited lifespan, are stored in user credential caches. The Kerberos server uses the tickets instead of usernames and passwords to authenticate users and network services.

A Kerberos server can be a switch that is configured as a network security server and that can authenticate users by using the Kerberos protocol.
The Kerberos credential scheme uses a process called single logon. This process authenticates a user once and then allows secure authentication (without encrypting another password) wherever that user credential is accepted.

This software release supports Kerberos 5, which allows organizations that are already using Kerberos 5 to use the same Kerberos authentication database on the KDC that they are already using on their other network hosts (such as UNIX servers and PCs).

In this software release, Kerberos supports these network services:

- Telnet
- rlogin
- rsh (Remote Shell Protocol)

Table 5-2 lists the common Kerberos-related terms and definitions:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentication</td>
<td>A process by which a user or service identifies itself to another service. For example, a client can authenticate to a switch or a switch can authenticate to another switch.</td>
</tr>
<tr>
<td>Authorization</td>
<td>A means by which the switch identifies what privileges the user has in a network or on the switch and what actions the user can perform.</td>
</tr>
<tr>
<td>Credential</td>
<td>A general term that refers to authentication tickets, such as TGTs and service credentials. Kerberos credentials verify the identity of a user or service. If a network service decides to trust the Kerberos server that issued a ticket, it can be used in place of re-entering a username and password. Credentials have a default lifespan of eight hours.</td>
</tr>
<tr>
<td>Instance</td>
<td>An authorization level label for Kerberos principals. Most Kerberos principals are of the form user@REALM (for example, <a href="mailto:smith@EXAMPLE.COM">smith@EXAMPLE.COM</a>). A Kerberos principal with a Kerberos instance has the form user/instance@REALM (for example, smith/admin@EXAMPLE.COM). The Kerberos instance can be used to specify the authorization level for the user if authentication is successful. The server of each network service might implement and enforce the authorization mappings of Kerberos instances but is not required to do so. Note: The Kerberos principal and instance names must be in all lowercase characters.</td>
</tr>
<tr>
<td>KDC</td>
<td>Key distribution center that consists of a Kerberos server and database program that is running on a network host.</td>
</tr>
<tr>
<td>Kerberized</td>
<td>A term that describes applications and services that have been modified to support the Kerberos credential infrastructure.</td>
</tr>
<tr>
<td>Kerberos realm</td>
<td>A domain consisting of users, hosts, and network services that are registered to a Kerberos server. The Kerberos server is trusted to verify the identity of a user or network service to another user or network service. Note: The Kerberos realm name must be in all uppercase characters.</td>
</tr>
</tbody>
</table>

Note: The Kerberos realm name must be in all uppercase characters.
Kerberos Operation

A Kerberos server can be a switch that is configured as a network security server and that can authenticate remote users by using the Kerberos protocol. Although you can customize Kerberos in a number of ways, remote users attempting to access network services must pass through three layers of security before they can access network services.

To authenticate to network services by using a switch as a Kerberos server, remote users must follow these steps:

1. Authenticating to a Boundary Switch, page 5-34
2. Obtaining a TGT from a KDC, page 5-35
3. Authenticating to Network Services, page 5-35

Authenticating to a Boundary Switch

This section describes the first layer of security through which a remote user must pass. The user must first authenticate to the boundary switch. This process then occurs:

1. The user opens an un-Kerberized Telnet connection to the boundary switch.
2. The switch prompts the user for a username and password.
3. The switch requests a TGT from the KDC for this user.
4. The KDC sends an encrypted TGT that includes the user identity to the switch.
5. The switch attempts to decrypt the TGT by using the password that the user entered.
   - If the decryption is successful, the user is authenticated to the switch.
   - If the decryption is not successful, the user repeats Step 2 either by re-entering the username and password (noting if Caps Lock or Num Lock is on or off) or by entering a different username and password.

A remote user who initiates a un-Kerberized Telnet session and authenticates to a boundary switch is inside the firewall, but the user must still authenticate directly to the KDC before getting access to the network services. The user must authenticate to the KDC because the TGT that the KDC issues is stored on the switch and cannot be used for additional authentication until the user logs on to the switch.

**Obtaining a TGT from a KDC**

This section describes the second layer of security through which a remote user must pass. The user must now authenticate to a KDC and obtain a TGT from the KDC to access network services.

For instructions about how to authenticate to a KDC, see the “Obtaining a TGT from a KDC” section in the “Security Server Protocols” chapter of the *Cisco IOS Security Configuration Guide, Release 12.2*, at this URL:


**Authenticating to Network Services**

This section describes the third layer of security through which a remote user must pass. The user with a TGT must now authenticate to the network services in a Kerberos realm.

For instructions about how to authenticate to a network service, see the “Authenticating to Network Services” section in the “Security Server Protocols” chapter of the *Cisco IOS Security Configuration Guide, Release 12.2*, at this URL:


**Configuring Kerberos**

So that remote users can authenticate to network services, you must configure the hosts and the KDC in the Kerberos realm to communicate and mutually authenticate users and network services. To do this, you must identify them to each other. You add entries for the hosts to the Kerberos database on the KDC and add KEYTAB files generated by the KDC to all hosts in the Kerberos realm. You also create entries for the users in the KDC database.

When you add or create entries for the hosts and users, follow these guidelines:

- The Kerberos principal name *must* be in all lowercase characters.
- The Kerberos instance name *must* be in all lowercase characters.
- The Kerberos realm name *must* be in all uppercase characters.
Note

A Kerberos server can be a switch that is configured as a network security server and that can authenticate users by using the Kerberos protocol.

To set up a Kerberos-authenticated server-client system, follow these steps:

- Configure the KDC by using Kerberos commands.
- Configure the switch to use the Kerberos protocol.

For instructions, see the “Kerberos Configuration Task List” section in the “Security Server Protocols” chapter of the Cisco IOS Security Configuration Guide, Release 12.2, at this URL:

Configuring the Switch for Local Authentication and Authorization

You can configure AAA to operate without a server by setting the switch to implement AAA in local mode. The switch then handles authentication and authorization. No accounting is available in this configuration.

Beginning in privileged EXEC mode, follow these steps to configure the switch for local AAA:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 aaa new-model</td>
<td>Enable AAA.</td>
</tr>
<tr>
<td>Step 3 aaa authentication login default local</td>
<td>Set the login authentication to use the local username database. The <code>default</code> keyword applies the local user database authentication to all ports.</td>
</tr>
<tr>
<td>Step 4 aaa authorization exec local</td>
<td>Configure user AAA authorization, check the local database, and allow the user to run an EXEC shell.</td>
</tr>
<tr>
<td>Step 5 aaa authorization network local</td>
<td>Configure user AAA authorization for all network-related service requests.</td>
</tr>
</tbody>
</table>
Configuring the Switch for Secure Shell

This section describes how to configure the Secure Shell (SSH) feature. To use this feature, you must install the cryptographic (encrypted) software image on your switch. You can download the cryptographic software files from www.hp.com/support. For more information, see the Cisco Gigabit Ethernet Switch Module for HP BladeSystem p-Class Release Notes for this release.

These sections contain this information:

- Understanding SSH, page 5-38
- Configuring SSH, page 5-39
- Displaying the SSH Configuration and Status, page 5-41
For SSH configuration examples, see the “SSH Configuration Examples” section in the “Configuring Secure Shell” chapter of the Cisco IOS Security Configuration Guide, Cisco IOS Release 12.2, at this URL:


For complete syntax and usage information for the commands used in this section, see the Cisco Gigabit Ethernet Switch Module for HP BladeSystem p-Class Command Reference Guide for this release and the command reference for Cisco IOS Release 12.2 at this URL:


### Understanding SSH

SSH is a protocol that provides a secure, remote connection to a device. SSH provides more security for remote connections than Telnet does by providing strong encryption when a device is authenticated. This software release supports SSH Version 1 (SSHv1) and SSH Version 2 (SSHv2).

This section consists of these topics:

- SSH Servers, Integrated Clients, and Supported Versions, page 5-38
- Limitations, page 5-39

### SSH Servers, Integrated Clients, and Supported Versions

The SSH feature has an SSH server and an SSH integrated client, which are applications that run on the switch. You can use an SSH client to connect to a switch running the SSH server. The SSH server works with the SSH client supported in this release and with non-Cisco SSH clients. The SSH client also works with the SSH server supported in this release and with non-Cisco SSH servers.

The switch supports an SSHv1 or an SSHv2 server.

The switch supports an SSHv1 client.

SSH supports the Data Encryption Standard (DES) encryption algorithm, the Triple DES (3DES) encryption algorithm, and password-based user authentication.

SSH also supports these user authentication methods:

- TACACS+ (for more information, see the “Controlling Switch Access with TACACS+” section on page 5-10)
- RADIUS (for more information, see the “Controlling Switch Access with RADIUS” section on page 5-17)
- Local authentication and authorization (for more information, see the “Configuring the Switch for Local Authentication and Authorization” section on page 5-36)

This software release does not support IP Security (IPSec).
Limitations

These limitations apply to SSH:

- The switch supports Rivest, Shamir, and Adelman (RSA) authentication.
- SSH supports only the execution-shell application.
- The SSH server and the SSH client are supported only on DES (56-bit) and 3DES (168-bit) data encryption software.
- The switch does not support the Advanced Encryption Standard (AES) symmetric encryption algorithm.

Configuring SSH

This section has this configuration information:

- Configuration Guidelines, page 5-39
- Setting Up the Switch to Run SSH, page 5-39 (required)
- Configuring the SSH Server, page 5-40 (required only if you are configuring the switch as an SSH server)

Configuration Guidelines

Follow these guidelines when configuring the switch as an SSH server or SSH client:

- An RSA key pair generated by a SSHv1 server can be used by an SSHv2 server, and the reverse.
- If you get CLI error messages after entering the `crypto key generate rsa` global configuration command, an RSA key pair has not been generated. Reconfigure the hostname and domain, and then enter the `crypto key generate rsa` command. For more information, see the “Setting Up the Switch to Run SSH” section on page 5-39.
- When generating the RSA key pair, the message `No host name specified` might appear. If it does, you must configure a hostname by using the `hostname` global configuration command.
- When generating the RSA key pair, the message `No domain specified` might appear. If it does, you must configure an IP domain name by using the `ip domain-name` global configuration command.
- When configuring the local authentication and authorization authentication method, make sure that AAA is disabled on the console.

Setting Up the Switch to Run SSH

Follow these steps to set up your switch to run SSH:

1. Download the cryptographic software image from [www.hp.com/support](http://www.hp.com/support). This step is required. For more information, see the Cisco Gigabit Ethernet Switch Module for HP BladeSystem p-Class Release Notes for this release.
2. Configure a hostname and IP domain name for the switch. Follow this procedure only if you are configuring the switch as an SSH server.
3. Generate an RSA key pair for the switch, which automatically enables SSH. Follow this procedure only if you are configuring the switch as an SSH server.

4. Configure user authentication for local or remote access. This step is required. For more information, see the “Configuring the Switch for Local Authentication and Authorization” section on page 5-36.

Beginning in privileged EXEC mode, follow these steps to configure a hostname and an IP domain name and to generate an RSA key pair. This procedure is required if you are configuring the switch as an SSH server.

### Command Purpose

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>hostname hostname</td>
<td>Configure a hostname for your switch.</td>
</tr>
<tr>
<td>3</td>
<td>ip domain-name domain_name</td>
<td>Configure a host domain for your switch.</td>
</tr>
<tr>
<td>4</td>
<td>crypto key generate rsa</td>
<td>Enable the SSH server for local and remote authentication on the switch and generate an RSA key pair.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>We recommend that a minimum modulus size of 1024 bits.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When you generate RSA keys, you are prompted to enter a modulus length. A longer modulus length might be more secure, but it takes longer to generate and to use.</td>
</tr>
<tr>
<td>5</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>6</td>
<td>show ip ssh</td>
<td>Show the version and configuration information for your SSH server.</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>Show the status of the SSH server on the switch.</td>
</tr>
<tr>
<td>7</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To delete the RSA key pair, use the **crypto key zeroize rsa** global configuration command. After the RSA key pair is deleted, the SSH server is automatically disabled.

### Configuring the SSH Server

Beginning in privileged EXEC mode, follow these steps to configure the SSH server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>ip ssh version [1</td>
<td>2]</td>
</tr>
<tr>
<td></td>
<td>• 1—Configure the switch to run SSH Version 1.</td>
</tr>
<tr>
<td></td>
<td>• 2—Configure the switch to run SSH Version 2.</td>
</tr>
<tr>
<td></td>
<td>If you do not enter this command or do not specify a keyword, the SSH server selects the latest SSH version supported by the SSH client. For example, if the SSH client supports SSHv1 and SSHv2, the SSH server selects SSHv2.</td>
</tr>
</tbody>
</table>
To return to the default SSH control parameters, use the `no ip ssh {timeout seconds | authentication-retries number}` global configuration command.

### Displaying the SSH Configuration and Status

To display the SSH server configuration and status, use one or more of the privileged EXEC commands in Table 5-3:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show ip ssh</code></td>
<td>Shows the version and configuration information for the SSH server.</td>
</tr>
<tr>
<td><code>show ssh</code></td>
<td>Shows the status of the SSH server connections on the switch.</td>
</tr>
</tbody>
</table>

From more information about these commands, see the “Secure Shell Commands” section in the “Other Security Features” chapter of the *Cisco IOS Security Command Reference, Cisco IOS Release 12.2*, at this URL:

Configuring the Switch for Secure Socket Layer HTTP

This section describes how to configure Secure Socket Layer (SSL) version 3.0 support for the HTTP 1.1 server and client. SSL provides server authentication, encryption, and message integrity, as well as HTTP client authentication, to allow secure HTTP communications. To use this feature, the cryptographic (encrypted) software image must be installed on your switch. You can download the cryptographic software image from www.hp.com/support. For more information about the crypto image, see the Cisco Gigabit Ethernet Switch Module for HP BladeSystem p-Class Release Notes for this release.

These sections contain this information:

- Understanding Secure HTTP Servers and Clients, page 5-42
- Configuring Secure HTTP Servers and Clients, page 5-44
- Displaying Secure HTTP Server and Client Status, page 5-48

For configuration examples and complete syntax and usage information for the commands used in this section, see the “HTTPS - HTTP Server and Client with SSL 3.0” feature description for Cisco IOS Release 12.2(15)T at this URL:


Understanding Secure HTTP Servers and Clients

On a secure HTTP connection, data to and from an HTTP server is encrypted before being sent over the Internet. HTTP with SSL encryption provides a secure connection to allow such functions as configuring a switch from a Web browser. Cisco's implementation of the secure HTTP server and secure HTTP client uses an implementation of SSL Version 3.0 with application-layer encryption. HTTP over SSL is abbreviated as HTTPS; the URL of a secure connection begins with https:// instead of http://.

The primary role of the HTTP secure server (the switch) is to listen for HTTPS requests on a designated port (the default HTTPS port is 443) and pass the request to the HTTP 1.1 Web server. The HTTP 1.1 server processes requests and passes responses (pages) back to the HTTP secure server, which, in turn, responds to the original request.

The primary role of the HTTP secure client (the web browser) is to respond to Cisco IOS application requests for HTTPS User Agent services, perform HTTPS User Agent services for the application, and pass the response back to the application.

Certificate Authority Trustpoints

Certificate authorities (CAs) manage certificate requests and issue certificates to participating network devices. These services provide centralized security key and certificate management for the participating devices. Specific CA servers are referred to as trustpoints.

When a connection attempt is made, the HTTPS server provides a secure connection by issuing a certified X.509v3 certificate, obtained from a specified CA trustpoint, to the client. The client (usually a Web browser), in turn, has a public key that allows it to authenticate the certificate.

For secure HTTP connections, we highly recommend that you configure a CA trustpoint. If a CA trustpoint is not configured for the device running the HTTPS server, the server certifies itself and generates the needed RSA key pair. Because a self-certified (self-signed) certificate does not provide...
Chapter 5 Configuring Switch-Based Authentication

Configuring the Switch for Secure Socket Layer HTTP

adequate security, the connecting client generates a notification that the certificate is self-certified, and the user has the opportunity to accept or reject the connection. This option is useful for internal network topologies (such as testing).

If you do not configure a CA trustpoint, when you enable a secure HTTP connection, either a temporary or a persistent self-signed certificate for the secure HTTP server (or client) is automatically generated.

- If the switch is not configured with a hostname and a domain name, a temporary self-signed certificate is generated. If the switch reboots, any temporary self-signed certificate is lost, and a new temporary new self-signed certificate is assigned.

- If the switch has been configured with a host and domain name, a persistent self-signed certificate is generated. This certificate remains active if you reboot the switch or if you disable the secure HTTP server so that it will be there the next time you re-enable a secure HTTP connection.

If a self-signed certificate has been generated, this information is included in the output of the `show running-config` privileged EXEC command. This is a partial sample output from that command displaying a self-signed certificate.

Switch# show running-config
Building configuration...

<output truncated>
crypto pki trustpoint TP-self-signed-3080755072
  enrollment selfsigned
  subject-name cn=IOS-Self-Signed-Certificate-3080755072
  revocation-check none
  rsakeypair TP-self-signed-3080755072
!crypto ca certificate chain TP-self-signed-3080755072
  certificate self-signed 01
    3082020F 30820208 A0030201 02020101 300D0609 2A864886 F70D0101 04050030
    59312F30 2D060355 04031326 494F532D 53656C66 2D536967 6E65642D 43657274
    69666966 6174652D 33303830 37353530 73323126 30240609 2A864886 F70D0109
    02161743 45322D13 3535302D 31322E73 75666669 636174652D 33303830 37353530
    73323126 30240609 2A864886 F70D0109
  !<output truncated>

You can remove this self-signed certificate by disabling the secure HTTP server and entering the `no crypto pki trustpoint TP-self-signed-3080755072` global configuration command. If you later re-enable a secure HTTP server, a new self-signed certificate is generated.

Note

The values that follow `TP self-signed` depend on the serial number of the device.

You can use an optional command (ip http secure-client-auth) to allow the HTTPS server to request an X.509v3 certificate from the client. Authenticating the client provides more security than server authentication by itself.

For additional information on Certificate Authorities, see the “Configuring Certification Authority Interoperability” chapter in the Cisco IOS Security Configuration Guide, Release 12.2.
Chapter 5      Configuring Switch-Based Authentication

CipherSuites

A CipherSuite specifies the encryption algorithm and the digest algorithm to use on a SSL connection. When connecting to the HTTPS server, the client Web browser offers a list of supported CipherSuites, and the client and server negotiate the best encryption algorithm to use from those on the list that are supported by both. For example, Netscape Communicator 4.76 supports U.S. security with RSA Public Key Cryptography, MD2, MD5, RC2-CBC, RC4, DES-CBC, and DES-EDE3-CBC.

For the best possible encryption, you should use a client browser that supports 128-bit encryption, such as Microsoft Internet Explorer Version 5.5 (or later) or Netscape Communicator Version 4.76 (or later). The SSL_RSA_WITH_DES_CBC_SHA CipherSuite provides less security than the other CipherSuites, as it does not offer 128-bit encryption.

The more secure and more complex CipherSuites require slightly more processing time. This list defines the CipherSuites supported by the switch and ranks them from fastest to slowest in terms of router processing load (speed):

1. SSL_RSA_WITH_DES_CBC_SHA—RSA key exchange (RSA Public Key Cryptography) with DES-CBC for message encryption and SHA for message digest
2. SSL_RSA_WITH_RC4_128_MD5—RSA key exchange with RC4 128-bit encryption and MD5 for message digest
3. SSL_RSA_WITH_RC4_128_SHA—RSA key exchange with RC4 128-bit encryption and SHA for message digest
4. SSL_RSA_WITH_3DES_EDE_CBC_SHA—RSA key exchange with 3DES and DES-EDE3-CBC for message encryption and SHA for message digest

RSA (in conjunction with the specified encryption and digest algorithm combinations) is used for both key generation and authentication on SSL connections. This usage is independent of whether or not a CA trustpoint is configured.

Configuring Secure HTTP Servers and Clients

These sections contain this configuration information:

- Default SSL Configuration, page 5-44
- SSL Configuration Guidelines, page 5-45
- Configuring a CA Trustpoint, page 5-45
- Configuring the Secure HTTP Server, page 5-46
- Configuring the Secure HTTP Client, page 5-47

Default SSL Configuration

The standard HTTP server is enabled.
SSL is enabled.
No CA trustpoints are configured.
No self-signed certificates are generated.
SSL Configuration Guidelines

When SSL is used in a switch cluster, the SSL session terminates at the cluster commander. Cluster member switches must run standard HTTP.

Before you configure a CA trustpoint, you should ensure that the system clock is set. If the clock is not set, the certificate is rejected due to an incorrect date.

Configuring a CA Trustpoint

For secure HTTP connections, we recommend that you configure an official CA trustpoint. A CA trustpoint is more secure than a self-signed certificate.

Beginning in privileged EXEC mode, follow these steps to configure a CA trustpoint:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>hostname hostname</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>ip domain-name domain-name</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>crypto key generate rsa</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>crypto ca trustpoint name</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>enrollment url url</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>enrollment http-proxy host-name port-number</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td>crl query url</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td>primary</td>
</tr>
<tr>
<td><strong>Step 10</strong></td>
<td>exit</td>
</tr>
<tr>
<td><strong>Step 11</strong></td>
<td>crypto ca authentication name</td>
</tr>
<tr>
<td><strong>Step 12</strong></td>
<td>crypto ca enroll name</td>
</tr>
<tr>
<td><strong>Step 13</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 14</strong></td>
<td>show crypto ca trustpoints</td>
</tr>
<tr>
<td><strong>Step 15</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>
Use the `no crypto ca trustpoint name` global configuration command to delete all identity information and certificates associated with the CA.

### Configuring the Secure HTTP Server

If you are using a certificate authority for certification, you should use the previous procedure to configure the CA trustpoint on the switch before enabling the HTTP server. If you have not configured a CA trustpoint, a self-signed certificate is generated the first time that you enable the secure HTTP server. After you have configured the server, you can configure options (path, access list to apply, maximum number of connections, or timeout policy) that apply to both standard and secure HTTP servers.

Beginning in privileged EXEC mode, follow these steps to configure a secure HTTP server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><code>show ip http server status</code></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>configure terminal</code></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>ip http secure-server</code></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>ip http secure-port port-number</code></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>ip http secure-ciphersuite</code></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><code>ip http secure-client-auth</code></td>
</tr>
</tbody>
</table>
| **Step 7** | `ip http secure-trustpoint name` | Specify the CA trustpoint to use to get an X.509v3 security certificate and to authenticate the client certificate connection.  
**Note** Use of this command assumes you have already configured a CA trustpoint according to the previous procedure. |
| **Step 8** | `ip http path path-name` | (Optional) Set a base HTTP path for HTML files. The path specifies the location of the HTTP server files on the local system (usually located in system flash memory). |
| **Step 9** | `ip http access-class access-list-number` | (Optional) Specify an access list to use to allow access to the HTTP server. |
| **Step 10** | `ip http max-connections value` | (Optional) Set the maximum number of concurrent connections that are allowed to the HTTP server. The range is 1 to 16; the default value is 5. |
Configuring the Switch for Secure Socket Layer HTTP

Use the `no ip http server` global configuration command to disable the standard HTTP server. Use the `no ip http secure-server` global configuration command to disable the secure HTTP server. Use the `no ip http secure-port` and the `no ip http secure-ciphersuite` global configuration commands to return to the default settings. Use the `no ip http secure-client-auth` global configuration command to remove the requirement for client authentication.

To verify the secure HTTP connection by using a Web browser, enter `https://URL`, where the URL is the IP address or hostname of the server switch. If you configure a port other than the default port, you must also specify the port number after the URL. For example:

https://209.165.129:1026

or

https://host.domain.com:1026

Configuring the Secure HTTP Client

The standard HTTP client and secure HTTP client are always enabled. A certificate authority is required for secure HTTP client certification. This procedure assumes that you have previously configured a CA trustpoint on the switch. If a CA trustpoint is not configured and the remote HTTPS server requires client authentication, connections to the secure HTTP client fail.

Beginning in privileged EXEC mode, follow these steps to configure a secure HTTP client:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>ip http client secure-trustpoint name</code></td>
<td>(Optional) Specify the CA trustpoint to be used if the remote HTTP server requests client authentication. Using this command assumes that you have already configured a CA trustpoint by using the previous procedure. The command is optional if client authentication is not needed or if a primary trustpoint has been configured.</td>
</tr>
</tbody>
</table>
Configuring the Switch for Secure Copy Protocol

The Secure Copy Protocol (SCP) feature provides a secure and authenticated method for copying switch configurations or switch image files. SCP relies on Secure Shell (SSH), an application and a protocol that provides a secure replacement for the Berkeley r-tools.

For SSH to work, the switch needs an RSA public/private key pair. This is the same with SCP, which relies on SSH for its secure transport.

Because SSH also relies on AAA authentication, and SCP relies further on AAA authorization, correct configuration is necessary.

- Before enabling SCP, you must correctly configure SSH, authentication, and authorization on the switch.
- Because SCP relies on SSH for its secure transport, the router must have an Rivest, Shamir, and Adelman (RSA) key pair.

Note When using SCP, you cannot enter the password into the copy command. You must enter the password when prompted.
Information About Secure Copy

To configure Secure Copy feature, you should understand these concepts.

The behavior of SCP is similar to that of remote copy (rcp), which comes from the Berkeley r-tools suite, except that SCP relies on SSH for security. SCP also requires that authentication, authorization, and accounting (AAA) authorization be configured so the router can determine whether the user has the correct privilege level.

A user who has appropriate authorization can use SCP to copy any file in the Cisco IOS File System (IFS) to and from a switch by using the `copy` command. An authorized administrator can also do this from a workstation.

For more information on how to configure and verify SCP, see the “Secure Copy Protocol” chapter of the *Cisco IOS New Features, Cisco IOS Release 12.2*, at this URL:

Configuring IEEE 802.1x Port-Based Authentication

This chapter describes how to configure IEEE 802.1x port-based authentication on the switch. IEEE 802.1x authentication prevents unauthorized devices (clients) from gaining access to the network.

For complete syntax and usage information for the commands used in this chapter, see the “RADIUS Commands” section in the Cisco IOS Security Command Reference, Release 12.2 and the command reference for this release.

This chapter consists of these sections:

- Understanding IEEE 802.1x Port-Based Authentication, page 6-1
- Configuring IEEE 802.1x Authentication, page 6-19
- Displaying IEEE 802.1x Statistics and Status, page 6-42

Understanding IEEE 802.1x Port-Based Authentication

The IEEE 802.1x standard defines a client-server-based access control and authentication protocol that prevents unauthorized clients from connecting to a LAN through publicly accessible ports unless they are properly authenticated. The authentication server authenticates each client connected to a switch port before making available any services offered by the switch or the LAN.

Until the client is authenticated, IEEE 802.1x access control allows only Extensible Authentication Protocol over LAN (EAPOL), Cisco Discovery Protocol (CDP), and Spanning Tree Protocol (STP) traffic through the port to which the client is connected. After authentication is successful, normal traffic can pass through the port.

These sections describe IEEE 802.1x port-based authentication:

- Device Roles, page 6-2
- Authentication Process, page 6-3
- Authentication Initiation and Message Exchange, page 6-5
- Ports in Authorized and Unauthorized States, page 6-7
- IEEE 802.1x Host Mode, page 6-8
- IEEE 802.1x Accounting, page 6-9
Understanding IEEE 802.1x Port-Based Authentication

IEEE 802.1x Accounting Attribute-Value Pairs, page 6-9
Using IEEE 802.1x Authentication with VLAN Assignment, page 6-10
Using IEEE 802.1x Authentication with Per-User ACLs, page 6-11
Using IEEE 802.1x Authentication with Guest VLAN, page 6-12
Using IEEE 802.1x Authentication with Restricted VLAN, page 6-13
Using IEEE 802.1x Authentication with Inaccessible Authentication Bypass, page 6-14
Using IEEE 802.1x Authentication with Voice VLAN Ports, page 6-15
Using IEEE 802.1x Authentication with Port Security, page 6-16
Using IEEE 802.1x Authentication with Wake-on-LAN, page 6-16
Using IEEE 802.1x Authentication with MAC Authentication Bypass, page 6-17
Using Web Authentication, page 6-18

Device Roles

With IEEE 802.1x port-based authentication, the devices in the network have specific roles as shown in Figure 6-1.

Figure 6-1  IEEE 802.1x Device Roles

- **Client**—the device (workstation) that requests access to the LAN and switch services and responds to requests from the switch. The workstation must be running IEEE 802.1x-compliant client software such as that offered in the Microsoft Windows XP operating system. (The client is the **supplicant** in the IEEE 802.1x standard.)

  Note  To resolve Windows XP network connectivity and IEEE 802.1x authentication issues, read the Microsoft Knowledge Base article at this URL:  
  http://support.microsoft.com/support/kb/articles/Q303/5/97.ASP

- **Authentication server**—performs the actual authentication of the client. The authentication server validates the identity of the client and notifies the switch whether or not the client is authorized to access the LAN and switch services. Because the switch acts as the proxy, the authentication service is transparent to the client. In this release, the RADIUS security system with Extensible Authentication Protocol (EAP) extensions is the only supported authentication server. It is available
in Cisco Secure Access Control Server Version 3.0 or later. RADIUS operates in a client/server model in which secure authentication information is exchanged between the RADIUS server and one or more RADIUS clients.

- **Switch** (edge switch or wireless access point)—controls the physical access to the network based on the authentication status of the client. The switch acts as an intermediary (proxy) between the client and the authentication server, requesting identity information from the client, verifying that information with the authentication server, and relaying a response to the client. The switch includes the RADIUS client, which is responsible for encapsulating and decapsulating the EAP frames and interacting with the authentication server. (The switch is the **authenticator** in the IEEE 802.1x standard.)

When the switch receives EAPOL frames and relays them to the authentication server, the Ethernet header is stripped, and the remaining EAP frame is re-encapsulated in the RADIUS format. The EAP frames are not modified during encapsulation, and the authentication server must support EAP within the native frame format. When the switch receives frames from the authentication server, the server’s frame header is removed, leaving the EAP frame, which is then encapsulated for Ethernet and sent to the client.

The devices that can act as intermediaries include the Catalyst 3750, Catalyst 3560, Catalyst 3550, Catalyst 2970, Catalyst 2960, CGESM switch, Catalyst 2955, Catalyst 2950, Catalyst 2940 switches, or a wireless access point. These devices must be running software that supports the RADIUS client and IEEE 802.1x authentication.

**Authentication Process**

When IEEE 802.1x port-based authentication is enabled and the client supports IEEE 802.1x-compliant client software, these events occur:

- If the client identity is valid and the IEEE 802.1x authentication succeeds, the switch grants the client access to the network.

- If IEEE 802.1x authentication times out while waiting for an EAPOL message exchange and MAC authentication bypass is enabled, the switch can use the client MAC address for authorization. If the client MAC address is valid and the authorization succeeds, the switch grants the client access to the network. If the client MAC address is invalid and the authorization fails, the switch assigns the client to a guest VLAN that provides limited services if a guest VLAN is configured.

- If the switch gets an invalid identity from an IEEE 802.1x-capable client and a restricted VLAN is specified, the switch can assign the client to a restricted VLAN that provides limited services.

- If the RADIUS authentication server is unavailable (down) and inaccessible authentication bypass is enabled, the switch grants the client access to the network by putting the port in the critical-authentication state in the RADIUS-configured or the user-specified access VLAN.

**Note**

Inaccessible authentication bypass is also referred to as critical authentication or the AAA fail policy.
Figure 6-2 shows the authentication process.

**Figure 6-2 Authentication Flowchart**

The switch re-authenticates a client when one of these situations occurs:

- Periodic re-authentication is enabled, and the re-authentication timer expires.

You can configure the re-authentication timer to use a switch-specific value or to be based on values from the RADIUS server.

After IEEE 802.1x authentication using a RADIUS server is configured, the switch uses timers based on the Session-Timeout RADIUS attribute (Attribute[27]) and the Termination-Action RADIUS attribute (Attribute [29]).

The Session-Timeout RADIUS attribute (Attribute[27]) specifies the time after which re-authentication occurs.
Understanding IEEE 802.1x Port-Based Authentication

The Termination-Action RADIUS attribute (Attribute [29]) specifies the action to take during re-authentication. The actions are Initialize and ReAuthenticate. When the Initialize action is set (the attribute value is DEFAULT), the IEEE 802.1x session ends, and connectivity is lost during re-authentication. When the ReAuthenticate action is set (the attribute value is RADIUS-Request), the session is not affected during re-authentication.

- You manually re-authenticate the client by entering the `dot1x re-authenticate interface interface-id` privileged EXEC command.

### Authentication Initiation and Message Exchange

During IEEE 802.1x authentication, the switch or the client can initiate authentication. If you enable authentication on a port by using the `dot1x port-control auto` interface configuration command, the switch initiates authentication when the link state changes from down to up or periodically as long as the port remains up and unauthenticated. The switch sends an EAP-request/identity frame to the client to request its identity. Upon receipt of the frame, the client responds with an EAP-response/identity frame.

However, if during bootup, the client does not receive an EAP-request/identity frame from the switch, the client can initiate authentication by sending an EAPOL-start frame, which prompts the switch to request the client’s identity.

**Note**

If IEEE 802.1x authentication is not enabled or supported on the network access device, any EAPOL frames from the client are dropped. If the client does not receive an EAP-request/identity frame after three attempts to start authentication, the client sends frames as if the port is in the authorized state. A port in the authorized state effectively means that the client has been successfully authenticated. For more information, see the “Ports in Authorized and Unauthorized States” section on page 6-7.

When the client supplies its identity, the switch begins its role as the intermediary, passing EAP frames between the client and the authentication server until authentication succeeds or fails. If the authentication succeeds, the switch port becomes authorized. If the authentication fails, authentication can be retried, the port might be assigned to a VLAN that provides limited services, or network access is not granted. For more information, see the “Ports in Authorized and Unauthorized States” section on page 6-7.
The specific exchange of EAP frames depends on the authentication method being used. Figure 6-3 shows a message exchange initiated by the client when the client uses the One-Time-Password (OTP) authentication method with a RADIUS server.

Figure 6-3  Message Exchange

If IEEE 802.1x authentication times out while waiting for an EAPOL message exchange and MAC authentication bypass is enabled, the switch can authorize the client when the switch detects an Ethernet packet from the client. The switch uses the MAC address of the client as its identity and includes this information in the RADIUS-access/request frame that is sent to the RADIUS server. After the server sends the switch the RADIUS-access/accept frame (authorization is successful), the port becomes authorized. If authorization fails and a guest VLAN is specified, the switch assigns the port to the guest VLAN. If the switch detects an EAPOL packet while waiting for an Ethernet packet, the switch stops the MAC authentication bypass process and stops IEEE 802.1x authentication.

Figure 6-4 shows the message exchange during MAC authentication bypass.
Ports in Authorized and Unauthorized States

During IEEE 802.1x authentication, depending on the switch port state, the switch can grant a client access to the network. The port starts in the unauthorized state. While in this state, the port that is not configured as a voice VLAN port disallows all ingress and egress traffic except for IEEE 802.1x authentication, CDP, and STP packets. When a client is successfully authenticated, the port changes to the authorized state, allowing all traffic for the client to flow normally. If the port is configured as a voice VLAN port, the port allows VoIP traffic and IEEE 802.1x protocol packets before the client is successfully authenticated.

If a client that does not support IEEE 802.1x authentication connects to an unauthorized IEEE 802.1x port, the switch requests the client’s identity. In this situation, the client does not respond to the request, the port remains in the unauthorized state, and the client is not granted access to the network.

In contrast, when an IEEE 802.1x-enabled client connects to a port that is not running the IEEE 802.1x standard, the client initiates the authentication process by sending the EAPOL-start frame. When no response is received, the client sends the request for a fixed number of times. Because no response is received, the client begins sending frames as if the port is in the authorized state.

You control the port authorization state by using the `dot1x port-control` interface configuration command and these keywords:

- **force-authorized**—disables IEEE 802.1x authentication and causes the port to change to the authorized state without any authentication exchange required. The port sends and receives normal traffic without IEEE 802.1x-based authentication of the client. This is the default setting.
- **force-unauthorized**—causes the port to remain in the unauthorized state, ignoring all attempts by the client to authenticate. The switch cannot provide authentication services to the client through the port.
- **auto**—enables IEEE 802.1x authentication and causes the port to begin in the unauthorized state, allowing only EAPOL frames to be sent and received through the port. The authentication process begins when the link state of the port changes from down to up or when an EAPOL-start frame is received. The switch requests the identity of the client and begins relaying authentication messages between the client and the authentication server. Each client attempting to access the network is uniquely identified by the switch by using the client MAC address.
Understanding IEEE 802.1x Port-Based Authentication

If the client is successfully authenticated (receives an Accept frame from the authentication server), the port state changes to authorized, and all frames from the authenticated client are allowed through the port. If the authentication fails, the port remains in the unauthorized state, but authentication can be retried. If the authentication server cannot be reached, the switch can resend the request. If no response is received from the server after the specified number of attempts, authentication fails, and network access is not granted.

When a client logs off, it sends an EAPOL-logoff message, causing the switch port to change to the unauthorized state.

If the link state of a port changes from up to down, or if an EAPOL-logoff frame is received, the port returns to the unauthorized state.

IEEE 802.1x Host Mode

You can configure an IEEE 802.1x port for single-host or for multiple-hosts mode. In single-host mode (see Figure 6-1 on page 6-2), only one client can be connected to the IEEE 802.1x-enabled switch port. The switch detects the client by sending an EAPOL frame when the port link state changes to the up state. If a client leaves or is replaced with another client, the switch changes the port link state to down, and the port returns to the unauthorized state.

In multiple-hosts mode, you can attach multiple hosts to a single IEEE 802.1x-enabled port. Figure 6-5 on page 6-8 shows IEEE 802.1x port-based authentication in a wireless LAN. In this mode, only one of the attached clients must be authorized for all clients to be granted network access. If the port becomes unauthorized (re-authentication fails or an EAPOL-logoff message is received), the switch denies network access to all of the attached clients. In this topology, the wireless access point is responsible for authenticating the clients attached to it, and it also acts as a client to the switch.

With the multiple-hosts mode enabled, you can use IEEE 802.1x authentication to authenticate the port and port security to manage network access for all MAC addresses, including that of the client.

Figure 6-5  Multiple Host Mode Example
IEEE 802.1x Accounting

The IEEE 802.1x standard defines how users are authorized and authenticated for network access but does not keep track of network usage. IEEE 802.1x accounting is disabled by default. You can enable IEEE 802.1x accounting to monitor this activity on IEEE 802.1x-enabled ports:

- User successfully authenticates.
- User logs off.
- Link-down occurs.
- Re-authentication successfully occurs.
- Re-authentication fails.

The switch does not log IEEE 802.1x accounting information. Instead, it sends this information to the RADIUS server, which must be configured to log accounting messages.

IEEE 802.1x Accounting Attribute-Value Pairs

The information sent to the RADIUS server is represented in the form of Attribute-Value (AV) pairs. These AV pairs provide data for different applications. (For example, a billing application might require information that is in the Acct-Input-Octets or the Acct-Output-Octets attributes of a RADIUS packet.) AV pairs are automatically sent by a switch that is configured for IEEE 802.1x accounting. Three types of RADIUS accounting packets are sent by a switch:

- START—sent when a new user session starts
- INTERIM—sent during an existing session for updates
- STOP—sent when a session terminates

Table 6-1 lists the AV pairs and when they are sent by the switch:

<table>
<thead>
<tr>
<th>Attribute Number</th>
<th>AV Pair Name</th>
<th>START</th>
<th>INTERIM</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute[1]</td>
<td>User-Name</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[4]</td>
<td>NAS-IP-Address</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[5]</td>
<td>NAS-Port</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[8]</td>
<td>Framed-IP-Address</td>
<td>Never</td>
<td>Sometimes¹</td>
<td>Sometimes¹</td>
</tr>
<tr>
<td>Attribute[25]</td>
<td>Class</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[30]</td>
<td>Called-Station-ID</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[31]</td>
<td>Calling-Station-ID</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[40]</td>
<td>Acct-Status-Type</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[41]</td>
<td>Acct-Delay-Time</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[42]</td>
<td>Acct-Input-Octets</td>
<td>Never</td>
<td>Never</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[43]</td>
<td>Acct-Output-Octets</td>
<td>Never</td>
<td>Never</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[44]</td>
<td>Acct-Session-ID</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
<tr>
<td>Attribute[45]</td>
<td>Acct-Authentic</td>
<td>Always</td>
<td>Always</td>
<td>Always</td>
</tr>
</tbody>
</table>
Understanding IEEE 802.1x Port-Based Authentication

You can view the AV pairs that are being sent by the switch by entering the `debug radius accounting` privileged EXEC command. For more information about this command, see the Cisco IOS Debug Command Reference, Release 12.2 at this URL: http://www.cisco.com/en/US/products/sw/iosswrel/ps1835/products_command_reference_book09186a00800872ce.html

For more information about AV pairs, see RFC 3580, “IEEE 802.1X Remote Authentication Dial In User Service (RADIUS) Usage Guidelines.”

Using IEEE 802.1x Authentication with VLAN Assignment

The RADIUS server sends the VLAN assignment to configure the switch port. The RADIUS server database maintains the username-to-VLAN mappings, assigning the VLAN based on the username of the client connected to the switch port. You can use this feature to limit network access for certain users.

When configured on the switch and the RADIUS server, IEEE 802.1x authentication with VLAN assignment has these characteristics:

- If no VLAN is supplied by the RADIUS server or if IEEE 802.1x authentication is disabled, the port is configured in its access VLAN after successful authentication. Recall that an access VLAN is a VLAN assigned to an access port. All packets sent from or received on this port belong to this VLAN.

- If IEEE 802.1x authentication is enabled but the VLAN information from the RADIUS server is not valid, the port returns to the unauthorized state and remains in the configured access VLAN. This prevents ports from appearing unexpectedly in an inappropriate VLAN because of a configuration error.

  Configuration errors could include specifying a malformed VLAN ID, a nonexistent VLAN ID, or an attempted assignment to a voice VLAN ID.

- If IEEE 802.1x authentication is enabled and all information from the RADIUS server is valid, the port is placed in the specified VLAN after authentication.

- If the multiple-hosts mode is enabled on an IEEE 802.1x port, all hosts are placed in the same VLAN (specified by the RADIUS server) as the first authenticated host.

- If IEEE 802.1x authentication and port security are enabled on a port, the port is placed in the RADIUS server-assigned VLAN.

- If IEEE 802.1x authentication is disabled on the port, it is returned to the configured access VLAN.

When the port is in the force authorized, force unauthorized, unauthorized, or shutdown state, it is put into the configured access VLAN.

If an IEEE 802.1x port is authenticated and put in the RADIUS server-assigned VLAN, any change to the port access VLAN configuration does not take effect.
The IEEE 802.1x authentication with VLAN assignment feature is not supported on trunk ports, dynamic ports, or with dynamic-access port assignment through a VLAN Membership Policy Server (VMPS).

To configure VLAN assignment you need to perform these tasks:

- Enable AAA authorization by using the `network` keyword to allow interface configuration from the RADIUS server.
- Enable IEEE 802.1x authentication. (The VLAN assignment feature is automatically enabled when you configure IEEE 802.1x authentication on an access port).
- Assign vendor-specific tunnel attributes in the RADIUS server. The RADIUS server must return these attributes to the switch:
  - [64] Tunnel-Type = VLAN
  - [65] Tunnel-Medium-Type = 802
  - [81] Tunnel-Private-Group-ID = VLAN name or VLAN ID

Attribute [64] must contain the value VLAN (type 13). Attribute [65] must contain the value 802 (type 6). Attribute [81] specifies the VLAN name or VLAN ID assigned to the IEEE 802.1x-authenticated user.

For examples of tunnel attributes, see the “Configuring the Switch to Use Vendor-Specific RADIUS Attributes” section on page 5-29.

**Using IEEE 802.1x Authentication with Per-User ACLs**

You can enable per-user access control lists (ACLs) to provide different levels of network access and service to an IEEE 802.1x-authenticated user. When the RADIUS server authenticates a user connected to an IEEE 802.1x port, it retrieves the ACL attributes based on the user identity and sends them to the switch. The switch applies the attributes to the IEEE 802.1x port for the duration of the user session. The switch removes the per-user ACL configuration when the session is over, if authentication fails, or if a link-down condition occurs. The switch does not save RADIUS-specified ACLs in the running configuration. When the port is unauthorized, the switch removes the ACL from the port.

You can configure only port ACLs on the switch port.

RADIUS supports per-user attributes, including vendor-specific attributes. These vendor-specific attributes (VSAs) are in octet-string format and are passed to the switch during the authentication process. The VSAs used for per-user ACLs are `inacl#<n>` for the ingress direction and `outacl#<n>` for the egress direction. MAC ACLs are supported only in the ingress direction. The switch supports VSAs only in the ingress direction. It does not support port ACLs in the egress direction on Layer 2 ports. For more information, see Chapter 26, “Configuring Network Security with ACLs.”

Use only the extended ACL syntax style to define the per-user configuration stored on the RADIUS server. When the definitions are passed from the RADIUS server, they are created by using the extended naming convention. However, if you use the Filter-Id attribute, it can point to a standard ACL.

You can use the Filter-Id attribute to specify an inbound or outbound ACL that is already configured on the switch. The attribute contains the ACL number followed by `.in` for ingress filtering or `.out` for egress filtering. If the RADIUS server does not allow the `.in` or `.out` syntax, the access list is applied to the outbound ACL by default. Because of limited support of Cisco IOS access lists on the switch, the Filter-Id attribute is supported only for IP ACLs numbered 1 to 199 and 1300 to 2699 (IP standard and IP extended ACLs).

Only one IEEE 802.1x-authenticated user is supported on a port. If the multiple-hosts mode is enabled on the port, the per-user ACL attribute is disabled for the associated port.
Understanding IEEE 802.1x Port-Based Authentication

The maximum size of the per-user ACL is 4000 ASCII characters but is limited by the maximum size of RADIUS-server per-user ACLs.

For examples of vendor-specific attributes, see the “Configuring the Switch to Use Vendor-Specific RADIUS Attributes” section on page 5-29. For more information about configuring ACLs, see Chapter 26, “Configuring Network Security with ACLs.”

To configure per-user ACLs, you need to perform these tasks:

- Enable AAA authentication.
- Enable AAA authorization by using the `network` keyword to allow interface configuration from the RADIUS server.
- Enable IEEE 802.1x authentication.
- Configure the user profile and VSAs on the RADIUS server.
- Configure the IEEE 802.1x port for single-host mode.

Using IEEE 802.1x Authentication with Guest VLAN

You can configure a guest VLAN for each IEEE 802.1x port on the switch to provide limited services to clients, such as downloading the IEEE 802.1x client. These clients might be upgrading their system for IEEE 802.1x authentication, and some hosts, such as Windows 98 systems, might not be IEEE 802.1x-capable.

When you enable a guest VLAN on an IEEE 802.1x port, the switch assigns clients to a guest VLAN when the switch does not receive a response to its EAP request/identity frame or when EAPOL packets are not sent by the client.

With Cisco IOS Release 12.2(25)SE1 and later, the switch maintains the EAPOL packet history. If an EAPOL packet is detected on the interface during the lifetime of the link, the switch determines that the device connected to that interface is an IEEE 802.1x-capable supplicant, and the interface does not change to the guest VLAN state. EAPOL history is cleared if the interface link status goes down. If no EAPOL packet is detected on the interface, the interface changes to the guest VLAN state.

Before Cisco IOS Release 12.2(25)SE1, the switch did not maintain the EAPOL packet history and allowed clients that failed authentication access to the guest VLAN, regardless of whether EAPOL packets had been detected on the interface. You can enable this behavior by using the `dot1x guest-vlan supplicant` global configuration command. However, in Cisco IOS Release 12.2(25)SEE, the `dot1x guest-vlan supplicant` global configuration command is no longer supported. Use a restricted VLAN to allow clients that failed authentication access to the network by entering the `dot1x auth-fail vlan vlan-id` interface configuration command.

In Cisco IOS Release 12.2(25)SEE and later, i no longer allows

**Note**

If an EAPOL packet is detected after the interface has changed to the guest VLAN, the interface reverts to an unauthorized state, and IEEE 802.1x authentication restarts.

Any number of IEEE 802.1x-incapable clients are allowed access when the switch port is moved to the guest VLAN. If an IEEE 802.1x-capable client joins the same port on which the guest VLAN is configured, the port is put into the unauthorized state in the user-configured access VLAN, and authentication is restarted.
Guest VLANs are supported on IEEE 802.1x ports in single-host or multiple-hosts mode.

You can configure any active VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x guest VLAN. The guest VLAN feature is not supported on trunk ports; it is supported only on access ports.

The switch supports *MAC authentication bypass* in Cisco IOS Release 12.2(25)SEE and later. When MAC authentication bypass is enabled on an IEEE 802.1x port, the switch can authorize clients based on the client MAC address when IEEE 802.1x authentication times out while waiting for an EAPOL message exchange. After detecting a client on an IEEE 802.1x port, the switch waits for an Ethernet packet from the client. The switch sends the authentication server a RADIUS-access/request frame with a username and password based on the MAC address. If authorization succeeds, the switch grants the client access to the network. If authorization fails, the switch assigns the port to the guest VLAN if one is specified. For more information, see the “Using IEEE 802.1x Authentication with MAC Authentication Bypass” section on page 6-17.

For more information, see the “Configuring a Guest VLAN” section on page 6-31.

**Using IEEE 802.1x Authentication with Restricted VLAN**

You can configure a restricted VLAN (also referred to as an *authentication failed VLAN*) for each IEEE 802.1x port on a switch to provide limited services to clients that cannot access the guest VLAN. These clients are IEEE 802.1x-compliant and cannot access another VLAN because they fail the authentication process. A restricted VLAN allows users without valid credentials in an authentication server (typically, visitors to an enterprise) to access a limited set of services. The administrator can control the services available to the restricted VLAN.

You can configure a VLAN to be both the guest VLAN and the restricted VLAN if you want to provide the same services to both types of users.

Without this feature, the client attempts and fails authentication indefinitely, and the switch port remains in the spanning-tree blocking state. With this feature, you can configure the switch port to be in the restricted VLAN after a specified number of authentication attempts (the default value is 3 attempts).

The authenticator counts the failed authentication attempts for the client. When this count exceeds the configured maximum number of authentication attempts, the port moves to the restricted VLAN. The failed attempt count increments when the RADIUS server replies with either an *EAP failure* or an empty response without an EAP packet. When the port moves into the restricted VLAN, the failed attempt counter resets.

Users who fail authentication remain in the restricted VLAN until the next re-authentication attempt. A port in the restricted VLAN tries to re-authenticate at configured intervals (the default is 60 seconds). If re-authentication fails, the port remains in the restricted VLAN. If re-authentication is successful, the port moves either to the configured VLAN or to a VLAN sent by the RADIUS server. You can disable re-authentication. If you do this, the only way to restart the authentication process is for the port to receive a *link down* or *EAP logoff* event. We recommend that you keep re-authentication enabled if a client might connect through a hub. When a client disconnects from the hub, the port might not receive the *link down* or *EAP logoff* event.

After a port moves to the restricted VLAN, a simulated EAP success message is sent to the client. This prevents clients from indefinitely attempting authentication. Some clients (for example, devices running Windows XP) cannot implement DHCP without EAP success.
Restricted VLANs are supported only on IEEE 802.1x ports in single-host mode and on Layer 2 ports. You can configure any active VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x restricted VLAN. The restricted VLAN feature is not supported on internal VLANs (routed ports) or trunk ports; it is supported only on access ports.

This feature works with port security. As soon as the port is authorized, a MAC address is provided to port security. If port security does not permit the MAC address or if the maximum secure address count is reached, the port becomes unauthorized and error disabled.

Other port security features such as dynamic ARP Inspection, DHCP snooping, and IP source guard can be configured independently on a restricted VLAN.

For more information, see the “Configuring a Restricted VLAN” section on page 6-32.

Using IEEE 802.1x Authentication with Inaccessible Authentication Bypass

When the switch cannot reach the configured RADIUS servers and hosts cannot be authenticated, you can configure the switch to allow network access to the hosts connected to critical ports. A critical port is enabled for the inaccessible authentication bypass feature, also referred to as critical authentication or the AAA fail policy.

When this feature is enabled, the switch checks the status of the configured RADIUS servers whenever the switch tries to authenticate a host connected to a critical port. If a server is available, the switch can authenticate the host. However, if all the RADIUS servers are unavailable, the switch grants network access to the host and puts the port in the critical-authentication state, which is a special case of the authentication state.

The behavior of the inaccessible authentication bypass feature depends on the authorization state of the port:

- If the port is unauthorized when a host connected to a critical port tries to authenticate and all servers are unavailable, the switch puts the port in the critical-authentication state in the RADIUS-configured or user-specified access VLAN.
- If the port is already authorized and re-authentication occurs, the switch puts the critical port in the critical-authentication state in the current VLAN, which might be the one previously assigned by the RADIUS server.
- If the RADIUS server becomes unavailable during an authentication exchange, the current exchanges times out, and the switch puts the critical port in the critical-authentication state during the next authentication attempt.

When a RADIUS server that can authenticate the host is available, all critical ports in the critical-authentication state are automatically re-authenticated.

Inaccessible authentication bypass interacts with these features:

- Guest VLAN—Inaccessible authentication bypass is compatible with guest VLAN. When a guest VLAN is enabled on IEEE 8021.x port, the features interact as follows:
  - If at least one RADIUS server is available, the switch assigns a client to a guest VLAN when the switch does not receive a response to its EAP request/identity frame or when EAPOL packets are not sent by the client.
  - If all the RADIUS servers are not available and the client is connected to a critical port, the switch authenticates the client and puts the critical port in the critical-authentication state in the RADIUS-configured or user-specified access VLAN.
Chapter 6  Configuring IEEE 802.1x Port-Based Authentication

Understanding IEEE 802.1x Port-Based Authentication

- If all the RADIUS servers are not available and the client is not connected to a critical port, the switch might not assign clients to the guest VLAN if one is configured.
- If all the RADIUS servers are not available and if a client is connected to a critical port and was previously assigned to a guest VLAN, the switch keeps the port in the guest VLAN.

- Restricted VLAN—If the port is already authorized in a restricted VLAN and the RADIUS servers are unavailable, the switch puts the critical port in the critical-authentication state in the restricted VLAN.

- IEEE 802.1x accounting—Accounting is not affected if the RADIUS servers are unavailable.

- Private VLAN—You can configure inaccessible authentication bypass on a private VLAN host port. The access VLAN must be a secondary private VLAN.

- Voice VLAN—Inaccessible authentication bypass is compatible with voice VLAN, but the RADIUS-configured or user-specified access VLAN and the voice VLAN must be different.

- Remote Switched Port Analyzer (RSPAN)—Do not configure an RSPAN VLAN as the RADIUS-configured or user-specified access VLAN for inaccessible authentication bypass.

Using IEEE 802.1x Authentication with Voice VLAN Ports

A voice VLAN port is a special access port associated with two VLAN identifiers:

- VVID to carry voice traffic to and from the IP phone. The VVID is used to configure the IP phone connected to the port.

- PVID to carry the data traffic to and from the workstation connected to the switch through the IP phone. The PVID is the native VLAN of the port.

The IP phone uses the VVID for its voice traffic, regardless of the authorization state of the port. This allows the phone to work independently of IEEE 802.1x authentication.

In single-host mode, only the IP phone is allowed on the voice VLAN. In multiple-hosts mode, additional clients can send traffic on the voice VLAN after a supplicant is authenticated on the PVID. When multiple-hosts mode is enabled, the supplicant authentication affects both the PVID and the VVID.

A voice VLAN port becomes active when there is a link, and the device MAC address appears after the first CDP message from the IP phone. Cisco IP phones do not relay CDP messages from other devices. As a result, if several IP phones are connected in series, the switch recognizes only the one directly connected to it. When IEEE 802.1x authentication is enabled on a voice VLAN port, the switch drops packets from unrecognized IP phones more than one hop away.

When IEEE 802.1x authentication is enabled on a port, you cannot configure a port VLAN that is equal to a voice VLAN.

Note

If you enable IEEE 802.1x authentication on an access port on which a voice VLAN is configured and to which a Cisco IP Phone is connected, the Cisco IP phone loses connectivity to the switch for up to 30 seconds.

For more information about voice VLANs, see Chapter 11, “Configuring Voice VLAN.”
Using IEEE 802.1x Authentication with Port Security

You can configure an IEEE 802.1x port with port security in either single-host or multiple-hosts mode. (You also must configure port security on the port by using the `switchport port-security` interface configuration command.) When you enable port security and IEEE 802.1x authentication on a port, IEEE 802.1x authentication authenticates the port, and port security manages network access for all MAC addresses, including that of the client. You can then limit the number or group of clients that can access the network through an IEEE 802.1x port.

These are some examples of the interaction between IEEE 802.1x authentication and port security on the switch:

- When a client is authenticated, and the port security table is not full, the client MAC address is added to the port security list of secure hosts. The port then proceeds to come up normally.
  
  When a client is authenticated and manually configured for port security, it is guaranteed an entry in the secure host table (unless port security static aging has been enabled).
  
  A security violation occurs if the client is authenticated, but the port security table is full. This can happen if the maximum number of secure hosts has been statically configured or if the client ages out of the secure host table. If the client address is aged, its place in the secure host table can be taken by another host.
  
  If the security violation is caused by the first authenticated host, the port becomes error-disabled and immediately shuts down.
  
  The port security violation modes determine the action for security violations. For more information, see the “Security Violations” section on page 18-9.

- When you manually remove an IEEE 802.1x client address from the port security table by using the `no switchport port-security mac-address` interface configuration command, you should re-authenticate the IEEE 802.1x client by using the `dot1x re-authenticate interface interface-id` privileged EXEC command.

- When an IEEE 802.1x client logs off, the port changes to an unauthenticated state, and all dynamic entries in the secure host table are cleared, including the entry for the client. Normal authentication then takes place.
  
- If the port is administratively shut down, the port becomes unauthenticated, and all dynamic entries are removed from the secure host table.

- Port security and a voice VLAN can be configured simultaneously on an IEEE 802.1x port that is in either single-host or multiple-hosts mode. Port security applies to both the voice VLAN identifier (VVID) and the port VLAN identifier (PVID).

For more information about enabling port security on your switch, see the “Configuring Port Security” section on page 18-7.

Using IEEE 802.1x Authentication with Wake-on-LAN

The IEEE 802.1x authentication with wake-on-LAN (WoL) feature allows dormant PCs to be powered when the switch receives a specific Ethernet frame, known as the magic packet. You can use this feature in environments where administrators need to connect to systems that have been powered down.

When a host that uses WoL is attached through an IEEE 802.1x port and the host powers off, the IEEE 802.1x port becomes unauthorized. The port can only receive and send EAPOL packets, and WoL magic packets cannot reach the host. When the PC is powered off, it is not authorized, and the switch port is not opened.
Chapter 6  Configuring IEEE 802.1x Port-Based Authentication

Understanding IEEE 802.1x Port-Based Authentication

When the switch uses IEEE 802.1x authentication with WoL, the switch forwards traffic to unauthorized IEEE 802.1x ports, including magic packets. While the port is unauthorized, the switch continues to block ingress traffic other than EAPOL packets. The host can receive packets but cannot send packets to other devices in the network.

**Note**
If PortFast is not enabled on the port, the port is forced to the bidirectional state.

When you configure a port as unidirectional by using the `dot1x control-direction in` interface configuration command, the port changes to the spanning-tree forwarding state. The port can send packets to the host but cannot receive packets from the host.

When you configure a port as bidirectional by using the `dot1x control-direction both` interface configuration command, the port is access-controlled in both directions. The port does not receive packets from or send packets to the host.

### Using IEEE 802.1x Authentication with MAC Authentication Bypass

You can configure the switch to authorize clients based on the client MAC address (see Figure 6-2 on page 6-4) by using the MAC authentication bypass feature. For example, you can enable this feature on IEEE 802.1x ports connected to devices such as printers.

If IEEE 802.1x authentication times out while waiting for an EAPOL response from the client, the switch tries to authorize the client by using MAC authentication bypass.

When the MAC authentication bypass feature is enabled on an IEEE 802.1x port, the switch uses the MAC address as the client identity. The authentication server has a database of client MAC addresses that are allowed network access. After detecting a client on an IEEE 802.1x port, the switch waits for an Ethernet packet from the client. The switch sends the authentication server a RADIUS-access/request frame with a username and password based on the MAC address. If authorization succeeds, the switch grants the client access to the network. If authorization fails, the switch assigns the port to the guest VLAN if one is configured.

If an EAPOL packet is detected on the interface during the lifetime of the link, the switch determines that the device connected to that interface is an IEEE 802.1x-capable supplicant and uses IEEE 802.1x authentication (not MAC authentication bypass) to authorize the interface. EAPOL history is cleared if the interface link status goes down.

If the switch already authorized a port by using MAC authentication bypass and detects an IEEE 802.1x supplicant, the switch does not unauthorize the client connected to the port. When re-authentication occurs, the switch uses IEEE 802.1x authentication as the preferred re-authentication process if the previous session ended because the Termination-Action RADIUS attribute value is DEFAULT.

Clients that were authorized with MAC authentication bypass can be re-authenticated. The re-authentication process is the same as that for clients that were authenticated with IEEE 802.1x. During re-authentication, the port remains in the previously assigned VLAN. If re-authentication is successful, the switch keeps the port in the same VLAN. If re-authentication fails, the switch assigns the port to the guest VLAN, if one is configured.

If re-authentication is based on the Session-Timeout RADIUS attribute (Attribute[27]) and the Termination-Action RADIUS attribute (Attribute [29]) and if the Termination-Action RADIUS attribute (Attribute [29]) action is Initialize, (the attribute value is DEFAULT), the MAC authentication bypass session ends, and connectivity is lost during re-authentication. If MAC authentication bypass is enabled and the IEEE 802.1x authentication times out, the switch uses the MAC authentication bypass feature to initiate re-authorization. For more information about these AV pairs, see RFC 3580, “IEEE 802.1X Remote Authentication Dial In User Service (RADIUS) Usage Guidelines.”
Understanding IEEE 802.1x Port-Based Authentication

MAC authentication bypass interacts with the features:

- IEEE 802.1x authentication—You can enable MAC authentication bypass only if IEEE 802.1x authentication is enabled on the port.
- Guest VLAN—If a client has an invalid MAC address identity, the switch assigns the client to a guest VLAN if one is configured.
- Restricted VLAN—This feature is not supported when the client connected to an IEEE 802.1x port is authenticated with MAC authentication bypass.
- Port security—See the “Using IEEE 802.1x Authentication with Port Security” section on page 6-16.
- Voice VLAN—See the “Using IEEE 802.1x Authentication with Voice VLAN Ports” section on page 6-15.
- VLAN Membership Policy Server (VMPS)—IEEE802.1x and VMPS are mutually exclusive.
- Private VLAN—You can assign a client to a private VLAN.
- Network admission control (NAC) Layer 2 IP validation—This feature takes effect after an IEEE 802.1x port is authenticated with MAC authentication bypass, including hosts in the exception list.

Using Web Authentication

You can use a web browser to authenticate a client that does not support IEEE 802.1x functionality.

You can configure a port to use only web authentication. You can also configure the port to first try and use IEEE 802.1x authentication and then to use web authorization if the client does not support IEEE 802.1x authentication.

Web authentication requires two Cisco Attribute-Value (AV) pair attributes:

- The first attribute, `priv-lvl=15`, must always be set to 15. This sets the privilege level of the user who is logging into the switch.
- The second attribute is an access list to be applied for web authenticated hosts. The syntax is similar to IEEE 802.1X per-user ACLs. However, instead of `ip:inacl`, this attribute must begin with `proxyacl`, and the `source` field in each entry must be `any`. (After authentication, the client IP address replaces the `any` field when the ACL is applied.)

For example:

```
proxyacl# 10=permit ip any 10.0.0.0 255.0.0.0
proxyacl# 20=permit ip any 11.1.0.0 255.255.0.0
proxyacl# 30=permit udp any any eq syslog
proxyacl# 40=permit udp any any eq tftp
```

**Note** The `proxyacl` entry determines the type of allowed network access.

For more information, see the “Configuring Web Authentication” section on page 6-38.
Configuring IEEE 802.1x Authentication

These sections contain this configuration information:

- Default IEEE 802.1x Authentication Configuration, page 6-19
- IEEE 802.1x Authentication Configuration Guidelines, page 6-21
- Configuring IEEE 802.1x Authentication, page 6-23 (required)
- Configuring the Switch-to-RADIUS-Server Communication, page 6-24 (required)
- Configuring the Host Mode, page 6-26 (optional)
- Configuring Periodic Re-Authentication, page 6-26 (optional)
- Manually Re-Authenticating a Client Connected to a Port, page 6-27 (optional)
- Changing the Quiet Period, page 6-27 (optional)
- Changing the Switch-to-Client Retransmission Time, page 6-28 (optional)
- Setting the Switch-to-Client Frame-Retransmission Number, page 6-29 (optional)
- Setting the Re-Authentication Number, page 6-29 (optional)
- Configuring IEEE 802.1x Accounting, page 6-30 (optional)
- Configuring a Guest VLAN, page 6-31 (optional)
- Configuring a Restricted VLAN, page 6-32 (optional)
- Configuring the Inaccessible Authentication Bypass Feature, page 6-33 (optional)
- Configuring IEEE 802.1x Authentication with WoL, page 6-36 (optional)
- Configuring MAC Authentication Bypass, page 6-37 (optional)
- “Configuring IEEE 802.1x Authentication Using a RADIUS Server” section on page 6-38 (optional)
- Disabling IEEE 802.1x Authentication on the Port, page 6-41 (optional)
- Resetting the IEEE 802.1x Authentication Configuration to the Default Values, page 6-42 (optional)

Default IEEE 802.1x Authentication Configuration

Table 6-2 shows the default IEEE 802.1x authentication configuration.

Table 6-2  Default IEEE 802.1x Authentication Configuration

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch IEEE 802.1x enable state</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Per-port IEEE 802.1x enable state</td>
<td>Disabled (force-authorized). The port sends and receives normal traffic without IEEE 802.1x-based authentication of the client.</td>
</tr>
<tr>
<td>AAA</td>
<td>Disabled.</td>
</tr>
</tbody>
</table>
### Table 6-2  Default IEEE 802.1x Authentication Configuration (continued)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIUS server</td>
<td></td>
</tr>
<tr>
<td>• IP address</td>
<td>• None specified.</td>
</tr>
<tr>
<td>• UDP authentication port</td>
<td>• 1812.</td>
</tr>
<tr>
<td>• Key</td>
<td>• None specified.</td>
</tr>
<tr>
<td>Host mode</td>
<td>Single-host mode.</td>
</tr>
<tr>
<td>Control direction</td>
<td>Bidirectional control.</td>
</tr>
<tr>
<td>Periodic re-authentication</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Number of seconds between re-authentication attempts</td>
<td>3600 seconds.</td>
</tr>
<tr>
<td>Re-authentication number</td>
<td>2 times (number of times that the switch restarts the authentication process before the port changes to the unauthorized state).</td>
</tr>
<tr>
<td>Quiet period</td>
<td>60 seconds (number of seconds that the switch remains in the quiet state following a failed authentication exchange with the client).</td>
</tr>
<tr>
<td>Retransmission time</td>
<td>30 seconds (number of seconds that the switch should wait for a response to an EAP request/identity frame from the client before resending the request).</td>
</tr>
<tr>
<td>Maximum retransmission number</td>
<td>2 times (number of times that the switch will send an EAP-request/identity frame before restarting the authentication process).</td>
</tr>
<tr>
<td>Client timeout period</td>
<td>30 seconds (when relaying a request from the authentication server to the client, the amount of time the switch waits for a response before resending the request to the client.)</td>
</tr>
<tr>
<td>Authentication server timeout period</td>
<td>30 seconds (when relaying a response from the client to the authentication server, the amount of time the switch waits for a reply before resending the response to the server. This setting is not configurable.)</td>
</tr>
<tr>
<td>Guest VLAN</td>
<td>None specified.</td>
</tr>
<tr>
<td>Inaccessible authentication bypass</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Restricted VLAN</td>
<td>None specified.</td>
</tr>
<tr>
<td>Authenticator (switch) mode</td>
<td>None specified.</td>
</tr>
<tr>
<td>MAC authentication bypass</td>
<td>Disabled.</td>
</tr>
</tbody>
</table>
IEEE 802.1x Authentication Configuration Guidelines

These section has configuration guidelines for these features:

- IEEE 802.1x Authentication, page 6-21
- VLAN Assignment, Guest VLAN, Restricted VLAN, and Inaccessible Authentication Bypass, page 6-22
- MAC Authentication Bypass, page 6-22

IEEE 802.1x Authentication

These are the IEEE 802.1x authentication configuration guidelines:

- When IEEE 802.1x authentication is enabled, ports are authenticated before any other Layer 2 feature is enabled.
- If you try to change the mode of an IEEE 802.1x-enabled port (for example, from access to trunk), an error message appears, and the port mode is not changed.
- If the VLAN to which an IEEE 802.1x-enabled port is assigned changes, this change is transparent and does not affect the switch. For example, this change occurs if a port is assigned to a RADIUS server-assigned VLAN and is then assigned to a different VLAN after re-authentication.
- If the VLAN to which an IEEE 802.1x port is assigned to shut down, disabled, or removed, the port becomes unauthorized. For example, the port is unauthorized after the access VLAN to which a port is assigned shuts down or is removed.
- The IEEE 802.1x protocol is supported on Layer 2 static-access ports and voice VLAN ports, but it is not supported on these port types:
  - Trunk port—If you try to enable IEEE 802.1x authentication on a trunk port, an error message appears, and IEEE 802.1x authentication is not enabled. If you try to change the mode of an IEEE 802.1x-enabled port to trunk, an error message appears, and the port mode is not changed.
  - Dynamic ports—A port in dynamic mode can negotiate with its neighbor to become a trunk port. If you try to enable IEEE 802.1x authentication on a dynamic port, an error message appears, and IEEE 802.1x authentication is not enabled. If you try to change the mode of an IEEE 802.1x-enabled port to dynamic, an error message appears, and the port mode is not changed.
  - Dynamic-access ports—If you try to enable IEEE 802.1x authentication on a dynamic-access (VLAN Query Protocol [VQP]) port, an error message appears, and IEEE 802.1x authentication is not enabled. If you try to change an IEEE 802.1x-enabled port to dynamic VLAN assignment, an error message appears, and the VLAN configuration is not changed.
  - EtherChannel port—Do not configure a port that is an active or a not-yet-active member of an EtherChannel as an IEEE 802.1x port. If you try to enable IEEE 802.1x authentication on an EtherChannel port, an error message appears, and IEEE 802.1x authentication is not enabled.
  - Switched Port Analyzer (SPAN) and Remote SPAN (RSPAN) destination ports—You can enable IEEE 802.1x authentication on a port that is a SPAN or RSPAN destination port. However, IEEE 802.1x authentication is disabled until the port is removed as a SPAN or RSPAN destination port. You can enable IEEE 802.1x authentication on a SPAN or RSPAN source port.
- Before globally enabling IEEE 802.1x authentication on a switch by entering the dot1x system-auth-control global configuration command, remove the EtherChannel configuration from the interfaces on which IEEE 802.1x authentication and EtherChannel are configured.
VLAN Assignment, Guest VLAN, Restricted VLAN, and Inaccessible Authentication Bypass

These are the configuration guidelines for VLAN assignment, guest VLAN, restricted VLAN, and inaccessible authentication bypass:

- When IEEE 802.1x authentication is enabled on a port, you cannot configure a port VLAN that is equal to a voice VLAN.
- The IEEE 802.1x authentication with VLAN assignment feature is not supported on trunk ports, dynamic ports, or with dynamic-access port assignment through a VMPS.
- You can configure any VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x guest VLAN. The guest VLAN feature is not supported on trunk ports; it is supported only on access ports.
- After you configure a guest VLAN for an IEEE 802.1x port to which a DHCP client is connected, you might need to get a host IP address from a DHCP server. You can change the settings for restarting the IEEE 802.1x authentication process on the switch before the DHCP process on the client times out and tries to get a host IP address from the DHCP server. Decrease the settings for the IEEE 802.1x authentication process (dot1x timeout quiet-period and dot1x timeout tx-period interface configuration commands). The amount to decrease the settings depends on the connected IEEE 802.1x client type.
- When configuring the inaccessible authentication bypass feature, follow these guidelines:
  - The feature is supported on IEEE 802.1x port in single-host mode and multihosts mode.
  - If the client is running Windows XP and the port to which the client is connected is in the critical-authentication state, Windows XP might report that the interface is not authenticated.
  - If the Windows XP client is configured for DHCP and has an IP address from the DHCP server, receiving an EAP-Success message on a critical port might not re-initiate the DHCP configuration process.
  - You can configure the inaccessible authentication bypass feature and the restricted VLAN on an IEEE 802.1x port. If the switch tries to re-authenticate a critical port in a restricted VLAN and all the RADIUS servers are unavailable, the switch changes the port state to the critical authentication state and remains in the restricted VLAN.
  - You can configure the inaccessible bypass feature and port security on the same switch port.
- You can configure any VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x restricted VLAN. The restricted VLAN feature is not supported on trunk ports; it is supported only on access ports.

MAC Authentication Bypass

These are the MAC authentication bypass configuration guidelines:

- Unless otherwise stated, the MAC authentication bypass guidelines are the same as the IEEE 802.1x authentication guidelines. For more information, see the “IEEE 802.1x Authentication” section on page 6-21.
- If you disable MAC authentication bypass from a port after the port has been authorized with its MAC address, the port state is not affected.
- If the port is in the unauthorized state and the client MAC address is not the authentication-server database, the port remains in the unauthorized state. However, if the client MAC address is added to the database, the switch can use MAC authentication bypass to re-authorize the port.
- If the port is in the authorized state, the port remains in this state until re-authorization occurs.
Upgrading from a Previous Software Release

In Cisco IOS Release 12.2(25)SEE, the implementation for IEEE 802.1x authentication changed from the previous releases. When IEEE 802.1x authentication is enabled, information about Port Fast is no longer added to the configuration and this information appears in the running configuration:

```
dot1x pae authenticator
```

Configuring IEEE 802.1x Authentication

To configure IEEE 802.1x port-based authentication, you must enable authentication, authorization, and accounting (AAA) and specify the authentication method list. A method list describes the sequence and authentication method to be queried to authenticate a user.

To allow per-user ACLs or VLAN assignment, you must enable AAA authorization to configure the switch for all network-related service requests.

This is the IEEE 802.1x AAA process:

1. A user connects to a port on the switch.
2. Authentication is performed.
3. VLAN assignment is enabled, as appropriate, based on the RADIUS server configuration.
4. The switch sends a start message to an accounting server.
5. Re-authentication is performed, as necessary.
6. The switch sends an interim accounting update to the accounting server that is based on the result of re-authentication.
7. The user disconnects from the port.
8. The switch sends a stop message to the accounting server.

Beginning in privileged EXEC mode, follow these steps to configure IEEE 802.1x port-based authentication:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>aaa new-model</td>
<td>Enable AAA.</td>
</tr>
<tr>
<td>Step 3</td>
<td>aaa authentication dot1x {default} method1</td>
<td>Create an IEEE 802.1x authentication method list. To create a default list that is used when a named list is not specified in the authentication command, use the default keyword followed by the method that is to be used in default situations. The default method list is automatically applied to all ports. For method1, enter the group radius keywords to use the list of all RADIUS servers for authentication. Note Though other keywords are visible in the command-line help string, only the group radius keywords are supported.</td>
</tr>
<tr>
<td>Step 4</td>
<td>dot1x system-auth-control</td>
<td>Enable IEEE 802.1x authentication globally on the switch.</td>
</tr>
</tbody>
</table>
### Configuring IEEE 802.1x Port-Based Authentication

#### Configuring the Switch-to-RADIUS-Server Communication

RADIUS security servers are identified by their hostname or IP address, hostname and specific UDP port numbers, or IP address and specific UDP port numbers. The combination of the IP address and UDP port number creates a unique identifier, which enables RADIUS requests to be sent to multiple UDP ports on a server at the same IP address. If two different host entries on the same RADIUS server are configured for the same service—for example, authentication—the second host entry configured acts as the fail-over backup to the first one. The RADIUS host entries are tried in the order that they were configured.

#### Command Purpose

<table>
<thead>
<tr>
<th>Step 5</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 5</td>
<td>aaa authorization network {default} group radius</td>
<td>(Optional) Configure the switch to use user-RADIUS authorization for all network-related service requests, such as per-user ACLs or VLAN assignment. <strong>Note</strong> For per-user ACLs, single-host mode must be configured. This setting is the default.</td>
</tr>
<tr>
<td>Step 6</td>
<td>radius-server host <em>ip-address</em></td>
<td>(Optional) Specify the IP address of the RADIUS server.</td>
</tr>
<tr>
<td>Step 7</td>
<td>radius-server key <em>string</em></td>
<td>(Optional) Specify the authentication and encryption key used between the switch and the RADIUS daemon running on the RADIUS server.</td>
</tr>
<tr>
<td>Step 8</td>
<td>interface <em>interface-id</em></td>
<td>Specify the port connected to the client that is to be enabled for IEEE 802.1x authentication, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 9</td>
<td>switchport mode access</td>
<td>(Optional) Set the port to access mode only if you configured the RADIUS server in Step 6 and Step 7.</td>
</tr>
<tr>
<td>Step 10</td>
<td>dot1x port-control auto</td>
<td>Enable IEEE 802.1x authentication on the port. For feature interaction information, see the “IEEE 802.1x Authentication Configuration Guidelines” section on page 6-21.</td>
</tr>
<tr>
<td>Step 11</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 12</td>
<td>show dot1x</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 13</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
Chapter 6  Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Port-Based Authentication

Beginning in privileged EXEC mode, follow these steps to configure the RADIUS server parameters on the switch. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>radius-server host {hostname \ ip-address} auth-port port-number key string</td>
</tr>
<tr>
<td></td>
<td>For hostname \ ip-address, specify the hostname or IP address of the remote RADIUS server.</td>
</tr>
<tr>
<td></td>
<td>For auth-port port-number, specify the UDP destination port for authentication requests. The default is 1812. The range is 0 to 65536.</td>
</tr>
<tr>
<td></td>
<td>For key string, specify the authentication and encryption key used between the switch and the RADIUS daemon running on the RADIUS server. The key is a text string that must match the encryption key used on the RADIUS server.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong> Always configure the key as the last item in the radius-server host command syntax because leading spaces are ignored, but spaces within and at the end of the key are used. If you use spaces in the key, do not enclose the key in quotation marks unless the quotation marks are part of the key. This key must match the encryption used on the RADIUS daemon.</td>
</tr>
<tr>
<td></td>
<td>If you want to use multiple RADIUS servers, re-enter this command.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To delete the specified RADIUS server, use the **no radius-server host {hostname \ ip-address}** global configuration command.

This example shows how to specify the server with IP address 172.20.39.46 as the RADIUS server, to use port 1612 as the authorization port, and to set the encryption key to rad123, matching the key on the RADIUS server:

```
Switch(config)# radius-server host 172.120.39.46 auth-port 6403 key rad123
```

You can globally configure the timeout, retransmission, and encryption key values for all RADIUS servers by using the **radius-server host** global configuration command. If you want to configure these options on a per-server basis, use the **radius-server timeout**, **radius-server retransmit**, and the **radius-server key** global configuration commands. For more information, see the “Configuring Settings for All RADIUS Servers” section on page 5-29.

You also need to configure some settings on the RADIUS server. These settings include the IP address of the switch and the key string to be shared by both the server and the switch. For more information, see the RADIUS server documentation.
Configuring the Host Mode

Beginning in privileged EXEC mode, follow these steps to allow multiple hosts (clients) on an IEEE 802.1x-authorized port that has the `dot1x port-control` interface configuration command set to `auto`. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the port to which multiple hosts are indirectly attached, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 dot1x host-mode multi-host</td>
<td>Allow multiple hosts (clients) on an IEEE 802.1x-authorized port.</td>
</tr>
<tr>
<td></td>
<td>Make sure that the <code>dot1x port-control</code> interface configuration command set is set to <code>auto</code> for the specified interface.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show dot1x interface interface-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable multiple hosts on the port, use the `no dot1x host-mode multi-host` interface configuration command.

This example shows how to enable IEEE 802.1x authentication and to allow multiple hosts:

```plaintext
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# dot1x port-control auto
Switch(config-if)# dot1x host-mode multi-host
```

Configuring Periodic Re-Authentication

You can enable periodic IEEE 802.1x client re-authentication and specify how often it occurs. If you do not specify a time period before enabling re-authentication, the number of seconds between attempts is 3600.

Beginning in privileged EXEC mode, follow these steps to enable periodic re-authentication of the client and to configure the number of seconds between re-authentication attempts. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 dot1x reauthentication</td>
<td>Enable periodic re-authentication of the client, which is disabled by default.</td>
</tr>
</tbody>
</table>
Chapter 6 Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Authentication

To disable periodic re-authentication, use the `no dot1x reauthentication` interface configuration command. To return to the default number of seconds between re-authentication attempts, use the `no dot1x timeout reauth-period` interface configuration command.

This example shows how to enable periodic re-authentication and set the number of seconds between re-authentication attempts to 4000:

```
Switch(config-if)# dot1x reauthentication
Switch(config-if)# dot1x timeout reauth-period 4000
```

Manually Re-Authenticating a Client Connected to a Port

You can manually re-authenticate the client connected to a specific port at any time by entering the `dot1x re-authenticate interface interface-id` privileged EXEC command. This step is optional. If you want to enable or disable periodic re-authentication, see the “Configuring Periodic Re-Authentication” section on page 6-26.

This example shows how to manually re-authenticate the client connected to a port:

```
Switch# dot1x re-authenticate interface gigabitethernet0/1
```

Changing the Quiet Period

When the switch cannot authenticate the client, the switch remains idle for a set period of time and then tries again. The `dot1x timeout quiet-period` interface configuration command controls the idle period. A failed authentication of the client might occur because the client provided an invalid password. You can provide a faster response time to the user by entering a number smaller than the default.

Beginning in privileged EXEC mode, follow these steps to change the quiet period. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>dot1x timeout quiet-period [seconds] server</td>
<td>Set the number of seconds between re-authentication attempts. The keywords have these meanings: - <code>seconds</code>—Sets the number of seconds from 1 to 65535; the default is 3600 seconds. - <code>server</code>—Sets the number of seconds based on the value of the Session-Timeout RADIUS attribute (Attribute[27]) and the Termination-Action RADIUS attribute (Attribute [29]). This command affects the behavior of the switch only if periodic re-authentication is enabled.</td>
</tr>
</tbody>
</table>

This command affects the behavior of the switch only if periodic re-authentication is enabled.

This example shows how to enable periodic re-authentication and set the number of seconds between re-authentication attempts to 4000:

```
Switch(config-if)# dot1x reauthentication
Switch(config-if)# dot1x timeout reauth-period 4000
```

Manually Re-Authenticating a Client Connected to a Port

You can manually re-authenticate the client connected to a specific port at any time by entering the `dot1x re-authenticate interface interface-id` privileged EXEC command. This step is optional. If you want to enable or disable periodic re-authentication, see the “Configuring Periodic Re-Authentication” section on page 6-26.

This example shows how to manually re-authenticate the client connected to a port:

```
Switch# dot1x re-authenticate interface gigabitethernet0/1
```

Changing the Quiet Period

When the switch cannot authenticate the client, the switch remains idle for a set period of time and then tries again. The `dot1x timeout quiet-period` interface configuration command controls the idle period. A failed authentication of the client might occur because the client provided an invalid password. You can provide a faster response time to the user by entering a number smaller than the default.

Beginning in privileged EXEC mode, follow these steps to change the quiet period. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
Configuring IEEE 802.1x Port-Based Authentication

Chapter 6

Configuring IEEE 802.1x Authentication

Configuring IEEE 802.1x Authentication

To return to the default quiet time, use the `no dot1x timeout quiet-period` interface configuration command.

This example shows how to set the quiet time on the switch to 30 seconds:

```
Switch(config-if)# dot1x timeout quiet-period 30
```

Changing the Switch-to-Client Retransmission Time

The client responds to the EAP-request/identity frame from the switch with an EAP-response/identity frame. If the switch does not receive this response, it waits a set period of time (known as the retransmission time) and then resends the frame.

**Note**

You should change the default value of this command only to adjust for unusual circumstances such as unreliable links or specific behavioral problems with certain clients and authentication servers.

Beginning in privileged EXEC mode, follow these steps to change the amount of time that the switch waits for client notification. This procedure is optional.

```
Step 1 configure terminal
Step 2 interface interface-id
Step 3 dot1x timeout tx-period seconds
Step 4 end
Step 5 show dot1x interface interface-id
Step 6 copy running-config startup-config
```

To return to the default retransmission time, use the `no dot1x timeout tx-period` interface configuration command.

This example shows how to set 60 as the number of seconds that the switch waits for a response to an EAP-request/identity frame from the client before resending the request:

```
Switch(config-if)# dot1x timeout tx-period 60
```
### Setting the Switch-to-Client Frame-Retransmission Number

In addition to changing the switch-to-client retransmission time, you can change the number of times that the switch sends an EAP-request/identity frame (assuming no response is received) to the client before restarting the authentication process.

**Note**
You should change the default value of this command only to adjust for unusual circumstances such as unreliable links or specific behavioral problems with certain clients and authentication servers.

Beginning in privileged EXEC mode, follow these steps to set the switch-to-client frame-retransmission number. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong> dot1x max-reauth-req count</td>
<td>Set the number of times that the switch sends an EAP-request/identity frame to the client before restarting the authentication process. The range is 1 to 10; the default is 2.</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show dot1x interface interface-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default retransmission number, use the `no dot1x max-reauth-req` interface configuration command.

This example shows how to set 5 as the number of times that the switch sends an EAP-request/identity request before restarting the authentication process:

```
Switch(config-if)# dot1x max-reauth-req 5
```

### Setting the Re-Authentication Number

You can also change the number of times that the switch restarts the authentication process before the port changes to the unauthorized state.

**Note**
You should change the default value of this command only to adjust for unusual circumstances such as unreliable links or specific behavioral problems with certain clients and authentication servers.

Beginning in privileged EXEC mode, follow these steps to set the re-authentication number. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>

---
Configuring IEEE 802.1x Port-Based Authentication

Chapter 6

Configuring IEEE 802.1x Authentication

To return to the default re-authentication number, use the `no dot1x max-reauth-req interface` configuration command.

This example shows how to set 4 as the number of times that the switch restarts the authentication process before the port changes to the unauthorized state:

```
Switch(config-if)# dot1x max-reauth-req 4
```

Configuring IEEE 802.1x Accounting

Enabling AAA system accounting with IEEE 802.1x accounting allows system reload events to be sent to the accounting RADIUS server for logging. The server can then infer that all active IEEE 802.1x sessions are closed.

Because RADIUS uses the unreliable UDP transport protocol, accounting messages might be lost due to poor network conditions. If the switch does not receive the accounting response message from the RADIUS server after a configurable number of retransmissions of an accounting request, this system message appears:

```
Accounting message %s for session %s failed to receive Accounting Response.
```

When the stop message is not sent successfully, this message appears:

```
00:09:55: %RADIUS-4-RADIUS_DEAD: RADIUS server 172.20.246.201:1645,1646 is not responding.
```

You must configure the RADIUS server to perform accounting tasks, such as logging start, stop, and interim-update messages and time stamps. To turn on these functions, enable logging of “Update/Watchdog packets from this AAA client” in your RADIUS server Network Configuration tab. Next, enable “CVS RADIUS Accounting” in your RADIUS server System Configuration tab.

Beginning in privileged EXEC mode, follow these steps to configure IEEE 802.1x accounting after AAA is enabled on your switch. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 3</td>
<td><code>dot1x max-reauth-req count</code> Set the number of times that the switch restarts the authentication process before the port changes to the unauthorized state. The range is 0 to 10; the default is 2.</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>show dot1x interface interface-id</code> Verify your entries.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>copy running-config startup-config</code> (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default re-authentication number, use the `no dot1x max-reauth-req interface` configuration command.

This example shows how to set 4 as the number of times that the switch restarts the authentication process before the port changes to the unauthorized state:

```
Switch(config-if)# dot1x max-reauth-req 4
```

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><code>configure terminal</code> Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>interface interface-id</code> Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>aaa accounting dot1x default start-stop group radius</code> Enable IEEE 802.1x accounting using the list of all RADIUS servers.</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>aaa accounting system default start-stop group radius</code> (Optional) Enables system accounting (using the list of all RADIUS servers) and generates system accounting reload event messages when the switch reloads.</td>
</tr>
</tbody>
</table>
Chapter 6      Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Port-Based Authentication

### Configuring IEEE 802.1x Port-Based Authentication

Use the `show radius statistics` privileged EXEC command to display the number of RADIUS messages that do not receive the accounting response message.

This example shows how to configure IEEE 802.1x accounting. The first command configures the RADIUS server, specifying 1813 as the UDP port for accounting:

```plaintext
Switch(config)# radius-server host 172.120.39.46 auth-port 1812 acct-port 1813 key rad123
Switch(config)# aaa accounting dot1x default start-stop group radius
Switch(config)# aaa accounting system default start-stop group radius
```

### Configuring a Guest VLAN

When you configure a guest VLAN, clients that are not IEEE 802.1x-capable are put into the guest VLAN when the server does not receive a response to its EAP request/identity frame. Clients that are IEEE 802.1x-capable but that fail authentication are not granted network access. The switch supports guest VLANs in single-host or multiple-hosts mode.

Beginning in privileged EXEC mode, follow these steps to configure a guest VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td><code>interface interface-id</code></td>
<td>Specify the port to be configured, and enter interface configuration mode. For the supported port types, see the “IEEE 802.1x Authentication Configuration Guidelines” section on page 6-21.</td>
</tr>
<tr>
<td>3</td>
<td><code>switchport mode access</code> or <code>switchport mode private-vlan host</code></td>
<td>Set the port to access mode, or Configure the port as a private-VLAN host port.</td>
</tr>
<tr>
<td>4</td>
<td><code>dot1x port-control auto</code></td>
<td>Enable IEEE 802.1x authentication on the port.</td>
</tr>
<tr>
<td>5</td>
<td><code>dot1x guest-vlan vlan-id</code></td>
<td>Specify an active VLAN as an IEEE 802.1x guest VLAN. The range is 1 to 4094. You can configure any active VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x guest VLAN.</td>
</tr>
<tr>
<td>6</td>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>7</td>
<td><code>show dot1x interface interface-id</code></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>8</td>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable and remove the guest VLAN, use the `no dot1x guest-vlan` interface configuration command. The port returns to the unauthorized state.

This example shows how to enable VLAN 2 as an IEEE 802.1x guest VLAN:

```plaintext
Switch(config)# interface gigabitethernet0/2
```
Configuring IEEE 802.1x Port-Based Authentication

Switch(config-if)# `dot1x guest-vlan 2`

This example shows how to set 3 as the quiet time on the switch, to set 15 as the number of seconds that the switch waits for a response to an EAP-request/identity frame from the client before re-sending the request, and to enable VLAN 2 as an IEEE 802.1x guest VLAN when an IEEE 802.1x port is connected to a DHCP client:

Switch(config-if)# `dot1x timeout quiet-period 3`
Switch(config-if)# `dot1x timeout tx-period 15`
Switch(config-if)# `dot1x guest-vlan 2`

**Configuring a Restricted VLAN**

When you configure a restricted VLAN on a switch, clients that are IEEE 802.1x-compliant are moved into the restricted VLAN when the authentication server does not receive a valid username and password. The switch supports restricted VLANs only in single-host mode.

Beginning in privileged EXEC mode, follow these steps to configure a restricted VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode. For the supported port types, see the “IEEE 802.1x Authentication Configuration Guidelines” section on page 6-21.</td>
</tr>
<tr>
<td><strong>Step 3</strong> switchport mode access</td>
<td>Set the port to access mode, or switchport mode private-vlan host</td>
</tr>
<tr>
<td>or</td>
<td>Configure the port as a private-VLAN host port.</td>
</tr>
<tr>
<td><strong>Step 4</strong> dot1x port-control auto</td>
<td>Enable IEEE 802.1x authentication on the port.</td>
</tr>
<tr>
<td><strong>Step 5</strong> dot1x auth-fail vlan vlan-id</td>
<td>Specify an active VLAN as an IEEE 802.1x restricted VLAN. The range is 1 to 4094. You can configure any active VLAN except an RSPAN VLAN or a voice VLAN as an IEEE 802.1x restricted VLAN.</td>
</tr>
<tr>
<td><strong>Step 6</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 7</strong> show dot1x interface interface-id</td>
<td>(Optional) Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 8</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable and remove the restricted VLAN, use the `no dot1x auth-fail vlan` interface configuration command. The port returns to the unauthorized state.

This example shows how to enable VLAN 2 as an IEEE 802.1x restricted VLAN:

Switch(config)# `interface gigabitethernet0/2`
Switch(config-if)# `dot1x auth-fail vlan 2`

You can configure the maximum number of authentication attempts allowed before a user is assigned to the restricted VLAN by using the `dot1x auth-fail max-attempts` interface configuration command. The range of allowable authentication attempts is 1 to 3. The default is 3 attempts.
Beginning in privileged EXEC mode, follow these steps to configure the maximum number of allowed authentication attempts. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td>Step 2</td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td>Step 3</td>
<td><strong>switchport mode access</strong></td>
</tr>
<tr>
<td></td>
<td>or <strong>switchport mode private-vlan host</strong></td>
</tr>
<tr>
<td>Step 4</td>
<td><strong>dot1x port-control auto</strong></td>
</tr>
<tr>
<td>Step 5</td>
<td><strong>dot1x auth-fail vlan vlan-id</strong></td>
</tr>
<tr>
<td>Step 6</td>
<td><strong>dot1x auth-fail max-attempts max attempts</strong></td>
</tr>
<tr>
<td>Step 7</td>
<td><strong>end</strong></td>
</tr>
<tr>
<td>Step 8</td>
<td><strong>show dot1x interface interface-id</strong></td>
</tr>
<tr>
<td>Step 9</td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>

To return to the default value, use the **no dot1x auth-fail max-attempts** interface configuration command.

This example shows how to set 2 as the number of authentication attempts allowed before the port moves to the restricted VLAN:

```
Switch(config-if)# dot1x auth-fail max-attempts 2
```

### Configuring the Inaccessible Authentication Bypass Feature

You can configure the inaccessible bypass feature, also referred to as critical authentication or the AAA fail policy.
Beginning in privileged EXEC mode, follow these steps to configure the port as a critical port and enable the inaccessible authentication bypass feature. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td>radius-server dead-criteria</td>
<td>(Optional) Set the conditions that are used to decide when a RADIUS</td>
</tr>
<tr>
<td>time time</td>
<td>server is considered unavailable or dead.</td>
</tr>
<tr>
<td>tries tries</td>
<td>The range for time is from 1 to 120 seconds. The switch dynamically</td>
</tr>
<tr>
<td></td>
<td>determines the default seconds value that is 10 to 60 seconds.</td>
</tr>
<tr>
<td></td>
<td>The range for tries is from 1 to 100. The switch dynamically determines</td>
</tr>
<tr>
<td></td>
<td>the default tries parameter that is 10 to 100.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>radius-server deadtime</td>
<td>(Optional) Set the number of minutes that a RADIUS server is not sent</td>
</tr>
<tr>
<td>minutes</td>
<td>requests. The range is from 0 to 1440 minutes (24 hours). The default is</td>
</tr>
<tr>
<td></td>
<td>0 minutes.</td>
</tr>
</tbody>
</table>
### Step 4

**radius-server host ip-address [acct-port udp-port] [auth-port udp-port] [test username name [idle-time time] [ignore-acct-port] [ignore-auth-port]] [key string]**

(Optional) Configure the RADIUS server parameters by using these keywords:

- **acct-port udp-port** — Specify the UDP port for the RADIUS accounting server. The range for the UDP port number is from 0 to 65536. The default is 1646.
- **auth-port udp-port** — Specify the UDP port for the RADIUS authentication server. The range for the UDP port number is from 0 to 65536. The default is 1645.

**Note** You should configure the UDP port for the RADIUS accounting server and the UDP port for the RADIUS authentication server to nondefault values.

- **test username name** — Enable automated testing of the RADIUS server status, and specify the username to be used.
- **idle-time time** — Set the interval of time in minutes after which the switch sends test packets to the server. The range is from 1 to 35791 minutes. The default is 60 minutes (1 hour).
- **ignore-acct-port** — Disable testing on the RADIUS-server accounting port.
- **ignore-auth-port** — Disable testing on the RADIUS-server authentication port.

- For **key string**, specify the authentication and encryption key used between the switch and the RADIUS daemon running on the RADIUS server. The key is a text string that must match the encryption key used on the RADIUS server.

**Note** Always configure the key as the last item in the `radius-server host` command syntax because leading spaces are ignored, but spaces within and at the end of the key are used. If you use spaces in the key, do not enclose the key in quotation marks unless the quotation marks are part of the key. This key must match the encryption used on the RADIUS daemon. You can also configure the authentication and encryption key by using the `radius-server key {0 string | 7 string | string}` global configuration command.

**Note** You can also configure the authentication and encryption key by using the `radius-server key {0 string | 7 string | string}` global configuration command.

### Step 5

**dot1x critical {eapol | recovery delay milliseconds}**

(Optional) Configure the parameters for inaccessible authentication bypass:

- **eapol** — Specify that the switch sends an EAPOL-Success message when the switch successfully authenticates the critical port.
- **recovery delay milliseconds** — Set the recovery delay period during which the switch waits to re-initialize a critical port when a RADIUS server that was unavailable becomes available. The range is from 1 to 10000 milliseconds. The default is 1000 milliseconds (a port can be re-initialized every second).
Configuring IEEE 802.1x Port-Based Authentication

Chapter 6

Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Authentication

To return to the RADIUS server default settings, use the no radius-server dead-criteria, the no radius-server deadtime, and the no radius-server host global configuration commands. To return to the default settings of inaccessible authentication bypass, use the no dot1x critical {eapol | recovery delay} global configuration command. To disable inaccessible authentication bypass, use the no dot1x critical interface configuration command.

This example shows how to configure the inaccessible authentication bypass feature:

Switch(config)# radius-server dead-criteria time 30 tries 20
Switch(config)# radius-server deadtime 60
Switch(config)# radius-server host 1.1.1.2 acct-port 1550 auth-port 1560 key abc1234 test
Switch(config)# dot1x critical eapol
Switch(config)# dot1x critical recovery delay 2000
Switch(config)# interface gigabitethernet 0/1
Switch(config-if)# dot1x critical
Switch(config-if)# dot1x critical vlan 20
Switch(config-if)# end

Configuring IEEE 802.1x Authentication with WoL

Beginning in privileged EXEC mode, follow these steps to enable IEEE 802.1x authentication with WoL. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
</tbody>
</table>
## Configuring IEEE 802.1x Port-Based Authentication

### Configuring IEEE 802.1x Authentication

To disable IEEE 802.1x authentication with WoL, use the `no dot1x control-direction` interface configuration command.

This example shows how to enable IEEE 802.1x authentication with WoL and set the port as bidirectional:

```console
Switch(config-if)# dot1x control-direction both
```

### Configuring MAC Authentication Bypass

Beginning in privileged EXEC mode, follow these steps to enable MAC authentication bypass. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>interface interface-id</code></td>
<td>Specify the port to be configured, and enter interface configuration mode. For the supported port types, see the “IEEE 802.1x Authentication Configuration Guidelines” section on page 6-21.</td>
</tr>
<tr>
<td><code>dot1x port-control auto</code></td>
<td>Enable IEEE 802.1x authentication on the port.</td>
</tr>
<tr>
<td><code>dot1x mac-auth-bypass [eap]</code></td>
<td>Enable MAC authentication bypass. (Optional) Use the <code>eap</code> keyword to configure the switch to use EAP for authorization.</td>
</tr>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><code>show dot1x interface interface-id</code></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable IEEE 802.1x authentication with WoL, use the `no dot1x control-direction` interface configuration command.

This example shows how to enable IEEE 802.1x authentication with WoL and set the port as bidirectional:

```console
Switch(config-if)# dot1x control-direction both
```
Configuring IEEE 802.1x Authentication Using a RADIUS Server

You can configure IEEE 802.1x authentication with a RADIUS server.

Beginning in privileged EXEC mode, follow these steps to configure IEEE 802.1x authentication with a RADIUS server. The procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 dot1x guest-vlan vlan-id</td>
<td>Specify an active VLAN as an IEEE 802.1x guest VLAN. The range is 1 to 4094. You can configure any active VLAN except an RSPAN VLAN, or a voice VLAN as an IEEE 802.1x guest VLAN.</td>
</tr>
<tr>
<td>Step 4 dot1x reauthentication</td>
<td>Enable periodic re-authentication of the client, which is disabled by default.</td>
</tr>
<tr>
<td>Step 5 dot1x timeout reauth-period {seconds</td>
<td>Set the number of seconds between re-authentication attempts. The keywords have these meanings:</td>
</tr>
<tr>
<td>server}</td>
<td>• seconds—Sets the number of seconds from 1 to 65535; the default is 3600 seconds.</td>
</tr>
<tr>
<td></td>
<td>• server—Sets the number of seconds based on the value of the Session-Timeout RADIUS attribute (Attribute[27]) and the Termination-Action RADIUS attribute (Attribute [29]).</td>
</tr>
<tr>
<td></td>
<td>This command affects the behavior of the switch only if periodic re-authentication is enabled.</td>
</tr>
<tr>
<td>Step 6 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7 show dot1x interface interface-id</td>
<td>Verify your IEEE 802.1x authentication configuration.</td>
</tr>
<tr>
<td>Step 8 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to configure IEEE 802.1x using a RADIUS server:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# dot1x reauthentication
Switch(config-if)# dot1x timeout reauth-period server
```

Configuring Web Authentication

Beginning in privileged EXEC mode, follow these steps to configure authentication, authorization, accounting (AAA) and RADIUS on a switch before configuring web authentication. The steps enable AAA by using RADIUS authentication and enable device tracking.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 aaa new-model</td>
<td>Enable AAA.</td>
</tr>
</tbody>
</table>
**Chapter 6  Configuring IEEE 802.1x Port-Based Authentication**

### Configuring IEEE 802.1x Port-Based Authentication

This example shows how to enable AAA, use RADIUS authentication and enable device tracking:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3</strong></td>
<td><code>aaa authentication login default group radius</code></td>
</tr>
<tr>
<td></td>
<td>Use RADIUS authentication. Before you can use this authentication method, you must configure the RADIUS server. For more information, see Chapter 5, “Configuring Switch-Based Authentication.” The console prompts you for a username and password on future attempts to access the switch console after entering the <code>aaa authentication login</code> command. If you do not want to be prompted for a username and password, configure a second login authentication list:</td>
</tr>
<tr>
<td><code>Switch(config)# configure terminal</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# aaa new-model</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# aaa authentication login default group radius</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# aaa authorization auth-proxy default group radius</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# radius-server host key key1</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# radius-server attribute 8 include-in-access-req</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# radius-server vsa send authentication</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# ip device tracking</code></td>
<td></td>
</tr>
<tr>
<td><code>Switch(config)# end</code></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>aaa authorization auth-proxy default group radius</code></td>
</tr>
<tr>
<td></td>
<td>Use RADIUS for authentication-proxy (auth-proxy) authorization.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>radius-server host key radius-key</code></td>
</tr>
<tr>
<td></td>
<td>Specify the authentication and encryption key for RADIUS communication between the switch and the RADIUS daemon.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><code>radius-server attribute 8 include-in-access-req</code></td>
</tr>
<tr>
<td></td>
<td>Configure the switch to send the Framed-IP-Address RADIUS attribute ([Attribute][8]) in access-request or accounting-request packets.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><code>radius-server vsa send authentication</code></td>
</tr>
<tr>
<td></td>
<td>Configure the network access server to recognize and use vendor-specific attributes (VSAs).</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><code>ip device tracking</code></td>
</tr>
<tr>
<td></td>
<td>Enable the IP device tracking table. To disable the IP device tracking table, use the <code>no ip device tracking</code> global configuration commands.</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td><code>end</code></td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

### Command Purpose

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><code>configure terminal</code></td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>ip admission name rule proxy http</code></td>
</tr>
<tr>
<td></td>
<td>Define a web authentication rule. <strong>Note</strong>: The same rule cannot be used for both web authentication and NAC Layer 2 IP validation.</td>
</tr>
</tbody>
</table>
Configuring IEEE 802.1x Port-Based Authentication

Chapter 6

Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Authentication

This example shows how to configure only web authentication on a switch port:

```
Switch# configure terminal
Switch(config)# ip admission name rule1 proxy http
Switch(config)# interface gigabit1/0/1
Switch(config-if)# switchport mode access
Switch(config-if)# ip access-group policy1 in
Switch(config-if)# ip admission rule1
Switch(config-if)# end
```

Beginning in privileged EXEC mode, follow these steps to configure a switch port for IEEE 802.1x authentication with web authentication as a fallback method:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>switchport mode access</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>ip access-group access-list in</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>ip admission rule</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td>show running-config interface interface-id</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

This example shows how to configure only web authentication on a switch port:

```
Switch# configure terminal
Switch(config)# ip admission name rule1 proxy http
Switch(config)# interface gigabit1/0/1
Switch(config-if)# switchport mode access
Switch(config-if)# ip access-group policy1 in
Switch(config-if)# ip admission rule1
Switch(config-if)# end
```

Beginning in privileged EXEC mode, follow these steps to configure a switch port for IEEE 802.1x authentication with web authentication as a fallback method:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>ip admission name rule proxy http</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>fallback profile fallback-profile</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>ip access-group policy in</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>ip admission rule</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td>switchport mode access</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td>dot1x port-control auto</td>
</tr>
<tr>
<td><strong>Step 10</strong></td>
<td>dot1x fallback fallback-profile</td>
</tr>
</tbody>
</table>

**Note**: Web authorization cannot be used as a fallback method for IEEE 802.1x if the port is configured for multidomain authentication.
Chapter 6 Configuring IEEE 802.1x Port-Based Authentication

Configuring IEEE 802.1x Authentication

This example shows how to configure IEEE 802.1x authentication with web authentication as a fallback method.

Switch(config) configure terminal
Switch(config)# ip admission name rule1 proxy http
Switch(config)# fallback profile fallback1
Switch(config-fallback-profile)# ip access-group default-policy in
Switch(config-fallback-profile)# ip admission rule1
Switch(config-fallback-profile)# exit
Switch(config)# interface gigabit1/0/1
Switch(config-if)# switchport mode access
Switch(config-if)# dot1x port-control auto
Switch(config-if)# dot1x fallback fallback1
Switch(config-if)# end

For more information about the ip admission name and dot1x fallback commands, see the command reference for this release.

Disabling IEEE 802.1x Authentication on the Port

You can disable IEEE 802.1x authentication on the port by using the no dot1x pae interface configuration command.

Beginning in privileged EXEC mode, follow these steps to disable IEEE 802.1x authentication on the port. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id Specify the port to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3</td>
<td>no dot1x pae Disable IEEE 802.1x authentication on the port.</td>
</tr>
<tr>
<td>Step 4</td>
<td>end Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5</td>
<td>show dot1x interface interface-id Verify your entries.</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To configure the port as an IEEE 802.1x port access entity (PAE) authenticator, which enables IEEE 802.1x on the port but does not allow clients connected to the port to be authorized, use the dot1x pae authenticator interface configuration command.

This example shows how to disable IEEE 802.1x authentication on the port:

Switch(config)# interface gigabitethernet0/1
Switch(config-if)# no dot1x pae authenticator
Resetting the IEEE 802.1x Authentication Configuration to the Default Values

Beginning in privileged EXEC mode, follow these steps to reset the IEEE 802.1x authentication configuration to the default values. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Enter interface configuration mode, and specify the port to be configured.</td>
</tr>
<tr>
<td>Step 3 dot1x default</td>
<td>Reset the IEEE 802.1x parameters to the default values.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show dot1x interface interface-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Displaying IEEE 802.1x Statistics and Status

To display IEEE 802.1x statistics for all ports, use the `show dot1x all statistics` privileged EXEC command. To display IEEE 802.1x statistics for a specific port, use the `show dot1x statistics interface interface-id` privileged EXEC command.

To display the IEEE 802.1x administrative and operational status for the switch, use the `show dot1x all [details | statistics | summary]` privileged EXEC command. To display the IEEE 802.1x administrative and operational status for a specific port, use the `show dot1x interface interface-id` privileged EXEC command.

For detailed information about the fields in these displays, see the command reference for this release.
Configuring Interface Characteristics

This chapter defines the types of interfaces on the switch and describes how to configure them. The chapter consists of these sections:

- Understanding Interface Types, page 7-1
- Using Interface Configuration Mode, page 7-4
- Configuring Ethernet Interfaces, page 7-9
- Configuring the System MTU, page 7-14
- Monitoring and Maintaining the Interfaces, page 7-16

Note

For complete syntax and usage information for the commands used in this chapter, see the switch command reference for this release and the online Cisco IOS Interface Command Reference, Release 12.2.

Understanding Interface Types

This section describes the different types of interfaces supported by the switch with references to chapters that contain more detailed information about configuring these interface types. The rest of the chapter describes configuration procedures for physical interface characteristics.

These sections describe the interface types:

- Port-Based VLANs, page 7-1
- Switch Ports, page 7-2
- EtherChannel Port Groups, page 7-3
- Connecting Interfaces, page 7-4

Port-Based VLANs

A VLAN is a switched network that is logically segmented by function, team, or application, without regard to the physical location of the users. For more information about VLANs, see Chapter 9, “Configuring VLANs.” Packets received on a port are forwarded only to ports that belong to the same VLAN as the receiving port. Network devices in different VLANs cannot communicate with one another without a Layer 3 device to route traffic between the VLANs.
VLAN partitions provide hard firewalls for traffic in the VLAN, and each VLAN has its own MAC address table. A VLAN comes into existence when a local port is configured to be associated with the VLAN, when the VLAN Trunking Protocol (VTP) learns of its existence from a neighbor on a trunk, or when a user creates a VLAN.

To configure normal-range VLANs (VLAN IDs 1 to 1005), use the `vlan vlan-id` global configuration command to enter config-vlan mode or the `vlan database` privileged EXEC command to enter VLAN database configuration mode. The VLAN configurations for VLAN IDs 1 to 1005 are saved in the VLAN database. To configure extended-range VLANs (VLAN IDs 1006 to 4094), you must use config-vlan mode with VTP mode set to transparent. Extended-range VLANs are not added to the VLAN database. When VTP mode is transparent, the VTP and VLAN configuration is saved in the switch running configuration, and you can save it in the switch startup configuration file by entering the `copy running-config startup-config` privileged EXEC command.

Add ports to a VLAN by using the `switchport` interface configuration commands:

- Identify the interface.
- For a trunk port, set trunk characteristics, and if desired, define the VLANs to which it can belong.
- For an access port, set and define the VLAN to which it belongs.

### Switch Ports

Switch ports are Layer 2-only interfaces associated with a physical port. Switch ports belong to one or more VLANs. A switch port can be an access port or a trunk port. You can configure a port as an access port or trunk port or let the Dynamic Trunking Protocol (DTP) operate on a per-port basis to set the switchport mode by negotiating with the port on the other end of the link. Switch ports are used for managing the physical interface and associated Layer 2 protocols.

Configure switch ports by using the `switchport` interface configuration commands.

For detailed information about configuring access port and trunk port characteristics, see Chapter 9, “Configuring VLANs.”

### Access Ports

An access port belongs to and carries the traffic of only one VLAN (unless it is configured as a voice VLAN port). Traffic is received and sent in native formats with no VLAN tagging. Traffic arriving on an access port is assumed to belong to the VLAN assigned to the port. If an access port receives a tagged packet (Inter-Switch Link [ISL] or IEEE 802.1Q tagged), the packet is dropped, and the source address is not learned.

Two types of access ports are supported:

- Static access ports are manually assigned to a VLAN (or through a RADIUS server for use with IEEE 802.1x. For more information, see the “Using IEEE 802.1x Authentication with VLAN Assignment” section on page 6-10.)
- VLAN membership of dynamic access ports is learned through incoming packets. By default, a dynamic access port is not a member of any VLAN, and forwarding to and from the port is enabled only when the VLAN membership of the port is discovered. Dynamic access ports on the switch are assigned to a VLAN by a VLAN Membership Policy Server (VMPS). The VMPS can be a Catalyst 6500 series switch; the Catalyst switch cannot be a VMPS server.

You can also configure an access port with an attached Cisco IP Phone to use one VLAN for voice traffic and another VLAN for data traffic from a device attached to the phone. For more information about voice VLAN ports, see Chapter 11, “Configuring Voice VLAN.”
Trunk Ports

A trunk port carries the traffic of multiple VLANs and by default is a member of all VLANs in the VLAN database. These trunk port types are supported:

- In an ISL trunk port, all received packets are expected to be encapsulated with an ISL header, and all transmitted packets are sent with an ISL header. Native (non-tagged) frames received from an ISL trunk port are dropped.

- An IEEE 802.1Q trunk port supports simultaneous tagged and untagged traffic. An IEEE 802.1Q trunk port is assigned a default port VLAN ID (PVID), and all untagged traffic travels on the port default PVID. All untagged traffic and tagged traffic with a NULL VLAN ID are assumed to belong to the port default PVID. A packet with a VLAN ID equal to the outgoing port default PVID is sent untagged. All other traffic is sent with a VLAN tag.

Although by default, a trunk port is a member of every VLAN known to the VTP, you can limit VLAN membership by configuring an allowed list of VLANs for each trunk port. The list of allowed VLANs does not affect any other port but the associated trunk port. By default, all possible VLANs (VLAN ID 1 to 4094) are in the allowed list. A trunk port can become a member of a VLAN only if VTP knows of the VLAN and if the VLAN is in the enabled state. If VTP learns of a new, enabled VLAN and the VLAN is in the allowed list for a trunk port, the trunk port automatically becomes a member of that VLAN and traffic is forwarded to and from the trunk port for that VLAN. If VTP learns of a new, enabled VLAN that is not in the allowed list for a trunk port, the port does not become a member of the VLAN, and no traffic for the VLAN is forwarded to or from the port.

For more information about trunk ports, see Chapter 9, “Configuring VLANs.”

EtherChannel Port Groups

EtherChannel port groups treat multiple switch ports as one switch port. These port groups act as a single logical port for high-bandwidth connections between switches or between switches and servers. An EtherChannel balances the traffic load across the links in the channel. If a link within the EtherChannel fails, traffic previously carried over the failed link changes to the remaining links. You can group multiple trunk ports into one logical trunk port or multiple access ports into one logical access port.

Most protocols operate over either single ports or aggregated switch ports and do not recognize the physical ports within the port group. Exceptions are the DTP, the Cisco Discovery Protocol (CDP), and the Port Aggregation Protocol (PAgP), which operate only on physical ports.

When you configure an EtherChannel, you create a port-channel logical interface and assign an interface to the EtherChannel. Use the channel-group interface configuration command to dynamically create the port-channel logical interface. This command binds the physical and logical ports together. For more information, see Chapter 28, “Configuring EtherChannels and Layer 2 Trunk Failover.”
Connecting Interfaces

Devices within a single VLAN can communicate directly through any switch. Ports in different VLANs cannot exchange data without going through a routing device. In the configuration shown in Figure 7-1, when Blade Server A in VLAN 20 sends data to Blade Server B in VLAN 30, the data must go from Blade Server A to the switch, to the router, back to the switch, and then to Blade Server B.

**Figure 7-1 Connecting VLANs with Layer 2 Switches**

Using Interface Configuration Mode

The switch supports these interface types:

- Physical ports—switch ports
- VLANs—switch virtual interfaces
- Port channels—EtherChannel interfaces

You can also configure a range of interfaces (see the “Configuring a Range of Interfaces” section on page 7-6).

To configure a physical interface (port), specify the interface type, module number, and switch port number, and enter interface configuration mode.

- Type—Gigabit Ethernet (gigabitethernet or gi) for 10/100/1000 Mb/s Ethernet port or small form-factor pluggable (SFP) module Gigabit Ethernet interfaces.
- Module number—The module or slot number on the switch (always 0 on the switch).

You can identify physical interfaces by physically checking the interface location on the switch. You can also use the `show` privileged EXEC commands to display information about a specific interface or all the interfaces on the switch. The remainder of this chapter primarily provides physical interface configuration procedures.
Procedures for Configuring Interfaces

These general instructions apply to all interface configuration processes.

**Step 1** Enter the `configure terminal` command at the privileged EXEC prompt:

```bash
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#
```

**Step 2** Enter the `interface` global configuration command. Identify the interface type and the number of the connector. In this example, Gigabit Ethernet port 1 is selected:

```bash
Switch(config)# interface gigabitethernet0/1
Switch(config-if)#
```

**Note** You do not need to add a space between the interface type and interface number. For example, in the preceding line, you can specify either `gigabitethernet 0/1`, `gigabitethernet0/1`, `gi 0/1`, or `gi0/1`.

**Step 3** Follow each `interface` command with the interface configuration commands that the interface requires. The commands that you enter define the protocols and applications that will run on the interface. The commands are collected and applied to the interface when you enter another interface command or enter `end` to return to privileged EXEC mode.

You can also configure a range of interfaces by using the `interface range` or `interface range macro` global configuration commands. Interfaces configured in a range must be the same type and must be configured with the same feature options.

**Step 4** After you configure an interface, verify its status by using the `show` privileged EXEC commands listed in the “Monitoring and Maintaining the Interfaces” section on page 7-16.

Enter the `show interfaces` privileged EXEC command to see a list of all interfaces on or configured for the switch. A report is provided for each interface that the device supports or for the specified interface.
Configuring a Range of Interfaces

You can use the `interface range` global configuration command to configure multiple interfaces with the same configuration parameters. When you enter the interface-range configuration mode, all command parameters that you enter are attributed to all interfaces within that range until you exit this mode.

Beginning in privileged EXEC mode, follow these steps to configure a range of interfaces with the same parameters:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface range `{port-range</td>
<td>macro macro_name}`</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>Use the normal configuration commands to apply the configuration parameters to all interfaces in the range. Each command is executed as it is entered.</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show interfaces <code>[interface-id]</code></td>
<td>Verify the configuration of the interfaces in the range.</td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

When using the `interface range` global configuration command, note these guidelines:

- Valid entries for `port-range`:
  - `vlan vlan-ID`, where the VLAN ID is 1 to 4094
  - `gigabitethernet module/{first port} - {last port}`, where the module is always 0
  - `port-channel port-channel-number - port-channel-number`, where the `port-channel-number` is 1 to 48

  **Note** Although the command-line interface shows options to set multiple VLANs, these options are not supported.

  **Note** When you use the `interface range` command with port channels, the first and last port-channel number must be active port channels.
• You must add a space between the first interface number and the hyphen when using the `interface range` command. For example, the command `interface range gigabitethernet0/1 - 4` is a valid range; the command `interface range gigabitethernet0/1-4` is not a valid range.

• The `interface range` command only works with VLAN interfaces that have been configured with the `interface vlan` command. The `show running-config` privileged EXEC command displays the configured VLAN interfaces. VLAN interfaces not displayed by the `show running-config` command cannot be used with the `interface range` command.

• All interfaces defined in a range must be the same type (all Gigabit Ethernet ports, all EtherChannel ports, or all VLANs), but you can enter multiple ranges in a command.

This example shows how to use the `interface range` global configuration command to set the speed on ports 1 to 4 to 100 Mb/s:

```
Switch# configure terminal
Switch(config)# interface range gigabitethernet0/1 - 4
Switch(config-if-range)# speed 100
```

If you enter multiple configuration commands while you are in interface-range mode, each command is executed as it is entered. The commands are not batched and executed after you exit interface-range mode. If you exit interface-range configuration mode while the commands are being executed, some commands might not be executed on all interfaces in the range. Wait until the command prompt reappears before exiting interface-range configuration mode.

### Configuring and Using Interface Range Macros

You can create an interface range macro to automatically select a range of interfaces for configuration. Before you can use the `macro` keyword in the `interface range macro` global configuration command string, you must use the `define interface-range` global configuration command to define the macro.

Beginning in privileged EXEC mode, follow these steps to define an interface range macro:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>define interface-range macro_name interface-range</code></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>interface range macro macro_name</code></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>end</code></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>`show running-config</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><code>copy running-config startup-config</code></td>
</tr>
</tbody>
</table>

Use the `no define interface-range macro_name` global configuration command to delete a macro.
When using the `define interface-range` global configuration command, note these guidelines:

- Valid entries for `interface-range`:
  - `vlan vlan-ID`, where the VLAN ID is 1 to 4094
    
    **Note** Although the command-line interface shows options to set multiple VLANs, these options are not supported.
    
  - `gigabitethernet module/[first port] - [last port]`, where the module is always 0
  - `port-channel port-channel-number - port-channel-number`, where the `port-channel-number` is 1 to 48.
    
    **Note** When you use the interface ranges with port channels, the first and last port-channel number must be active port channels.

- You must add a space between the first interface number and the hyphen when entering an `interface-range`. For example, `gigabitethernet0/1 - 4` is a valid range; `gigabitethernet0/1-4` is not a valid range.
- The VLAN interfaces must have been configured with the `interface vlan` command. The `show running-config` privileged EXEC command displays the configured VLAN interfaces. VLAN interfaces not displayed by the `show running-config` command cannot be used as `interface-ranges`.
- All interfaces defined as in a range must be the same type (all Gigabit Ethernet ports, all EtherChannel ports, or all VLANs), but you can combine multiple interface types in a macro.

This example shows how to define an interface-range named `enet_list` to include ports 1 and 2 and to verify the macro configuration:

```
Switch(config)# define interface-range enet_list gigabitethernet0/1 - 2
Switch(config)# end
Switch(config)# show running-config | include define
define interface-range enet_list GigabitEthernet0/1 - 2
```

This example shows how to create a multiple-interface macro named `macro1`:

```
Switch(config)# define interface-range macro1 gigabitethernet0/1 - 2, gigabitethernet0/5 - 7
Switch(config)# end
```

This example shows how to enter interface-range configuration mode for the interface-range macro `enet_list`:

```
Switch(config)# interface range macro enet_list
```

This example shows how to delete the interface-range macro `enet_list` and to verify that it was deleted.

```
Switch(config)# no define interface-range enet_list
Switch(config)# end
Switch(config)# show running-config | include define
```
Configuring Ethernet Interfaces

These sections contain this configuration information:

- Default Ethernet Interface Configuration, page 7-9
- Interface Speed and Duplex Mode, page 7-10
- Configuring IEEE 802.3x Flow Control, page 7-12
- Configuring Auto-MDIX on an Interface, page 7-13
- Adding a Description for an Interface, page 7-14

Default Ethernet Interface Configuration

Table 7-1 shows the Ethernet interface default configuration. For more details on the VLAN parameters listed in the table, see Chapter 9, “Configuring VLANS.” For details on controlling traffic to the port, see Chapter 18, “Configuring Port-Based Traffic Control.”

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowed VLAN range</td>
<td>VLANs 1 to 4094.</td>
</tr>
<tr>
<td>Default VLAN (for access ports)</td>
<td>VLAN 1.</td>
</tr>
<tr>
<td>Native VLAN (for IEEE 802.1Q trunks)</td>
<td>VLAN 1.</td>
</tr>
<tr>
<td>VLAN trunking</td>
<td>Switchport mode dynamic auto (supports DTP).</td>
</tr>
<tr>
<td>Port enable state</td>
<td>All ports are enabled.</td>
</tr>
<tr>
<td>Port description</td>
<td>None defined.</td>
</tr>
<tr>
<td>Speed</td>
<td>Autonegotiate.</td>
</tr>
<tr>
<td>Duplex mode</td>
<td>Autonegotiate.</td>
</tr>
<tr>
<td>Flow control</td>
<td>Flow control is set to <strong>receive: off</strong>. It is always off for sent packets.</td>
</tr>
<tr>
<td>EtherChannel (PAgP)</td>
<td>Disabled on all Ethernet ports. See Chapter 28, “Configuring EtherChannnels and Layer 2 Trunk Failover.”</td>
</tr>
<tr>
<td>Port blocking (unknown multicast and unknown unicast traffic)</td>
<td>Disabled (not blocked). See the “Configuring Port Blocking” section on page 18-6.</td>
</tr>
<tr>
<td>Broadcast, multicast, and unicast storm control</td>
<td>Disabled. See the “Default Storm Control Configuration” section on page 18-3.</td>
</tr>
<tr>
<td>Protected port</td>
<td>Disabled. See the “Configuring Protected Ports” section on page 18-5.</td>
</tr>
<tr>
<td>Port security</td>
<td>Disabled. See the “Default Port Security Configuration” section on page 18-10.</td>
</tr>
</tbody>
</table>
# Interface Speed and Duplex Mode

Ethernet interfaces on the switch operate at 10, 100, or 1000 Mb/s and in either full- or half-duplex mode. In full-duplex mode, two stations can send and receive traffic at the same time. Normally, 10-Mb/s ports operate in half-duplex mode, which means that stations can either receive or send traffic.

Switch models include Gigabit Ethernet (10/100/1000-Mb/s) ports and small form-factor pluggable (SFP) module slots supporting SFP modules.

These sections describe how to configure the interface speed and duplex mode:

- **Speed and Duplex Configuration Guidelines**, page 7-10
- **Setting the Interface Speed and Duplex Parameters**, page 7-11

## Speed and Duplex Configuration Guidelines

When configuring an interface speed and duplex mode, note these guidelines:

- Gigabit Ethernet (10/100/1000-Mb/s) ports support all speed options and all duplex options (auto, half, and full). However, Gigabit Ethernet ports operating at 1000 Mb/s do not support half-duplex mode.

- For SFP module ports, the speed and duplex CLI options change depending on the SFP module type:
  - The 1000BASE-\(x\) (where \(-x\) is -BX, -CWDM, -LX, -SX, and -ZX) SFP module ports support the `nonegotiate` keyword in the `speed` interface configuration command. Duplex options are not supported.
  - The 1000BASE-T SFP module ports support the same speed and duplex options as the 10/100/1000-Mbps ports.
  - The 100BASE-\(x\) (where \(-x\) is -BX, -CWDM, -LX, -SX, and -ZX) SFP module ports support only 100 Mbps. These modules support full- and half- duplex options but do not support autonegotiation.

For information about which SFP modules are supported on your switch, see the product release notes.

- You cannot configure duplex mode on SFP module ports; they operate in full-duplex mode except in these situations:
  - You can configure Cisco 1000BASE-T SFP modules for auto, full, or half-duplex mode.
  - Cisco 1000BASE-SX SFP modules can operate only in full-duplex mode.
• If you are connected to a device that does not support autonegotiation, you can configure speed on copper SFP module ports; however, you can only configure fiber SFP module ports to not negotiate (nonegotiate).

• If both ends of the line support autonegotiation, we highly recommend the default setting of auto negotiation.

• If one interface supports autonegotiation and the other end does not, configure duplex and speed on both interfaces; do not use the auto setting on the supported side.

• When STP is enabled and a port is reconfigured, the switch can take up to 30 seconds to check for loops. The port LED is amber while STP reconfigures.

Caution
Changing the interface speed and duplex mode configuration might shut down and re-enable the interface during the reconfiguration.

Setting the Interface Speed and Duplex Parameters

Beginning in privileged EXEC mode, follow these steps to set the speed and duplex mode for a physical interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the physical interface to be configured, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
| Step 3 speed {10 | 100 | 1000 | auto [10 | 100 | 1000] | nonegotiate} | Enter the appropriate speed parameter for the interface:  
  • Enter 10, 100, or 1000 to set a specific speed for the interface. The 1000 keyword is available only for 10/100/1000 Mb/s ports.  
  • Enter auto to enable the interface to autonegotiate speed with the connected device. If you use the 10, 100, or the 1000 keywords with the auto keyword, the port autonegotiates only at the specified speeds.  
  • The nonegotiate keyword is available only for SFP module ports. SFP module ports operate only at 1000 Mb/s but can be configured to not negotiate if connected to a device that does not support autonegotiation. 
  For more information about speed settings, see the “Speed and Duplex Configuration Guidelines” section on page 7-10. |
| Step 4 duplex {auto | full | half} | Enter the duplex parameter for the interface.  
  Enable half-duplex mode (for interfaces operating only at 10 or 100 Mb/s). You cannot configure half-duplex mode for interfaces operating at 1000 Mb/s.  
  For more information about duplex settings, see the “Speed and Duplex Configuration Guidelines” section on page 7-10. |
| Step 5 end                   | Return to privileged EXEC mode.                                          |
| Step 6 show interfaces interface-id | Display the interface speed and duplex mode configuration.             |
| Step 7 copy running-config startup-config | (Optional) Save your entries in the configuration file.                |
Use the **no speed** and **no duplex** interface configuration commands to return the interface to the default speed and duplex settings (autonegotiate). To return all interface settings to the defaults, use the **default interface interface-id** interface configuration command.

This example shows how to set the interface speed to 100 Mb/s on a 10/100/1000 Mb/s port:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# speed 100
```

### Configuring IEEE 802.3x Flow Control

Flow control enables connected Ethernet ports to control traffic rates during congestion by allowing congested nodes to pause link operation at the other end. If one port experiences congestion and cannot receive any more traffic, it notifies the other port by sending a pause frame to stop sending until the condition clears. Upon receipt of a pause frame, the sending device stops sending any data packets, which prevents any loss of data packets during the congestion period.

**Note**

Switchports can receive, but not send, pause frames.

You use the **flowcontrol** interface configuration command to set the interface’s ability to **receive** pause frames to **on**, **off**, or **desired**. The default state is **off**.

When set to **desired**, an interface can operate with an attached device that is required to send flow-control packets or with an attached device that is not required to but can send flow-control packets.

These rules apply to flow control settings on the device:

- **receive on** (or **desired**): The port cannot send pause frames but can operate with an attached device that is required to or can send pause frames; the port can receive pause frames.
- **receive off**: Flow control does not operate in either direction. In case of congestion, no indication is given to the link partner, and no pause frames are sent or received by either device.

**Note**

For details on the command settings and the resulting flow control resolution on local and remote ports, see the **flowcontrol** interface configuration command in the command reference for this release.

Beginning in privileged EXEC mode, follow these steps to configure flow control on an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the physical interface to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong> flowcontrol {receive} {on</td>
<td>off</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show interfaces interface-id</td>
<td>Verify the interface flow control settings.</td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
To disable flow control, use the `flowcontrol receive off` interface configuration command.

This example shows how to turn on flow control on a port:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# flowcontrol receive on
Switch(config-if)# end
```

### Configuring Auto-MDIX on an Interface

When automatic medium-dependent interface crossover (auto-MDIX) is enabled on an interface, the interface automatically detects the required cable connection type (straight through or crossover) and configures the connection appropriately. When connecting switches without the auto-MDIX feature, you must use straight-through cables to connect to devices such as servers, workstations, or routers and crossover cables to connect to other switches or repeaters. With auto-MDIX enabled, you can use either type of cable to connect to other devices, and the interface automatically corrects for any incorrect cabling. For more information about cabling requirements, see the hardware installation guide.

Auto-MDIX is enabled by default. When you enable auto-MDIX, you must also set the interface speed and duplex to `auto` so that the feature operates correctly. Auto-MDIX is supported on all 10/100/1000-Mb/s interfaces and on 10/100/1000BASE-T SFP-module interfaces. It is not supported on 1000BASE-SX or -LX SFP module interfaces.

Table 7-2 shows the link states that result from auto-MDIX settings and correct and incorrect cabling.

<table>
<thead>
<tr>
<th>Local Side Auto-MDIX</th>
<th>Remote Side Auto-MDIX</th>
<th>With Correct Cabling</th>
<th>With Incorrect Cabling</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>On</td>
<td>Link up</td>
<td>Link up</td>
</tr>
<tr>
<td>On</td>
<td>Off</td>
<td>Link up</td>
<td>Link up</td>
</tr>
<tr>
<td>Off</td>
<td>On</td>
<td>Link up</td>
<td>Link up</td>
</tr>
<tr>
<td>Off</td>
<td>Off</td>
<td>Link up</td>
<td>Link down</td>
</tr>
</tbody>
</table>

Beginning in privileged EXEC mode, follow these steps to configure auto-MDIX on an interface:

1. **configure terminal**
   - Enter global configuration mode
2. **interface interface-id**
   - Specify the physical interface to be configured, and enter interface configuration mode.
3. **speed auto**
   - Configure the interface to autonegotiate speed with the connected device.
4. **duplex auto**
   - Configure the interface to autonegotiate duplex mode with the connected device.
5. **mdix auto**
   - Enable auto-MDIX on the interface.
6. **end**
   - Return to privileged EXEC mode.
7. **show controllers ethernet-controller interface-id phy**
   - Verify the operational state of the auto-MDIX feature on the interface.
8. **copy running-config startup-config**
   - (Optional) Save your entries in the configuration file.
To disable auto-MDIX, use the `no mdix auto` interface configuration command. This example shows how to enable auto-MDIX on a port:

```plaintext
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# speed auto
Switch(config-if)# duplex auto
Switch(config-if)# mdix auto
Switch(config-if)# end
```

**Adding a Description for an Interface**

You can add a description about an interface to help you remember its function. The description appears in the output of these privileged EXEC commands: `show configuration`, `show running-config`, and `show interfaces`.

Beginning in privileged EXEC mode, follow these steps to add a description for an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the interface for which you are adding a description, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong> description string</td>
<td>Add a description (up to 240 characters) for an interface.</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show interfaces interface-id description</td>
<td>Verify your entry.</td>
</tr>
<tr>
<td>or show running-config</td>
<td></td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Use the `no description` interface configuration command to delete the description.

This example shows how to add a description on a port and how to verify the description:

```plaintext
Switch# config terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# description Connects to Marketing
Switch(config-if)# end
Switch# show interfaces gigabitethernet0/2 description
Interface Status          Protocol Description
Gi0/2  admin down  down  Connects to Marketing
```

**Configuring the System MTU**

The default maximum transmission unit (MTU) size for frames received and transmitted on all interfaces on the switch is 1500 bytes. You can increase the MTU size for all interfaces operating at 10 or 100 Mb/s by using the `system mtu` global configuration command. You can increase the MTU size to support jumbo frames on all Gigabit Ethernet interfaces by using the `system mtu jumbo` global configuration command.
Gigabit Ethernet ports are not affected by the `system mtu` command; 10/100 ports are not affected by the `system jumbo mtu` command. If you do not configure the `system mtu jumbo` command, the setting of the `system mtu` command applies to all Gigabit Ethernet interfaces.

You cannot set the MTU size for an individual interface; you set it for all 10/100 or all Gigabit Ethernet interfaces on the switch. When you change the system or jumbo MTU size, you must reset the switch before the new configuration takes effect.

Frames sizes that can be received by the switch CPU are limited to 1998 bytes, no matter what value was entered with the `system mtu` or `system mtu jumbo` commands. Although frames that are forwarded are typically not received by the CPU, in some cases packets are sent to the CPU, such as traffic sent to control traffic, SNMP, or Telnet.

**Note**
If Gigabit Ethernet interfaces are configured to accept frames greater than the 10/100 interfaces, jumbo frames received on a Gigabit Ethernet interface and sent on a 10/100 interface are dropped.

Beginning in privileged EXEC mode, follow these steps to change MTU size for all 10/100 or Gigabit Ethernet interfaces:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td><code>system mtu</code> <em>bytes</em></td>
<td>(Optional) Change the MTU size for all interfaces on the switch that are operating at 10 or 100 Mb/s. The range is 1500 to 1998 bytes; the default is 1500 bytes.</td>
</tr>
<tr>
<td>3</td>
<td><code>system mtu jumbo</code> <em>bytes</em></td>
<td>(Optional) Change the MTU size for all Gigabit Ethernet interfaces on the switch. The range is 1500 to 9000 bytes; the default is 1500 bytes.</td>
</tr>
<tr>
<td>4</td>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>5</td>
<td><code>copy running-config startup-config</code></td>
<td>Save your entries in the configuration file.</td>
</tr>
<tr>
<td>6</td>
<td><code>reload</code></td>
<td>Reload the operating system.</td>
</tr>
</tbody>
</table>

If you enter a value that is outside the allowed range for the specific type of interface, the value is not accepted.

Once the switch reloads, you can verify your settings by entering the `show system mtu` privileged EXEC command.

This example shows how to set the maximum packet size for a Gigabit Ethernet port to 1800 bytes:

```
Switch(config)# system jumbo mtu 1800
Switch(config)# exit
Switch# reload
```

This example shows the response when you try to set Gigabit Ethernet interfaces to an out-of-range number:

```
Switch(config)# system mtu jumbo 25000
^%
% Invalid input detected at '^' marker.
```
Chapter 7  Configuring Interface Characteristics

Monitoring and Maintaining the Interfaces

These sections contain interface monitoring and maintenance information:

- Monitoring Interface Status, page 7-16
- Clearing and Resetting Interfaces and Counters, page 7-17
- Shutting Down and Restarting the Interface, page 7-17

Monitoring Interface Status

Commands entered at the privileged EXEC prompt display information about the interface, including the versions of the software and the hardware, the configuration, and statistics about the interfaces. Table 7-3 lists some of these interface monitoring commands. (You can display the full list of show commands by using the `show ?` command at the privileged EXEC prompt.) These commands are fully described in the Cisco IOS Interface Command Reference, Release 12.2.

Table 7-3  Show Commands for Interfaces

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show interfaces</code> [interface-id]</td>
<td>Display the status and configuration of all interfaces or a specific interface.</td>
</tr>
<tr>
<td><code>show interfaces interface-id status [err-disabled]</code></td>
<td>Display interface status or a list of interfaces in an error-disabled state.</td>
</tr>
<tr>
<td><code>show interfaces [interface-id] switchport</code></td>
<td>Display administrative and operational status of switching ports.</td>
</tr>
<tr>
<td><code>show interfaces [interface-id] description</code></td>
<td>Display the description configured on an interface or all interfaces and the interface status.</td>
</tr>
<tr>
<td><code>show ip interface [interface-id]</code></td>
<td>Display the usability status of all interfaces configured for IP routing or the specified interface.</td>
</tr>
<tr>
<td><code>show interface [interface-id] stats</code></td>
<td>Display the input and output packets by the switching path for the interface.</td>
</tr>
<tr>
<td><code>show interfaces transceiver properties</code></td>
<td>(Optional) Display speed and duplex settings on the interface.</td>
</tr>
<tr>
<td>`show interfaces [interface-id] [transceiver properties</td>
<td>detail] module number`</td>
</tr>
<tr>
<td><code>show running-config interface [interface-id]</code></td>
<td>Display the running configuration in RAM for the interface.</td>
</tr>
<tr>
<td><code>show version interface-id</code></td>
<td>Display the hardware configuration, software version, the names and sources of configuration files, and the bootup images.</td>
</tr>
<tr>
<td><code>show controllers ethernet-controller interface-id phy</code></td>
<td>Display the operational state of the auto-MDIX feature on the interface.</td>
</tr>
</tbody>
</table>
Clearing and Resetting Interfaces and Counters

Table 7-4 lists the privileged EXEC mode clear commands that you can use to clear counters and reset interfaces.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear counters [interface-id]</td>
<td>Clear interface counters.</td>
</tr>
<tr>
<td>clear interface interface-id</td>
<td>Reset the hardware logic on an interface.</td>
</tr>
<tr>
<td>clear line [number</td>
<td>console 0</td>
</tr>
</tbody>
</table>

To clear the interface counters shown by the show interfaces privileged EXEC command, use the clear counters privileged EXEC command. The clear counters command clears all current interface counters from the interface unless you specify optional arguments that clear only a specific interface type from a specific interface number.

Note: The clear counters privileged EXEC command does not clear counters retrieved by using Simple Network Management Protocol (SNMP), but only those seen with the show interface privileged EXEC command.

Shutting Down and Restarting the Interface

Shutting down an interface disables all functions on the specified interface and marks the interface as unavailable on all monitoring command displays. This information is communicated to other network servers through all dynamic routing protocols. The interface is not mentioned in any routing updates.

Beginning in privileged EXEC mode, follow these steps to shut down an interface:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td></td>
<td>interface { vlan vlan-id }</td>
<td>Select the interface to be configured.</td>
</tr>
<tr>
<td></td>
<td>shutdown</td>
<td>Shut down an interface.</td>
</tr>
<tr>
<td></td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td></td>
<td>show running-config</td>
<td>Verify your entry.</td>
</tr>
</tbody>
</table>

Use the no shutdown interface configuration command to restart the interface.

To verify that an interface is disabled, enter the show interfaces privileged EXEC command. A disabled interface is shown as administratively down in the display.
Chapter 7  Configuring Interface Characteristics

Monitoring and Maintaining the Interfaces
Configuring Smartports Macros

This chapter describes how to configure and apply Smartports macros on the switch.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Understanding Smartports Macros, page 8-1
- Configuring Smartports Macros, page 8-2
- Displaying Smartports Macros, page 8-8

Understanding Smartports Macros

Smartports macros provide a convenient way to save and share common configurations. You can use Smartports macros to enable features and settings based on the location of a switch in the network and for mass configuration deployments across the network.

Each Smartports macro is a set of command-line interface (CLI) commands that you define. Smartports macros do not contain new CLI commands; they are simply a group of existing CLI commands.

When you apply a Smartports macro on an interface, the CLI commands within the macro are configured on the interface. When the macro is applied to an interface, the existing interface configurations are not lost. The new commands are added to the interface and are saved in the running configuration file.

There are Cisco-default Smartports macros embedded in the switch software (see Table 8-1). You can display these macros and the commands they contain by using the show parser macro user EXEC command.

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cisco-global</td>
<td>Use this global configuration macro to enable rapid PVST+, loop guard, and dynamic port error recovery for link state failures.</td>
</tr>
<tr>
<td>cisco-desktop</td>
<td>Use this interface configuration macro for increased network security and reliability when connecting a desktop device, such as a PC, to a switch port.</td>
</tr>
</tbody>
</table>
Cisco also provides a collection of pretested, Cisco-recommended baseline configuration templates for Catalyst switches. The online reference guide templates provide the CLI commands that you can use to create Smartports macros based on the usage of the port. You can use the configuration templates to create Smartports macros to build and deploy Cisco-recommended network designs and configurations. For more information about Cisco-recommended configuration templates, see this Smartports website: http://www.cisco.com/go/smartports

### Configuring Smartports Macros

You can create a new Smartports macro or use an existing macro as a template to create a new macro that is specific to your application. After you create the macro, you can apply it globally to a switch or to a switch interface or range of interfaces.

These sections contain this configuration information:

- Default Smartports Macro Configuration, page 8-2
- Smartports Macro Configuration Guidelines, page 8-3
- Creating Smartports Macros, page 8-4
- Applying Smartports Macros, page 8-5
- Applying Cisco-Default Smartports Macros, page 8-6

### Default Smartports Macro Configuration

There are no Smartports macros enabled.
Smartports Macro Configuration Guidelines

Follow these guidelines when configuring macros on your switch:

- When creating a macro, do not use the `exit` or `end` commands or change the command mode by using `interface interface-id`. This could cause commands that follow `exit`, `end`, or `interface interface-id` to execute in a different command mode.

- When creating a macro, all CLI commands should be in the same configuration mode.

- When creating a macro that requires the assignment of unique values, use the `parameter value` keywords to designate values specific to the interface. Keyword matching is case sensitive. All matching occurrences of the keyword are replaced with the corresponding value. Any full match of a keyword, even if it is part of a larger string, is considered a match and is replaced by the corresponding value.

- Macro names are case sensitive. For example, the commands `macro name Sample-Macro` and `macro name sample-macro` will result in two separate macros.

- Some macros might contain keywords that require a parameter value. You can use the `macro global apply macro-name` global configuration command or the `macro apply macro-name` interface configuration command to display a list of any required values in the macro. If you apply a macro without entering the keyword values, the commands are invalid and are not applied.

- When a macro is applied globally to a switch or to a switch interface, all existing configuration on the interface is retained. This is helpful when applying an incremental configuration.

- If you modify a macro definition by adding or deleting commands, the changes are not reflected on the interface where the original macro was applied. You need to reapply the updated macro on the interface to apply the new or changed commands.

- You can use the `macro global trace macro-name` global configuration command or the `macro trace macro-name` interface configuration command to apply and debug a macro to find any syntax or configuration errors. If a command fails because of a syntax error or a configuration error, the macro continues to apply the remaining commands.

- Some CLI commands are specific to certain interface types. If a macro is applied to an interface that does not accept the configuration, the macro will fail the syntax check or the configuration check, and the switch will return an error message.

- Applying a macro to an interface range is the same as applying a macro to a single interface. When you use an interface range, the macro is applied sequentially to each interface within the range. If a macro command fails on one interface, it is still applied to the remaining interfaces.

- When you apply a macro to a switch or a switch interface, the macro name is automatically added to the switch or interface. You can display the applied commands and macro names by using the `show running-config` user EXEC command.

There are Cisco-default Smartports macros embedded in the switch software (see Table 8-1). You can display these macros and the commands they contain by using the `show parser macro` user EXEC command.
Follow these guidelines when you apply a Cisco-default Smartports macro on an interface:

- Display all macros on the switch by using the `show parser macro` user EXEC command. Display the contents of a specific macro by using the `show parser macro macro-name` user EXEC command.

- Keywords that begin with `$` mean that a unique parameter value is required. Append the Cisco-default macro with the required values by using the `parameter value` keywords.

  The Cisco-default macros use the `$` character to help identify required keywords. There is no restriction on using the `$` character to define keywords when you create a macro.

### Creating Smartports Macros

Beginning in privileged EXEC mode, follow these steps to create a Smartports macro:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>macro name macro-name</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show parser macro name macro-name</td>
</tr>
</tbody>
</table>

The `no` form of the `macro name` global configuration command only deletes the macro definition. It does not affect the configuration of those interfaces on which the macro is already applied.

This example shows how to create a macro that defines the switchport access VLAN and the number of secure MAC addresses and also includes two help string keywords by using `# macro keywords`:

```
Switch(config)# macro name test
switchport access vlan $VLANID
switchport port-security maximum $MAX
#macro keywords $VLANID $MAX
@
```
Applying Smartports Macros

Beginning in privileged EXEC mode, follow these steps to apply a Smartports macro:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>
| **Step 2** macro global {apply | trace} macro-name [parameter {value}] [parameter {value}] [parameter {value}] | Apply each individual command defined in the macro to the switch by entering `macro global apply macro-name`. Specify `macro global trace macro-name` to apply and debug a macro to find any syntax or configuration errors.  
(Optional) Specify unique parameter values that are specific to the switch. You can enter up to three keyword-value pairs. Parameter keyword matching is case sensitive. All matching occurrences of the keyword are replaced with the corresponding value.  
Some macros might contain keywords that require a parameter value. You can use the `macro global apply macro-name ?` command to display a list of any required values in the macro. If you apply a macro without entering the keyword values, the commands are invalid and are not applied. |
| **Step 3** macro global description text     | (Optional) Enter a description about the macro that is applied to the switch.                                                                                                                   |
| **Step 4** interface interface-id            | (Optional) Enter interface configuration mode, and specify the interface on which to apply the macro.                                                                                           |
| **Step 5** default interface interface-id    | (Optional) Clear all configuration from the specified interface.                                                                                                                               |
| **Step 6** macro {apply | trace} macro-name [parameter {value}] [parameter {value}] [parameter {value}] | Apply each individual command defined in the macro to the interface by entering `macro apply macro-name`. Specify `macro trace macro-name` to apply and debug a macro to find any syntax or configuration errors.  
(Optional) Specify unique parameter values that are specific to the interface. You can enter up to three keyword-value pairs. Parameter keyword matching is case sensitive. All matching occurrences of the keyword are replaced with the corresponding value.  
Some macros might contain keywords that require a parameter value. You can use the `macro apply macro-name ?` command to display a list of any required values in the macro. If you apply a macro without entering the keyword values, the commands are invalid and are not applied. |
| **Step 7** macro description text             | (Optional) Enter a description about the macro that is applied to the interface.                                                                                                               |
| **Step 8** end                               | Return to privileged EXEC mode.                                                                                                                                                                |
| **Step 9** show parser macro description [interface interface-id] | Verify that the macro is applied to the interface.                                                                                                                                               |
| **Step 10** copy running-config startup-config | (Optional) Save your entries in the configuration file.                                                                                                                                           |

You can delete a global macro-applied configuration on a switch only by entering the `no` version of each command that is in the macro. You can delete a macro-applied configuration on an interface by entering the `default interface interface-id` interface configuration command.
This example shows how to apply the user-created macro called **snmp**, to set the hostname address to **test-server**, and to set the IP precedence value to **7**:

```
Switch(config)# macro global apply snmp ADDRESS test-server VALUE 7
```

This example shows how to debug the user-created macro called **snmp** by using the **macro global trace** global configuration command to find any syntax or configuration errors in the macro when it is applied to the switch.

```
Switch(config)# macro global trace snmp VALUE 7
```

Applying command...'snmp-server enable traps port-security'
Applying command...'snmp-server enable traps link-up'
Applying command...'snmp-server enable traps link-down'
Applying command...'snmp-server host'
%Error Unknown error.
Applying command...'snmp-server ip precedence 7'

This example shows how to apply the user-created macro called **desktop-config** and to verify the configuration.

```
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# macro apply desktop-config
Switch(config-if)# end
Switch# show parser macro description
Interface   Macro Description
------------- ----------------------------------
Gi0/2  desktop-config
```

This example shows how to apply the user-created macro called **desktop-config** and to replace all occurrences of VLAN 1 with VLAN 25:

```
Switch(config-if)# macro apply desktop-config vlan 25
```

### Applying Cisco-Default Smartports Macros

Beginning in privileged EXEC mode, follow these steps to apply a Smartports macro:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>show parser macro</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>show parser macro <strong>macro-name</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>configure terminal <strong>macro-name</strong></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>macro global {apply</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>interface <strong>interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>default interface <strong>interface-id</strong></td>
</tr>
</tbody>
</table>
You can delete a global macro-applied configuration on a switch only by entering the `no` version of each command that is in the macro. You can delete a macro-applied configuration on an interface by entering the `default interface interface-id` interface configuration command.

This example shows how to display the `cisco-desktop` macro, how to apply the macro, and to set the access VLAN ID to 25 on an interface:

```
Switch# show parser macro cisco-desktop
--------------------------------------------------------------
Macro name : cisco-desktop
Macro type : default
# Basic interface - Enable data VLAN only
# Recommended value for access vlan (AVID) should not be 1
switchport access vlan $AVID
switchport mode access
# Enable port security limiting port to a single
# MAC address -- that of desktop
switchport port-security
switchport port-security maximum 1
# Ensure port-security age is greater than one minute
# and use inactivity timer
switchport port-security violation restrict
switchport port-security aging time 2
switchport port-security aging type inactivity
# Configure port as an edge network port
spanning-tree portfast
spanning-tree bpduguard enable
--------------------------------------------------------------
```

```
Switch# configure terminal
Switch(config)# gigabitethernet0/4
Switch(config-if)# macro apply cisco-desktop $AVID 25
```

<table>
<thead>
<tr>
<th>Step 7</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>`macro [apply</td>
<td>trace] macro-name [parameter {value}] [parameter {value}] [parameter {value}]`</td>
<td>Append the Cisco-default macro with the required values by using the <code>parameter value</code> keywords, and apply the macro to the interface. Keywords that begin with <code>$</code> mean that a unique parameter value is required. You can use the <code>macro apply macro-name ?</code> command to display a list of any required values in the macro. If you apply a macro without entering the keyword values, the commands are invalid and are not applied.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 8</th>
<th>end</th>
<th>Return to privileged EXEC mode.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 9</td>
<td><code>show running-config interface interface-id</code></td>
<td>Verify that the macro is applied to an interface.</td>
</tr>
<tr>
<td>Step 10</td>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

You can delete a global macro-applied configuration on a switch only by entering the `no` version of each command that is in the macro. You can delete a macro-applied configuration on an interface by entering the `default interface interface-id` interface configuration command.
Displaying Smartports Macros

To display the Smartports macros, use one or more of the privileged EXEC commands in Table 8-2.

Table 8-2  Commands for Displaying Smartports Macros

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show parser macro</td>
<td>Displays all configured macros.</td>
</tr>
<tr>
<td>show parser macro name  macro-name</td>
<td>Displays a specific macro.</td>
</tr>
<tr>
<td>show parser macro brief</td>
<td>Displays the configured macro names.</td>
</tr>
<tr>
<td>show parser macro description [interface interface-id]</td>
<td>Displays the macro description for all interfaces or for a specified interface.</td>
</tr>
</tbody>
</table>
This chapter describes how to configure normal-range VLANs (VLAN IDs 1 to 1005) and extended-range VLANs (VLAN IDs 1006 to 4094) on the switch. It includes information about VLAN membership modes, VLAN configuration modes, VLAN trunks, and dynamic VLAN assignment from a VLAN Membership Policy Server (VMPS).

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

The chapter consists of these sections:

- Understanding VLANs, page 9-1
- Configuring Normal-Range VLANs, page 9-4
- Configuring Extended-Range VLANs, page 9-11
- Displaying VLANs, page 9-14
- Configuring VLAN Trunks, page 9-14
- Configuring VMPS, page 9-25

Understanding VLANs

A VLAN is a switched network that is logically segmented by function, project team, or application, without regard to the physical locations of the users. VLANs have the same attributes as physical LANs, but you can group end stations even if they are not physically located on the same LAN segment. Any switch port can belong to a VLAN, and unicast, broadcast, and multicast packets are forwarded and flooded only to end stations in the VLAN. Each VLAN is considered a logical network, and packets destined for stations that do not belong to the VLAN must be forwarded through a router or a switch supporting fallback bridging, as shown in Figure 9-1. Because a VLAN is considered a separate logical network, it contains its own bridge Management Information Base (MIB) information and can support its own implementation of spanning tree. See Chapter 12, “Configuring STP.”

Note: Before you create VLANs, you must decide whether to use VLAN Trunking Protocol (VTP) to maintain global VLAN configuration for your network. For more information on VTP, see Chapter 10, “Configuring VTP.”
Figure 9-1 shows an example of VLANs segmented into logically defined networks.

VLANs are often associated with IP subnetworks. For example, all the end stations in a particular IP subnet belong to the same VLAN. Interface VLAN membership on the switch is assigned manually on an interface-by-interface basis. When you assign switch interfaces to VLANs by using this method, it is known as interface-based, or static, VLAN membership.

Traffic between VLANs must be routed or fallback bridged.

Supported VLANs

The switch supports VLANs in VTP client, server, and transparent modes. VLANs are identified by a number from 1 to 4094. VLAN IDs 1002 through 1005 are reserved for Token Ring and FDDI VLANs. VTP only learns normal-range VLANs, with VLAN IDs 1 to 1005; VLAN IDs greater than 1005 are extended-range VLANs and are not stored in the VLAN database. The switch must be in VTP transparent mode when you create VLAN IDs from 1006 to 4094.

Although the switch supports a total of 1005 (normal range and extended range) VLANs, the number of configured features affects the use of the switch hardware.

The switch supports per-VLAN spanning-tree plus (PVST+) or rapid PVST+ with a maximum of 128 spanning-tree instances. One spanning-tree instance is allowed per VLAN. See the “Normal-Range VLAN Configuration Guidelines” section on page 9-5 for more information about the number of spanning-tree instances and the number of VLANs. The switch supports both Inter-Switch Link (ISL) and IEEE 802.1Q trunking methods for sending VLAN traffic over Ethernet ports.
VLAN Port Membership Modes

You configure a port to belong to a VLAN by assigning a membership mode that specifies the kind of traffic the port carries and the number of VLANs to which it can belong. Table 9-1 lists the membership modes and membership and VTP characteristics.

Table 9-1  Port Membership Modes and Characteristics

<table>
<thead>
<tr>
<th>Membership Mode</th>
<th>VLAN Membership Characteristics</th>
<th>VTP Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static-access</td>
<td>A static-access port can belong to one VLAN and is manually assigned to that VLAN. For more information, see the “Assigning Static-Access Ports to a VLAN” section on page 9-10.</td>
<td>VTP is not required. If you do not want VTP to globally propagate information, set the VTP mode to transparent. To participate in VTP, there must be at least one trunk port on the switch connected to a trunk port of a second switch.</td>
</tr>
<tr>
<td>Trunk (IEEE 802.1Q)</td>
<td>A trunk port is a member of all VLANs by default, including extended-range VLANs, but membership can be limited by configuring the allowed-VLAN list. You can also modify the pruning-eligible list to block flooded traffic to VLANs on trunk ports that are included in the list. For information about configuring trunk ports, see the “Configuring an Ethernet Interface as a Trunk Port” section on page 9-17.</td>
<td>VTP is recommended but not required. VTP maintains VLAN configuration consistency by managing the addition, deletion, and renaming of VLANs on a network-wide basis. VTP exchanges VLAN configuration messages with other switches over trunk links.</td>
</tr>
<tr>
<td>Dynamic access</td>
<td>A dynamic-access port can belong to one VLAN (VLAN ID 1 to 4094) and is dynamically assigned by a VMPS. The VMPS can be a Catalyst 5000 or Catalyst 6500 series switch, for example, but never a CGESM switch, which is a VMPS client. You can have dynamic-access ports and trunk ports on the same switch, but you must connect the dynamic-access port to an end station or hub and not to another switch. For configuration information, see the “Configuring Dynamic-Access Ports on VMPS Clients” section on page 9-28.</td>
<td>VTP is required. Configure the VMPS and the client with the same VTP domain name. To participate in VTP, at least one trunk port on the switch must be connected to a trunk port of a second switch.</td>
</tr>
<tr>
<td>Voice VLAN</td>
<td>A voice VLAN port is an access port attached to a Cisco IP Phone, configured to use one VLAN for voice traffic and another VLAN for data traffic from a device attached to the phone. For more information about voice VLAN ports, see Chapter 11, “Configuring Voice VLAN.”</td>
<td>VTP is not required; it has no affect on a voice VLAN.</td>
</tr>
</tbody>
</table>

For more detailed definitions of access and trunk modes and their functions, see Table 9-4 on page 9-16. When a port belongs to a VLAN, the switch learns and manages the addresses associated with the port on a per-VLAN basis. For more information, see the “Managing the MAC Address Table” section on page 4-19.
Chapter 9    Configuring VLANs

Configuring Normal-Range VLANs

Normal-range VLANs are VLANs with VLAN IDs 1 to 1005. If the switch is in VTP server or VTP transparent mode, you can add, modify or remove configurations for VLANs 2 to 1001 in the VLAN database. (VLAN IDs 1 and 1002 to 1005 are automatically created and cannot be removed.)

When the switch is in VTP transparent mode, you can also create extended-range VLANs (VLANs with IDs from 1006 to 4094), but these VLANs are not saved in the VLAN database. See the “Configuring Extended-Range VLANs” section on page 9-11.

Configurations for VLAN IDs 1 to 1005 are written to the file vlan.dat (VLAN database), and you can display them by entering the show vlan privileged EXEC command. The vlan.dat file is stored in flash memory.

You can cause inconsistency in the VLAN database if you attempt to manually delete the vlan.dat file. If you want to modify the VLAN configuration, use the commands described in these sections and in the command reference for this release. To change the VTP configuration, see Chapter 10, “Configuring VTP.”

You use the interface configuration mode to define the port membership mode and to add and remove ports from VLANs. The results of these commands are written to the running-configuration file, and you can display the file by entering the show running-config privileged EXEC command.

You can set these parameters when you create a new normal-range VLAN or modify an existing VLAN in the VLAN database:

- VLAN ID
- VLAN name
- VLAN type (Ethernet, Fiber Distributed Data Interface [FDDI], FDDI network entity title [NET], TrBRF, or TrCRF, Token Ring, Token Ring-Net)
- VLAN state (active or suspended)
- Maximum transmission unit (MTU) for the VLAN
- Security Association Identifier (SAID)
- Bridge identification number for TrBRF VLANs
- Ring number for FDDI and TrCRF VLANs
- Parent VLAN number for TrCRF VLANs
- Spanning Tree Protocol (STP) type for TrCRF VLANs
- VLAN number to use when translating from one VLAN type to another

This section does not provide configuration details for most of these parameters. For complete information on the commands and parameters that control VLAN configuration, see the command reference for this release.
These sections contain normal-range VLAN configuration information:

- Token Ring VLANs, page 9-5
- Normal-Range VLAN Configuration Guidelines, page 9-5
- VLAN Configuration Mode Options, page 9-6
- Saving VLAN Configuration, page 9-7
- Default Ethernet VLAN Configuration, page 9-7
- Creating or Modifying an Ethernet VLAN, page 9-8
- Deleting a VLAN, page 9-10
- Assigning Static-Access Ports to a VLAN, page 9-10

**Token Ring VLANs**

Although the switch does not support Token Ring connections, a remote device such as a Catalyst 5000 series switch with Token Ring connections could be managed from one of the supported switches. Switches running VTP Version 2 advertise information about these Token Ring VLANs:

- Token Ring TrBRF VLANs
- Token Ring TrCRF VLANs

For more information on configuring Token Ring VLANs, see the *Catalyst 5000 Series Software Configuration Guide*.

**Normal-Range VLAN Configuration Guidelines**

Follow these guidelines when creating and modifying normal-range VLANs in your network:

- The switch supports 1005 VLANs in VTP client, server, and transparent modes.
- Normal-range VLANs are identified with a number between 1 and 1001. VLAN numbers 1002 through 1005 are reserved for Token Ring and FDDI VLANs.
- VLAN configuration for VLANs 1 to 1005 are always saved in the VLAN database. If the VTP mode is transparent, VTP and VLAN configuration are also saved in the switch running configuration file.
- The switch also supports VLAN IDs 1006 through 4094 in VTP transparent mode (VTP disabled). These are extended-range VLANs and configuration options are limited. Extended-range VLANs are not saved in the VLAN database. See the “Configuring Extended-Range VLANs” section on page 9-11.
- Before you can create a VLAN, the switch must be in VTP server mode or VTP transparent mode. If the switch is a VTP server, you must define a VTP domain or VTP will not function.
- The switch does not support Token Ring or FDDI media. The switch does not forward FDDI, FDDI-Net, TrCRF, or TrBRF traffic, but it does propagate the VLAN configuration through VTP.
- The switch supports 128 spanning-tree instances. If a switch has more active VLANs than supported spanning-tree instances, spanning tree can be enabled on 128 VLANs and is disabled on the remaining VLANs. If you have already used all available spanning-tree instances on a switch, adding another VLAN anywhere in the VTP domain creates a VLAN on that switch that is not running spanning-tree. If you have the default allowed list on the trunk ports of that switch (which is to allow all VLANs), the new VLAN is carried on all trunk ports. Depending on the topology of...
the network, this could create a loop in the new VLAN that would not be broken, particularly if there are several adjacent switches that all have run out of spanning-tree instances. You can prevent this possibility by setting allowed lists on the trunk ports of switches that have used up their allocation of spanning-tree instances.

If the number of VLANs on the switch exceeds the number of supported spanning-tree instances, we recommend that you configure the IEEE 802.1s Multiple STP (MSTP) on your switch to map multiple VLANs to a single spanning-tree instance. For more information about MSTP, see Chapter 13, “Configuring MSTP.”

**VLAN Configuration Mode Options**

You can configure normal-range VLANs (with VLAN IDs 1 to 1005) by using these two configuration modes:

- **VLAN Configuration in config-vlan Mode, page 9-6**
  
  You access config-vlan mode by entering the `vlan vlan-id` global configuration command.

- **VLAN Configuration in VLAN Database Configuration Mode, page 9-6**
  
  You access VLAN database configuration mode by entering the `vlan database` privileged EXEC command.

**VLAN Configuration in config-vlan Mode**

To access config-vlan mode, enter the `vlan` global configuration command with a VLAN ID. Enter a new VLAN ID to create a VLAN, or enter an existing VLAN ID to modify that VLAN. You can use the default VLAN configuration (Table 9-2) or enter multiple commands to configure the VLAN. For more information about commands available in this mode, see the `vlan` global configuration command description in the command reference for this release. When you have finished the configuration, you must exit config-vlan mode for the configuration to take effect. To display the VLAN configuration, enter the `show vlan` privileged EXEC command.

You must use this config-vlan mode when creating extended-range VLANs (VLAN IDs greater than 1005). See the “Configuring Extended-Range VLANs” section on page 9-11.

**VLAN Configuration in VLAN Database Configuration Mode**

To access VLAN database configuration mode, enter the `vlan database` privileged EXEC command. Then enter the `vlan` command with a new VLAN ID to create a VLAN, or enter an existing VLAN ID to modify the VLAN. You can use the default VLAN configuration (Table 9-2) or enter multiple commands to configure the VLAN. For more information about keywords available in this mode, see the `vlan` VLAN database configuration command description in the command reference for this release. When you have finished the configuration, you must enter `apply` or `exit` for the configuration to take effect. When you enter the `exit` command, it applies all commands and updates the VLAN database. VTP messages are sent to other switches in the VTP domain, and the privileged EXEC mode prompt appears.
Chapter 9  Configuring VLANs

Saving VLAN Configuration

The configurations of VLAN IDs 1 to 1005 are always saved in the VLAN database (vlan.dat file). If the VTP mode is transparent, they are also saved in the switch running configuration file. You can enter the `copy running-config startup-config` privileged EXEC command to save the configuration in the startup configuration file. To display the VLAN configuration, enter the `show vlan` privileged EXEC command.

When you save VLAN and VTP information (including extended-range VLAN configuration information) in the startup configuration file and reboot the switch, the switch configuration is selected as follows:

- If the VTP mode is transparent in the startup configuration, and the VLAN database and the VTP domain name from the VLAN database matches that in the startup configuration file, the VLAN database is ignored (cleared), and the VTP and VLAN configurations in the startup configuration file are used. The VLAN database revision number remains unchanged in the VLAN database.
- If the VTP mode or domain name in the startup configuration does not match the VLAN database, the domain name and VTP mode and configuration for the first 1005 VLANs use the VLAN database information.
- If VTP mode is server, the domain name and VLAN configuration for the first 1005 VLANs use the VLAN database information.

Caution

If the VLAN database configuration is used at startup and the startup configuration file contains extended-range VLAN configuration, this information is lost when the system boots up.

Default Ethernet VLAN Configuration

Table 9-2 shows the default configuration for Ethernet VLANs.

Note

The switch supports Ethernet interfaces exclusively. Because FDDI and Token Ring VLANs are not locally supported, you only configure FDDI and Token Ring media-specific characteristics for VTP global advertisements to other switches.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLAN ID</td>
<td>1</td>
<td>1 to 4094.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: Extended-range VLANs (VLAN IDs 1006 to 4094) are not saved in the VLAN database.</td>
</tr>
<tr>
<td>VLAN name</td>
<td>VLANxxxx, where xxxx represents four numeric digits (including leading zeros) equal to the VLAN ID number</td>
<td>No range</td>
</tr>
<tr>
<td>IEEE 802.10 SAID</td>
<td>1000001 (100000 plus the VLAN ID)</td>
<td>1 to 4294967294</td>
</tr>
<tr>
<td>MTU size</td>
<td>1500</td>
<td>1500 to 18190</td>
</tr>
</tbody>
</table>
Creating or Modifying an Ethernet VLAN

Each Ethernet VLAN in the VLAN database has a unique, 4-digit ID that can be a number from 1 to 1001. VLAN IDs 1002 to 1005 are reserved for Token Ring and FDDI VLANs. To create a normal-range VLAN to be added to the VLAN database, assign a number and name to the VLAN.

- **Configuring Normal-Range VLANs**

- **Creating or Modifying an Ethernet VLAN**

  Each Ethernet VLAN in the VLAN database has a unique, 4-digit ID that can be a number from 1 to 1001. VLAN IDs 1002 to 1005 are reserved for Token Ring and FDDI VLANs. To create a normal-range VLAN to be added to the VLAN database, assign a number and name to the VLAN.

  - **Translational bridge 1**
  - **Translational bridge 2**
  - **VLAN state**
  - **Remote SPAN**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translational bridge 1</td>
<td>0</td>
<td>0 to 1005</td>
</tr>
<tr>
<td>Translational bridge 2</td>
<td>0</td>
<td>0 to 1005</td>
</tr>
<tr>
<td>VLAN state</td>
<td>active</td>
<td>active, suspend</td>
</tr>
<tr>
<td>Remote SPAN</td>
<td>disabled</td>
<td>enabled, disabled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command</td>
<td>Purpose</td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>vlan vlan-id</td>
<td>Enter a VLAN ID, and enter config-vlan mode. Enter a new VLAN ID to create a VLAN, or enter an existing VLAN ID to modify that VLAN.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: The available VLAN ID range for this command is 1 to 4094. For information about adding VLAN IDs greater than 1005 (extended-range VLANs), see the “Configuring Extended-Range VLANs” section on page 9-11.</td>
</tr>
<tr>
<td>Step 3</td>
<td>name vlan-name</td>
<td>(Optional) Enter a name for the VLAN. If no name is entered for the VLAN, the default is to append the vlan-id with leading zeros to the word VLAN. For example, VLAN0004 is a default VLAN name for VLAN 4.</td>
</tr>
<tr>
<td>Step 4</td>
<td>mtu mtu-size</td>
<td>(Optional) Change the MTU size (or other VLAN characteristic).</td>
</tr>
<tr>
<td>Step 5</td>
<td>remote-span</td>
<td>(Optional) Configure the VLAN as the RSPAN VLAN for a remote SPAN session. For more information on remote SPAN, see Chapter 22, “Configuring SPAN and RSPAN.”</td>
</tr>
<tr>
<td>Step 6</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7</td>
<td>show vlan [name vlan-name</td>
<td>id vlan-id]</td>
</tr>
<tr>
<td>Step 8</td>
<td>copy running-config startup config</td>
<td>(Optional) If the switch is in VTP transparent mode, the VLAN configuration is saved in the running configuration file as well as in the VLAN database. This saves the configuration in the switch startup configuration file.</td>
</tr>
</tbody>
</table>
To return the VLAN name to the default settings, use the `no name`, `no mtu`, or `no remote-span` config-vlan commands.

This example shows how to use config-vlan mode to create Ethernet VLAN 20, name it `test20`, and add it to the VLAN database:

```
Switch# configure terminal
Switch(config)# vlan 20
Switch(config-vlan)# name test20
Switch(config-vlan)# end
```

You can also create or modify Ethernet VLANs by using the VLAN database configuration mode.

```
Note
VLAN database configuration mode does not support RSPAN VLAN configuration or extended-range VLANs.
```

Beginning in privileged EXEC mode, follow these steps to use VLAN database configuration mode to create or modify an Ethernet VLAN:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 vlan database</td>
<td>Enter VLAN database configuration mode.</td>
</tr>
<tr>
<td>Step 2 vlan vlan-id name vlan-name</td>
<td>Add an Ethernet VLAN by assigning a number to it. The range is 1 to 1001. You can create or modify a range of consecutive VLANs by entering <code>vlan first-vlan-id end last-vlan-id</code>.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong> When entering a VLAN ID in VLAN database configuration mode, do not enter leading zeros. If no name is entered for the VLAN, the default is to append the <code>vlan-id</code> with leading zeros to the word VLAN. For example, VLAN0004 is a default VLAN name for VLAN 4.</td>
</tr>
<tr>
<td>Step 3 vlan vlan-id mtu mtu-size</td>
<td>(Optional) To modify a VLAN, identify the VLAN and change a characteristic, such as the MTU size.</td>
</tr>
<tr>
<td>Step 4 exit</td>
<td>Update the VLAN database, propagate it throughout the administrative domain, and return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show vlan {name vlan-name</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td>id vlan-id}</td>
</tr>
<tr>
<td>Step 6 copy running-config startup config</td>
<td>(Optional) If the switch is in VTP transparent mode, the VLAN configuration is saved in the running configuration file as well as in the VLAN database. This saves the configuration in the switch startup configuration file.</td>
</tr>
</tbody>
</table>

To return the VLAN name to the default settings, use the `no vlan vlan-id name` or `no vlan vlan-id mtu` VLAN database configuration command.

This example shows how to use VLAN configuration mode to create Ethernet VLAN 20, name it `test20`, and add it to the VLAN database:

```
Switch# vlan database
Switch(vlan)# vlan 20 name test20
Switch(vlan)# exit
APPLY completed.
Exiting....
```
Deleting a VLAN

When you delete a VLAN from a switch that is in VTP server mode, the VLAN is removed from the VLAN database for all switches in the VTP domain. When you delete a VLAN from a switch that is in VTP transparent mode, the VLAN is deleted only on that specific switch.

You cannot delete the default VLANs for the different media types: Ethernet VLAN 1 and FDDI or Token Ring VLANs 1002 to 1005.

Caution

When you delete a VLAN, any ports assigned to that VLAN become inactive. They remain associated with the VLAN (and thus inactive) until you assign them to a new VLAN.

Beginning in privileged EXEC mode, follow these steps to delete a VLAN on the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 no vlan vlan-id</td>
<td>Remove the VLAN by entering the VLAN ID.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show vlan brief</td>
<td>Verify the VLAN removal.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup config</td>
<td>(Optional) If the switch is in VTP transparent mode, the VLAN configuration is saved in the running configuration file as well as in the VLAN database. This saves the configuration in the switch startup configuration file.</td>
</tr>
</tbody>
</table>

To delete a VLAN by using VLAN database configuration mode, use the **vlan database** privileged EXEC command to enter VLAN database configuration mode and the **no vlan vlan-id** VLAN database configuration command.

Assigning Static-Access Ports to a VLAN

You can assign a static-access port to a VLAN without having VTP globally propagate VLAN configuration information by disabling VTP (VTP transparent mode).

If you are assigning a port on a cluster member switch to a VLAN, first use the **rcommand** privileged EXEC command to log in to the cluster member switch.

Note

If you assign an interface to a VLAN that does not exist, the new VLAN is created. (See the “Creating or Modifying an Ethernet VLAN” section on page 9-8.)

Beginning in privileged EXEC mode, follow these steps to assign a port to a VLAN in the VLAN database:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Enter the interface to be added to the VLAN.</td>
</tr>
</tbody>
</table>
Chapter 9  Configuring VLANs

Configuring Extended-Range VLANs

When the switch is in VTP transparent mode (VTP disabled), you can create extended-range VLANs (in the range 1006 to 4094). Extended-range VLANs enable service providers to extend their infrastructure to a greater number of customers. The extended-range VLAN IDs are allowed for any switchport commands that allow VLAN IDs. You always use config-vlan mode (accessed by entering the `vlan vlan-id` global configuration command) to configure extended-range VLANs. The extended range is not supported in VLAN database configuration mode (accessed by entering the `vlan database` privileged EXEC command).

Extended-range VLAN configurations are not stored in the VLAN database, but because VTP mode is transparent, they are stored in the switch running configuration file, and you can save the configuration in the startup configuration file by using the `copy running-config startup-config` privileged EXEC command.

Note

Although the switch supports 4094 VLAN IDs, see the “Supported VLANs” section on page 9-2 for the actual number of VLANs supported.

These sections contain extended-range VLAN configuration information:

- Default VLAN Configuration, page 9-12
- Extended-Range VLAN Configuration Guidelines, page 9-12
- Creating an Extended-Range VLAN, page 9-12

---

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 3</td>
<td><code>switchport mode access</code> Define the VLAN membership mode for the port (Layer 2 access port).</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>switchport access vlan vlan-id</code> Assign the port to a VLAN. Valid VLAN IDs are 1 to 4094.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>show running-config interface interface-id</code> Verify the VLAN membership mode of the interface.</td>
</tr>
<tr>
<td>Step 7</td>
<td><code>show interfaces interface-id switchport</code> Verify your entries in the Administrative Mode and the Access Mode VLAN fields of the display.</td>
</tr>
<tr>
<td>Step 8</td>
<td><code>copy running-config startup-config</code> (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return an interface to its default configuration, use the `default interface interface-id` interface configuration command.

This example shows how to configure a port as an access port in VLAN 2:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 2
Switch(config-if)# end
```
Configuring Extended-Range VLANs

Default VLAN Configuration

See Table 9-2 on page 9-7 for the default configuration for Ethernet VLANs. You can change only the MTU size and the remote SPAN configuration state on extended-range VLANs; all other characteristics must remain at the default state.

Extended-Range VLAN Configuration Guidelines

Follow these guidelines when creating extended-range VLANs:

- To add an extended-range VLAN, you must use the `vlan vlan-id` global configuration command and access config-vlan mode. You cannot add extended-range VLANs in VLAN database configuration mode (accessed by entering the `vlan database` privileged EXEC command).
- VLAN IDs in the extended range are not saved in the VLAN database and are not recognized by VTP.
- You cannot include extended-range VLANs in the pruning eligible range.
- The switch must be in VTP transparent mode when you create extended-range VLANs. If VTP mode is server or client, an error message is generated, and the extended-range VLAN is rejected.
- You can set the VTP mode to transparent in global configuration mode or in VLAN database configuration mode. See the “Disabling VTP (VTP Transparent Mode)” section on page 10-12. You should save this configuration to the startup configuration so that the switch boots up in VTP transparent mode. Otherwise, you lose the extended-range VLAN configuration if the switch resets.
- STP is enabled by default on extended-range VLANs, but you can disable it by using the `no spanning-tree vlan vlan-id` global configuration command. When the maximum number of spanning-tree instances are on the switch, spanning tree is disabled on any newly created VLANs. If the number of VLANs on the switch exceeds the maximum number of spanning-tree instances, we recommend that you configure the IEEE 802.1s Multiple STP (MSTP) on your switch to map multiple VLANs to a single spanning-tree instance. For more information about MSTP, see Chapter 13, “Configuring MSTP.”
- Although the switch supports a total of 1005 (normal-range and extended-range) VLANs, the number of configured features affects the use of the switch hardware. If you try to create an extended-range VLAN and there are not enough hardware resources available, an error message is generated, and the extended-range VLAN is rejected.

Creating an Extended-Range VLAN

You create an extended-range VLAN in global configuration mode by entering the `vlan` global configuration command with a VLAN ID from 1006 to 4094. This command accesses the config-vlan mode. The extended-range VLAN has the default Ethernet VLAN characteristics (see Table 9-2) and the MTU size, and RSPAN configuration are the only parameters you can change. See the description of the `vlan` global configuration command in the command reference for the default settings of all parameters. If you enter an extended-range VLAN ID when the switch is not in VTP transparent mode, an error message is generated when you exit from config-vlan mode, and the extended-range VLAN is not created.

Extended-range VLANs are not saved in the VLAN database; they are saved in the switch running configuration file. You can save the extended-range VLAN configuration in the switch startup configuration file by using the `copy running-config startup-config` privileged EXEC command.
Beginning in privileged EXEC mode, follow these steps to create an extended-range VLAN:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>vtp mode transparent</td>
</tr>
<tr>
<td></td>
<td>Configure the switch for VTP transparent mode, disabling VTP.</td>
</tr>
<tr>
<td>Step 3</td>
<td>vlan vlan-id</td>
</tr>
<tr>
<td></td>
<td>Enter an extended-range VLAN ID and enter config-vlan mode. The range is 1006 to 4094.</td>
</tr>
<tr>
<td>Step 4</td>
<td>mtu mtu-size</td>
</tr>
<tr>
<td></td>
<td>(Optional) Modify the VLAN by changing the MTU size.</td>
</tr>
<tr>
<td></td>
<td>Note</td>
</tr>
<tr>
<td></td>
<td>Although all VLAN commands appear in the CLI help in config-vlan mode, only the mtu mtu-size, and remote-span commands are supported for extended-range VLANs.</td>
</tr>
<tr>
<td>Step 5</td>
<td>remote-span</td>
</tr>
<tr>
<td></td>
<td>(Optional) Configure the VLAN as the RSPAN VLAN. See the “Configuring a VLAN as an RSPAN VLAN” section on page 22-16.</td>
</tr>
<tr>
<td>Step 6</td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7</td>
<td>show vlan id vlan-id</td>
</tr>
<tr>
<td></td>
<td>Verify that the VLAN has been created.</td>
</tr>
<tr>
<td>Step 8</td>
<td>copy running-config startup config</td>
</tr>
<tr>
<td></td>
<td>Save your entries in the switch startup configuration file. To save extended-range VLAN configurations, you need to save the VTP transparent mode configuration and the extended-range VLAN configuration in the switch startup configuration file. Otherwise, if the switch resets, it will default to VTP server mode, and the extended-range VLAN IDs will not be saved.</td>
</tr>
</tbody>
</table>

To delete an extended-range VLAN, use the no vlan vlan-id global configuration command.

The procedure for assigning static-access ports to an extended-range VLAN is the same as for normal-range VLANs. See the “Assigning Static-Access Ports to a VLAN” section on page 9-10.

This example shows how to create a new extended-range VLAN with all default characteristics, enter config-vlan mode, and save the new VLAN in the switch startup configuration file:

```
Switch(config)# vtp mode transparent
Switch(config)# vlan 2000
Switch(config-vlan)# end
Switch# copy running-config startup config
```
Displaying VLANs

Use the `show vlan` privileged EXEC command to display a list of all VLANs on the switch, including extended-range VLANs. The display includes VLAN status, ports, and configuration information. To view normal-range VLANs in the VLAN database (1 to 1005), use the `show VLAN database` privileged EXEC command.

Table 9-3 lists the commands for monitoring VLANs.

<table>
<thead>
<tr>
<th>Command</th>
<th>Command Mode</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show vlan</code></td>
<td>VLAN database configuration</td>
<td>Display status of VLANs in the VLAN database.</td>
</tr>
<tr>
<td><code>show current [vlan-id]</code></td>
<td>VLAN database configuration</td>
<td>Display status of all or the specified VLAN in the VLAN database.</td>
</tr>
<tr>
<td><code>show interfaces [vlan vlan-id]</code></td>
<td>Privileged EXEC</td>
<td>Display characteristics for all interfaces or for the specified VLAN configured on the switch.</td>
</tr>
<tr>
<td><code>show vlan [id vlan-id]</code></td>
<td>Privileged EXEC</td>
<td>Display parameters for all VLANs or the specified VLAN on the switch.</td>
</tr>
</tbody>
</table>

For more details about the show command options and explanations of output fields, see the command reference for this release.

Configuring VLAN Trunks

These sections contain this conceptual information:

- Trunking Overview, page 9-14
- Encapsulation Types, page 9-16
- Default Layer 2 Ethernet Interface VLAN Configuration, page 9-17
- Configuring an Ethernet Interface as a Trunk Port, page 9-17
- Configuring Trunk Ports for Load Sharing, page 9-22

Trunking Overview

A trunk is a point-to-point link between one or more Ethernet switch interfaces and another networking device such as a router or a switch. Ethernet trunks carry the traffic of multiple VLANs over a single link, and you can extend the VLANs across an entire network.

Two trunking encapsulations are available on all Ethernet interfaces:

- Inter-Switch Link (ISL)—Cisco-proprietary trunking encapsulation.
- IEEE 802.1Q—industry-standard trunking encapsulation.
Figure 9-2 shows a network of blade switches that are connected by ISL trunks.

**Figure 9-2 Blade Switches in an ISL Trunking Environment**

You can configure a trunk on a single Ethernet interface or on an EtherChannel bundle. For more information about EtherChannel, see Chapter 28, “Configuring EtherChannels and Layer 2 Trunk Failover.”

Ethernet trunk interfaces support different trunking modes (see Table 9-4). You can set an interface as trunking or nontrunking or to negotiate trunking with the neighboring interface. To autonegotiate trunking, the interfaces must be in the same VTP domain.

Trunk negotiation is managed by the Dynamic Trunking Protocol (DTP), which is a Point-to-Point Protocol. However, some internetworking devices might forward DTP frames improperly, which could cause misconfigurations.

To avoid this, you should configure interfaces connected to devices that do not support DTP to not forward DTP frames, that is, to turn off DTP.

- If you do not intend to trunk across those links, use the `switchport mode access` interface configuration command to disable trunking.
- To enable trunking to a device that does not support DTP, use the `switchport mode trunk` and `switchport nonegotiate` interface configuration commands to cause the interface to become a trunk but to not generate DTP frames. Use the `switchport trunk encapsulation isl` or `switchport trunk encapsulation dot1q` interface to select the encapsulation type on the trunk port.

You can also specify on DTP interfaces whether the trunk uses ISL or IEEE 802.1Q encapsulation or if the encapsulation type is autonegotiated. The DTP supports autonegotiation of both ISL and IEEE 802.1Q trunks.
Configuring VLAN Trunks

Table 9-4  Layer 2 Interface Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>switchport mode access</td>
<td>Puts the interface (access port) into permanent nontrunking mode and negotiates to convert the link into a nontrunk link. The interface becomes a nontrunk interface regardless of whether or not the neighboring interface is a trunk interface.</td>
</tr>
<tr>
<td>switchport mode dynamic auto</td>
<td>Makes the interface able to convert the link to a trunk link. The interface becomes a trunk interface if the neighboring interface is set to trunk or desirable mode. The default switchport mode for all Ethernet interfaces is dynamic auto.</td>
</tr>
<tr>
<td>switchport mode dynamic desirable</td>
<td>Makes the interface actively attempt to convert the link to a trunk link. The interface becomes a trunk interface if the neighboring interface is set to trunk, desirable, or auto mode.</td>
</tr>
<tr>
<td>switchport mode trunk</td>
<td>Puts the interface into permanent trunking mode and negotiates to convert the neighboring link into a trunk link. The interface becomes a trunk interface even if the neighboring interface is not a trunk interface.</td>
</tr>
<tr>
<td>switchport nonegotiate</td>
<td>Prevents the interface from generating DTP frames. You can use this command only when the interface switchport mode is access or trunk. You must manually configure the neighboring interface as a trunk interface to establish a trunk link.</td>
</tr>
</tbody>
</table>

Encapsulation Types

Table 9-5 lists the Ethernet trunk encapsulation types and keywords.

Table 9-5  Ethernet Trunk Encapsulation Types

<table>
<thead>
<tr>
<th>Encapsulation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>switchport trunk encapsulation isl</td>
<td>Specifies ISL encapsulation on the trunk link.</td>
</tr>
<tr>
<td>switchport trunk encapsulation dot1q</td>
<td>Specifies IEEE 802.1Q encapsulation on the trunk link.</td>
</tr>
<tr>
<td>switchport trunk encapsulation negotiate</td>
<td>Specifies that the interface negotiate with the neighboring interface to become an ISL (preferred) or IEEE 802.1Q trunk, depending on the configuration and capabilities of the neighboring interface. This is the default for the switch.</td>
</tr>
</tbody>
</table>

The trunking mode, the trunk encapsulation type, and the hardware capabilities of the two connected interfaces decide whether a link becomes an ISL or IEEE 802.1Q trunk.

IEEE 802.1Q Configuration Considerations

The IEEE 802.1Q trunks impose these limitations on the trunking strategy for a network:

- In a network of Cisco switches connected through IEEE 802.1Q trunks, the switches maintain one spanning-tree instance for each VLAN allowed on the trunks. Non-Cisco devices might support one spanning-tree instance for all VLANs.

When you connect a Cisco switch to a non-Cisco device through an IEEE 802.1Q trunk, the Cisco switch combines the spanning-tree instance of the VLAN of the trunk with the spanning-tree instance of the non-Cisco IEEE 802.1Q switch. However, spanning-tree information for each VLAN is maintained by Cisco switches separated by a cloud of non-Cisco IEEE 802.1Q switches. The non-Cisco IEEE 802.1Q cloud separating the Cisco switches is treated as a single trunk link between the switches.
• Make sure the native VLAN for an IEEE 802.1Q trunk is the same on both ends of the trunk link. If the native VLAN on one end of the trunk is different from the native VLAN on the other end, spanning-tree loops might result.

• Disabling spanning tree on the native VLAN of an IEEE 802.1Q trunk without disabling spanning tree on every VLAN in the network can potentially cause spanning-tree loops. We recommend that you leave spanning tree enabled on the native VLAN of an IEEE 802.1Q trunk or disable spanning tree on every VLAN in the network. Make sure your network is loop-free before disabling spanning tree.

**Default Layer 2 Ethernet Interface VLAN Configuration**

Table 9-6 shows the default Layer 2 Ethernet interface VLAN configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface mode</td>
<td>switchport mode dynamic auto</td>
</tr>
</tbody>
</table>
| Trunk encapsulation            | switchport trunk encapsulation
| Allowed VLAN range             | VLANs 1 to 4094                      |
| VLAN range eligible for pruning| VLANs 2 to 1001                      |
| Default VLAN (for access ports)| VLAN 1                               |
| Native VLAN (for IEEE 802.1Q trunks) | VLAN 1                             |

**Configuring an Ethernet Interface as a Trunk Port**

Because trunk ports send and receive VTP advertisements, to use VTP you must ensure that at least one trunk port is configured on the switch and that this trunk port is connected to the trunk port of a second switch. Otherwise, the switch cannot receive any VTP advertisements.

These sections contain this configuration information:

• Interaction with Other Features, page 9-18
• Defining the Allowed VLANs on a Trunk, page 9-19
• Changing the Pruning-Eligible List, page 9-20
• Configuring the Native VLAN for Untagged Traffic, page 9-21

**Note**

By default, trunks negotiate encapsulation. If the neighboring interface supports ISL and IEEE 802.1Q encapsulation and both interfaces are set to negotiate the encapsulation type, the trunk uses ISL encapsulation.
Interaction with Other Features

Trunking interacts with other features in these ways:

- A trunk port cannot be a secure port.

- Trunk ports can be grouped into EtherChannel port groups, but all trunks in the group must have the same configuration. When a group is first created, all ports follow the parameters set for the first port to be added to the group. If you change the configuration of one of these parameters, the switch propagates the setting you entered to all ports in the group:
  - allowed-VLAN list.
  - STP port priority for each VLAN.
  - STP Port Fast setting.
  - trunk status: if one port in a port group ceases to be a trunk, all ports cease to be trunks.

- We recommend that you configure no more than 24 trunk ports in PVST mode and no more than 40 trunk ports in MST mode.

- If you try to enable IEEE 802.1x on a trunk port, an error message appears, and IEEE 802.1x is not enabled. If you try to change the mode of an IEEE 802.1x-enabled port to trunk, the port mode is not changed.

- A port in dynamic mode can negotiate with its neighbor to become a trunk port. If you try to enable IEEE 802.1x on a dynamic port, an error message appears, and IEEE 802.1x is not enabled. If you try to change the mode of an IEEE 802.1x-enabled port to dynamic, the port mode is not changed.

Configuring a Trunk Port

Beginning in privileged EXEC mode, follow these steps to configure a port as a trunk port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>interface interface-id</strong> Specify the port to be configured for trunking, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>**switchport trunk encapsulation {isl</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>**switchport mode {dynamic {auto</td>
</tr>
</tbody>
</table>
  - **dynamic auto**—Set the interface to a trunk link if the neighboring interface is set to trunk or desirable mode. This is the default.
  - **dynamic desirable**—Set the interface to a trunk link if the neighboring interface is set to trunk, desirable, or auto mode.
  - **trunk**—Set the interface in permanent trunking mode and negotiate to convert the link to a trunk link even if the neighboring interface is not a trunk interface. |
9-19

Cisco Gigabit Ethernet Switch Module for HP p-Class BladeSystem Software Configuration Guide

Chapter 9  Configuring VLANs

Configuring VLAN Trunks

To return an interface to its default configuration, use the `default interface interface-id` interface configuration command. To reset all trunking characteristics of a trunking interface to the defaults, use the `no switchport trunk` interface configuration command. To disable trunking, use the `switchport mode access` interface configuration command to configure the port as a static-access port.

This example shows how to configure a port as an IEEE 802.1Q trunk. The example assumes that the neighbor interface is configured to support IEEE 802.1Q trunking.

```
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)\# interface gigabitethernet0/2
Switch(config-if)\# switchport mode dynamic desirable
Switch(config-if)\# switchport trunk encapsulation dot1q
Switch(config-if)\# end
```

Defining the Allowed VLANs on a Trunk

By default, a trunk port sends traffic to and receives traffic from all VLANs. All VLAN IDs, 1 to 4094, are allowed on each trunk. However, you can remove VLANs from the allowed list, preventing traffic from those VLANs from passing over the trunk. To restrict the traffic a trunk carries, use the `switchport trunk allowed vlan remove vlan-list` interface configuration command to remove specific VLANs from the allowed list.

Note

VLAN 1 is the default VLAN on all trunk ports in all Cisco switches, and it has previously been a requirement that VLAN 1 always be enabled on every trunk link. You can use the VLAN 1 minimization feature to disable VLAN 1 on any individual VLAN trunk link so that no user traffic (including spanning-tree advertisements) is sent or received on VLAN 1.

To reduce the risk of spanning-tree loops or storms, you can disable VLAN 1 on any individual VLAN trunk port by removing VLAN 1 from the allowed list. When you remove VLAN 1 from a trunk port, the interface continues to send and receive management traffic, for example, Cisco Discovery Protocol (CDP), Port Aggregation Protocol (PAgP), Link Aggregation Control Protocol (LACP), DTP, and VTP in VLAN 1.

If a trunk port with VLAN 1 disabled is converted to a nontrunk port, it is added to the access VLAN. If the access VLAN is set to 1, the port will be added to VLAN 1, regardless of the `switchport trunk allowed` setting. The same is true for any VLAN that has been disabled on the port.

---

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 5</strong></td>
<td><code>switchport access vlan vlan-id</code> (Optional) Specify the default VLAN, which is used if the interface stops trunking.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><code>switchport trunk native vlan vlan-id</code> Specify the native VLAN for IEEE 802.1Q trunks.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><code>show interfaces interface-id switchport</code> Display the switchport configuration of the interface in the Administrative Mode and the Administrative Trunking Encapsulation fields of the display.</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td><code>show interfaces interface-id trunk</code> Display the trunk configuration of the interface.</td>
</tr>
<tr>
<td><strong>Step 10</strong></td>
<td><code>copy running-config startup-config</code> (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

---

Step 5

Switchport access vlan vlan-id (Optional) Specify the default VLAN, which is used if the interface stops trunking.

Step 6

Switchport trunk native vlan vlan-id Specify the native VLAN for IEEE 802.1Q trunks.

Step 7

End Return to privileged EXEC mode.

Step 8

Show interfaces interface-id switchport Display the switchport configuration of the interface in the Administrative Mode and the Administrative Trunking Encapsulation fields of the display.

Step 9

Show interfaces interface-id trunk Display the trunk configuration of the interface.

Step 10

Copy running-config startup-config (Optional) Save your entries in the configuration file.
A trunk port can become a member of a VLAN if the VLAN is enabled, if VTP knows of the VLAN, and if the VLAN is in the allowed list for the port. When VTP detects a newly enabled VLAN and the VLAN is in the allowed list for a trunk port, the trunk port automatically becomes a member of the enabled VLAN. When VTP detects a new VLAN and the VLAN is not in the allowed list for a trunk port, the trunk port does not become a member of the new VLAN.

Beginning in privileged EXEC mode, follow these steps to modify the allowed list of a trunk:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>switchport mode trunk</td>
</tr>
<tr>
<td>Step 4</td>
<td>switchport trunk allowed vlan {add</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td>Step 6</td>
<td>show interfaces interface-id switchport</td>
</tr>
<tr>
<td>Step 7</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default allowed VLAN list of all VLANs, use the no switchport trunk allowed vlan interface configuration command.

This example shows how to remove VLAN 2 from the allowed VLAN list on a port:

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport trunk allowed vlan remove 2
Switch(config-if)# end
```

### Changing the Pruning-Eligible List

The pruning-eligible list applies only to trunk ports. Each trunk port has its own eligibility list. VTP pruning must be enabled for this procedure to take effect. The “Enabling VTP Pruning” section on page 10-14 describes how to enable VTP pruning.

Beginning in privileged EXEC mode, follow these steps to remove VLANs from the pruning-eligible list on a trunk port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
</tbody>
</table>
Configuring VLAN Trunks

Chapter 9  Configuring VLANs

Configuring VLAN Trunks

**Configuring VLAN Trunks**

**Step 3**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>`switchport trunk pruning vlan {add</td>
<td>except</td>
</tr>
</tbody>
</table>

**Step 4**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

**Step 5**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show interfaces interface-id switchport</code></td>
<td>Verify your entries in the <code>Pruning VLANs Enabled</code> field of the display.</td>
</tr>
</tbody>
</table>

**Step 6**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default pruning-eligible list of all VLANs, use the `no switchport trunk pruning vlan` interface configuration command.

**Configuring the Native VLAN for Untagged Traffic**

A trunk port configured with IEEE 802.1Q tagging can receive both tagged and untagged traffic. By default, the switch forwards untagged traffic in the native VLAN configured for the port. The native VLAN is VLAN 1 by default.

**Note**

The native VLAN can be assigned any VLAN ID.

For information about IEEE 802.1Q configuration issues, see the “IEEE 802.1Q Configuration Considerations” section on page 9-16.

Beginning in privileged EXEC mode, follow these steps to configure the native VLAN on an IEEE 802.1Q trunk:

**Step 1**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

**Step 2**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>interface interface-id</code></td>
<td>Define the interface that is configured as the IEEE 802.1Q trunk, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>

**Step 3**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>switchport trunk native vlan vlan-id</code></td>
<td>Configure the VLAN that is sending and receiving untagged traffic on the trunk port. For <code>vlan-id</code>, the range is 1 to 4094.</td>
</tr>
</tbody>
</table>

**Step 4**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

**Step 5**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show interfaces interface-id switchport</code></td>
<td>Verify your entries in the <code>Trunking Native Mode VLAN</code> field.</td>
</tr>
</tbody>
</table>

**Step 6**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
To return to the default native VLAN, VLAN 1, use the `no switchport trunk native vlan` interface configuration command.

If a packet has a VLAN ID that is the same as the outgoing port native VLAN ID, the packet is sent untagged; otherwise, the switch sends the packet with a tag.

### Configuring Trunk Ports for Load Sharing

Load sharing divides the bandwidth supplied by parallel trunks connecting switches. To avoid loops, STP normally blocks all but one parallel link between switches. Using load sharing, you divide the traffic between the links according to which VLAN the traffic belongs.

You configure load sharing on trunk ports by using STP port priorities or STP path costs. For load sharing using STP port priorities, both load-sharing links must be connected to the same switch. For load sharing using STP path costs, each load-sharing link can be connected to the same switch or to two different switches. For more information about STP, see Chapter 12, “Configuring STP.”

### Load Sharing Using STP Port Priorities

When two ports on the same switch form a loop, the switch uses the STP port priority to decide which port is enabled and which port is in a blocking state. You can set the priorities on a parallel trunk port so that the port carries all the traffic for a given VLAN. The trunk port with the higher priority (lower values) for a VLAN is forwarding traffic for that VLAN. The trunk port with the lower priority (higher values) for the same VLAN remains in a blocking state for that VLAN. One trunk port sends or receives all traffic for the VLAN.

Figure 9-3 shows two trunks connecting supported switches. In this example, the switches are configured as follows:

- VLANs 8 through 10 are assigned a port priority of 16 on Trunk 1.
- VLANs 3 through 6 retain the default port priority of 128 on Trunk 1.
- VLANs 3 through 6 are assigned a port priority of 16 on Trunk 2.
- VLANs 8 through 10 retain the default port priority of 128 on Trunk 2.

In this way, Trunk 1 carries traffic for VLANs 8 through 10, and Trunk 2 carries traffic for VLANs 3 through 6. If the active trunk fails, the trunk with the lower priority takes over and carries the traffic for all of the VLANs. No duplication of traffic occurs over any trunk port.

![Figure 9-3 Load Sharing by Using STP Port Priorities](image-url)
Beginning in privileged EXEC mode, follow these steps to configure the network shown in Figure 9-3.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 config terminal</td>
<td>Enter global configuration mode on Switch A.</td>
</tr>
<tr>
<td>Step 2 vtp domain domain-name</td>
<td>Configure a VTP administrative domain.</td>
</tr>
<tr>
<td></td>
<td>The domain name can be 1 to 32 characters.</td>
</tr>
<tr>
<td>Step 3 vtp mode server</td>
<td>Configure Switch A as the VTP server.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show vtp status</td>
<td>Verify the VTP configuration on both Switch A and Switch B.</td>
</tr>
<tr>
<td></td>
<td>In the display, check the VTP Operating Mode and the VTP Domain Name fields.</td>
</tr>
<tr>
<td>Step 6 show vlan</td>
<td>Verify that the VLANs exist in the database on Switch A.</td>
</tr>
<tr>
<td>Step 7 config terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 8 interface gigabitethernet 0/1</td>
<td>Define the interface to be configured as a trunk, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 9 switchport trunk encapsulation {isl</td>
<td>dot1q</td>
</tr>
<tr>
<td>Step 10 switchport mode trunk</td>
<td>Configure the port as a trunk port.</td>
</tr>
<tr>
<td>Step 11 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 12 show interfaces gigabitethernet 0/1 switchport</td>
<td>Verify the VLAN configuration.</td>
</tr>
<tr>
<td>Step 13</td>
<td>Repeat Steps 7 through 11 on Switch A for a second port in the switch.</td>
</tr>
<tr>
<td>Step 14</td>
<td>Repeat Steps 7 through 11 on Switch B to configure the trunk ports that connect to the trunk ports configured on Switch A.</td>
</tr>
<tr>
<td>Step 15 show vlan</td>
<td>When the trunk links come up, VTP passes the VTP and VLAN information to Switch B. Verify that Switch B has learned the VLAN configuration.</td>
</tr>
<tr>
<td>Step 16 config terminal</td>
<td>Enter global configuration mode on Switch A.</td>
</tr>
<tr>
<td>Step 17 interface gigabitethernet 0/1</td>
<td>Define the interface to set the STP port priority, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 18 spanning-tree vlan 8-10 port-priority 16</td>
<td>Assign the port priority of 16 for VLANs 8 through 10.</td>
</tr>
<tr>
<td>Step 19 exit</td>
<td>Return to global configuration mode.</td>
</tr>
<tr>
<td>Step 20 interface gigabitethernet 0/2</td>
<td>Define the interface to set the STP port priority, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 21 spanning-tree vlan 3-6 port-priority 16</td>
<td>Assign the port priority of 16 for VLANs 3 through 6.</td>
</tr>
<tr>
<td>Step 22 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 23 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 24 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
Load Sharing Using STP Path Cost

You can configure parallel trunks to share VLAN traffic by setting different path costs on a trunk and associating the path costs with different sets of VLANs, blocking different ports for different VLANs. The VLANs keep the traffic separate and maintain redundancy in the event of a lost link.

In Figure 9-4, Trunk ports 1 and 2 are configured as 100BASE-T ports. These VLAN path costs are assigned:

- VLANs 2 through 4 are assigned a path cost of 30 on Trunk port 1.
- VLANs 8 through 10 retain the default 100BASE-T path cost on Trunk port 1 of 19.
- VLANs 8 through 10 are assigned a path cost of 30 on Trunk port 2.
- VLANs 2 through 4 retain the default 100BASE-T path cost on Trunk port 2 of 19.

**Figure 9-4 Load-Sharing Trunks with Traffic Distributed by Path Cost**

Beginning in privileged EXEC mode, follow these steps to configure the network shown in Figure 9-4:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><code>configure terminal</code> Enter global configuration mode on Switch A.</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>interface gigabitethernet0/1</code> Define the interface to be configured as a trunk, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3</td>
<td>`switchport trunk encapsulation {isl</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>switchport mode trunk</code> Configure the port as a trunk port. The trunk defaults to ISL trunking.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>exit</code> Return to global configuration mode.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>end</code> Repeat Steps 2 through 5 on a second interface in Switch A.</td>
</tr>
<tr>
<td>Step 7</td>
<td><code>show running-config</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 8</td>
<td><code>show vlan</code> Verify your entries. In the display, make sure that the interfaces are configured as trunk ports.</td>
</tr>
<tr>
<td>Step 9</td>
<td><code>configure terminal</code> When the trunk links come up, Switch A receives the VTP information from the other switches. Verify that Switch A has learned the VLAN configuration.</td>
</tr>
<tr>
<td>Step 10</td>
<td><code>interface gigabitethernet0/1</code> Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 11</td>
<td><code>configure terminal</code> Define the interface on which to set the STP cost, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
Configuring VMPS

The VLAN Query Protocol (VQP) is used to support dynamic-access ports, which are not permanently assigned to a VLAN, but give VLAN assignments based on the MAC source addresses seen on the port. Each time an unknown MAC address is seen, the switch sends a VQP query to a remote VMPS; the query includes the newly seen MAC address and the port on which it was seen. The VMPS responds with a VLAN assignment for the port. The switch cannot be a VMPS server but can act as a client to the VMPS and communicate with it through VQP.

These sections contain this information:

- “Understanding VMPS” section on page 9-25
- “Default VMPS Client Configuration” section on page 9-26
- “VMPS Configuration Guidelines” section on page 9-27
- “Configuring the VMPS Client” section on page 9-27
- “Monitoring the VMPS” section on page 9-30
- “Troubleshooting Dynamic-Access Port VLAN Membership” section on page 9-30
- “VMPS Configuration Example” section on page 9-30

Understanding VMPS

Each time the client switch receives the MAC address of a new host, it sends a VQP query to the VMPS. When the VMPS receives this query, it searches its database for a MAC-address-to-VLAN mapping. The server response is based on this mapping and whether or not the server is in open or secure mode. In secure mode, the server shuts down the port when an illegal host is detected. In open mode, the server simply denies the host access to the port.

If the port is currently unassigned (that is, it does not yet have a VLAN assignment), the VMPS provides one of these responses:

- If the host is allowed on the port, the VMPS sends the client a vlan-assignment response containing the assigned VLAN name and allowing access to the host.
- If the host is not allowed on the port and the VMPS is in open mode, the VMPS sends an access-denied response.
• If the VLAN is not allowed on the port and the VMPS is in secure mode, the VMPS sends a "port-shutdown" response.

If the port already has a VLAN assignment, the VMPS provides one of these responses:
• If the VLAN in the database matches the current VLAN on the port, the VMPS sends an "success" response, allowing access to the host.
• If the VLAN in the database does not match the current VLAN on the port and active hosts exist on the port, the VMPS sends an "access-denied" or a "port-shutdown" response, depending on the secure mode of the VMPS.

If the switch receives an "access-denied" response from the VMPS, it continues to block traffic to and from the host MAC address. The switch continues to monitor the packets directed to the port and sends a query to the VMPS when it identifies a new host address. If the switch receives a "port-shutdown" response from the VMPS, it disables the port. The port must be manually re-enabled by using the CLI or SNMP.

Dynamic-Access Port VLAN Membership

A dynamic-access port can belong to only one VLAN with an ID from 1 to 4094. When the link comes up, the switch does not forward traffic to or from this port until the VMPS provides the VLAN assignment. The VMPS receives the source MAC address from the first packet of a new host connected to the dynamic-access port and attempts to match the MAC address to a VLAN in the VMPS database.

If there is a match, the VMPS sends the VLAN number for that port. If the client switch was not previously configured, it uses the domain name from the first VTP packet it receives on its trunk port from the VMPS. If the client switch was previously configured, it includes its domain name in the query packet to the VMPS to obtain its VLAN number. The VMPS verifies that the domain name in the packet matches its own domain name before accepting the request and responds to the client with the assigned VLAN number for the client. If there is no match, the VMPS either denies the request or shuts down the port (depending on the VMPS secure mode setting).

Multiple hosts (MAC addresses) can be active on a dynamic-access port if they are all in the same VLAN; however, the VMPS shuts down a dynamic-access port if more than 20 hosts are active on the port.

If the link goes down on a dynamic-access port, the port returns to an isolated state and does not belong to a VLAN. Any hosts that come online through the port are checked again through the VQP with the VMPS before the port is assigned to a VLAN.

Dynamic-access ports can be used for direct host connections, or they can connect to a network. A maximum of 20 MAC addresses are allowed per port on the switch. A dynamic-access port can belong to only one VLAN at a time, but the VLAN can change over time, depending on the MAC addresses seen.

Default VMPS Client Configuration

Table 9-7 shows the default VMPS and dynamic-access port configuration on client switches.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMPS domain server</td>
<td>None</td>
</tr>
<tr>
<td>VMPS reconfirm interval</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>
Chapter 9 Configuring VLANs

Configuring VMPS

These guidelines and restrictions apply to dynamic-access port VLAN membership:

- You should configure the VMPS before you configure ports as dynamic-access ports.
- When you configure a port as a dynamic-access port, the spanning-tree Port Fast feature is automatically enabled for that port. The Port Fast mode accelerates the process of bringing the port into the forwarding state.
- IEEE 802.1x ports cannot be configured as dynamic-access ports. If you try to enable IEEE 802.1x on a dynamic-access (VQP) port, an error message appears, and IEEE 802.1x is not enabled. If you try to change an IEEE 802.1x-enabled port to dynamic VLAN assignment, an error message appears, and the VLAN configuration is not changed.
- Trunk ports cannot be dynamic-access ports, but you can enter the `switchport access vlan dynamic` interface configuration command for a trunk port. In this case, the switch retains the setting and applies it if the port is later configured as an access port.
  You must turn off trunking on the port before the dynamic-access setting takes effect.
- Dynamic-access ports cannot be monitor ports.
- Secure ports cannot be dynamic-access ports. You must disable port security on a port before it becomes dynamic.
- Dynamic-access ports cannot be members of an EtherChannel group.
- Port channels cannot be configured as dynamic-access ports.
- The VTP management domain of the VMPS client and the VMPS server must be the same.
- The VLAN configured on the VMPS server should not be a voice VLAN.

Configuring the VMPS Client

You configure dynamic VLANs by using the VMPS (server). The switch can be a VMPS client; it cannot be a VMPS server.

Entering the IP Address of the VMPS

You must first enter the IP address of the server to configure the switch as a client.

Note

If the VMPS is being defined for a cluster of switches, enter the address on the command switch.
Beginning in privileged EXEC mode, follow these steps to enter the IP address of the VMPS:

### Command

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>vmps server ipaddress primary</td>
<td>Enter the IP address of the switch acting as the primary VMPS server.</td>
</tr>
<tr>
<td>3</td>
<td>(Optional) vmps server ipaddress</td>
<td>Enter the IP address of the switch acting as a secondary VMPS server. You can enter up to three secondary server addresses.</td>
</tr>
<tr>
<td>4</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>5</td>
<td>show vmps</td>
<td>Verify your entries in the VMPS Domain Server field of the display.</td>
</tr>
<tr>
<td>6</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

**Note** You must have IP connectivity to the VMPS for dynamic-access ports to work. You can test for IP connectivity by pinging the IP address of the VMPS and verifying that you get a response.

### Configuring Dynamic-Access Ports on VMPS Clients

If you are configuring a port on a cluster member switch as a dynamic-access port, first use the `rcommand` privileged EXEC command to log in to the cluster member switch.

**Caution** Dynamic-access port VLAN membership is for end stations or hubs connected to end stations. Connecting dynamic-access ports to other switches can cause a loss of connectivity.

Beginning in privileged EXEC mode, follow these steps to configure a dynamic-access port on a VMPS client switch:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>interface interface-id</td>
<td>Specify the switch port that is connected to the end station, and enter interface configuration mode.</td>
</tr>
<tr>
<td>3</td>
<td>switchport mode access</td>
<td>Set the port to access mode.</td>
</tr>
<tr>
<td>4</td>
<td>switchport access vlan dynamic</td>
<td>Configure the port as eligible for dynamic VLAN membership. The dynamic-access port must be connected to an end station.</td>
</tr>
<tr>
<td>5</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>6</td>
<td>show interfaces interface-id switchport</td>
<td>Verify your entries in the Operational Mode field of the display.</td>
</tr>
<tr>
<td>7</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return an interface to its default configuration, use the `default interface interface-id` interface configuration command. To return an interface to its default switchport mode (dynamic auto), use the `no switchport mode` interface configuration command. To reset the access mode to the default VLAN for the switch, use the `no switchport access vlan` interface configuration command.
Reconfirming VLAN Memberships

Beginning in privileged EXEC mode, follow these steps to confirm the dynamic-access port VLAN membership assignments that the switch has received from the VMPS:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>vmps reconfirm</td>
</tr>
<tr>
<td>Step 2</td>
<td>show vmps</td>
</tr>
</tbody>
</table>

Changing the Reconfirmation Interval

VMPS clients periodically reconfirm the VLAN membership information received from the VMPS. You can set the number of minutes after which reconfirmation occurs.

If you are configuring a member switch in a cluster, this parameter must be equal to or greater than the reconfirmation setting on the command switch. You must also first use the rcommand privileged EXEC command to log in to the member switch.

Beginning in privileged EXEC mode, follow these steps to change the reconfirmation interval:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>vmps reconfirm minutes</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show vmps</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the no vmps reconfirm global configuration command.

Changing the Retry Count

Beginning in privileged EXEC mode, follow these steps to change the number of times that the switch attempts to contact the VMPS before querying the next server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>vmps retry count</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show vmps</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the no vmps retry global configuration command.
Monitoring the VMPS

You can display information about the VMPS by using the `show vmps` privileged EXEC command. The switch displays this information about the VMPS:

- **VMPS VQP Version**—the version of VQP used to communicate with the VMPS. The switch queries the VMPS that is using VQP Version 1.
- **Reconfirm Interval**—the number of minutes the switch waits before reconfirming the VLAN-to-MAC-address assignments.
- **Server Retry Count**—the number of times VQP resends a query to the VMPS. If no response is received after this many tries, the switch starts to query the secondary VMPS.
- **VMPS domain server**—the IP address of the configured VLAN membership policy servers. The switch sends queries to the one marked `current`. The one marked `primary` is the primary server.
- **VMPS Action**—the result of the most recent reconfirmation attempt. A reconfirmation attempt can occur automatically when the reconfirmation interval expires, or you can force it by entering the `vmps reconfirm` privileged EXEC command or its SNMP equivalent.

This is an example of output for the `show vmps` privileged EXEC command:

```
Switch# show vmps
VQP Client Status:  
-------------------
VMPS VQP Version:  1
Reconfirm Interval: 60 min
Server Retry Count: 3
VMPS domain server: 172.20.128.86 (primary, current)
                   172.20.128.87

Reconfirmation status
---------------------
VMPS Action:         other
```

Troubleshooting Dynamic-Access Port VLAN Membership

The VMPS shuts down a dynamic-access port under these conditions:

- The VMPS is in secure mode, and it does not allow the host to connect to the port. The VMPS shuts down the port to prevent the host from connecting to the network.
- More than 20 active hosts reside on a dynamic-access port.

To re-enable a disabled dynamic-access port, enter the `shutdown` interface configuration command followed by the `no shutdown` interface configuration command.

VMPS Configuration Example

Figure 9-5 shows a network with a VMPS server switch and VMPS client switches with dynamic-access ports. In this example, these assumptions apply:

- The VMPS server and the VMPS client are separate switches.
- The Catalyst 6500 series Switch A is the primary VMPS server.
- The Catalyst 6500 series Switch C and Switch J are secondary VMPS servers.
- End stations are connected to the clients, Switch B and Switch I.
- The database configuration file is stored on the TFTP server with the IP address 172.20.22.7.

Figure 9-5  Dynamic Port VLAN Membership Configuration

- End station 1
- End station 2
- Dynamic-access port
- Trunk port
- Catalyst 6500 series switch A
- Primary VMPS Server 1
- 172.20.26.150
- Client switch B
- 172.20.26.151
- Switch C
- 172.20.26.152
- Switch D
- 172.20.26.153
- Switch E
- 172.20.26.154
- Switch F
- 172.20.26.155
- Switch G
- 172.20.26.156
- Switch H
- 172.20.26.157
- Client switch I
- 172.20.26.158
- Trunk port
- Catalyst 6500 series switch B
- Dynamic-access port
- 172.20.26.159
- Secondary VMPS Server 2
- Secondary VMPS Server 3
- TFTP server
- 172.20.22.7

Ethernet (Trunk link)
Configuring VTP

This chapter describes how to use the VLAN Trunking Protocol (VTP) and the VLAN database for managing VLANs with the switch.

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

The chapter consists of these sections:
- Understanding VTP, page 10-1
- Configuring VTP, page 10-6
- Monitoring VTP, page 10-16

Understanding VTP

VTP is a Layer 2 messaging protocol that maintains VLAN configuration consistency by managing the addition, deletion, and renaming of VLANs on a network-wide basis. VTP minimizes misconfigurations and configuration inconsistencies that can cause several problems, such as duplicate VLAN names, incorrect VLAN-type specifications, and security violations.

Before you create VLANs, you must decide whether to use VTP in your network. Using VTP, you can make configuration changes centrally on one or more switches and have those changes automatically communicated to all the other switches in the network. Without VTP, you cannot send information about VLANs to other switches.

VTP is designed to work in an environment where updates are made on a single switch and are sent through VTP to other switches in the domain. It does not work well in a situation where multiple updates to the VLAN database occur simultaneously on switches in the same domain, which would result in an inconsistency in the VLAN database.

The switch supports 1005 VLANs, but the number of configured features affects the usage of the switch hardware. If the switch is notified by VTP of a new VLAN and the switch is already using the maximum available hardware resources, it sends a message that there are not enough hardware resources available and shuts down the VLAN. The output of the show vlan user EXEC command shows the VLAN in a suspended state.

VTP only learns about normal-range VLANs (VLAN IDs 1 to 1005). Extended-range VLANs (VLAN IDs greater than 1005) are not supported by VTP or stored in the VTP VLAN database.
The VTP Domain

A VTP domain (also called a VLAN management domain) consists of one switch or several interconnected switches under the same administrative responsibility sharing the same VTP domain name. A switch can be in only one VTP domain. You make global VLAN configuration changes for the domain.

By default, the switch is in the VTP no-management-domain state until it receives an advertisement for a domain over a trunk link (a link that carries the traffic of multiple VLANs) or until you configure a domain name. Until the management domain name is specified or learned, you cannot create or modify VLANs on a VTP server, and VLAN information is not propagated over the network.

If the switch receives a VTP advertisement over a trunk link, it inherits the management domain name and the VTP configuration revision number. The switch then ignores advertisements with a different domain name or an earlier configuration revision number.

Caution

Before adding a VTP client switch to a VTP domain, always verify that its VTP configuration revision number is lower than the configuration revision number of the other switches in the VTP domain. Switches in a VTP domain always use the VLAN configuration of the switch with the highest VTP configuration revision number. If you add a switch that has a revision number higher than the revision number in the VTP domain, it can erase all VLAN information from the VTP server and VTP domain.

See the “Adding a VTP Client Switch to a VTP Domain” section on page 10-14 for the procedure for verifying and resetting the VTP configuration revision number.

When you make a change to the VLAN configuration on a VTP server, the change is propagated to all switches in the VTP domain. VTP advertisements are sent over all IEEE trunk connections, including Inter-Switch Link (ISL) and IEEE 802.1Q. VTP dynamically maps VLANs with unique names and internal index associates across multiple LAN types. Mapping eliminates excessive device administration required from network administrators.

If you configure a switch for VTP transparent mode, you can create and modify VLANs, but the changes are not sent to other switches in the domain, and they affect only the individual switch. However, configuration changes made when the switch is in this mode are saved in the switch running configuration and can be saved to the switch startup configuration file.

For domain name and password configuration guidelines, see the “VTP Configuration Guidelines” section on page 10-8.
VTP Modes

You can configure a supported switch to be in one of the VTP modes listed in Table 10-1.

<table>
<thead>
<tr>
<th>VTP Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTP server</td>
<td>In VTP server mode, you can create, modify, and delete VLANs, and specify other configuration parameters (such as the VTP version) for the entire VTP domain. VTP servers advertise their VLAN configurations to other switches in the same VTP domain and synchronize their VLAN configurations with other switches based on advertisements received over trunk links. In VTP server mode, VLAN configurations are saved in NVRAM. VTP server is the default mode.</td>
</tr>
<tr>
<td>VTP client</td>
<td>A VTP client behaves like a VTP server and transmits and receives VTP updates on its trunks, but you cannot create, change, or delete VLANs on a VTP client. VLANs are configured on another switch in the domain that is in server mode. In VTP client mode, VLAN configurations are not saved in NVRAM.</td>
</tr>
<tr>
<td>VTP transparent</td>
<td>VTP transparent switches do not participate in VTP. A VTP transparent switch does not advertise its VLAN configuration and does not synchronize its VLAN configuration based on received advertisements. However, in VTP Version 2, transparent switches do forward VTP advertisements that they receive from other switches through their trunk interfaces. You can create, modify, and delete VLANs on a switch in VTP transparent mode. The switch must be in VTP transparent mode when you create extended-range VLANs. See the “Configuring Extended-Range VLANs” section on page 9-11. When the switch is in VTP transparent mode, the VTP and VLAN configurations are saved in NVRAM, but they are not advertised to other switches. In this mode, VTP mode and domain name are saved in the switch running configuration, and you can save this information in the switch startup configuration file by using the <code>copy running-config startup-config</code> privileged EXEC command.</td>
</tr>
</tbody>
</table>

VTP Advertisements

Each switch in the VTP domain sends periodic global configuration advertisements from each trunk port to a reserved multicast address. Neighboring switches receive these advertisements and update their VTP and VLAN configurations as necessary.

---

**Note** Because trunk ports send and receive VTP advertisements, you must ensure that at least one trunk port is configured on the switch and that this trunk port is connected to the trunk port of another switch. Otherwise, the switch cannot receive any VTP advertisements. For more information on trunk ports, see the “Configuring VLAN Trunks” section on page 9-14.

VTP advertisements distribute this global domain information:

- VTP domain name
- VTP configuration revision number
- Update identity and update timestamp
Understanding VTP

MD5 digest VLAN configuration, including maximum transmission unit (MTU) size for each VLAN.

Frame format

VTP advertisements distribute this VLAN information for each configured VLAN:

- VLAN IDs (ISL and IEEE 802.1Q)
- VLAN name
- VLAN type
- VLAN state
- Additional VLAN configuration information specific to the VLAN type

VTP Version 2

If you use VTP in your network, you must decide whether to use Version 1 or Version 2. By default, VTP operates in Version 1.

VTP Version 2 supports these features that are not supported in Version 1:

- Token Ring support—VTP Version 2 supports Token Ring Bridge Relay Function (TrBRF) and Token Ring Concentrator Relay Function (TrCRF) VLANs. For more information about Token Ring VLANs, see the “Configuring Normal-Range VLANs” section on page 9-4.
- Unrecognized Type-Length-Value (TLV) support—A VTP server or client propagates configuration changes to its other trunks, even for TLVs it is not able to parse. The unrecognized TLV is saved in NVRAM when the switch is operating in VTP server mode.
- Version-Dependent Transparent Mode—In VTP Version 1, a VTP transparent switch inspects VTP messages for the domain name and version and forwards a message only if the version and domain name match. Because VTP Version 2 supports only one domain, it forwards VTP messages in transparent mode without inspecting the version and domain name.
- Consistency Checks—In VTP Version 2, VLAN consistency checks (such as VLAN names and values) are performed only when you enter new information through the CLI or SNMP. Consistency checks are not performed when new information is obtained from a VTP message or when information is read from NVRAM. If the MD5 digest on a received VTP message is correct, its information is accepted.

VTP Pruning

VTP pruning increases network available bandwidth by restricting flooded traffic to those trunk links that the traffic must use to reach the destination devices. Without VTP pruning, a switch floods broadcast, multicast, and unknown unicast traffic across all trunk links within a VTP domain even though receiving switches might discard them. VTP pruning is disabled by default.

VTP pruning blocks unneeded flooded traffic to VLANs on trunk ports that are included in the pruning-eligible list. Only VLANs included in the pruning-eligible list can be pruned. By default, VLANs 2 through 1001 are pruning eligible switch trunk ports. If the VLANs are configured as pruning-ineligible, the flooding continues. VTP pruning is supported with VTP Version 1 and Version 2.
Figure 10-1 shows a switched network without VTP pruning enabled. Port 1 on Switch A and Port 2 on Switch D are assigned to the Red VLAN. If a broadcast is sent from the host connected to Switch A, Switch A floods the broadcast and every switch in the network receives it, even though Switches C, E, and F have no ports in the Red VLAN.

**Figure 10-1 Flooding Traffic without VTP Pruning**

![Flooding Traffic without VTP Pruning Diagram]

Figure 10-2 shows a switched network with VTP pruning enabled. The broadcast traffic from Switch A is not forwarded to Switches C, E, and F because traffic for the Red VLAN has been pruned on the links shown (Port 5 on Switch B and Port 4 on Switch D).

**Figure 10-2 Optimized Flooded Traffic with VTP Pruning**

![Optimized Flooded Traffic with VTP Pruning Diagram]

Enabling VTP pruning on a VTP server enables pruning for the entire management domain. Making VLANs pruning-eligible or pruning-ineligible affects pruning eligibility for those VLANs on that trunk only (not on all switches in the VTP domain).
See the “Enabling VTP Pruning” section on page 10-14. VTP pruning takes effect several seconds after you enable it. VTP pruning does not prune traffic from VLANs that are pruning-ineligible. VLAN 1 and VLANs 1002 to 1005 are always pruning-ineligible; traffic from these VLANs cannot be pruned. Extended-range VLANs (VLAN IDs higher than 1005) are also pruning-ineligible.

VTP pruning is not designed to function in VTP transparent mode. If one or more switches in the network are in VTP transparent mode, you should do one of these:

- Turn off VTP pruning in the entire network.
- Turn off VTP pruning by making all VLANs on the trunk of the switch upstream to the VTP transparent switch pruning ineligible.

To configure VTP pruning on an interface, use the `switchport trunk pruning vlan` interface configuration command (see the “Changing the Pruning-Eligible List” section on page 9-20). VTP pruning operates when an interface is trunking. You can set VLAN pruning-eligibility, whether or not VTP pruning is enabled for the VTP domain, whether or not any given VLAN exists, and whether or not the interface is currently trunking.

# Configuring VTP

These sections contain this configuration information:

- Default VTP Configuration, page 10-6
- VTP Configuration Options, page 10-7
- VTP Configuration Guidelines, page 10-8
- Configuring a VTP Server, page 10-9
- Configuring a VTP Client, page 10-11
- Disabling VTP (VTP Transparent Mode), page 10-12
- Enabling VTP Version 2, page 10-13
- Enabling VTP Pruning, page 10-14
- Adding a VTP Client Switch to a VTP Domain, page 10-14

# Default VTP Configuration

Table 10-2 shows the default VTP configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTP domain name</td>
<td>Null.</td>
</tr>
<tr>
<td>VTP mode</td>
<td>Server.</td>
</tr>
<tr>
<td>VTP version</td>
<td>Version 1 (Version 2 is disabled).</td>
</tr>
<tr>
<td>VTP password</td>
<td>None.</td>
</tr>
<tr>
<td>VTP pruning</td>
<td>Disabled.</td>
</tr>
</tbody>
</table>
VTP Configuration Options

You can configure VTP by using these configuration modes.

- **VTP Configuration in Global Configuration Mode, page 10-7**
- **VTP Configuration in VLAN Database Configuration Mode, page 10-7**

You access VLAN database configuration mode by entering the `vlan database` privileged EXEC command.

For detailed information about `vtp` commands, see the command reference for this release.

VTP Configuration in Global Configuration Mode

You can use the `vtp` global configuration command to set the VTP password, the version, the VTP file name, the interface providing updated VTP information, the domain name, and the mode, and to disable or enable pruning. For more information about available keywords, see the command descriptions in the command reference for this release. The VTP information is saved in the VTP VLAN database. When VTP mode is transparent, the VTP domain name and mode are also saved in the switch running configuration file, and you can save it in the switch startup configuration file by entering the `copy running-config startup-config` privileged EXEC command. You must use this command if you want to save VTP mode as transparent, even if the switch resets.

When you save VTP information in the switch startup configuration file and reboot the switch, the switch configuration is selected as follows:

- If the VTP mode is transparent in the startup configuration and the VLAN database and the VTP domain name from the VLAN database matches that in the startup configuration file, the VLAN database is ignored (cleared), and the VTP and VLAN configurations in the startup configuration file are used. The VLAN database revision number remains unchanged in the VLAN database.
- If the VTP mode or domain name in the startup configuration do not match the VLAN database, the domain name and VTP mode and configuration for the first 1005 VLANs use the VLAN database information.

VTP Configuration in VLAN Database Configuration Mode

You can configure all VTP parameters in VLAN database configuration mode, which you access by entering the `vlan database` privileged EXEC command. For more information about available keywords, see the `vtp` VLAN database configuration command description in the command reference for this release. When you enter the `exit` command in VLAN database configuration mode, it applies all the commands that you entered and updates the VLAN database. VTP messages are sent to other switches in the VTP domain, and the privileged EXEC mode prompt appears.

If VTP mode is transparent, the domain name and the mode (transparent) are saved in the switch running configuration, and you can save this information in the switch startup configuration file by entering the `copy running-config startup-config` privileged EXEC command.
VTP Configuration Guidelines

These sections describe guidelines you should follow when implementing VTP in your network.

Domain Names

When configuring VTP for the first time, you must always assign a domain name. You must configure all switches in the VTP domain with the same domain name. Switches in VTP transparent mode do not exchange VTP messages with other switches, and you do not need to configure a VTP domain name for them.

Note

If NVRAM and DRAM storage is sufficient, all switches in a VTP domain should be in VTP server mode.

Caution

Do not configure a VTP domain if all switches are operating in VTP client mode. If you configure the domain, it is impossible to make changes to the VLAN configuration of that domain. Make sure that you configure at least one switch in the VTP domain for VTP server mode.

Passwords

You can configure a password for the VTP domain, but it is not required. If you do configure a domain password, all domain switches must share the same password and you must configure the password on each switch in the management domain. Switches without a password or with the wrong password reject VTP advertisements.

If you configure a VTP password for a domain, a switch that is booted without a VTP configuration does not accept VTP advertisements until you configure it with the correct password. After the configuration, the switch accepts the next VTP advertisement that uses the same password and domain name in the advertisement.

If you are adding a new switch to an existing network with VTP capability, the new switch learns the domain name only after the applicable password has been configured on it.

Caution

When you configure a VTP domain password, the management domain does not function properly if you do not assign a management domain password to each switch in the domain.

VTP Version

Follow these guidelines when deciding which VTP version to implement:

- All switches in a VTP domain must run the same VTP version.
- A VTP Version 2-capable switch can operate in the same VTP domain as a switch running VTP Version 1 if Version 2 is disabled on the Version 2-capable switch (Version 2 is disabled by default).
Configuring VTP

- Do not enable VTP Version 2 on a switch unless all of the switches in the same VTP domain are Version-2-capable. When you enable Version 2 on a switch, all of the Version-2-capable switches in the domain enable Version 2. If there is a Version 1-only switch, it does not exchange VTP information with switches that have Version 2 enabled.

- If there are TrBRF and TrCRF Token Ring networks in your environment, you must enable VTP Version 2 for Token Ring VLAN switching to function properly. To run Token Ring and Token Ring-Net, disable VTP Version 2.

**Configuration Requirements**

When you configure VTP, you must configure a trunk port so that the switch can send and receive VTP advertisements to and from other switches in the domain.

For more information, see the “Configuring VLAN Trunks” section on page 9-14.

If you are configuring VTP on a cluster member switch to a VLAN, use the `rcommand` privileged EXEC command to log in to the member switch. For more information about the command, see the command reference for this release.

If you are configuring extended-range VLANs on the switch, the switch must be in VTP transparent mode.

**Configuring a VTP Server**

When a switch is in VTP server mode, you can change the VLAN configuration and have it propagated throughout the network.

**Note**

If extended-range VLANs are configured on the switch, you cannot change VTP mode to server. You receive an error message, and the configuration is not allowed.

Beginning in privileged EXEC mode, follow these steps to configure the switch as a VTP server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td>vtp mode server</td>
<td>Configure the switch for VTP server mode (the default).</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>vtp domain <em>domain-name</em></td>
<td>Configure the VTP administrative-domain name. The name can be 1 to 32 characters. All switches operating in VTP server or client mode under the same administrative responsibility must be configured with the same domain name.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td></td>
</tr>
<tr>
<td>vtp password <em>password</em></td>
<td>(Optional) Set the password for the VTP domain. The password can be 8 to 64 characters. If you configure a VTP password, the VTP domain does not function properly if you do not assign the same password to each switch in the domain.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td></td>
</tr>
<tr>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td></td>
</tr>
<tr>
<td>show vtp status</td>
<td>Verify your entries in the <strong>VTP Operating Mode</strong> and the <strong>VTP Domain Name</strong> fields of the display.</td>
</tr>
</tbody>
</table>
When you configure a domain name, it cannot be removed; you can only reassign a switch to a different domain.

To return the switch to a no-password state, use the `no vtp password` global configuration command.

This example shows how to use global configuration mode to configure the switch as a VTP server with the domain name `eng_group` and the password `mypassword`:

```
Switch# config terminal
Switch(config)# vtp mode server
Switch(config)# vtp domain eng_group
Switch(config)# vtp password mypassword
Switch(config)# end
```

You can also use VLAN database configuration mode to configure VTP parameters.

Beginning in privileged EXEC mode, follow these steps to use VLAN database configuration mode to configure the switch as a VTP server:

```
Step 1
vlan database
Enter VLAN database configuration mode.

Step 2
vtp server
Configure the switch for VTP server mode (the default).

Step 3
vtp domain domain-name
Configure a VTP administrative-domain name. The name can be 1 to 32 characters. All switches operating in VTP server or client mode under the same administrative responsibility must be configured with the same domain name.

Step 4
vtp password password
(Optional) Set a password for the VTP domain. The password can be 8 to 64 characters.
If you configure a VTP password, the VTP domain does not function properly if you do not assign the same password to each switch in the domain.

Step 5
exit
Update the VLAN database, propagate it throughout the administrative domain, and return to privileged EXEC mode.

Step 6
show vtp status
Verify your entries in the VTP Operating Mode and the VTP Domain Name fields of the display.
```

When you configure a domain name, it cannot be removed; you can only reassign a switch to a different domain.

To return the switch to a no-password state, use the `no vtp password` VLAN database configuration command.

This example shows how to use VLAN database configuration mode to configure the switch as a VTP server with the domain name `eng_group` and the password `mypassword`:

```
Switch# vlan database
Switch(vlan)# vtp server
Switch(vlan)# vtp domain eng_group
Switch(vlan)# vtp password mypassword
Switch(vlan)# exit
APPLY completed.
Exiting....
Switch#
```
Configuring a VTP Client

When a switch is in VTP client mode, you cannot change its VLAN configuration. The client switch receives VTP updates from a VTP server in the VTP domain and then modifies its configuration accordingly.

Follow these guidelines:

- If extended-range VLANs are configured on the switch, you cannot change VTP mode to client. You receive an error message, and the configuration is not allowed.
- If you configure the switch for VTP client mode, the switch does not create the VLAN database file (vlan.dat). If the switch is then powered off, it resets the VTP configuration to the default. To keep the VTP configuration with VTP client mode after the switch restarts, you must first configure the VTP domain name before the VTP mode.

Caution

If all switches are operating in VTP client mode, do not configure a VTP domain name. If you do, it is impossible to make changes to the VLAN configuration of that domain. Therefore, make sure you configure at least one switch as a VTP server.

Beginning in privileged EXEC mode, follow these steps to configure the switch as a VTP client:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>vtp mode client</td>
</tr>
<tr>
<td>Step 3</td>
<td>vtp domain domain-name</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4</td>
<td>vtp password password</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td>Step 6</td>
<td>show vtp status</td>
</tr>
</tbody>
</table>

Use the **no vtp mode** global configuration command to return the switch to VTP server mode. To return the switch to a no-password state, use the **no vtp password** privileged EXEC command. When you configure a domain name, it cannot be removed; you can only reassign a switch to a different domain.

Note

You can also configure a VTP client by using the **vlan database** privileged EXEC command to enter VLAN database configuration mode and entering the **vtp client** command, similar to the second procedure under “Configuring a VTP Server” section on page 10-9. Use the **no vtp client** VLAN database configuration command to return the switch to VTP server mode or the **no vtp password** VLAN database configuration command to return the switch to a no-password state. When you configure a domain name, it cannot be removed; you can only reassign a switch to a different domain.
### Disabling VTP (VTP Transparent Mode)

When you configure the switch for VTP transparent mode, VTP is disabled on the switch. The switch does not send VTP updates and does not act on VTP updates received from other switches. However, a VTP transparent switch running VTP Version 2 does forward received VTP advertisements on its trunk links.

**Note**
Before you create extended-range VLANs (VLAN IDs 1006 to 4094), you must set VTP mode to transparent by using the `vtp mode transparent` global configuration command. Save this configuration to the startup configuration so that the switch boots up in VTP transparent mode. Otherwise, you lose the extended-range VLAN configuration if the switch resets and boots up in VTP server mode (the default).

Beginning in privileged EXEC mode, follow these steps to configure VTP transparent mode and save the VTP configuration in the switch startup configuration file:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: <code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2: <code>vtp mode transparent</code></td>
<td>Configure the switch for VTP transparent mode (disable VTP).</td>
</tr>
<tr>
<td>Step 3: <code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4: <code>show vtp status</code></td>
<td>Verify your entries in the <code>VTP Operating Mode</code> and the <code>VTP Domain Name</code> fields of the display.</td>
</tr>
<tr>
<td>Step 5: <code>copy running-config startup-config</code></td>
<td>(Optional) Save the configuration in the startup configuration file.</td>
</tr>
</tbody>
</table>

**Note** Only VTP mode and domain name are saved in the switch running configuration and can be copied to the startup configuration file.

To return the switch to VTP server mode, use the `no vtp mode` global configuration command.

**Note** If extended-range VLANs are configured on the switch, you cannot change the VTP mode to server. You receive an error message, and the configuration is not allowed.

**Note** You can also configure VTP transparent mode by using the `vlan database` privileged EXEC command to enter VLAN database configuration mode and by entering the `vtp transparent` command, similar to the second procedure under the “Configuring a VTP Server” section on page 10-9. Use the `no vtp transparent` VLAN database configuration command to return the switch to VTP server mode. If extended-range VLANs are configured on the switch, you cannot change VTP mode to server. You receive an error message, and the configuration is not allowed.
Enabling VTP Version 2

VTP Version 2 is disabled by default on VTP Version 2-capable switches. When you enable VTP Version 2 on a switch, every VTP Version 2-capable switch in the VTP domain enables Version 2. You can only configure the version when the switches are in VTP server or transparent mode.

---

**Caution**

VTP Version 1 and VTP Version 2 are not interoperable on switches in the same VTP domain. Every switch in the VTP domain must use the same VTP version. Do not enable VTP Version 2 unless every switch in the VTP domain supports Version 2.

---

**Note**

In TrCRF and TrBRF Token ring environments, you must enable VTP Version 2 for Token Ring VLAN switching to function properly. For Token Ring and Token Ring-Net media, VTP Version 2 must be disabled.

For more information on VTP version configuration guidelines, see the “VTP Version” section on page 10-8.

Beginning in privileged EXEC mode, follow these steps to enable VTP Version 2:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>vtp version 2</strong> Enable VTP Version 2 on the switch.</td>
</tr>
<tr>
<td></td>
<td>VTP Version 2 is disabled by default on VTP Version 2-capable switches.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>end</strong> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>show vtp status</strong> In the <em>VTP V2 Mode</em> field of the display, verify</td>
</tr>
<tr>
<td></td>
<td>that VTP Version 2 is enabled.</td>
</tr>
</tbody>
</table>

To disable VTP Version 2, use the **no vtp version** global configuration command.

---

**Note**

You can also enable VTP Version 2 by using the **vlan database** privileged EXEC command to enter VLAN database configuration mode and by entering the **vtp v2-mode** VLAN database configuration command. To disable VTP Version 2, use the **no vtp v2-mode** VLAN database configuration command.
Enabling VTP Pruning

Pruning increases available bandwidth by restricting flooded traffic to those trunk links that the traffic must use to access the destination devices. You can only enable VTP pruning on a switch in VTP server mode.

Beginning in privileged EXEC mode, follow these steps to enable VTP pruning in the VTP domain:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>vtp pruning</td>
<td>Enable pruning in the VTP administrative domain. By default, pruning is disabled. You need to enable pruning on only one switch in VTP server mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>show vtp status</td>
<td>Verify your entries in the VTP Pruning Mode field of the display.</td>
</tr>
</tbody>
</table>

To disable VTP pruning, use the **no vtp pruning** global configuration command.

**Note**

You can also enable VTP pruning by using the **vlan database** privileged EXEC command to enter VLAN database configuration mode and entering the **vtp pruning** VLAN database configuration command. To disable VTP pruning, use the **no vtp pruning** VLAN database configuration command. You can also enable VTP Version 2 by using the **vtp pruning** privileged EXEC command.

Pruning is supported with VTP Version 1 and Version 2. If you enable pruning on the VTP server, it is enabled for the entire VTP domain.

Only VLANs included in the pruning-eligible list can be pruned. By default, VLANs 2 through 1001 are pruning-eligible on trunk ports. Reserved VLANs and extended-range VLANs cannot be pruned. To change the pruning-eligible VLANs, see the “Changing the Pruning-Eligible List” section on page 9-20.

Adding a VTP Client Switch to a VTP Domain

Before adding a VTP client to a VTP domain, always verify that its VTP configuration revision number is lower than the configuration revision number of the other switches in the VTP domain. Switches in a VTP domain always use the VLAN configuration of the switch with the highest VTP configuration revision number. If you add a switch that has a revision number higher than the revision number in the VTP domain, it can erase all VLAN information from the VTP server and VTP domain.
Beginning in privileged EXEC mode, follow these steps to verify and reset the VTP configuration revision number on a switch before adding it to a VTP domain:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>show vtp status</strong> Check the VTP configuration revision number.</td>
</tr>
<tr>
<td></td>
<td>If the number is 0, add the switch to the VTP domain.</td>
</tr>
<tr>
<td></td>
<td>If the number is greater than 0, follow these steps:</td>
</tr>
<tr>
<td></td>
<td>a. Write down the domain name.</td>
</tr>
<tr>
<td></td>
<td>b. Write down the configuration revision number.</td>
</tr>
<tr>
<td></td>
<td>c. Continue with the next steps to reset the switch configuration revision number.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>vtp domain domain-name</strong> Change the domain name from the original one displayed in Step 1 to a new name.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>end</strong> The VLAN information on the switch is updated and the configuration revision number is reset to 0. You return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>show vtp status</strong> Verify that the configuration revision number has been reset to 0.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><strong>vtp domain domain-name</strong> Enter the original domain name on the switch.</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><strong>end</strong> The VLAN information on the switch is updated, and you return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td><strong>show vtp status</strong> (Optional) Verify that the domain name is the same as in Step 1 and that the configuration revision number is 0.</td>
</tr>
</tbody>
</table>

You can also change the VTP domain name by entering the **vlan database** privileged EXEC command to enter VLAN database configuration mode and by entering the **vtp domain domain-name** command. In this mode, you must enter the **exit** command to update VLAN information and return to privileged EXEC mode.

After resetting the configuration revision number, add the switch to the VTP domain.

**Note** You can use the **vtp mode transparent** global configuration command or the **vtp transparent** VLAN database configuration command to disable VTP on the switch, and then change its VLAN information without affecting the other switches in the VTP domain.
Monitoring VTP

You monitor VTP by displaying VTP configuration information: the domain name, the current VTP revision, and the number of VLANs. You can also display statistics about the advertisements sent and received by the switch.

Table 10-3 shows the privileged EXEC commands for monitoring VTP activity.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show vtp status</td>
<td>Display the VTP switch configuration information.</td>
</tr>
<tr>
<td>show vtp counters</td>
<td>Display counters about VTP messages that have been sent and received.</td>
</tr>
</tbody>
</table>
CHAPTER 11

Configuring Voice VLAN

This chapter describes how to configure the voice VLAN feature on the switch. Voice VLAN is referred to as an auxiliary VLAN in some Catalyst 6500 family switch documentation.

Note

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:

- Understanding Voice VLAN, page 11-1
- Configuring Voice VLAN, page 11-3
- Displaying Voice VLAN, page 11-6

Understanding Voice VLAN

The voice VLAN feature enables access ports to carry IP voice traffic from an IP phone. When the switch is connected to a Cisco 7960 IP Phone, the phone sends voice traffic with Layer 3 IP precedence and Layer 2 class of service (CoS) values, which are both set to 5 by default. Because the sound quality of an IP phone call can deteriorate if the data is unevenly sent, the switch supports quality of service (QoS) based on IEEE 802.1p CoS. QoS uses classification and scheduling to send network traffic from the switch in a predictable manner. For more information on QoS, see Chapter 27, “Configuring QoS.”

The Cisco 7960 IP Phone is a configurable device, and you can configure it to forward traffic with an IEEE 802.1p priority. You can configure the switch to trust or override the traffic priority assigned by a Cisco IP Phone.

The Cisco IP Phone contains an integrated three-port 10/100 switch as shown in Figure 11-1. The ports provide dedicated connections to these devices:

- Port 1 connects to the switch or other voice-over-IP (VoIP) device.
- Port 2 is an internal 10/100 interface that carries the IP Phone traffic.
- Port 3 (access port) connects to a PC or other device.
Figure 11-1 shows one way to connect a Cisco 7960 IP Phone.

**Figure 11-1  Cisco 7960 IP Phone Connected to a Switch**

Cisco IP Phone Voice Traffic

You can configure an access port with an attached Cisco IP Phone to use one VLAN for voice traffic and another VLAN for data traffic from a device attached to the phone. You can configure access ports on the switch to send Cisco Discovery Protocol (CDP) packets that instruct an attached phone to send voice traffic to the switch in any of these ways:

- In the voice VLAN tagged with a Layer 2 CoS priority value
- In the access VLAN tagged with a Layer 2 CoS priority value
- In the access VLAN, untagged (no Layer 2 CoS priority value)

**Note**  In all configurations, the voice traffic carries a Layer 3 IP precedence value (the default is 5 for voice traffic and 3 for voice control traffic).

Cisco IP Phone Data Traffic

The switch can also process tagged data traffic (traffic in IEEE 802.1Q or IEEE 802.1p frame types) from the device attached to the access port on the Cisco IP Phone (see Figure 11-1). You can configure Layer 2 access ports on the switch to send CDP packets that instruct the attached phone to configure the phone access port in one of these modes:

- In trusted mode, all traffic received through the access port on the Cisco IP Phone passes through the phone unchanged.
- In untrusted mode, all traffic in IEEE 802.1Q or IEEE 802.1p frames received through the access port on the Cisco IP Phone receive a configured Layer 2 CoS value. The default Layer 2 CoS value is 0. Untrusted mode is the default.
Configuring Voice VLAN

These sections contain this configuration information:

- Default Voice VLAN Configuration, page 11-3
- Voice VLAN Configuration Guidelines, page 11-3
- Configuring a Port Connected to a Cisco 7960 IP Phone, page 11-4

Default Voice VLAN Configuration

The voice VLAN feature is disabled by default.

When the voice VLAN feature is enabled, all untagged traffic is sent according to the default CoS priority of the port.

The CoS value is not trusted for IEEE 802.1p or IEEE 802.1Q tagged traffic.

Voice VLAN Configuration Guidelines

These are the voice VLAN configuration guidelines:

- You should configure voice VLAN on switch access ports; voice VLAN is not supported on trunk ports.

  Note Voice VLAN is only supported on access ports and not on trunk ports, even though the configuration is allowed.

- The voice VLAN should be present and active on the switch for the IP phone to correctly communicate on the voice VLAN. Use the `show vlan` privileged EXEC command to see if the VLAN is present (listed in the display). If the VLAN is not listed, see Chapter 9, “Configuring VLANs,” for information on how to create the voice VLAN.

- Before you enable voice VLAN, we recommend that you enable QoS on the switch by entering the `mls qos` global configuration command and configure the port trust state to trust by entering the `mls qos trust cos` interface configuration command. If you use the auto-QoS feature, these settings are automatically configured. For more information, see Chapter 27, “Configuring QoS.”

- You must enable CDP on the switch port connected to the Cisco IP Phone to send the configuration to the phone. (CDP is globally enabled by default on all switch interfaces.)

- The Port Fast feature is automatically enabled when voice VLAN is configured. When you disable voice VLAN, the Port Fast feature is not automatically disabled.


- If the Cisco IP Phone and a device attached to the phone are in the same VLAN, they must be in the same IP subnet. These conditions indicate that they are in the same VLAN:
  - They both use IEEE 802.1p or untagged frames.
  - The Cisco IP Phone uses IEEE 802.1p frames, and the device uses untagged frames.
  - The Cisco IP Phone uses untagged frames, and the device uses IEEE 802.1p frames.
  - The Cisco IP Phone uses IEEE 802.1Q frames, and the voice VLAN is the same as the access VLAN.
- The Cisco IP Phone and a device attached to the phone cannot communicate if they are in the same VLAN and subnet but use different frame types because traffic in the same subnet is not routed (routing would eliminate the frame type difference).
- You cannot configure static secure MAC addresses in the voice VLAN.
- Voice VLAN ports can also be these port types:
  - Dynamic access port. See the “Configuring Dynamic-Access Ports on VMPS Clients” section on page 9-28 for more information.
  - IEEE 802.1x authenticated port. See the “Configuring IEEE 802.1x Authentication” section on page 6-23 for more information.

  **Note** If you enable IEEE 802.1x on an access port on which a voice VLAN is configured and to which a Cisco IP Phone is connected, the phone loses connectivity to the switch for up to 30 seconds.

  - Protected port. See the “Configuring Protected Ports” section on page 18-5 for more information.
  - A source or destination port for a SPAN or RSPAN session.
  - Secure port. See the “Configuring Port Security” section on page 18-7 for more information.

  **Note** When you enable port security on an interface that is also configured with a voice VLAN, you must set the maximum allowed secure addresses on the port to two plus the maximum number of secure addresses allowed on the access VLAN. When the port is connected to a Cisco IP Phone, the phone requires up to two MAC addresses. The phone address is learned on the voice VLAN and might also be learned on the access VLAN. Connecting a PC to the phone requires additional MAC addresses.

### Configuring a Port Connected to a Cisco 7960 IP Phone

Because a Cisco 7960 IP Phone also supports a connection to a PC or other device, a port connecting the switch to a Cisco IP Phone can carry mixed traffic. You can configure a port to decide how the Cisco IP Phone carries voice traffic and data traffic.

These sections contain this configuration information:

- **Configuring Cisco IP Phone Voice Traffic**, page 11-5
- **Configuring the Priority of Incoming Data Frames**, page 11-6
Configuring Cisco IP Phone Voice Traffic

You can configure a port connected to the Cisco IP Phone to send CDP packets to the phone to configure the way in which the phone sends voice traffic. The phone can carry voice traffic in IEEE 802.1Q frames for a specified voice VLAN with a Layer 2 CoS value. It can use IEEE 802.1p priority tagging to give voice traffic a higher priority and forward all voice traffic through the native (access) VLAN. The Cisco IP Phone can also send untagged voice traffic or use its own configuration to send voice traffic in the access VLAN. In all configurations, the voice traffic carries a Layer 3 IP precedence value (the default is 5).

Beginning in privileged EXEC mode, follow these steps to configure voice traffic on a port:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
<td>Specify the interface connected to the phone, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3</td>
<td>mls qos trust cos</td>
<td>Configure the interface to classify incoming traffic packets by using the packet CoS value. For untagged packets, the port default CoS value is used. Note Before configuring the port trust state, you must first globally enable QoS by using the mls qos global configuration command.</td>
</tr>
</tbody>
</table>
| Step 4 | switchport voice vlan {vlan-id | dot1p | none | untagged} | Configure how the Cisco IP Phone carries voice traffic:  
  
  - **vlan-id**—Configure the phone to forward all voice traffic through the specified VLAN. By default, the Cisco IP Phone forwards the voice traffic with an IEEE 802.1Q priority of 5. Valid VLAN IDs are 1 to 4094.  
  
  - **dot1p**—Configure the phone to use IEEE 802.1p priority tagging for voice traffic and to use the default native VLAN (VLAN 0) to carry all traffic. By default, the Cisco IP Phone forwards the voice traffic with an IEEE 802.1p priority of 5.  
  
  - **none**—Allow the phone to use its own configuration to send untagged voice traffic.  
  
  - **untagged**—Configure the phone to send untagged voice traffic. |
| Step 5 | end                                  | Return to privileged EXEC mode.                                                                                                       |
| Step 6 | show interfaces interface-id         | Verify your voice VLAN entries.                                                                                                       |
|        | switchport or show running-config    | Verify your QoS and voice VLAN entries.                                                                                               |
|        | interface-id                         | |
| Step 7 | copy running-config startup-config   | (Optional) Save your entries in the configuration file.                                                                               |
To return the port to its default setting, use the `no switchport voice vlan` interface configuration command.

## Configuring the Priority of Incoming Data Frames

You can connect a PC or other data device to a Cisco IP Phone port. To process tagged data traffic (in IEEE 802.1Q or IEEE 802.1p frames), you can configure the switch to send CDP packets to instruct the phone how to send data packets from the device attached to the access port on the Cisco IP Phone. The PC can generate packets with an assigned CoS value. You can configure the phone to not change (trust) or to override (not trust) the priority of frames arriving on the phone port from connected devices.

Beginning in privileged EXEC mode, follow these steps to set the priority of data traffic received from the nonvoice port on the Cisco IP Phone:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the interface connected to the Cisco IP Phone, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
| **Step 3** switchport priority extend \{cos value | trust\} | Set the priority of data traffic received from the Cisco IP Phone access port:  
  - `cos value`—Configure the phone to override the priority received from the PC or the attached device with the specified CoS value. The value is a number from 0 to 7, with 7 as the highest priority. The default priority is `cos 0`.  
  - `trust`—Configure the phone access port to trust the priority received from the PC or the attached device. |
| **Step 4** end                   | Return to privileged EXEC mode.                                          |
| **Step 5** show interfaces interface-id switchport | Verify your entries.                                                   |
| **Step 6** copy running-config startup-config | (Optional) Save your entries in the configuration file.                  |

This example shows how to configure a port connected to a Cisco IP Phone to not change the priority of frames received from the PC or the attached device:

```
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport priority extend trust
Switch(config-if)# end
```

To return the port to its default setting, use the `no switchport priority extend` interface configuration command.

## Displaying Voice VLAN

To display voice VLAN configuration for an interface, use the `show interfaces interface-id switchport` privileged EXEC command.
Configuring STP

This chapter describes how to configure the Spanning Tree Protocol (STP) on port-based VLANs on the switch. The switch can use either the per-VLAN spanning-tree plus (PVST+) protocol based on the IEEE 802.1D standard and Cisco proprietary extensions, or the rapid per-VLAN spanning-tree plus (rapid-PVST+) protocol based on the IEEE 802.1w standard.

For information about the Multiple Spanning Tree Protocol (MSTP) and how to map multiple VLANs to the same spanning-tree instance, see Chapter 13, “Configuring MSTP.” For information about other spanning-tree features such as Port Fast, UplinkFast, root guard, and so forth, see Chapter 14, “Configuring Optional Spanning-Tree Features.”

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Understanding Spanning-Tree Features, page 12-1
- Configuring Spanning-Tree Features, page 12-10
- Displaying the Spanning-Tree Status, page 12-22

Understanding Spanning-Tree Features

These sections contain this conceptual information:
- STP Overview, page 12-2
- Spanning-Tree Topology and BPDUs, page 12-3
- Bridge ID, Switch Priority, and Extended System ID, page 12-4
- Spanning-Tree Interface States, page 12-4
- How a Switch or Port Becomes the Root Switch or Root Port, page 12-7
- Spanning Tree and Redundant Connectivity, page 12-8
- Spanning-Tree Address Management, page 12-8
- Accelerated Aging to Retain Connectivity, page 12-8
- Spanning-Tree Modes and Protocols, page 12-9
- Supported Spanning-Tree Instances, page 12-9
Understanding Spanning-Tree Features

- Spanning-Tree Interoperability and Backward Compatibility, page 12-10
- STP and IEEE 802.1Q Trunks, page 12-10

For configuration information, see the “Configuring Spanning-Tree Features” section on page 12-10.

For information about optional spanning-tree features, see Chapter 14, “Configuring Optional Spanning-Tree Features.”

**STP Overview**

STP is a Layer 2 link management protocol that provides path redundancy while preventing loops in the network. For a Layer 2 Ethernet network to function properly, only one active path can exist between any two stations. Multiple active paths among end stations cause loops in the network. If a loop exists in the network, end stations might receive duplicate messages. Switches might also learn end-station MAC addresses on multiple Layer 2 interfaces. These conditions result in an unstable network. Spanning-tree operation is transparent to end stations, which cannot detect whether they are connected to a single LAN segment or a switched LAN of multiple segments.

The STP uses a spanning-tree algorithm to select one switch of a redundantly connected network as the root of the spanning tree. The algorithm calculates the best loop-free path through a switched Layer 2 network by assigning a role to each port based on the role of the port in the active topology:

- **Root**—A forwarding port elected for the spanning-tree topology
- **Designated**—A forwarding port elected for every switched LAN segment
- **Alternate**—A blocked port providing an alternate path to the root bridge in the spanning tree
- **Backup**—A blocked port in a loopback configuration

The switch that has all of its ports as the designated role or as the backup role is the root switch. The switch that has at least one of its ports in the designated role is called the designated switch.

Spanning tree forces redundant data paths into a standby (blocked) state. If a network segment in the spanning tree fails and a redundant path exists, the spanning-tree algorithm recalculates the spanning-tree topology and activates the standby path. Switches send and receive spanning-tree frames, called bridge protocol data units (BPDU), at regular intervals. The switches do not forward these frames but use them to construct a loop-free path. BPDU contains information about the sending switch and its ports, including switch and MAC addresses, switch priority, port priority, and path cost. Spanning tree uses this information to elect the root switch and root port for the switched network and the root port and designated port for each switched segment.

When two ports on a switch are part of a loop, the spanning-tree port priority and path cost settings control which port is put in the forwarding state and which is put in the blocking state. The spanning-tree port priority value represents the location of a port in the network topology and how well it is located to pass traffic. The path cost value represents the media speed.

Note

- The switch sends keepalive messages (to ensure the connection is up) only on interfaces that do not have small form-factor pluggable (SFP) modules.
Spanning-Tree Topology and BPDUs

The stable, active spanning-tree topology of a switched network is controlled by these elements:

- The unique bridge ID (switch priority and MAC address) associated with each VLAN on each switch.
- The spanning-tree path cost to the root switch.
- The port identifier (port priority and MAC address) associated with each Layer 2 interface.

When the switches in a network are powered up, each functions as the root switch. Each switch sends a configuration BPDU through all of its ports. The BPDUs communicate and compute the spanning-tree topology. Each configuration BPDU contains this information:

- The unique bridge ID of the switch that the sending switch identifies as the root switch
- The spanning-tree path cost to the root
- The bridge ID of the sending switch
- Message age
- The identifier of the sending interface
- Values for the hello, forward delay, and max-age protocol timers

When a switch receives a configuration BPDU that contains superior information (lower bridge ID, lower path cost, and so forth), it stores the information for that port. If this BPDU is received on the root port of the switch, the switch also forwards it with an updated message to all attached LANs for which it is the designated switch.

If a switch receives a configuration BPDU that contains inferior information to that currently stored for that port, it discards the BPDU. If the switch is a designated switch for the LAN from which the inferior BPDU was received, it sends that LAN a BPDU containing the up-to-date information stored for that port. In this way, inferior information is discarded, and superior information is propagated on the network.

A BPDU exchange results in these actions:

- One switch in the network is elected as the root switch (the logical center of the spanning-tree topology in a switched network).
  
  For each VLAN, the switch with the highest switch priority (the lowest numerical priority value) is elected as the root switch. If all switches are configured with the default priority (32768), the switch with the lowest MAC address in the VLAN becomes the root switch. The switch priority value occupies the most significant bits of the bridge ID, as shown in Table 12-1 on page 12-4.

- A root port is selected for each switch (except the root switch). This port provides the best path (lowest cost) when the switch forwards packets to the root switch.

- The shortest distance to the root switch is calculated for each switch based on the path cost.

- A designated switch for each LAN segment is selected. The designated switch incurs the lowest path cost when forwarding packets from that LAN to the root switch. The port through which the designated switch is attached to the LAN is called the designated port.

All paths that are not needed to reach the root switch from anywhere in the switched network are placed in the spanning-tree blocking mode.
Bridge ID, Switch Priority, and Extended System ID

The IEEE 802.1D standard requires that each switch has a unique bridge identifier (bridge ID), which controls the selection of the root switch. Because each VLAN is considered as a different logical bridge with PVST+ and rapid PVST+, the same switch must have a different bridge IDs for each configured VLAN. Each VLAN on the switch has a unique 8-byte bridge ID. The 2 most-significant bytes are used for the switch priority, and the remaining 6 bytes are derived from the switch MAC address.

The switch supports the IEEE 802.1t spanning-tree extensions, and some of the bits previously used for the switch priority are now used as the VLAN identifier. The result is that fewer MAC addresses are reserved for the switch, and a larger range of VLAN IDs can be supported, all while maintaining the uniqueness of the bridge ID. As shown in Table 12-1, the 2 bytes previously used for the switch priority are reallocated into a 4-bit priority value and a 12-bit extended system ID value equal to the VLAN ID.

Spanning tree uses the extended system ID, the switch priority, and the allocated spanning-tree MAC address to make the bridge ID unique for each VLAN.

Support for the extended system ID affects how you manually configure the root switch, the secondary root switch, and the switch priority of a VLAN. For example, when you change the switch priority value, you change the probability that the switch will be elected as the root switch. Configuring a higher value decreases the probability; a lower value increases the probability. For more information, see the “Configuring the Root Switch” section on page 12-14, the “Configuring a Secondary Root Switch” section on page 12-16, and the “Configuring the Switch Priority of a VLAN” section on page 12-19.

### Table 12-1 Switch Priority Value and Extended System ID

<table>
<thead>
<tr>
<th>Switch Priority Value</th>
<th>Extended System ID (Set Equal to the VLAN ID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit 16</td>
<td>Bit 15</td>
</tr>
<tr>
<td>32768</td>
<td>16384</td>
</tr>
</tbody>
</table>

Spanning-Tree Interface States

Propagation delays can occur when protocol information passes through a switched LAN. As a result, topology changes can take place at different times and at different places in a switched network. When an interface transitions directly from nonparticipation in the spanning-tree topology to the forwarding state, it can create temporary data loops. Interfaces must wait for new topology information to propagate through the switched LAN before starting to forward frames. They must allow the frame lifetime to expire for forwarded frames that have used the old topology.

Each Layer 2 interface on a switch using spanning tree exists in one of these states:

- **Blocking**—The interface does not participate in frame forwarding.
- **Listening**—The first transitional state after the blocking state when the spanning tree decides that the interface should participate in frame forwarding.
- **Learning**—The interface prepares to participate in frame forwarding.
- **Forwarding**—The interface forwards frames.
- **Disabled**—The interface is not participating in spanning tree because of a shutdown port, no link on the port, or no spanning-tree instance running on the port.
An interface moves through these states:

- From initialization to blocking
- From blocking to listening or to disabled
- From listening to learning or to disabled
- From learning to forwarding or to disabled
- From forwarding to disabled

Figure 12-1 illustrates how an interface moves through the states.

**Figure 12-1  Spanning-Tree Interface States**

When you power up the switch, spanning tree is enabled by default, and every interface in the switch, VLAN, or network goes through the blocking state and the transitory states of listening and learning. Spanning tree stabilizes each interface at the forwarding or blocking state.

When the spanning-tree algorithm places a Layer 2 interface in the forwarding state, this process occurs:

1. The interface is in the listening state while spanning tree waits for protocol information to move the interface to the blocking state.
2. While spanning tree waits the forward-delay timer to expire, it moves the interface to the learning state and resets the forward-delay timer.
3. In the learning state, the interface continues to block frame forwarding as the switch learns end-station location information for the forwarding database.
4. When the forward-delay timer expires, spanning tree moves the interface to the forwarding state, where both learning and frame forwarding are enabled.
**Blocking State**

A Layer 2 interface in the blocking state does not participate in frame forwarding. After initialization, a BPDU is sent to each switch interface. A switch initially functions as the root until it exchanges BPDUs with other switches. This exchange establishes which switch in the network is the root or root switch. If there is only one switch in the network, no exchange occurs, the forward-delay timer expires, and the interface moves to the listening state. An interface always enters the blocking state after switch initialization.

An interface in the blocking state performs these functions:
- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Receives BPDUs

**Listening State**

The listening state is the first state a Layer 2 interface enters after the blocking state. The interface enters this state when the spanning tree decides that the interface should participate in frame forwarding.

An interface in the listening state performs these functions:
- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Receives BPDUs

**Learning State**

A Layer 2 interface in the learning state prepares to participate in frame forwarding. The interface enters the learning state from the listening state.

An interface in the learning state performs these functions:
- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Learns addresses
- Receives BPDUs

**Forwarding State**

A Layer 2 interface in the forwarding state forwards frames. The interface enters the forwarding state from the learning state.

An interface in the forwarding state performs these functions:
- Receives and forwards frames received on the interface
- Forwards frames switched from another interface
- Learns addresses
- Receives BPDUs
Disabled State

A Layer 2 interface in the disabled state does not participate in frame forwarding or in the spanning tree. An interface in the disabled state is nonoperational.

A disabled interface performs these functions:

- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Does not receive BPDUs

How a Switch or Port Becomes the Root Switch or Root Port

If all switches in a network are enabled with default spanning-tree settings, the switch with the lowest MAC address becomes the root switch. In Figure 12-2, Switch A is elected as the root switch because the switch priority of all the switches is set to the default (32768) and Switch A has the lowest MAC address. However, because of traffic patterns, number of forwarding interfaces, or link types, Switch A might not be the ideal root switch. By increasing the priority (lowering the numerical value) of the ideal switch so that it becomes the root switch, you force a spanning-tree recalculation to form a new topology with the ideal switch as the root.

![Figure 12-2  Spanning-Tree Topology](image)

When the spanning-tree topology is calculated based on default parameters, the path between source and destination end stations in a switched network might not be ideal. For instance, connecting higher-speed links to an interface that has a higher number than the root port can cause a root-port change. The goal is to make the fastest link the root port.

For example, assume that one port on Switch B is a Gigabit Ethernet link and that another port on Switch B (a 10/100 link) is the root port. Network traffic might be more efficient over the Gigabit Ethernet link. By changing the spanning-tree port priority on the Gigabit Ethernet port to a higher priority (lower numerical value) than the root port, the Gigabit Ethernet port becomes the new root port.
Spanning Tree and Redundant Connectivity

You can create a redundant backbone with spanning tree by connecting two switch interfaces to another device or to two different devices, as shown in Figure 12-3. Spanning tree automatically disables one interface but enables it if the other one fails. If one link is high-speed and the other is low-speed, the low-speed link is always disabled. If the speeds are the same, the port priority and port ID are added together, and spanning tree disables the link with the lowest value.

![Figure 12-3 Spanning Tree and Redundant Connectivity](image)

You can also create redundant links between switches by using EtherChannel groups. For more information, see Chapter 28, “Configuring EtherChannels and Layer 2 Trunk Failover.”

Spanning-Tree Address Management

IEEE 802.1D specifies 17 multicast addresses, ranging from 0x00180C200000 to 0x0180C2000010, to be used by different bridge protocols. These addresses are static addresses that cannot be removed.

Regardless of the spanning-tree state, each switch receives but does not forward packets destined for addresses between 0x0180C2000000 and 0x0180C2000010.

If spanning tree is enabled, the CPU on the switch receives packets destined for 0x0180C2000000 and 0x0180C2000010. If spanning tree is disabled, the switch forwards those packets as unknown multicast addresses.

Accelerated Aging to Retain Connectivity

The default for aging dynamic addresses is 5 minutes, the default setting of the `mac address-table aging-time` global configuration command. However, a spanning-tree reconfiguration can cause many station locations to change. Because these stations could be unreachable for 5 minutes or more during a reconfiguration, the address-aging time is accelerated so that station addresses can be dropped from the address table and then relearned. The accelerated aging is the same as the forward-delay parameter value (spanning-tree vlan vlan-id forward-time seconds global configuration command) when the spanning tree reconfigures.
Because each VLAN is a separate spanning-tree instance, the switch accelerates aging on a per-VLAN basis. A spanning-tree reconfiguration on one VLAN can cause the dynamic addresses learned on that VLAN to be subject to accelerated aging. Dynamic addresses on other VLANs can be unaffected and remain subject to the aging interval entered for the switch.

**Spanning-Tree Modes and Protocols**

The switch supports these spanning-tree modes and protocols:

- **PVST+**—This spanning-tree mode is based on the IEEE 802.1D standard and Cisco proprietary extensions. It is the default spanning-tree mode used on all Ethernet port-based VLANs. The PVST+ runs on each VLAN on the switch up to the maximum supported, ensuring that each has a loop-free path through the network.
  
  The PVST+ provides Layer 2 load balancing for the VLAN on which it runs. You can create different logical topologies by using the VLANs on your network to ensure that all of your links are used but that no one link is oversubscribed. Each instance of PVST+ on a VLAN has a single root switch. This root switch propagates the spanning-tree information associated with that VLAN to all other switches in the network. Because each switch has the same information about the network, this process ensures that the network topology is maintained.

- **Rapid PVST+**—This spanning-tree mode is the same as PVST+ except that it uses a rapid convergence based on the IEEE 802.1w standard. To provide rapid convergence, the rapid PVST+ immediately deletes dynamically learned MAC address entries on a per-port basis upon receiving a topology change. By contrast, PVST+ uses a short aging time for dynamically learned MAC address entries.
  
  The rapid PVST+ uses the same configuration as PVST+ (except where noted), and the switch needs only minimal extra configuration. The benefit of rapid PVST+ is that you can migrate a large PVST+ install base to rapid PVST+ without having to learn the complexities of the MSTP configuration and without having to reprovision your network. In rapid-PVST+ mode, each VLAN runs its own spanning-tree instance up to the maximum supported.

- **MSTP**—This spanning-tree mode is based on the IEEE 802.1s standard. You can map multiple VLANs to the same spanning-tree instance, which reduces the number of spanning-tree instances required to support a large number of VLANs. The MSTP runs on top of the RSTP (based on IEEE 802.1w), which provides for rapid convergence of the spanning tree by eliminating the forward delay and by quickly transitioning root ports and designated ports to the forwarding state. You cannot run MSTP without RSTP.
  
  The most common initial deployment of MSTP is in the backbone and distribution layers of a Layer 2 switched network. For more information, see Chapter 13, “Configuring MSTP.”

For information about the number of supported spanning-tree instances, see the next section.

**Supported Spanning-Tree Instances**

In PVST+ or rapid-PVST+ mode, the switch supports up to 128 spanning-tree instances.

In MSTP mode, the switch supports up to 65 MST instances. The number of VLANs that can be mapped to a particular MST instance is unlimited.

For information about how spanning tree interoperates with the VLAN Trunking Protocol (VTP), see the “Spanning-Tree Configuration Guidelines” section on page 12-12.
Spanning-Tree Interoperability and Backward Compatibility

Table 12-2 lists the interoperability and compatibility among the supported spanning-tree modes in a network.

<table>
<thead>
<tr>
<th>PVST+</th>
<th>MSTP</th>
<th>Rapid PVST+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVST+</td>
<td>Yes</td>
<td>Yes (reverts to PVST+)</td>
</tr>
<tr>
<td>MSTP</td>
<td>Yes (with restrictions)</td>
<td>Yes (reverts to PVST+)</td>
</tr>
<tr>
<td>Rapid PVST+</td>
<td>Yes (reverts to PVST+)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In a mixed MSTP and PVST+ network, the common spanning-tree (CST) root must be inside the MST backbone, and a PVST+ switch cannot connect to multiple MST regions.

When a network contains switches running rapid PVST+ and switches running PVST+, we recommend that the rapid-PVST+ switches and PVST+ switches be configured for different spanning-tree instances. In the rapid-PVST+ spanning-tree instances, the root switch must be a rapid-PVST+ switch. In the PVST+ instances, the root switch must be a PVST+ switch. The PVST+ switches should be at the edge of the network.

STP and IEEE 802.1Q Trunks

The IEEE 802.1Q standard for VLAN trunks imposes some limitations on the spanning-tree strategy for a network. The standard requires only one spanning-tree instance for all VLANs allowed on the trunks. However, in a network of Cisco switches connected through IEEE 802.1Q trunks, the switches maintain one spanning-tree instance for each VLAN allowed on the trunks.

When you connect a Cisco switch to a non-Cisco device through an IEEE 802.1Q trunk, the Cisco switch uses PVST+ to provide spanning-tree interoperability. If rapid PVST+ is enabled, the switch uses it instead of PVST+. The switch combines the spanning-tree instance of the IEEE 802.1Q VLAN of the trunk with the spanning-tree instance of the non-Cisco IEEE 802.1Q switch.

However, all PVST+ or rapid-PVST+ information is maintained by Cisco switches separated by a cloud of non-Cisco IEEE 802.1Q switches. The non-Cisco IEEE 802.1Q cloud separating the Cisco switches is treated as a single trunk link between the switches.

PVST+ is automatically enabled on IEEE 802.1Q trunks, and no user configuration is required. The external spanning-tree behavior on access ports and Inter-Switch Link (ISL) trunk ports is not affected by PVST+.

For more information on IEEE 802.1Q trunks, see Chapter 9, “Configuring VLANs.”

Configuring Spanning-Tree Features

These sections contain this configuration information:

- Default Spanning-Tree Configuration, page 12-11
- Spanning-Tree Configuration Guidelines, page 12-12
- Changing the Spanning-Tree Mode., page 12-13 (required)
Default Spanning-Tree Configuration

Table 12-3 shows the default spanning-tree configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable state</td>
<td>Enabled on VLAN 1. For more information, see the “Supported Spanning-Tree Instances” section on page 12-9.</td>
</tr>
<tr>
<td>Spanning-tree mode</td>
<td>PVST+. (Rapid PVST+ and MSTP are disabled.)</td>
</tr>
<tr>
<td>Switch priority</td>
<td>32768.</td>
</tr>
<tr>
<td>Spanning-tree port priority (configurable on a per-interface basis)</td>
<td>128.</td>
</tr>
<tr>
<td>Spanning-tree port cost (configurable on a per-interface basis)</td>
<td>1000 Mb/s: 4. 100 Mb/s: 19. 10 Mb/s: 100.</td>
</tr>
<tr>
<td>Spanning-tree VLAN port priority (configurable on a per-VLAN basis)</td>
<td>128.</td>
</tr>
<tr>
<td>Spanning-tree VLAN port cost (configurable on a per-VLAN basis)</td>
<td>1000 Mb/s: 4. 100 Mb/s: 19. 10 Mb/s: 100.</td>
</tr>
<tr>
<td>Spanning-tree timers</td>
<td>Hello time: 2 seconds. Forward-delay time: 15 seconds. Maximum-aging time: 20 seconds. Transmit hold count: 6 BPDUs</td>
</tr>
</tbody>
</table>
Spanning-Tree Configuration Guidelines

If more VLANs are defined in the VTP than there are spanning-tree instances, you can enable PVST+ or rapid PVST+ on only 128 VLANs on the switch. The remaining VLANs operate with spanning tree disabled. However, you can map multiple VLANs to the same spanning-tree instances by using MSTP. For more information, see Chapter 13, “Configuring MSTP.”

If 128 instances of spanning tree are already in use, you can disable spanning tree on one of the VLANs and then enable it on the VLAN where you want it to run. Use the `no spanning-tree vlan vlan-id` global configuration command to disable spanning tree on a specific VLAN, and use the `spanning-tree vlan vlan-id` global configuration command to enable spanning tree on the desired VLAN.

**Caution**

Switches that are not running spanning tree still forward BPDUs that they receive so that the other switches on the VLAN that have a running spanning-tree instance can break loops. Therefore, spanning tree must be running on enough switches to break all the loops in the network; for example, at least one switch on each loop in the VLAN must be running spanning tree. It is not absolutely necessary to run spanning tree on all switches in the VLAN. However, if you are running spanning tree only on a minimal set of switches, an incautious change to the network that introduces another loop into the VLAN can result in a broadcast storm.

**Note**

If you have already used all available spanning-tree instances on your switch, adding another VLAN anywhere in the VTP domain creates a VLAN that is not running spanning tree on that switch. If you have the default allowed list on the trunk ports of that switch, the new VLAN is carried on all trunk ports. Depending on the topology of the network, this could create a loop in the new VLAN that will not be broken, particularly if there are several adjacent switches that have all run out of spanning-tree instances. You can prevent this possibility by setting up allowed lists on the trunk ports of switches that have used up their allocation of spanning-tree instances. Setting up allowed lists is not necessary in many cases and can make it more labor-intensive to add another VLAN to the network.

Spanning-tree commands control the configuration of VLAN spanning-tree instances. You create a spanning-tree instance when you assign an interface to a VLAN. The spanning-tree instance is removed when the last interface is moved to another VLAN. You can configure switch and port parameters before a spanning-tree instance is created; these parameters are applied when the spanning-tree instance is created.

The switch supports PVST+, rapid PVST+, and MSTP, but only one version can be active at any time. (For example, all VLANs run PVST+, all VLANs run rapid PVST+, or all VLANs run MSTP.) For information about the different spanning-tree modes and how they interoperate, see the “Spanning-Tree Interoperability and Backward Compatibility” section on page 12-10.

For configuration guidelines about UplinkFast and BackboneFast, see the “Optional Spanning-Tree Configuration Guidelines” section on page 14-10.

**Caution**

Loop guard works only on point-to-point links. We recommend that each end of the link has a directly connected device that is running STP.
## Changing the Spanning-Tree Mode.

The switch supports three spanning-tree modes: PVST+, rapid PVST+, or MSTP. By default, the switch runs the PVST+ protocol.

Beginning in privileged EXEC mode, follow these steps to change the spanning-tree mode. If you want to enable a mode that is different from the default mode, this procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> spanning-tree mode { pvst</td>
<td>mst</td>
</tr>
<tr>
<td></td>
<td>- Select <strong>pvst</strong> to enable PVST+ (the default setting).</td>
</tr>
<tr>
<td></td>
<td>- Select <strong>mst</strong> to enable MSTP (and RSTP). For more configuration steps, see Chapter 13, “Configuring MSTP.”</td>
</tr>
<tr>
<td></td>
<td>- Select <strong>rapid-pvst</strong> to enable rapid PVST+.</td>
</tr>
<tr>
<td><strong>Step 3</strong> interface interface-id</td>
<td>(Recommended for rapid-PVST+ mode only) Specify an interface to configure, and enter interface configuration mode. Valid interfaces include physical ports, VLANs, and port channels. The VLAN ID range is 1 to 4094. The port-channel range is 1 to 48.</td>
</tr>
<tr>
<td><strong>Step 4</strong> spanning-tree link-type point-to-point</td>
<td>(Recommended for rapid-PVST+ mode only) Specify that the link type for this port is point-to-point.</td>
</tr>
<tr>
<td></td>
<td>If you connect this port (local port) to a remote port through a point-to-point link and the local port becomes a designated port, the switch negotiates with the remote port and rapidly changes the local port to the forwarding state.</td>
</tr>
<tr>
<td><strong>Step 5</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 6</strong> clear spanning-tree detected-protocols</td>
<td>(Recommended for rapid-PVST+ mode only) If any port on the switch is connected to a port on a legacy IEEE 802.1D switch, restart the protocol migration process on the entire switch.</td>
</tr>
<tr>
<td></td>
<td>This step is optional if the designated switch detects that this switch is running rapid PVST+.</td>
</tr>
<tr>
<td><strong>Step 7</strong> show spanning-tree summary and</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>show spanning-tree interface interface-id</td>
<td></td>
</tr>
<tr>
<td><strong>Step 8</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the **no spanning-tree mode** global configuration command. To return the port to its default setting, use the **no spanning-tree link-type** interface configuration command.
Disabling Spanning Tree

Spanning tree is enabled by default on VLAN 1 and on all newly created VLANs up to the spanning-tree limit specified in the “Supported Spanning-Tree Instances” section on page 12-9. Disable spanning tree only if you are sure there are no loops in the network topology.

Caution

When spanning tree is disabled and loops are present in the topology, excessive traffic and indefinite packet duplication can drastically reduce network performance.

Beginning in privileged EXEC mode, follow these steps to disable spanning-tree on a per-VLAN basis. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 no spanning-tree vlan</td>
<td>For vlan-id, the range is 1 to 4094.</td>
</tr>
<tr>
<td>vlan-id</td>
<td></td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show spanning-tree vlan</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>vlan-id</td>
<td></td>
</tr>
<tr>
<td>Step 5 copy running-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
<tr>
<td>startup-config</td>
<td></td>
</tr>
</tbody>
</table>

To re-enable spanning-tree, use the spanning-tree vlan vlan-id global configuration command.

Configuring the Root Switch

The switch maintains a separate spanning-tree instance for each active VLAN configured on it. A bridge ID, consisting of the switch priority and the switch MAC address, is associated with each instance. For each VLAN, the switch with the lowest bridge ID becomes the root switch for that VLAN.

To configure a switch to become the root for the specified VLAN, use the spanning-tree vlan vlan-id root global configuration command to modify the switch priority from the default value (32768) to a significantly lower value. When you enter this command, the software checks the switch priority of the root switches for each VLAN. Because of the extended system ID support, the switch sets its own priority for the specified VLAN to 24576 if this value will cause this switch to become the root for the specified VLAN.

If any root switch for the specified VLAN has a switch priority lower than 24576, the switch sets its own priority for the specified VLAN to 4096 less than the lowest switch priority. (4096 is the value of the least-significant bit of a 4-bit switch priority value as shown in Table 12-1 on page 12-4.)

Note

The spanning-tree vlan vlan-id root global configuration command fails if the value necessary to be the root switch is less than 1.

Note

If your network consists of switches that both do and do not support the extended system ID, it is unlikely that the switch with the extended system ID support will become the root switch. The extended system ID increases the switch priority value every time the VLAN number is greater than the priority of the connected switches running older software.
Note: The root switch for each spanning-tree instance should be a backbone or distribution switch. Do not configure an access switch as the spanning-tree primary root.

Use the **diameter** keyword to specify the Layer 2 network diameter (that is, the maximum number of switch hops between any two end stations in the Layer 2 network). When you specify the network diameter, the switch automatically sets an optimal hello time, forward-delay time, and maximum-age time for a network of that diameter, which can significantly reduce the convergence time. You can use the **hello** keyword to override the automatically calculated hello time.

Note: After configuring the switch as the root switch, we recommend that you avoid manually configuring the hello time, forward-delay time, and maximum-age time through the `spanning-tree vlan vlan-id hello-time`, `spanning-tree vlan vlan-id forward-time`, and the `spanning-tree vlan vlan-id max-age` global configuration commands.

Beginning in privileged EXEC mode, follow these steps to configure a switch to become the root for the specified VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>spanning-tree vlan vlan-id root primary</code></td>
</tr>
<tr>
<td>[diameter net-diameter [hello-time seconds]]</td>
<td>Configure a switch to become the root for the specified VLAN.</td>
</tr>
<tr>
<td></td>
<td>• For <code>vlan-id</code>, you can specify a single VLAN identified by VLAN ID number, a range of</td>
</tr>
<tr>
<td></td>
<td>VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to</td>
</tr>
<tr>
<td></td>
<td>4094.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>diameter net-diameter</code>, specify the maximum number of switches between</td>
</tr>
<tr>
<td></td>
<td>any two end stations. The range is 2 to 7.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>hello-time seconds</code>, specify the interval in seconds between the</td>
</tr>
<tr>
<td></td>
<td>generation of configuration messages by the root switch. The range is 1 to 10; the default</td>
</tr>
<tr>
<td></td>
<td>is 2.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>end</code></td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>show spanning-tree detail</code></td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>copy running-config startup-config</code></td>
</tr>
<tr>
<td></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id root` global configuration command.
Configuring a Secondary Root Switch

When you configure a switch as the secondary root, the switch priority is modified from the default value (32768) to 28672. The switch is then likely to become the root switch for the specified VLAN if the primary root switch fails. This is assuming that the other network switches use the default switch priority of 32768 and therefore are unlikely to become the root switch.

You can execute this command on more than one switch to configure multiple backup root switches. Use the same network diameter and hello-time values that you used when you configured the primary root switch with the `spanning-tree vlan vlan-id root primary` global configuration command.

Beginning in privileged EXEC mode, follow these steps to configure a switch to become the secondary root for the specified VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree vlan vlan-id root secondary [diameter net-diameter [hello-time seconds]]</td>
</tr>
<tr>
<td></td>
<td>• For <code>vlan-id</code>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>diameter net-diameter</code>, specify the maximum number of switches between any two end stations. The range is 2 to 7.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>hello-time seconds</code>, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10; the default is 2.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree detail</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id root` global configuration command.

Configuring Port Priority

If a loop occurs, spanning tree uses the port priority when selecting an interface to put into the forwarding state. You can assign higher priority values (lower numerical values) to interfaces that you want selected first and lower priority values (higher numerical values) that you want selected last. If all interfaces have the same priority value, spanning tree puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.
Beginning in privileged EXEC mode, follow these steps to configure the port priority of an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td></td>
<td>Specify an interface to configure, and enter interface configuration mode. Valid interfaces include physical ports and port-channel logical interfaces (port-channel port-channel-number).</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>spanning-tree port-priority priority</td>
</tr>
<tr>
<td></td>
<td>Configure the port priority for an interface. For priority, the range is 0 to 240, in increments of 16; the default is 128. Valid values are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. All other values are rejected. The lower the number, the higher the priority.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>spanning-tree vlan vlan-id port-priority priority</td>
</tr>
</tbody>
</table>
| | Configure the port priority for a VLAN.  
  - For vlan-id, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094.  
  - For priority, the range is 0 to 240, in increments of 16; the default is 128. Valid values are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. All other values are rejected. The lower the number, the higher the priority. |
| **Step 5** | end |
| | Return to privileged EXEC mode. |
| **Step 6** | show spanning-tree interface interface-id |
| or | show spanning-tree vlan vlan-id |
| | Verify your entries. |
| **Step 7** | copy running-config startup-config |
| | (Optional) Save your entries in the configuration file. |

**Note**  
The **show spanning-tree interface interface-id** privileged EXEC command displays information only if the port is in a link-up operative state. Otherwise, you can use the **show running-config interface** privileged EXEC command to confirm the configuration.

To return to the default setting, use the **no spanning-tree [vlan vlan-id] port-priority** interface configuration command. For information on how to configure load sharing on trunk ports by using spanning-tree port priorities, see the “Configuring Trunk Ports for Load Sharing” section on page 9-22.
Chapter 12  Configuring STP

Configuring Path Cost

The spanning-tree path cost default value is derived from the media speed of an interface. If a loop occurs, spanning tree uses cost when selecting an interface to put in the forwarding state. You can assign lower cost values to interfaces that you want selected first and higher cost values that you want selected last. If all interfaces have the same cost value, spanning tree puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

Beginning in privileged EXEC mode, follow these steps to configure the cost of an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>spanning-tree cost cost</td>
</tr>
<tr>
<td>Step 4</td>
<td>spanning-tree vlan vlan-id cost cost</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td>Step 6</td>
<td>show spanning-tree interface interface-id</td>
</tr>
<tr>
<td>Step 7</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

Note The show spanning-tree interface interface-id privileged EXEC command displays information only for ports that are in a link-up operative state. Otherwise, you can use the show running-config privileged EXEC command to confirm the configuration.
To return to the default setting, use the `no spanning-tree vlan vlan-id cost` interface configuration command. For information on how to configure load sharing on trunk ports by using spanning-tree path costs, see the “Configuring Trunk Ports for Load Sharing” section on page 9-22.

## Configuring the Switch Priority of a VLAN

You can configure the switch priority and make it more likely that the switch will be chosen as the root switch.

**Note**

Exercise care when using this command. For most situations, we recommend that you use the `spanning-tree vlan vlan-id root primary` and the `spanning-tree vlan vlan-id root secondary` global configuration commands to modify the switch priority.

Beginning in privileged EXEC mode, follow these steps to configure the switch priority of a VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> spanning-tree vlan vlan-id priority priority</td>
<td>Configure the switch priority of a VLAN.</td>
</tr>
<tr>
<td>- For <code>vlan-id</code>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094.</td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong> show spanning-tree vlan vlan-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id priority` global configuration command.
Configuring Spanning-Tree Timers

Table 12-4 describes the timers that affect the entire spanning-tree performance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hello timer</td>
<td>Controls how often the switch broadcasts hello messages to other switches.</td>
</tr>
<tr>
<td>Forward-delay timer</td>
<td>Controls how long each of the listening and learning states last before the interface begins forwarding.</td>
</tr>
<tr>
<td>Maximum-age timer</td>
<td>Controls the amount of time the switch stores protocol information received on an interface.</td>
</tr>
<tr>
<td>Transmit hold count</td>
<td>Controls the number of BPDUs that can be sent before pausing for 1 second.</td>
</tr>
</tbody>
</table>

The sections that follow provide the configuration steps.

Configuring the Hello Time

You can configure the interval between the generation of configuration messages by the root switch by changing the hello time.

**Note**

Exercise care when using this command. For most situations, we recommend that you use the `spanning-tree vlan vlan-id root primary` and the `spanning-tree vlan vlan-id root secondary` global configuration commands to modify the hello time.

Beginning in privileged EXEC mode, follow these steps to configure the hello time of a VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>Command</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>spanning-tree vlan vlan-id hello-time seconds</td>
<td>Configure the hello time of a VLAN. The hello time is the interval between the generation of configuration messages by the root switch. These messages mean that the switch is alive.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 3</strong></td>
</tr>
<tr>
<td></td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 4</strong></td>
</tr>
<tr>
<td></td>
<td>show spanning-tree vlan vlan-id</td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 5</strong></td>
</tr>
<tr>
<td></td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id hello-time` global configuration command.
Configuring the Forwarding-Delay Time for a VLAN

Beginning in privileged EXEC mode, follow these steps to configure the forwarding-delay time for a VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree vlan vlan-id forward-time seconds</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree vlan vlan-id</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id forward-time` global configuration command.

Configuring the Maximum-Aging Time for a VLAN

Beginning in privileged EXEC mode, follow these steps to configure the maximum-aging time for a VLAN. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree vlan vlan-id max-age seconds</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree vlan vlan-id</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree vlan vlan-id max-age` global configuration command.
### Configuring the Transmit Hold-Count

You can configure the BPDU burst size by changing the transmit hold count value.

**Note** Changing this parameter to a higher value can have a significant impact on CPU utilization, especially in Rapid-PVST mode. Lowering this value can slow down convergence in certain scenarios. We recommend that you maintain the default setting.

Beginning in privileged EXEC mode, follow these steps to configure the transmit hold-count. This procedure is optional.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>spanning-tree transmit hold-count value</td>
<td>Configure the number of BPDUs that can be sent before pausing for 1 second. For value, the range is 1 to 20; the default is 6.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>4</td>
<td>show spanning-tree detail</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no spanning-tree transmit hold-count value` global configuration command.

### Displaying the Spanning-Tree Status

To display the spanning-tree status, use one or more of the privileged EXEC commands in Table 12-5:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show spanning-tree active</td>
<td>Displays spanning-tree information on active interfaces only.</td>
</tr>
<tr>
<td>show spanning-tree detail</td>
<td>Displays a detailed summary of interface information.</td>
</tr>
<tr>
<td>show spanning-tree interface interface-id</td>
<td>Displays spanning-tree information for the specified interface.</td>
</tr>
<tr>
<td>show spanning-tree summary [totals]</td>
<td>Displays a summary of interface states or displays the total lines of the STP state section.</td>
</tr>
</tbody>
</table>

You can clear spanning-tree counters by using the `clear spanning-tree [interface interface-id]` privileged EXEC command.

For information about other keywords for the `show spanning-tree` privileged EXEC command, see the command reference for this release.
CHAPTER 13

Configuring MSTP

This chapter describes how to configure the Cisco implementation of the IEEE 802.1s Multiple STP (MSTP) on the switch.

Note

The multiple spanning-tree (MST) implementation in Cisco IOS Release 12.2(25)SEDis based on the IEEE 802.1s standard. The MST implementations in earlier Cisco IOS releases are prestandard.

The MSTP enables multiple VLANs to be mapped to the same spanning-tree instance, reducing the number of spanning-tree instances needed to support a large number of VLANs. The MSTP provides for multiple forwarding paths for data traffic and enables load balancing. It improves the fault tolerance of the network because a failure in one instance (forwarding path) does not affect other instances (forwarding paths). The most common initial deployment of MSTP is in the backbone and distribution layers of a Layer 2 switched network. This deployment provides the highly available network required in a service-provider environment.

When the switch is in the MST mode, the Rapid Spanning Tree Protocol (RSTP), which is based on IEEE 802.1w, is automatically enabled. The RSTP provides rapid convergence of the spanning tree through explicit handshaking that eliminates the IEEE 802.1D forwarding delay and quickly transitions root ports and designated ports to the forwarding state.

Both MSTP and RSTP improve the spanning-tree operation and maintain backward compatibility with equipment that is based on the (original) IEEE 802.1D spanning tree, with existing Cisco-proprietary Multiple Instance STP (MISTP), and with existing Cisco per-VLAN spanning-tree plus (PVST+) and rapid per-VLAN spanning-tree plus (rapid PVST+). For information about PVST+ and rapid PVST+, see Chapter 12, “Configuring STP.” For information about other spanning-tree features such as Port Fast, UplinkFast, root guard, and so forth, see Chapter 14, “Configuring Optional Spanning-Tree Features.”

Note

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:

- Understanding MSTP, page 13-2
- Understanding RSTP, page 13-8
- Configuring MSTP Features, page 13-14
- Displaying the MST Configuration and Status, page 13-26
Understanding MSTP

MSTP, which uses RSTP for rapid convergence, enables VLANs to be grouped into a spanning-tree instance, with each instance having a spanning-tree topology independent of other spanning-tree instances. This architecture provides multiple forwarding paths for data traffic, enables load balancing, and reduces the number of spanning-tree instances required to support a large number of VLANs.

These sections describe how the MSTP works:
- Multiple Spanning-Tree Regions, page 13-2
- IST, CIST, and CST, page 13-3
- Hop Count, page 13-5
- Boundary Ports, page 13-6
- IEEE 802.1s Implementation, page 13-6
- Interoperability with IEEE 802.1D STP, page 13-8

For configuration information, see the “Configuring MSTP Features” section on page 13-14.

Multiple Spanning-Tree Regions

For switches to participate in multiple spanning-tree (MST) instances, you must consistently configure the switches with the same MST configuration information. A collection of interconnected switches that have the same MST configuration comprises an MST region as shown in Figure 13-1 on page 13-4.

The MST configuration controls to which MST region each switch belongs. The configuration includes the name of the region, the revision number, and the MST VLAN-to-instance assignment map. You configure the switch for a region by using the `spanning-tree mst configuration` global configuration command, after which the switch enters the MST configuration mode. From this mode, you can map VLANs to an MST instance by using the `instance` MST configuration command, specify the region name by using the `name` MST configuration command, and set the revision number by using the `revision` MST configuration command.

A region can have one or multiple members with the same MST configuration. Each member must be capable of processing RSTP bridge protocol data units (BPDUs). There is no limit to the number of MST regions in a network, but each region can support up to 65 spanning-tree instances. Instances can be identified by any number in the range from 0 to 4094. You can assign a VLAN to only one spanning-tree instance at a time.
IST, CIST, and CST

Unlike PVST+ and rapid PVST+ in which all the spanning-tree instances are independent, the MSTP establishes and maintains two types of spanning trees:

- An internal spanning tree (IST), which is the spanning tree that runs in an MST region.

  Within each MST region, the MSTP maintains multiple spanning-tree instances. Instance 0 is a special instance for a region, known as the internal spanning tree (IST). All other MST instances are numbered from 1 to 4094.

  The IST is the only spanning-tree instance that sends and receives BPDUs. All of the other spanning-tree instance information is contained in M-records, which are encapsulated within MSTP BPDUs. Because the MSTP BPDU carries information for all instances, the number of BPDUs that need to be processed to support multiple spanning-tree instances is significantly reduced.

  All MST instances within the same region share the same protocol timers, but each MST instance has its own topology parameters, such as root switch ID, root path cost, and so forth. By default, all VLANs are assigned to the IST.

  An MST instance is local to the region; for example, MST instance 1 in region A is independent of MST instance 1 in region B, even if regions A and B are interconnected.

- A common and internal spanning tree (CIST), which is a collection of the ISTs in each MST region, and the common spanning tree (CST) that interconnects the MST regions and single spanning trees.

  The spanning tree computed in a region appears as a subtree in the CST that encompasses the entire switched domain. The CIST is formed by the spanning-tree algorithm running among switches that support the IEEE 802.1w, IEEE 802.1s, and IEEE 802.1D standards. The CIST inside an MST region is the same as the CST outside a region.

For more information, see the “Operations Within an MST Region” section on page 13-3 and the “Operations Between MST Regions” section on page 13-4.

Note

The implementation of the IEEE 802.1s standard, changes some of the terminology associated with MST implementations. For a summary of these changes, see Table 12-1 on page 12-4.

Operations Within an MST Region

The IST connects all the MSTP switches in a region. When the IST converges, the root of the IST becomes the CIST regional root (called the IST master before the implementation of the IEEE 802.1s standard) as shown in Figure 13-1 on page 13-4. It is the switch within the region with the lowest switch ID and path cost to the CIST root. The CIST regional root is also the CIST root if there is only one region in the network. If the CIST root is outside the region, one of the MSTP switches at the boundary of the region is selected as the CIST regional root.

When an MSTP switch initializes, it sends BPDUs claiming itself as the root of the CIST and the CIST regional root, with both of the path costs to the CIST root and to the CIST regional root set to zero. The switch also initializes all of its MST instances and claims to be the root for all of them. If the switch receives superior MST root information (lower switch ID, lower path cost, and so forth) than currently stored for the port, it relinquishes its claim as the CIST regional root.

During initialization, a region might have many subregions, each with its own CIST regional root. As switches receive superior IST information, they leave their old subregions and join the new subregion that contains the true CIST regional root. Thus all subregions shrink, except for the one that contains the true CIST regional root.
For correct operation, all switches in the MST region must agree on the same CIST regional root. Therefore, any two switches in the region only synchronize their port roles for an MST instance if they converge to a common CIST regional root.

### Operations Between MST Regions

If there are multiple regions or legacy IEEE 802.1D switches within the network, MSTP establishes and maintains the CST, which includes all MST regions and all legacy STP switches in the network. The MST instances combine with the IST at the boundary of the region to become the CST.

The IST connects all the MSTP switches in the region and appears as a subtree in the CIST that encompasses the entire switched domain. The root of the subtree is the CIST regional root. The MST region appears as a virtual switch to adjacent STP switches and MST regions.

Figure 13-1 shows a network with three MST regions and a legacy IEEE 802.1D switch (D). The CIST regional root for region 1 (A) is also the CIST root. The CIST regional root for region 2 (B) and the CIST regional root for region 3 (C) are the roots for their respective subtrees within the CIST. The RSTP runs in all regions.

![Figure 13-1 MST Regions, CIST Masters, and CST Root](image)

Only the CST instance sends and receives BPDUs, and MST instances add their spanning-tree information into the BPDUs to interact with neighboring switches and compute the final spanning-tree topology. Because of this, the spanning-tree parameters related to BPDU transmission (for example,
hello time, forward time, max-age, and max-hops) are configured only on the CST instance but affect all MST instances. Parameters related to the spanning-tree topology (for example, switch priority, port VLAN cost, and port VLAN priority) can be configured on both the CST instance and the MST instance. MSTP switches use Version 3 RSTP BPDUs or IEEE 802.1D STP BPDUs to communicate with legacy IEEE 802.1D switches. MSTP switches use MSTP BPDUs to communicate with MSTP switches.

### IEEE 802.1s Terminology

Some MST naming conventions used in Cisco’s prestandard implementation have been changed to identify some *internal* or *regional* parameters. These parameters are significant only within an MST region, as opposed to external parameters that are relevant to the whole network. Because the CIST is the only spanning-tree instance that spans the whole network, only the CIST parameters require the external rather than the internal or regional qualifiers.

- The CIST root is the root switch for the unique instance that spans the whole network, the CIST.
- The CIST external root path cost is the cost to the CIST root. This cost is left unchanged within an MST region. Remember that an MST region looks like a single switch for the CIST. The CIST external root path cost is the root path cost calculated between these virtual switches and switches that do not belong to any region.
- The CIST regional root was called the IST master in the prestandard implementation. If the CIST root is in the region, the CIST regional root is the CIST root. Otherwise, the CIST regional root is the closest switch to the CIST root in the region. The CIST regional root acts as a root switch for the IST.
- The CIST internal root path cost is the cost to the CIST regional root in a region. This cost is only relevant to the IST, instance 0.

Table 13-1 on page 13-5 compares the IEEE standard and the Cisco prestandard terminology.

<table>
<thead>
<tr>
<th>IEEE Standard</th>
<th>Cisco Prestandard</th>
<th>Cisco Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIST regional root</td>
<td>IST master</td>
<td>CIST regional root</td>
</tr>
<tr>
<td>CIST internal root path cost</td>
<td>IST master path cost</td>
<td>CIST internal path cost</td>
</tr>
<tr>
<td>CIST external root path cost</td>
<td>Root path cost</td>
<td>Root path cost</td>
</tr>
<tr>
<td>MSTI regional root</td>
<td>Instance root</td>
<td>Instance root</td>
</tr>
<tr>
<td>MSTI internal root path cost</td>
<td>Root path cost</td>
<td>Root path cost</td>
</tr>
</tbody>
</table>

### Hop Count

The IST and MST instances do not use the message-age and maximum-age information in the configuration BPDU to compute the spanning-tree topology. Instead, they use the path cost to the root and a hop-count mechanism similar to the IP time-to-live (TTL) mechanism.

By using the `spanning-tree mst max-hops` global configuration command, you can configure the maximum hops inside the region and apply it to the IST and all MST instances in that region. The hop count achieves the same result as the message-age information (triggers a reconfiguration). The root switch of the instance always sends a BPDU (or M-record) with a cost of 0 and the hop count set to the
maximum value. When a switch receives this BPDU, it decrements the received remaining hop count by one and propagates this value as the remaining hop count in the BPDU it generates. When the count reaches zero, the switch discards the BPDU and ages the information held for the port.

The message-age and maximum-age information in the RSTP portion of the BPDU remain the same throughout the region, and the same values are propagated by the region designated ports at the boundary.

**Boundary Ports**

In the Cisco prestandard implementation, a boundary port connects an MST region to a single spanning-tree region running RSTP, to a single spanning-tree region running PVST+ or rapid PVST+, or to another MST region with a different MST configuration. A boundary port also connects to a LAN, the designated switch of which is either a single spanning-tree switch or a switch with a different MST configuration.

There is no definition of a boundary port in the IEEE 802.1s standard. The IEEE 802.1Q-2002 standard identifies two kinds of messages that a port can receive: internal (coming from the same region) and external. When a message is external, it is received only by the CIST. If the CIST role is root or alternate, or if the external BPDU is a topology change, it could have an impact on the MST instances. When a message is internal, the CIST part is received by the CIST, and each MST instance receives its respective M-record. The Cisco prestandard implementation treats a port that receives an external message as a boundary port. This means a port cannot receive a mix of internal and external messages.

An MST region includes both switches and LANs. A segment belongs to the region of its designated port. Therefore, a port in a different region than the designated port for a segment is a boundary port. This definition allows two ports internal to a region to share a segment with a port belonging to a different region, creating the possibility of receiving both internal and external messages on a port.

The primary change from the Cisco prestandard implementation is that a designated port is not defined as boundary, unless it is running in an STP-compatible mode.

---

**Note**  
If there is a legacy STP switch on the segment, messages are always considered external.

The other change from the prestandard implementation is that the CIST regional root switch ID field is now inserted where an RSTP or legacy IEEE 802.1Q switch has the sender switch ID. The whole region performs like a single virtual switch by sending a consistent sender switch ID to neighboring switches. In this example, switch C would receive a BPDU with the same consistent sender switch ID of root, whether or not A or B is designated for the segment.

**IEEE 802.1s Implementation**

The Cisco implementation of the IEEE MST standard includes features required to meet the standard, as well as some of the desirable prestandard functionality that is not yet incorporated into the published standard.
Port Role Naming Change

The boundary role is no longer in the final MST standard, but this boundary concept is maintained in Cisco’s implementation. However, an MST instance port at a boundary of the region might not follow the state of the corresponding CIST port. Two cases exist now:

- The boundary port is the root port of the CIST regional root—When the CIST instance port is proposed and is in sync, it can send back an agreement and move to the forwarding state only after all the corresponding MSTI ports are in sync (and thus forwarding). The MSTI ports now have a special master role.

- The boundary port is not the root port of the CIST regional root—The MSTI ports follow the state and role of the CIST port. The standard provides less information, and it might be difficult to understand why an MSTI port can be alternately blocking when it receives no BPDUs (MRecords). In this case, although the boundary role no longer exists, the show commands identify a port as boundary in the type column of the output.

Interoperation Between Legacy and Standard Switches

Because automatic detection of prestandard switches can fail, you can use an interface configuration command to identify prestandard ports. A region cannot be formed between a standard and a prestandard switch, but they can interoperate by using the CIST. Only the capability of load balancing over different instances is lost in that particular case. The CLI displays different flags depending on the port configuration when a port receives prestandard BPDUs. A syslog message also appears the first time a switch receives a prestandard BPDU on a port that has not been configured for prestandard BPDU transmission.

Figure 13-2 illustrates this scenario. Assume that A is a standard switch and B a prestandard switch, both configured to be in the same region. A is the root switch for the CIST, and thus B has a root port (BX) on segment X and an alternate port (BY) on segment Y. If segment Y flaps, and the port on BY becomes the alternate before sending out a single prestandard BPDU, AY cannot detect that a prestandard switch is connected to Y and continues to send standard BPDUs. The port BY is thus fixed in a boundary, and no load balancing is possible between A and B. The same problem exists on segment X, but B might transmit topology changes.

![Figure 13-2 Standard and Prestandard Switch Interoperation](image)

Note: We recommend that you minimize the interaction between standard and prestandard MST implementations.
Detecting Unidirectional Link Failure

This feature is not yet present in the IEEE MST standard, but it is included in this Cisco IOS release. The software checks the consistency of the port role and state in the received BPDUs to detect unidirectional link failures that could cause bridging loops.

When a designated port detects a conflict, it keeps its role, but reverts to discarding state because disrupting connectivity in case of inconsistency is preferable to opening a bridging loop.

Figure 13-3 illustrates a unidirectional link failure that typically creates a bridging loop. Switch A is the root switch, and its BPDUs are lost on the link leading to switch B. RSTP and MST BPDUs include the role and state of the sending port. With this information, switch A can detect that switch B does not react to the superior BPDUs it sends and that switch B is the designated, not root switch. As a result, switch A blocks (or keeps blocking) its port, thus preventing the bridging loop.

Interoperability with IEEE 802.1D STP

A switch running MSTP supports a built-in protocol migration mechanism that enables it to interoperate with legacy IEEE 802.1D switches. If this switch receives a legacy IEEE 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only IEEE 802.1D BPDUs on that port. An MSTP switch also can detect that a port is at the boundary of a region when it receives a legacy BPDU, an MSTP BPDU (Version 3) associated with a different region, or an RSTP BPDU (Version 2).

However, the switch does not automatically revert to the MSTP mode if it no longer receives IEEE 802.1D BPDUs because it cannot detect whether the legacy switch has been removed from the link unless the legacy switch is the designated switch. A switch might also continue to assign a boundary role to a port when the switch to which this switch is connected has joined the region. To restart the protocol migration process (force the renegotiation with neighboring switches), use the clear spanning-tree detected-protocols privileged EXEC command.

If all the legacy switches on the link are RSTP switches, they can process MSTP BPDUs as if they are RSTP BPDUs. Therefore, MSTP switches send either a Version 0 configuration and TCN BPDUs or Version 3 MSTP BPDUs on a boundary port. A boundary port connects to a LAN, the designated switch of which is either a single spanning-tree switch or a switch with a different MST configuration.

Understanding RSTP

The RSTP takes advantage of point-to-point wiring and provides rapid convergence of the spanning tree. Reconfiguration of the spanning tree can occur in less than 1 second (in contrast to 50 seconds with the default settings in the IEEE 802.1D spanning tree).
These sections describe how the RSTP works:

- **Port Roles and the Active Topology, page 13-9**
- **Rapid Convergence, page 13-10**
- **Synchronization of Port Roles, page 13-11**
- **Bridge Protocol Data Unit Format and Processing, page 13-12**

For configuration information, see the “Configuring MSTP Features” section on page 13-14.

**Port Roles and the Active Topology**

The RSTP provides rapid convergence of the spanning tree by assigning port roles and by learning the active topology. The RSTP builds upon the IEEE 802.1D STP to select the switch with the highest switch priority (lowest numerical priority value) as the root switch as described in the “Spanning-Tree Topology and BPDUs” section on page 12-3. Then the RSTP assigns one of these port roles to individual ports:

- Root port—Provides the best path (lowest cost) when the switch forwards packets to the root switch.
- Designated port—Connects to the designated switch, which incurs the lowest path cost when forwarding packets from that LAN to the root switch. The port through which the designated switch is attached to the LAN is called the designated port.
- Alternate port—Offers an alternate path toward the root switch to that provided by the current root port.
- Backup port—Acts as a backup for the path provided by a designated port toward the leaves of the spanning tree. A backup port can exist only when two ports are connected in a loopback by a point-to-point link or when a switch has two or more connections to a shared LAN segment.
- Disabled port—Has no role within the operation of the spanning tree.

A port with the root or a designated port role is included in the active topology. A port with the alternate or backup port role is excluded from the active topology.

In a stable topology with consistent port roles throughout the network, the RSTP ensures that every root port and designated port immediately transition to the forwarding state while all alternate and backup ports are always in the discarding state (equivalent to blocking in IEEE 802.1D). The port state controls the operation of the forwarding and learning processes. Table 13-2 provides a comparison of IEEE 802.1D and RSTP port states.

<table>
<thead>
<tr>
<th>Operational Status</th>
<th>STP Port State (IEEE 802.1D)</th>
<th>RSTP Port State</th>
<th>Is Port Included in the Active Topology?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabled</td>
<td>Blocking</td>
<td>Discarding</td>
<td>No</td>
</tr>
<tr>
<td>Enabled</td>
<td>Listening</td>
<td>Discarding</td>
<td>No</td>
</tr>
<tr>
<td>Enabled</td>
<td>Learning</td>
<td>Learning</td>
<td>Yes</td>
</tr>
<tr>
<td>Enabled</td>
<td>Forwarding</td>
<td>Forwarding</td>
<td>Yes</td>
</tr>
<tr>
<td>Disabled</td>
<td>Disabled</td>
<td>Discarding</td>
<td>No</td>
</tr>
</tbody>
</table>

To be consistent with Cisco STP implementations, this guide defines the port state as *blocking* instead of *discarding*. Designated ports start in the listening state.
Rapid Convergence

The RSTP provides for rapid recovery of connectivity following the failure of a switch, a switch port, or a LAN. It provides rapid convergence for edge ports, new root ports, and ports connected through point-to-point links as follows:

- **Edge ports**—If you configure a port as an edge port on an RSTP switch by using the `spanning-tree portfast` interface configuration command, the edge port immediately transitions to the forwarding state. An edge port is the same as a Port Fast-enabled port, and you should enable it only on ports that connect to a single end station.

- **Root ports**—If the RSTP selects a new root port, it blocks the old root port and immediately transitions the new root port to the forwarding state.

- **Point-to-point links**—If you connect a port to another port through a point-to-point link and the local port becomes a designated port, it negotiates a rapid transition with the other port by using the proposal-agreement handshake to ensure a loop-free topology.

As shown in Figure 13-4, Switch A is connected to Switch B through a point-to-point link, and all of the ports are in the blocking state. Assume that the priority of Switch A is a smaller numerical value than the priority of Switch B. Switch A sends a proposal message (a configuration BPDU with the proposal flag set) to Switch B, proposing itself as the designated switch.

After receiving the proposal message, Switch B selects as its new root port the port from which the proposal message was received, forces all nonedge ports to the blocking state, and sends an agreement message (a BPDU with the agreement flag set) through its new root port.

After receiving Switch B’s agreement message, Switch A also immediately transitions its designated port to the forwarding state. No loops in the network are formed because Switch B blocked all of its nonedge ports and because there is a point-to-point link between Switches A and B.

When Switch C is connected to Switch B, a similar set of handshaking messages are exchanged. Switch C selects the port connected to Switch B as its root port, and both ends immediately transition to the forwarding state. With each iteration of this handshaking process, one more switch joins the active topology. As the network converges, this proposal-agreement handshaking progresses from the root toward the leaves of the spanning tree.

The switch learns the link type from the port duplex mode: a full-duplex port is considered to have a point-to-point connection; a half-duplex port is considered to have a shared connection. You can override the default setting that is controlled by the duplex setting by using the `spanning-tree link-type` interface configuration command.
When the switch receives a proposal message on one of its ports and that port is selected as the new root port, the RSTP forces all other ports to synchronize with the new root information.

The switch is synchronized with superior root information received on the root port if all other ports are synchronized. An individual port on the switch is synchronized if

- That port is in the blocking state.
- It is an edge port (a port configured to be at the edge of the network).

If a designated port is in the forwarding state and is not configured as an edge port, it transitions to the blocking state when the RSTP forces it to synchronize with new root information. In general, when the RSTP forces a port to synchronize with root information and the port does not satisfy any of the above conditions, its port state is set to blocking.
After ensuring that all of the ports are synchronized, the switch sends an agreement message to the designated switch corresponding to its root port. When the switches connected by a point-to-point link are in agreement about their port roles, the RSTP immediately transitions the port states to forwarding. The sequence of events is shown in Figure 13-5.

**Figure 13-5  Sequence of Events During Rapid Convergence**

![Figure 13-5 Sequence of Events During Rapid Convergence](image)

### Bridge Protocol Data Unit Format and Processing

The RSTP BPDU format is the same as the IEEE 802.1D BPDU format except that the protocol version is set to 2. A new 1-byte Version 1 Length field is set to zero, which means that no version 1 protocol information is present. Table 13-3 shows the RSTP flag fields.

**Table 13-3  RSTP BPDU Flags**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Topology change (TC)</td>
</tr>
<tr>
<td>1</td>
<td>Proposal</td>
</tr>
<tr>
<td>2–3:</td>
<td>Port role:</td>
</tr>
<tr>
<td>00</td>
<td>Unknown</td>
</tr>
<tr>
<td>01</td>
<td>Alternate port</td>
</tr>
<tr>
<td>10</td>
<td>Root port</td>
</tr>
<tr>
<td>11</td>
<td>Designated port</td>
</tr>
<tr>
<td>4</td>
<td>Learning</td>
</tr>
<tr>
<td>5</td>
<td>Forwarding</td>
</tr>
<tr>
<td>6</td>
<td>Agreement</td>
</tr>
<tr>
<td>7</td>
<td>Topology change acknowledgement (TCA)</td>
</tr>
</tbody>
</table>
The sending switch sets the proposal flag in the RSTP BPDU to propose itself as the designated switch on that LAN. The port role in the proposal message is always set to the designated port.

The sending switch sets the agreement flag in the RSTP BPDU to accept the previous proposal. The port role in the agreement message is always set to the root port.

The RSTP does not have a separate topology change notification (TCN) BPDU. It uses the topology change (TC) flag to show the topology changes. However, for interoperability with IEEE 802.1D switches, the RSTP switch processes and generates TCN BPDUs.

The learning and forwarding flags are set according to the state of the sending port.

**Processing Superior BPDU Information**

If a port receives superior root information (lower switch ID, lower path cost, and so forth) than currently stored for the port, the RSTP triggers a reconfiguration. If the port is proposed and is selected as the new root port, RSTP forces all the other ports to synchronize.

If the BPDU received is an RSTP BPDU with the proposal flag set, the switch sends an agreement message after all of the other ports are synchronized. If the BPDU is an IEEE 802.1D BPDU, the switch does not set the proposal flag and starts the forward-delay timer for the port. The new root port requires twice the forward-delay time to transition to the forwarding state.

If the superior information received on the port causes the port to become a backup or alternate port, RSTP sets the port to the blocking state but does not send the agreement message. The designated port continues sending BPDUs with the proposal flag set until the forward-delay timer expires, at which time the port transitions to the forwarding state.

**Processing Inferior BPDU Information**

If a designated port receives an inferior BPDU (higher switch ID, higher path cost, and so forth than currently stored for the port) with a designated port role, it immediately replies with its own information.

**Topology Changes**

This section describes the differences between the RSTP and the IEEE 802.1D in handling spanning-tree topology changes.

- **Detection**—Unlike IEEE 802.1D in which any transition between the blocking and the forwarding state causes a topology change, only transitions from the blocking to the forwarding state cause a topology change with RSTP (only an increase in connectivity is considered a topology change). State changes on an edge port do not cause a topology change. When an RSTP switch detects a topology change, it deletes the learned information on all of its nonedge ports except on those from which it received the TC notification.

- **Notification**—Unlike IEEE 802.1D, which uses TCN BPDUs, the RSTP does not use them. However, for IEEE 802.1D interoperability, an RSTP switch processes and generates TCN BPDUs.

- **Acknowledgement**—When an RSTP switch receives a TCN message on a designated port from an IEEE 802.1D switch, it replies with an IEEE 802.1D configuration BPDU with the TCA bit set. However, if the TC-while timer (the same as the topology-change timer in IEEE 802.1D) is active on a root port connected to an IEEE 802.1D switch and a configuration BPDU with the TCA bit set is received, the TC-while timer is reset.

This behavior is only required to support IEEE 802.1D switches. The RSTP BPDUs never have the TCA bit set.
Propagating—When an RSTP switch receives a TC message from another switch through a designated or root port, it propagates the change to all of its nonedge, designated ports and to the root port (excluding the port on which it is received). The switch starts the TC-while timer for all such ports and flushes the information learned on them.

Protocol migration—For backward compatibility with IEEE 802.1D switches, RSTP selectively sends IEEE 802.1D configuration BPDUs and TCN BPDUs on a per-port basis.

When a port is initialized, the migrate-delay timer is started (specifies the minimum time during which RSTP BPDUs are sent), and RSTP BPDUs are sent. While this timer is active, the switch processes all BPDUs received on that port and ignores the protocol type.

If the switch receives an IEEE 802.1D BPDU after the port migration-delay timer has expired, it assumes that it is connected to an IEEE 802.1D switch and starts using only IEEE 802.1D BPDUs. However, if the RSTP switch is using IEEE 802.1D BPDUs on a port and receives an RSTP BPDU after the timer has expired, it restarts the timer and starts using RSTP BPDUs on that port.

### Configuring MSTP Features

These sections contain this configuration information:

- Default MSTP Configuration, page 13-14
- MSTP Configuration Guidelines, page 13-15
- Specifying the MST Region Configuration and Enabling MSTP, page 13-16 (required)
- Configuring the Root Switch, page 13-17 (optional)
- Configuring a Secondary Root Switch, page 13-18 (optional)
- Configuring Port Priority, page 13-19 (optional)
- Configuring Path Cost, page 13-20 (optional)
- Configuring the Switch Priority, page 13-21 (optional)
- Configuring the Hello Time, page 13-22 (optional)
- Configuring the Forwarding-Delay Time, page 13-23 (optional)
- Configuring the Maximum-Aging Time, page 13-23 (optional)
- Configuring the Maximum-Hop Count, page 13-24 (optional)
- Specifying the Link Type to Ensure Rapid Transitions, page 13-24 (optional)
- Designating the Neighbor Type, page 13-25 (optional)
- Restarting the Protocol Migration Process, page 13-25 (optional)

### Default MSTP Configuration

Table 13-4 shows the default MSTP configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spanning-tree mode</td>
<td>PVST+ (Rapid PVST+ and MSTP are disabled).</td>
</tr>
<tr>
<td>Switch priority (configurable on a per-CIST port basis)</td>
<td>32768.</td>
</tr>
</tbody>
</table>
Chapter 13      Configuring MSTP

Configuring MSTP Features

For information about the supported number of spanning-tree instances, see the “Supported Spanning-Tree Instances” section on page 12-9.

MSTP Configuration Guidelines

These are the configuration guidelines for MSTP:

- When you enable MST by using the `spanning-tree mode mst` global configuration command, RSTP is automatically enabled.

- For two or more switches to be in the same MST region, they must have the same VLAN-to-instance map, the same configuration revision number, and the same name.

- The switch supports up to 65 MST instances. The number of VLANs that can be mapped to a particular MST instance is unlimited.

- PVST+, rapid PVST+, and MSTP are supported, but only one version can be active at any time. (For example, all VLANs run PVST+, all VLANs run rapid PVST+, or all VLANs run MSTP.) For more information, see the “Spanning-Tree Interoperability and Backward Compatibility” section on page 12-10. For information on the recommended trunk port configuration, see the “Interaction with Other Features” section on page 9-18.

- VTP propagation of the MST configuration is not supported. However, you can manually configure the MST configuration (region name, revision number, and VLAN-to-instance mapping) on each switch within the MST region by using the command-line interface (CLI) or through the SNMP support.

- For load balancing across redundant paths in the network to work, all VLAN-to-instance mapping assignments must match; otherwise, all traffic flows on a single link.

- All MST boundary ports must be forwarding for load balancing between a PVST+ and an MST cloud or between a rapid-PVST+ and an MST cloud. For this to occur, the IST master of the MST cloud should also be the root of the CST. If the MST cloud consists of multiple MST regions, one of the MST regions must contain the CST root, and all of the other MST regions must have a better path to the root contained within the MST cloud than a path through the PVST+ or rapid-PVST+ cloud. You might have to manually configure the switches in the clouds.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spanning-tree port priority (configurable on a per-CIST port basis)</td>
<td>128.</td>
</tr>
<tr>
<td>Spanning-tree port cost (configurable on a per-CIST port basis)</td>
<td>1000 Mb/s: 4.</td>
</tr>
<tr>
<td></td>
<td>100 Mb/s: 19.</td>
</tr>
<tr>
<td></td>
<td>10 Mb/s: 100.</td>
</tr>
<tr>
<td>Hello time</td>
<td>2 seconds.</td>
</tr>
<tr>
<td>Forward-delay time</td>
<td>15 seconds.</td>
</tr>
<tr>
<td>Maximum-aging time</td>
<td>20 seconds.</td>
</tr>
<tr>
<td>Maximum hop count</td>
<td>20 hops.</td>
</tr>
</tbody>
</table>

For information about the supported number of spanning-tree instances, see the “Supported Spanning-Tree Instances” section on page 12-9.
Partitioning the network into a large number of regions is not recommended. However, if this situation is unavoidable, we recommend that you partition the switched LAN into smaller LANs interconnected by routers or non-Layer 2 devices.

For configuration guidelines about MSTP, see the “Optional Spanning-Tree Configuration Guidelines” section on page 14-10.

### Specifying the MST Region Configuration and Enabling MSTP

For two or more switches to be in the same MST region, they must have the same VLAN-to-instance mapping, the same configuration revision number, and the same name.

A region can have one member or multiple members with the same MST configuration; each member must be capable of processing RSTP BPDUs. There is no limit to the number of MST regions in a network, but each region can only support up to 65 spanning-tree instances. You can assign a VLAN to only one spanning-tree instance at a time.

Beginning in privileged EXEC mode, follow these steps to specify the MST region configuration and enable MSTP. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 spanning-tree mst config</td>
<td>Enter MST configuration mode.</td>
</tr>
<tr>
<td>Step 3 instance instance-id vlan vlan-range</td>
<td>Map VLANs to an MST instance.</td>
</tr>
<tr>
<td></td>
<td>- For instance-id, the range is 0 to 4094.</td>
</tr>
<tr>
<td></td>
<td>- For vlan vlan-range, the range is 1 to 4094.</td>
</tr>
<tr>
<td></td>
<td>When you map VLANs to an MST instance, the mapping is incremental, and the VLANs specified in the command are added to or removed from the VLANs that were previously mapped.</td>
</tr>
<tr>
<td></td>
<td>To specify a VLAN range, use a hyphen; for example, instance 1 vlan 1-63 maps VLANs 1 through 63 to MST instance 1.</td>
</tr>
<tr>
<td></td>
<td>To specify a VLAN series, use a comma; for example, instance 1 vlan 10, 20, 30 maps VLANs 10, 20, and 30 to MST instance 1.</td>
</tr>
<tr>
<td>Step 4 name name</td>
<td>Specify the configuration name. The name string has a maximum length of 32 characters and is case sensitive.</td>
</tr>
<tr>
<td>Step 5 revision version</td>
<td>Specify the configuration revision number. The range is 0 to 65535.</td>
</tr>
<tr>
<td>Step 6 show pending</td>
<td>Verify your configuration by displaying the pending configuration.</td>
</tr>
<tr>
<td>Step 7 exit</td>
<td>Apply all changes, and return to global configuration mode.</td>
</tr>
<tr>
<td>Step 8 spanning-tree mode mst</td>
<td>Enable MSTP. RSTP is also enabled.</td>
</tr>
</tbody>
</table>

**Caution** Changing spanning-tree modes can disrupt traffic because all spanning-tree instances are stopped for the previous mode and restarted in the new mode.

You cannot run both MSTP and PVST+ or both MSTP and rapid PVST+ at the same time.
To return to the default MST region configuration, use the no spanning-tree mst configuration global configuration command. To return to the default VLAN-to-instance map, use the no instance instance-id [vlan vlan-range] MST configuration command. To return to the default name, use the no name MST configuration command. To return to the default revision number, use the no revision MST configuration command. To re-enable PVST+, use the no spanning-tree mode or the spanning-tree mode pvst global configuration command.

This example shows how to enter MST configuration mode, map VLANs 10 to 20 to MST instance 1, name the region region1, set the configuration revision to 1, display the pending configuration, apply the changes, and return to global configuration mode:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)# instance 1 vlan 10-20
Switch(config-mst)# name region1
Switch(config-mst)# revision 1
Switch(config-mst)# show pending
Pending MST configuration
Name [region1]
Revision 1
Instance Vlans Mapped
-------- ---------------------
0         1-9,21-4094
1         10-20
--------------------------
```

```
Switch(config-mst)# exit
Switch(config)#
```

### Configuring the Root Switch

The switch maintains a spanning-tree instance for the group of VLANs mapped to it. A switch ID, consisting of the switch priority and the switch MAC address, is associated with each instance. For a group of VLANs, the switch with the lowest switch ID becomes the root switch.

To configure a switch to become the root, use the spanning-tree mst instance-id root global configuration command to modify the switch priority from the default value (32768) to a significantly lower value so that the switch becomes the root switch for the specified spanning-tree instance. When you enter this command, the switch checks the switch priorities of the root switches. Because of the extended system ID support, the switch sets its own priority for the specified instance to 24576 if this value will cause this switch to become the root for the specified spanning-tree instance.

If any root switch for the specified instance has a switch priority lower than 24576, the switch sets its own priority to 4096 less than the lowest switch priority. (4096 is the value of the least-significant bit of a 4-bit switch priority value as shown in Table 12-1 on page 12-4.)

If your network consists of switches that both do and do not support the extended system ID, it is unlikely that the switch with the extended system ID support will become the root switch. The extended system ID increases the switch priority value every time the VLAN number is greater than the priority of the connected switches running older software.
The root switch for each spanning-tree instance should be a backbone or distribution switch. Do not configure an access switch as the spanning-tree primary root.

Use the **diameter** keyword, which is available only for MST instance 0, to specify the Layer 2 network diameter (that is, the maximum number of switch hops between any two end stations in the Layer 2 network). When you specify the network diameter, the switch automatically sets an optimal hello time, forward-delay time, and maximum-age time for a network of that diameter, which can significantly reduce the convergence time. You can use the **hello** keyword to override the automatically calculated hello time.

**Note**

After configuring the switch as the root switch, we recommend that you avoid manually configuring the hello time, forward-delay time, and maximum-age time through the `spanning-tree mst hello-time`, `spanning-tree mst forward-time`, and the `spanning-tree mst max-age` global configuration commands.

Beginning in privileged EXEC mode, follow these steps to configure a switch as the root switch. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 spanning-tree mst instance-id root primary [diameter net-diameter [hello-time seconds]]</td>
<td>Configure a switch as the root switch.</td>
</tr>
<tr>
<td></td>
<td>• For <strong>instance-id</strong>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <strong>diameter</strong> <strong>net-diameter</strong>, specify the maximum number of switches between any two end stations. The range is 2 to 7. This keyword is available only for MST instance 0.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <strong>hello-time</strong> <strong>seconds</strong>, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10 seconds; the default is 2 seconds.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show spanning-tree mst instance-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the **no spanning-tree mst instance-id root** global configuration command.

**Configuring a Secondary Root Switch**

When you configure a switch with the extended system ID support as the secondary root, the switch priority is modified from the default value (32768) to 28672. The switch is then likely to become the root switch for the specified instance if the primary root switch fails. This is assuming that the other network switches use the default switch priority of 32768 and therefore are unlikely to become the root switch.
You can execute this command on more than one switch to configure multiple backup root switches. Use the same network diameter and hello-time values that you used when you configured the primary root switch with the `spanning-tree mst instance-id root primary` global configuration command.

Beginning in privileged EXEC mode, follow these steps to configure a switch as the secondary root switch. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>spanning-tree mst instance-id root secondary [diameter net-diameter [hello-time seconds]]</td>
</tr>
<tr>
<td></td>
<td>Configure a switch as the secondary root switch.</td>
</tr>
<tr>
<td></td>
<td>• For <code>instance-id</code>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>diameter net-diameter</code>, specify the maximum number of switches between any two end stations. The range is 2 to 7. This keyword is available only for MST instance 0.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For <code>hello-time seconds</code>, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10 seconds; the default is 2 seconds.</td>
</tr>
<tr>
<td></td>
<td>Use the same network diameter and hello-time values that you used when configuring the primary root switch. See the “Configuring the Root Switch” section on page 13-17.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show spanning-tree mst instance-id</td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst instance-id root` global configuration command.

### Configuring Port Priority

If a loop occurs, the MSTP uses the port priority when selecting an interface to put into the forwarding state. You can assign higher priority values (lower numerical values) to interfaces that you want selected first and lower priority values (higher numerical values) that you want selected last. If all interfaces have the same priority value, the MSTP puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.
Beginning in privileged EXEC mode, follow these steps to configure the MSTP port priority of an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>spanning-tree mst instance-id port-priority priority</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show spanning-tree mst interface interface-id</td>
</tr>
<tr>
<td>or show spanning-tree mst instance-id</td>
<td></td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

**Note**

The `show spanning-tree mst interface interface-id` privileged EXEC command displays information only if the port is in a link-up operative state. Otherwise, you can use the `show running-config interface` privileged EXEC command to confirm the configuration.

To return the interface to its default setting, use the `no spanning-tree mst instance-id port-priority` interface configuration command.

### Configuring Path Cost

The MSTP path cost default value is derived from the media speed of an interface. If a loop occurs, the MSTP uses cost when selecting an interface to put in the forwarding state. You can assign lower cost values to interfaces that you want selected first and higher cost values that you want selected last. If all interfaces have the same cost value, the MSTP puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.
Beginning in privileged EXEC mode, follow these steps to configure the MSTP cost of an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>spanning-tree mst instance-id cost cost</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show spanning-tree mst interface interface-id</td>
</tr>
<tr>
<td>or</td>
<td>show spanning-tree mst instance-id</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

**Note**

The `show spanning-tree mst interface interface-id` privileged EXEC command displays information only for ports that are in a link-up operative state. Otherwise, you can use the `show running-config` privileged EXEC command to confirm the configuration.

To return the interface to its default setting, use the `no spanning-tree mst instance-id cost` interface configuration command.

### Configuring the Switch Priority

You can configure the switch priority and make it more likely that this will be chosen as the root switch.

**Note**

Exercise care when using this command. For most situations, we recommend that you use the `spanning-tree mst instance-id root primary` and the `spanning-tree mst instance-id root secondary` global configuration commands to modify the switch priority.
Beginning in privileged EXEC mode, follow these steps to configure the switch priority. This procedure is optional.

### Command Purpose

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>spanning-tree mst instance-id priority priority</td>
</tr>
<tr>
<td></td>
<td>• For instance-id, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094.</td>
</tr>
<tr>
<td></td>
<td>• For priority, the range is 0 to 61440 in increments of 4096; the default is 32768. The lower the number, the more likely the switch will be chosen as the root switch.</td>
</tr>
<tr>
<td></td>
<td>Priority values are 0, 4096, 8192, 12288, 16384, 20480, 24576, 28672, 32768, 36864, 40960, 45056, 49152, 53248, 57344, and 61440. All other values are rejected.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show spanning-tree mst instance-id</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst instance-id priority` global configuration command.

### Configuring the Hello Time

You can configure the interval between the generation of configuration messages by the root switch by changing the hello time.

Beginning in privileged EXEC mode, follow these steps to configure the hello time for all MST instances. This procedure is optional.

### Command Purpose

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>spanning-tree mst hello-time seconds</td>
</tr>
<tr>
<td></td>
<td>For seconds, the range is 1 to 10; the default is 2.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show spanning-tree mst</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst hello-time` global configuration command.
Configuring the Forwarding-Delay Time

Beginning in privileged EXEC mode, follow these steps to configure the forwarding-delay time for all MST instances. This procedure is optional.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree mst forward-time</td>
<td>Configure the forward time for all MST instances. The forward delay is</td>
</tr>
<tr>
<td></td>
<td>seconds</td>
<td>the number of seconds a port waits before changing from its spanning-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tree learning and listening states to the forwarding state.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For seconds, the range is 4 to 30; the default is 15.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree mst</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst forward-time` global configuration command.

Configuring the Maximum-Aging Time

Beginning in privileged EXEC mode, follow these steps to configure the maximum-aging time for all MST instances. This procedure is optional.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree mst max-age</td>
<td>Configure the maximum-aging time for all MST instances. The maximum-</td>
</tr>
<tr>
<td></td>
<td>seconds</td>
<td>aging time is the number of seconds a switch waits without receiving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spanning-tree configuration messages before attempting a reconfiguration.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For seconds, the range is 6 to 40; the default is 20.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree mst</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst max-age` global configuration command.
### Configuring the Maximum-Hop Count

Beginning in privileged EXEC mode, follow these steps to configure the maximum-hop count for all MST instances. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>spanning-tree mst max-hops <em>hop-count</em></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show spanning-tree mst</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the switch to its default setting, use the `no spanning-tree mst max-hops` global configuration command.

### Specifying the Link Type to Ensure Rapid Transitions

If you connect a port to another port through a point-to-point link and the local port becomes a designated port, the RSTP negotiates a rapid transition with the other port by using the proposal-agreement handshake to ensure a loop-free topology as described in the "Rapid Convergence" section on page 13-10.

By default, the link type is controlled from the duplex mode of the interface: a full-duplex port is considered to have a point-to-point connection; a half-duplex port is considered to have a shared connection. If you have a half-duplex link physically connected point-to-point to a single port on a remote switch running MSTP, you can override the default setting of the link type and enable rapid transitions to the forwarding state.

Beginning in privileged EXEC mode, follow these steps to override the default link-type setting. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface <em>interface-id</em></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>spanning-tree link-type point-to-point</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show spanning-tree mst interface <em>interface-id</em></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the port to its default setting, use the `no spanning-tree link-type` interface configuration command.
Designating the Neighbor Type

A topology could contain both prestandard and IEEE 802.1s standard compliant devices. By default, ports can automatically detect prestandard devices, but they can still receive both standard and prestandard BPDUs. When there is a mismatch between a device and its neighbor, only the CIST runs on the interface.

You can choose to set a port to send only prestandard BPDUs. The prestandard flag appears in all the show commands, even if the port is in STP compatibility mode.

Beginning in privileged EXEC mode, follow these steps to override the default link-type setting. This procedure is optional.

**Command** | **Purpose**
--- | ---
Step 1 configure terminal | Enter global configuration mode.
Step 2 interface interface-id | Specify an interface to configure, and enter interface configuration mode. Valid interfaces include physical ports.
Step 3 spanning-tree mst pre-standard | Specify that the port can send only prestandard BPDUs.
Step 4 end | Return to privileged EXEC mode.
Step 5 show spanning-tree mst interface interface-id | Verify your entries.
Step 6 copy running-config startup-config | (Optional) Save your entries in the configuration file.

To return the port to its default setting, use the `no spanning-tree mst prestandard` interface configuration command.

Restarting the Protocol Migration Process

A switch running MSTP supports a built-in protocol migration mechanism that enables it to interoperate with legacy IEEE 802.1D switches. If this switch receives a legacy IEEE 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only IEEE 802.1D BPDUs on that port. An MSTP switch also can detect that a port is at the boundary of a region when it receives a legacy BPDU, an MST BPDU (Version 3) associated with a different region, or an RST BPDU (Version 2).

However, the switch does not automatically revert to the MSTP mode if it no longer receives IEEE 802.1D BPDUs because it cannot detect whether the legacy switch has been removed from the link unless the legacy switch is the designated switch. A switch also might continue to assign a boundary role to a port when the switch to which it is connected has joined the region.

To restart the protocol migration process (force the renegotiation with neighboring switches) on the switch, use the `clear spanning-tree detected-protocols` privileged EXEC command.

To restart the protocol migration process on a specific interface, use the `clear spanning-tree detected-protocols interface interface-id` privileged EXEC command.
Displaying the MST Configuration and Status

To display the spanning-tree status, use one or more of the privileged EXEC commands in Table 13-5:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show spanning-tree mst configuration</td>
<td>Displays the MST region configuration.</td>
</tr>
<tr>
<td>show spanning-tree mst configuration digest</td>
<td>Displays the MD5 digest included in the current MSTCI.</td>
</tr>
<tr>
<td>show spanning-tree mst instance-id</td>
<td>Displays MST information for the specified instance.</td>
</tr>
<tr>
<td>show spanning-tree mst interface interface-id</td>
<td>Displays MST information for the specified interface.</td>
</tr>
</tbody>
</table>

For information about other keywords for the `show spanning-tree` privileged EXEC command, see the command reference for this release.
Configuring Optional Spanning-Tree Features

This chapter describes how to configure optional spanning-tree features on the switch. You can configure all of these features when your switch is running the per-VLAN spanning-tree plus (PVST+). You can configure only the noted features when your switch is running the Multiple Spanning Tree Protocol (MSTP) or the rapid per-VLAN spanning-tree plus (rapid-PVST+) protocol.

For information on configuring the PVST+ and rapid PVST+, see Chapter 12, “Configuring STP.” For information about the Multiple Spanning Tree Protocol (MSTP) and how to map multiple VLANs to the same spanning-tree instance, see Chapter 13, “Configuring MSTP.”

This chapter consists of these sections:

- Understanding Optional Spanning-Tree Features, page 14-1
- Configuring Optional Spanning-Tree Features, page 14-9
- Displaying the Spanning-Tree Status, page 14-16

Understanding Optional Spanning-Tree Features

These sections contain this conceptual information:

- Understanding Port Fast, page 14-2
- Understanding BPDU Guard, page 14-2
- Understanding BPDU Filtering, page 14-3
- Understanding UplinkFast, page 14-3
- Understanding BackboneFast, page 14-5
- Understanding EtherChannel Guard, page 14-7
- Understanding Root Guard, page 14-8
- Understanding Loop Guard, page 14-9
Understanding Port Fast

Port Fast immediately brings an interface configured as an access or trunk port to the forwarding state from a blocking state, bypassing the listening and learning states.

Port Fast is enabled by default on interfaces that are connected to a blade server (ports 1 to 16), as shown in Figure 14-1, to allow those devices to immediately connect to the network, rather than waiting for the spanning tree to converge.

Interfaces connected to a blade server should not receive bridge protocol data units (BPDUs). An interface with Port Fast enabled goes through the normal cycle of spanning-tree status changes when the switch is restarted.

Because the purpose of Port Fast is to minimize the time interfaces must wait for spanning-tree to converge, it is effective only when used on interfaces connected to end stations. If you enable Port Fast on an interface connecting to another switch, you risk creating a spanning-tree loop.

You can enable this feature by using the `spanning-tree portfast` interface configuration or the `spanning-tree portfast default` global configuration command.

![Figure 14-1 Port Fast-Enabled Interfaces](image)

Understanding BPDU Guard

The BPDU guard feature can be globally enabled on the switch or can be enabled per port, but the feature operates with some differences.

At the global level, you enable BPDU guard on Port Fast-enabled ports by using the `spanning-tree portfast bpduguard default` global configuration command. Spanning tree shuts down ports that are in a Port Fast-operational state if any BPU is received on them. In a valid configuration, Port Fast-enabled ports do not receive BPDUs. Receiving a BPU on a Port Fast-enabled port means an invalid configuration, such as the connection of an unauthorized device, and the BPDU guard feature puts the port in the error-disabled state. When this happens, the switch shuts down the entire port on which the violation occurred.
To prevent the port from shutting down, you can use the `errdisable detect cause bpduguard shutdownvlan` global configuration command to shut down just the offending VLAN on the port where the violation occurred.

At the interface level, you enable BPDU guard on any port by using the `spanning-tree bpduguard enable` interface configuration command without also enabling the Port Fast feature. When the port receives a BPDU, it is put in the error-disabled state.

The BPDU guard feature provides a secure response to invalid configurations because you must manually put the interface back in service. Use the BPDU guard feature in a service-provider network to prevent an access port from participating in the spanning tree.

### Understanding BPDU Filtering

The BPDU filtering feature can be globally enabled on the switch or can be enabled per interface, but the feature operates with some differences.

At the global level, you can enable BPDU filtering on Port Fast-enabled interfaces by using the `spanning-tree portfast bpdufilter default` global configuration command. This command prevents interfaces that are in a Port Fast-operational state from sending or receiving BPDUs. The interfaces still send a few BPDUs at link-up before the switch begins to filter outbound BPDUs. You should globally enable BPDU filtering on a switch so that hosts connected to these interfaces do not receive BPDUs. If a BPDU is received on a Port Fast-enabled interface, the interface loses its Port Fast-operational status, and BPDU filtering is disabled.

At the interface level, you can enable BPDU filtering on any interface by using the `spanning-tree bpdufilter enable` interface configuration command without also enabling the Port Fast feature. This command prevents the interface from sending or receiving BPDUs.

---

**Caution**

Enabling BPDU filtering on an interface is the same as disabling spanning tree on it and can result in spanning-tree loops.

You can enable the BPDU filtering feature for the entire switch or for an interface.

### Understanding UplinkFast

Switches in hierarchical networks can be grouped into backbone switches, distribution switches, and access switches. Figure 14-2 shows a complex network where distribution switches and access switches each have at least one redundant link that spanning tree blocks to prevent loops.
Understanding Optional Spanning-Tree Features

Figure 14-2  Switches in a Hierarchical Network

If a switch loses connectivity, it begins using the alternate paths as soon as the spanning tree selects a new root port. By enabling UplinkFast with the `spanning-tree uplinkfast` global configuration command, you can accelerate the choice of a new root port when a link or switch fails or when the spanning tree reconfigures itself. The root port transitions to the forwarding state immediately without going through the listening and learning states, as it would with the normal spanning-tree procedures.

When the spanning tree reconfigures the new root port, other interfaces flood the network with multicast packets, one for each address that was learned on the interface. You can limit these bursts of multicast traffic by reducing the max-update-rate parameter (the default for this parameter is 150 packets per second). However, if you enter zero, station-learning frames are not generated, so the spanning-tree topology converges more slowly after a loss of connectivity.

**Note**

UplinkFast is most useful in wiring-closet switches at the access or edge of the network. It is not appropriate for backbone devices. This feature might not be useful for other types of applications.

UplinkFast provides fast convergence after a direct link failure and achieves load balancing between redundant Layer 2 links using uplink groups. An uplink group is a set of Layer 2 interfaces (per VLAN), only one of which is forwarding at any given time. Specifically, an uplink group consists of the root port (which is forwarding) and a set of blocked ports, except for self-looping ports. The uplink group provides an alternate path in case the currently forwarding link fails.

**Figure 14-3** shows an example topology with no link failures. Switch A, the root switch, is connected directly to Switch B over link L1 and to Switch C over link L2. The Layer 2 interface on Switch C that is connected directly to Switch B is in a blocking state.
If Switch C detects a link failure on the currently active link L2 on the root port (a direct link failure), UplinkFast unblocks the blocked interface on Switch C and transitions it to the forwarding state without going through the listening and learning states, as shown in Figure 14-4. This change takes approximately 1 to 5 seconds.

**Understanding BackboneFast**

BackboneFast detects indirect failures in the core of the backbone. BackboneFast is a complementary technology to the UplinkFast feature, which responds to failures on links directly connected to access switches. BackboneFast optimizes the maximum-age timer, which controls the amount of time the switch stores protocol information received on an interface. When a switch receives an inferior BPDU from the designated port of another switch, the BPDU is a signal that the other switch might have lost its path to the root, and BackboneFast tries to find an alternate path to the root.

BackboneFast, which is enabled by using the `spanning-tree backbonefast` global configuration command, starts when a root port or blocked interface on a switch receives inferior BPDUs from its designated switch. An inferior BPDU identifies a switch that declares itself as both the root bridge and the designated switch. When a switch receives an inferior BPDU, it means that a link to which the switch is not directly connected (an indirect link) has failed (that is, the designated switch has lost its connection to the root switch). Under spanning-tree rules, the switch ignores inferior BPDUs for the configured maximum aging time specified by the `spanning-tree vlan vlan-id max-age` global configuration command.
The switch tries to find if it has an alternate path to the root switch. If the inferior BPDU arrives on a blocked interface, the root port and other blocked interfaces on the switch become alternate paths to the root switch. (Self-looped ports are not considered alternate paths to the root switch.) If the inferior BPDU arrives on the root port, all blocked interfaces become alternate paths to the root switch. If the inferior BPDU arrives on the root port and there are no blocked interfaces, the switch assumes that it has lost connectivity to the root switch, causes the maximum aging time on the root port to expire, and becomes the root switch according to normal spanning-tree rules.

If the switch has alternate paths to the root switch, it uses these alternate paths to send a root link query (RLQ) request. The switch sends the RLQ request on all alternate paths and waits for an RLQ reply from other switches in the network.

If the switch discovers that it still has an alternate path to the root, it expires the maximum aging time on the interface that received the inferior BPDU. If all the alternate paths to the root switch indicate that the switch has lost connectivity to the root switch, the switch expires the maximum aging time on the interface that received the RLQ reply. If one or more alternate paths can still connect to the root switch, the switch makes all interfaces on which it received an inferior BPDU its designated ports and moves them from the blocking state (if they were in the blocking state), through the listening and learning states, and into the forwarding state.

Figure 14-5 shows an example topology with no link failures. Switch A, the root switch, connects directly to Switch B over link L1 and to Switch C over link L2. The Layer 2 interface on Switch C that connects directly to Switch B is in the blocking state.

Figure 14-6 shows how BackboneFast reconfigures the topology to account for the failure of link L1.
Figure 14-6  BackboneFast Example After Indirect Link Failure

If a new switch is introduced into a shared-medium topology as shown in Figure 14-7, BackboneFast is not activated because the inferior BPDUs did not come from the recognized designated switch (Switch B). The new switch begins sending inferior BPDUs that indicate it is the root switch. However, the other switches ignore these inferior BPDUs, and the new switch learns that Switch B is the designated switch to Switch A, the root switch.

Figure 14-7  Adding a Switch in a Shared-Medium Topology

Understanding EtherChannel Guard

You can use EtherChannel guard to detect an EtherChannel misconfiguration between the switch and a connected device. A misconfiguration can occur if the switch interfaces are configured in an EtherChannel, but the interfaces on the other device are not. A misconfiguration can also occur if the channel parameters are not the same at both ends of the EtherChannel. For EtherChannel configuration guidelines, see the “EtherChannel Configuration Guidelines” section on page 28-9.

If the switch detects a misconfiguration on the other device, EtherChannel guard places the switch interfaces in the error-disabled state, and displays an error message.

You can enable this feature by using the spanning-tree etherchannel guard misconfig global configuration command.
Understanding Root Guard

The Layer 2 network of a service provider (SP) can include many connections to switches that are not owned by the SP. In such a topology, the spanning tree can reconfigure itself and select a customer switch as the root switch, as shown in Figure 14-8. You can avoid this situation by enabling root guard on SP switch interfaces that connect to switches in your customer’s network. If spanning-tree calculations cause an interface in the customer network to be selected as the root port, root guard then places the interface in the root-inconsistent (blocked) state to prevent the customer’s switch from becoming the root switch or being in the path to the root.

If a switch outside the SP network becomes the root switch, the interface is blocked (root-inconsistent state), and spanning tree selects a new root switch. The customer’s switch does not become the root switch and is not in the path to the root.

If the switch is operating in multiple spanning-tree (MST) mode, root guard forces the interface to be a designated port. If a boundary port is blocked in an internal spanning-tree (IST) instance because of root guard, the interface also is blocked in all MST instances. A boundary port is an interface that connects to a LAN, the designated switch of which is either an IEEE 802.1D switch or a switch with a different MST region configuration.

Root guard enabled on an interface applies to all the VLANs to which the interface belongs. VLANs can be grouped and mapped to an MST instance.

You can enable this feature by using the spanning-tree guard root interface configuration command.

---

**Caution**

Misuse of the root-guard feature can cause a loss of connectivity.
Understanding Loop Guard

You can use loop guard to prevent alternate or root ports from becoming designated ports because of a failure that leads to a unidirectional link. This feature is most effective when it is enabled on the entire switched network. Loop guard prevents alternate and root ports from becoming designated ports, and spanning tree does not send BPDUs on root or alternate ports.

You can enable this feature by using the `spanning-tree loopguard default` global configuration command.

When the switch is operating in PVST+ or rapid-PVST+ mode, loop guard prevents alternate and root ports from becoming designated ports, and spanning tree does not send BPDUs on root or alternate ports.

When the switch is operating in MST mode, BPDUs are not sent on nonboundary ports only if the interface is blocked by loop guard in all MST instances. On a boundary port, loop guard blocks the interface in all MST instances.

Configuring Optional Spanning-Tree Features

These sections contain this configuration information:
- Default Optional Spanning-Tree Configuration, page 14-9
- Optional Spanning-Tree Configuration Guidelines, page 14-10
- Enabling Port Fast, page 14-10 (optional)
- Enabling BPDU Guard, page 14-11 (optional)
- Enabling BPDU Filtering, page 14-12 (optional)
- Enabling UplinkFast for Use with Redundant Links, page 14-13 (optional)
- Enabling BackboneFast, page 14-13 (optional)
- Enabling EtherChannel Guard, page 14-14 (optional)
- Enabling Root Guard, page 14-15 (optional)
- Enabling Loop Guard, page 14-15 (optional)

Default Optional Spanning-Tree Configuration

Table 14-1 shows the default optional spanning-tree configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Fast, BPDU filtering, BPDU guard</td>
<td>Globally disabled (unless they are individually configured per interface).</td>
</tr>
<tr>
<td>UplinkFast</td>
<td>Globally disabled.</td>
</tr>
<tr>
<td>BackboneFast</td>
<td>Globally disabled.</td>
</tr>
<tr>
<td>EtherChannel guard</td>
<td>Globally enabled.</td>
</tr>
<tr>
<td>Root guard</td>
<td>Disabled on all interfaces.</td>
</tr>
<tr>
<td>Loop guard</td>
<td>Disabled on all interfaces.</td>
</tr>
</tbody>
</table>
Optional Spanning-Tree Configuration Guidelines

You can configure PortFast, BPDU guard, BPDU filtering, EtherChannel guard, root guard, or loop guard if your switch is running PVST+, rapid PVST+, or MSTP.

You can configure the UplinkFast or the BackboneFast feature for rapid PVST+ or for the MSTP, but the feature remains disabled (inactive) until you change the spanning-tree mode to PVST+.

Enabling Port Fast

An interface with the Port Fast feature enabled is moved directly to the spanning-tree forwarding state without waiting for the standard forward-time delay.

⚠️ **Caution**

Use Port Fast *only* when connecting a single end station to an access or trunk port. Enabling this feature on an interface connected to a switch or hub could prevent spanning tree from detecting and disabling loops in your network, which could cause broadcast storms and address-learning problems.

If you enable the voice VLAN feature, the Port Fast feature is automatically enabled. When you disable voice VLAN, the Port Fast feature is not automatically disabled. For more information, see Chapter 11, “Configuring Voice VLAN.”

You can enable this feature if your switch is running PVST+, rapid PVST+, or MSTP.

Beginning in privileged EXEC mode, follow these steps to enable Port Fast. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>spanning-tree portfast [trunk]</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show spanning-tree interface interface-id portfast</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>
You can use the `spanning-tree portfast default` global configuration command to globally enable the Port Fast feature on all nontrunking ports.

To disable the Port Fast feature, use the `spanning-tree portfast disable` interface configuration command.

**Enabling BPDU Guard**

When you globally enable BPDU guard on ports that are Port Fast-enabled (the ports are in a Port Fast-operational state), spanning tree shuts down Port Fast-enabled ports that receive BPDU's.

In a valid configuration, Port Fast-enabled ports do not receive BPDU's. Receiving a BPDU on a Port Fast-enabled port means an invalid configuration, such as the connection of an unauthorized device, and the BPDU guard feature puts the port in the error-disabled state. When this happens, the switch shuts down the entire port on which the violation occurred.

To prevent the port from shutting down, you can use the `errdisable detect cause bpduguard shutdown vlan` global configuration command to shut down just the offending VLAN on the port where the violation occurred.

The BPDU guard feature provides a secure response to invalid configurations because you must manually put the port back in service. Use the BPDU guard feature in a service-provider network to prevent an access port from participating in the spanning tree.

**Caution**

Configure Port Fast only on ports that connect to end stations; otherwise, an accidental topology loop could cause a data packet loop and disrupt switch and network operation.

You also can use the `spanning-tree bpduguard enable` interface configuration command to enable BPDU guard on any port without also enabling the Port Fast feature. When the port receives a BPDU, it is put it in the error-disabled state.

You can enable the BPDU guard feature if your switch is running PVST+, rapid PVST+, or MSTP.

Beginning in privileged EXEC mode, follow these steps to globally enable the BPDU guard feature. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>spanning-tree portfast bpduguard default</strong> Globally enable BPDU guard. By default, BPDU guard is disabled.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>interface interface-id</strong> Specify the interface connected to an end station, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>spanning-tree portfast</strong> Enable the Port Fast feature.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>end</strong> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>show running-config</strong> Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><strong>copy running-config startup-config</strong> (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
To disable BPDU guard, use the **no spanning-tree portfast bpduguard default** global configuration command.

You can override the setting of the **no spanning-tree portfast bpduguard default** global configuration command by using the **spanning-tree bpduguard enable** interface configuration command.

### Enabling BPDU Filtering

When you globally enable BPDU filtering on Port Fast-enabled interfaces, it prevents interfaces that are in a Port Fast-operational state from sending or receiving BPDUs. The interfaces still send a few BPDUs at link-up before the switch begins to filter outbound BPDUs. You should globally enable BPDU filtering on a switch so that hosts connected to these interfaces do not receive BPDUs. If a BPDU is received on a Port Fast-enabled interface, the interface loses its Port Fast-operational status, and BPDU filtering is disabled.

**Caution**

Configure Port Fast only on interfaces that connect to end stations; otherwise, an accidental topology loop could cause a data packet loop and disrupt switch and network operation.

You can also use the **spanning-tree bpdufilter enable** interface configuration command to enable BPDU filtering on any interface without also enabling the Port Fast feature. This command prevents the interface from sending or receiving BPDUs.

**Caution**

Enabling BPDU filtering on an interface is the same as disabling spanning tree on it and can result in spanning-tree loops.

You can enable the BPDU filtering feature if your switch is running PVST+, rapid PVST+, or MSTP. Beginning in privileged EXEC mode, follow these steps to globally enable the BPDU filtering feature. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree portfast bpdufilter default</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 4</td>
<td>spanning-tree portfast</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td>Step 6</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 7</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable BPDU filtering, use the **no spanning-tree portfast bpdufilter default** global configuration command.

You can override the setting of the **no spanning-tree portfast bpdufilter default** global configuration command by using the **spanning-tree bpdufilter enable** interface configuration command.
Enabling UplinkFast for Use with Redundant Links

UplinkFast cannot be enabled on VLANs that have been configured with a switch priority. To enable UplinkFast on a VLAN with switch priority configured, first restore the switch priority on the VLAN to the default value by using the `no spanning-tree vlan vlan-id priority` global configuration command.

**Note**
When you enable UplinkFast, it affects all VLANs on the switch. You cannot configure UplinkFast on an individual VLAN.

You can configure the UplinkFast feature for rapid PVST+ or for the MSTP, but the feature remains disabled (inactive) until you change the spanning-tree mode to PVST+.

Beginning in privileged EXEC mode, follow these steps to enable UplinkFast. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>spanning-tree uplinkfast [max-update-rate pkts-per-second]</td>
</tr>
<tr>
<td></td>
<td>Enable UplinkFast.</td>
</tr>
<tr>
<td></td>
<td>(Optional) For pkts-per-second, the range is 0 to 32000 packets per second; the default is 150.</td>
</tr>
<tr>
<td></td>
<td>If you set the rate to 0, station-learning frames are not generated, and the spanning-tree topology converges more slowly after a loss of connectivity.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4</td>
<td>show spanning-tree summary</td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

When UplinkFast is enabled, the switch priority of all VLANs is set to 49152. If you change the path cost to a value less than 3000 and you enable UplinkFast or UplinkFast is already enabled, the path cost of all interfaces and VLAN trunks is increased by 3000 (if you change the path cost to 3000 or above, the path cost is not altered). The changes to the switch priority and the path cost reduce the chance that a switch will become the root switch.

When UplinkFast is disabled, the switch priorities of all VLANs and path costs of all interfaces are set to default values if you did not modify them from their defaults.

To return the update packet rate to the default setting, use the `no spanning-tree uplinkfast max-update-rate` global configuration command. To disable UplinkFast, use the `no spanning-tree uplinkfast` command.

Enabling BackboneFast

You can enable BackboneFast to detect indirect link failures and to start the spanning-tree reconfiguration sooner.

**Note**
If you use BackboneFast, you must enable it on all switches in the network. BackboneFast is not supported on Token Ring VLANs. This feature is supported for use with third-party switches.
You can configure the BackboneFast feature for rapid PVST+ or for the MSTP, but the feature remains disabled (inactive) until you change the spanning-tree mode to PVST+.

Beginning in privileged EXEC mode, follow these steps to enable BackboneFast. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2: spanning-tree backbonefast</td>
<td>Enable BackboneFast.</td>
</tr>
<tr>
<td>Step 3: end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4: show spanning-tree summary</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5: copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable the BackboneFast feature, use the `no spanning-tree backbonefast` global configuration command.

### Enabling EtherChannel Guard

You can enable EtherChannel guard to detect an EtherChannel misconfiguration if your switch is running PVST+, rapid PVST+, or MSTP.

Beginning in privileged EXEC mode, follow these steps to enable EtherChannel guard. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2: spanning-tree etherchannel guard misconfig</td>
<td>Enable EtherChannel guard.</td>
</tr>
<tr>
<td>Step 3: end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4: show spanning-tree summary</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5: copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable the EtherChannel guard feature, use the `no spanning-tree etherchannel guard misconfig` global configuration command.

You can use the `show interfaces status err-disabled` privileged EXEC command to show which switch ports are disabled because of an EtherChannel misconfiguration. On the remote device, you can enter the `show etherchannel summary` privileged EXEC command to verify the EtherChannel configuration.

After the configuration is corrected, enter the `shutdown` and `no shutdown` interface configuration commands on the port-channel interfaces that were misconfigured.
Enabling Root Guard

Root guard enabled on an interface applies to all the VLANs to which the interface belongs. Do not enable the root guard on interfaces to be used by the UplinkFast feature. With UplinkFast, the backup interfaces (in the blocked state) replace the root port in the case of a failure. However, if root guard is also enabled, all the backup interfaces used by the UplinkFast feature are placed in the root-inconsistent state (blocked) and are prevented from reaching the forwarding state.

Note
You cannot enable both root guard and loop guard at the same time.

You can enable this feature if your switch is running PVST+, rapid PVST+, or MSTP.

Beginning in privileged EXEC mode, follow these steps to enable root guard on an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>spanning-tree guard root</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable root guard, use the no spanning-tree guard interface configuration command.

Enabling Loop Guard

You can use loop guard to prevent alternate or root ports from becoming designated ports because of a failure that leads to a unidirectional link. This feature is most effective when it is configured on the entire switched network. Loop guard operates only on interfaces that are considered point-to-point by the spanning tree.

Note
You cannot enable both loop guard and root guard at the same time.

You can enable this feature if your switch is running PVST+, rapid PVST+, or MSTP.

Beginning in privileged EXEC mode, follow these steps to enable loop guard. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>show spanning-tree active or show spanning-tree mst</td>
</tr>
<tr>
<td>Step 2</td>
<td>configure terminal</td>
</tr>
</tbody>
</table>
To globally disable loop guard, use the `no spanning-tree loopguard default` global configuration command. You can override the setting of the `no spanning-tree loopguard default` global configuration command by using the `spanning-tree guard loop` interface configuration command.

**Displaying the Spanning-Tree Status**

To display the spanning-tree status, use one or more of the privileged EXEC commands in Table 14-2:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show spanning-tree active</code></td>
<td>Displays spanning-tree information on active interfaces only.</td>
</tr>
<tr>
<td><code>show spanning-tree detail</code></td>
<td>Displays a detailed summary of interface information.</td>
</tr>
<tr>
<td><code>show spanning-tree interface interface-id</code></td>
<td>Displays spanning-tree information for the specified interface.</td>
</tr>
<tr>
<td><code>show spanning-tree mst interface interface-id</code></td>
<td>Displays MST information for the specified interface.</td>
</tr>
<tr>
<td><code>show spanning-tree summary [totals]</code></td>
<td>Displays a summary of interface states or displays the total lines of the spanning-tree state section.</td>
</tr>
</tbody>
</table>

To globally disable loop guard, use the `no spanning-tree loopguard default` global configuration command. You can override the setting of the `no spanning-tree loopguard default` global configuration command by using the `spanning-tree guard loop` interface configuration command.

You can clear spanning-tree counters by using the `clear spanning-tree [interface interface-id]` privileged EXEC command.

For information about other keywords for the `show spanning-tree` privileged EXEC command, see the command reference for this release.
Configuring Flex Links and the MAC Address-Table Move Update Feature

This chapter describes how to configure Flex Links, a pair of interfaces on the switch that provide a mutual backup. It also describes how to configure the MAC address-table move update feature, also referred to as the Flex Links bidirectional fast convergence feature.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

The chapter consists of these sections:
- Understanding Flex Links and the MAC Address-Table Move Update, page 15-1
- Configuring Flex Links and MAC Address-Table Move Update, page 15-5
- Monitoring Flex Links and the MAC Address-Table Move Update, page 15-11

Understanding Flex Links and the MAC Address-Table Move Update

This section contains this information:
- Flex Links, page 15-1
- VLAN Flex Link Load Balancing and Support, page 15-2
- MAC Address-Table Move Update, page 15-3

Flex Links

Flex Links are a pair of a Layer 2 interfaces (switch ports or port channels) where one interface is configured to act as a backup to the other. The feature provides an alternative solution to the Spanning Tree Protocol (STP). Users can disable STP and still retain basic link redundancy. Flex Links are typically configured in service provider or enterprise networks where customers do not want to run STP on the switch. If the switch is running STP, Flex Links is not necessary because STP already provides link-level redundancy or backup.
You configure Flex Links on one Layer 2 interface (the active link) by assigning another Layer 2 interface as the Flex Link or backup link. When one of the links is up and forwarding traffic, the other link is in standby mode, ready to begin forwarding traffic if the other link shuts down. At any given time, only one of the interfaces is in the linkup state and forwarding traffic. If the primary link shuts down, the standby link starts forwarding traffic. When the active link comes back up, it goes into standby mode and does not forward traffic. STP is disabled on Flex Link interfaces.

In Figure 15-1, ports 1 and 2 on switch A are connected to uplink switches B and C. Because they are configured as Flex Links, only one of the interfaces is forwarding traffic; the other is in standby mode. If port 1 is the active link, it begins forwarding traffic between port 1 and switch B; the link between port 2 (the backup link) and switch C is not forwarding traffic. If port 1 goes down, port 2 comes up and starts forwarding traffic to switch C. When port 1 comes back up, it goes into standby mode and does not forward traffic; port 2 continues forwarding traffic.

You can also choose to configure a preemption mechanism, specifying the preferred port for forwarding traffic. For example, in the example in Figure 15-1, you can configure the Flex Links pair with preemption mode. In the scenario shown, when port 1 comes back up and has more bandwidth than port 2, port 1 begins forwarding traffic after 60 seconds. Port 2 becomes the standby port. You do this by entering the interface configuration `switchport backup interface preemption mode bandwidth` and `switchport backup interface preemption delay` commands.

![Figure 15-1 Flex Links Configuration Example](image)

If a primary (forwarding) link goes down, a trap notifies the network management stations. If the standby link goes down, a trap notifies the users.

Flex Links are supported only on Layer 2 ports and port channels, not on VLANs.

**VLAN Flex Link Load Balancing and Support**

VLAN Flex Link load-balancing allows users to configure a Flex Link pair so that both ports simultaneously forward the traffic for some mutually exclusive VLANs. For example, if Flex Link ports are configured for 1-100 VLANs, the traffic of the first 50 VLANs can be forwarded on one port and the rest on the other port. If one of the ports fail, the other active port forwards all the traffic. When the failed port comes back up, it resumes forwarding traffic in the preferred vlans. This way, apart from providing the redundancy, this Flex Link pair can be used for load balancing. Also, Flex Link VLAN load-balancing does not impose any restrictions on uplink switches.
Chapter 15  Configuring Flex Links and the MAC Address-Table Move Update Feature

Understanding Flex Links and the MAC Address-Table Move Update

Figure 15-2  VLAN Flex Links Load Balancing Configuration Example

MAC Address-Table Move Update

The MAC address-table move update feature allows the switch to provide rapid bidirectional convergence when a primary (forwarding) link goes down and the standby link begins forwarding traffic.

In Figure 15-3, switch A is an access switch, and ports 1 and 2 on switch A are connected to uplink switches B and D through a Flex Link pair. Port 1 is forwarding traffic, and port 2 is in the backup state. Traffic from the PC to the server is forwarded from port 1 to port 3. The MAC address of the PC has been learned on port 3 of switch C. Traffic from the server to the PC is forwarded from port 3 to port 1.

If the MAC address-table move update feature is not configured and port 1 goes down, port 2 starts forwarding traffic. However, for a short time, switch C keeps forwarding traffic from the server to the PC through port 3, and the PC does not get the traffic because port 1 is down. If switch C removes the MAC address of the PC on port 3 and relearns it on port 4, traffic can then be forwarded from the server to the PC through port 2.

If the MAC address-table move update feature is configured and enabled on the switches in Figure 15-3 and port 1 goes down, port 2 starts forwarding traffic from the PC to the server. The switch sends a MAC address-table move update packet from port 2. Switch C gets this packet on port 4 and immediately learns the MAC address of the PC on port 4, which reduces the reconvergence time.

You can configure the access switch, switch A, to send MAC address-table move update messages. You can also configure the uplink switches B, C, and D to get and process the MAC address-table move update messages. When switch C gets a MAC address-table move update message from switch A, switch C learns the MAC address of the PC on port 4. Switch C updates the MAC address table, including the forwarding table entry for the PC. The switch then starts forwarding traffic from the server to the PC through port 4, which reduces the loss of traffic from the server to the PC.
Figure 15-3  MAC Address-Table Move Update Example

Switch C
Port 3
Port 4
Switch B
Port 1
Switch D
Port 2
Switch A

Server
PC

Understanding Flex Links and the MAC Address-Table Move Update
Chapter 15      Configuring Flex Links and the MAC Address-Table Move Update Feature

Configuring Flex Links and MAC Address-Table Move Update

These sections contain this information:
- Configuration Guidelines, page 15-5
- Default Configuration, page 15-5

Configuration Guidelines

Follow these guidelines to configure Flex Links:
- You can configure only one Flex Link backup link for any active link, and it must be a different interface from the active interface.
- An interface can belong to only one Flex Link pair. An interface can be a backup link for only one active link. An active link cannot belong to another Flex Link pair.
- Neither of the links can be a port that belongs to an EtherChannel. However, you can configure two port channels (EtherChannel logical interfaces) as Flex Links, and you can configure a port channel and a physical interface as Flex Links, with either the port channel or the physical interface as the active link.
- A backup link does not have to be the same type (Gigabit Ethernet, or port channel) as the active link. However, you should configure both Flex Links with similar characteristics so that there are no loops or changes in behavior if the standby link begins to forward traffic.
- STP is disabled on Flex Link ports. A Flex Link port does not participate in STP, even if the VLANs present on the port are configured for STP. When STP is not enabled, be sure that there are no loops in the configured topology.

Follow this guideline to configure VLAN load balancing on the Flex Links feature:
For Flex Link VLAN load balancing, you must choose the preferred VLANs on the backup interface.

Follow these guidelines to configure MAC address-table move update feature:
- You can enable and configure this feature on the access switch to send the MAC address-table move updates.
- You can enable and configure this feature on the uplink switches to get the MAC address-table move updates.

Default Configuration

The Flex Links are not configured, and there are no backup interfaces defined.
The preemption mode is off.
The preemption delay is 35 seconds.
The MAC address-table move update feature is not configured on the switch.
Configuring Flex Links and MAC Address-Table Move Update

This section contains this information:

- Configuring Flex Links, page 15-6
- Configuring VLAN Load Balancing on Flex Links, page 15-8
- Configuring the MAC Address-Table Move Update Feature, page 15-9

Configuring Flex Links

Beginning in privileged EXEC mode, follow these steps to configure a pair of Flex Links:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>switchport backup interface interface-id</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show interface [interface-id] switchport backup</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup config</td>
</tr>
</tbody>
</table>

This example shows how to configure an interface with a backup interface and to verify the configuration:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport backup interface gigabitethernet0/2
Switch(config-if)# end

Switch# show interface switchport backup
Switch Backup Interface Pairs:
Active Interface Backup Interface State
GigabitEthernet0/1 GigabitEthernet0/2 Active Up/Backup Standby
```
Beginning in privileged EXEC mode, follow these steps to configure a preemption scheme for a pair of Flex Links:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>switchport backup interface interface-id</strong></td>
</tr>
</tbody>
</table>
| **Step 4** | **switchport backup interface interface-id preemption mode [forced | bandwidth | off]** | Configure a preemption mechanism and delay for a Flex Link interface pair. You can configure the preemption as:  
- Forced—the active interface always preempts the backup.  
- Bandwidth—the interface with the higher bandwidth always acts as the active interface.  
- Off—no preemption happens from active to backup. |
| **Step 5** | **switchport backup interface interface-id preemption delay delay-time** | Configure the time delay until a port preempts another port.  
**Note** Setting a delay time only works with forced and bandwidth modes. |
| **Step 6** | **end** | Return to privileged EXEC mode. |
| **Step 7** | **show interface [interface-id] switchport backup** | Verify the configuration. |
| **Step 8** | **copy running-config startup config** | (Optional) Save your entries in the switch startup configuration file. |

This example shows how to configure the preemption mode as *forced* for a backup interface pair and to verify the configuration:

```
Switch# configure terminal  
Switch(config)# interface gigabitethernet0/1  
Switch(config-if)# switchport backup interface gigabitethernet0/2 preemption mode forced  
Switch(config-if)# switchport backup interface gigabitethernet0/2 preemption delay 50  
Switch(config-if)# end

Switch# show interface switchport backup detail  
Active Interface Backup Interface State  
-----------------------------------------------  
GigabitEthernet0/21 GigabitEthernet0/2 Active Up/Backup Standby  
Interface Pair : Gi0/1, Gi0/2  
Preemption Mode : forced  
Preemption Delay : 50 seconds  
Bandwidth : 100000 Kbit (Gi0/1), 100000 Kbit (Gi0/2)  
Mac Address Move Update Vlan : auto
```
Configuring VLAN Load Balancing on Flex Links

Beginning in privileged EXEC mode, follow these steps to configure VLAN load balancing on Flex Links:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>switchport backup interface interface-id prefer vlan vlan-id</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show interfaces [interface-id] switchport backup</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup config</td>
</tr>
</tbody>
</table>

In the following example, VLANs 1 to 50, 60, and 100 to 120 are configured on the switch:

`Switch(config)#interface gigabitEthernet 0/6
Switch(config-if)#switchport backup interface gigabitEthernet 0/8 prefer vlan 60,100-120`

When both interfaces are up, Gi0/8 forwards traffic for VLANs 60 and 100 to 120 and Gi0/6 forwards traffic for VLANs 1 to 50.

`Switch#show interfaces switchport backup
Switch Backup Interface Pairs:
Active Interface                  Backup Interface                  State
------------------------------------------------------------------------
GigabitEthernet0/6                GigabitEthernet0/8                  Active Up/Backup Standby

Vlans Preferred on Active Interface: 1-50
Vlans Preferred on Backup Interface: 60, 100-120`

When a Flex Link interface goes down (LINK_DOWN), VLANs preferred on this interface are moved to the peer interface of the Flex Link pair. In this example, if interface Gi0/6 goes down, Gi0/8 carries all VLANs of the Flex Link pair.

`Switch#show interfaces switchport backup
Switch Backup Interface Pairs:
Active Interface                  Backup Interface                  State
------------------------------------------------------------------------
GigabitEthernet0/6                GigabitEthernet0/8                  Active Down/Backup Up

Vlans Preferred on Active Interface: 1-50
Vlans Preferred on Backup Interface: 60, 100-120`
When a Flex Link interface comes up, VLANs preferred on this interface are blocked on the peer interface and moved to the forwarding state on the interface that has just come up. In this example, if interface Gi0/6 comes up, VLANs preferred on this interface are blocked on the peer interface Gi0/8 and forwarded on Gi0/6.

```
Switch# show interfaces switchport backup
Switch Backup Interface Pairs:
Active Interface        Backup Interface        State
------------------------------------------------------------------------
GigabitEthernet0/6    GigabitEthernet0/8    Active Up/Backup Standby
Vlans Preferred on Active Interface: 1-50
Vlans Preferred on Backup Interface: 60, 100-120
```

```
Switch# show interfaces switchport backup detail
Switch Backup Interface Pairs:
Active Interface        Backup Interface        State
------------------------------------------------------------------------
FastEthernet0/3       FastEthernet0/4       Active Down/Backup Up
Vlans Preferred on Active Interface: 1-2,5-4094
Vlans Preferred on Backup Interface: 3-4
Preemption Mode      : off
Bandwidth            : 10000 Kbit (Fa0/3), 100000 Kbit (Fa0/4)
Mac Address Move Update Vlan : auto
```

### Configuring the MAC Address-Table Move Update Feature

This section contains this information:
- Configuring a switch to send MAC address-table move updates
- Configuring a switch to get MAC address-table move updates

Beginning in privileged EXEC mode, follow these steps to configure an access switch to send MAC address-table move updates:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td>interface interface-id</td>
<td>Specify the interface, and enter interface configuration mode. The interface can be a physical Layer 2 interface or a port channel (logical interface). The port-channel range is 1 to 48.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>switchport backup interface interface-id</td>
<td>Configure a physical Layer 2 interface (or port channel), as part of a Flex Link pair with the interface. The MAC address-table move update VLAN is the lowest VLAN ID on the interface.</td>
</tr>
<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>switchport backup interface interface-id mmu primary vlan vlan-id</td>
<td>Configure a physical Layer 2 interface (or port channel) and specify the VLAN ID on the interface, which is used for sending the MAC address-table move update. When one link is forwarding traffic, the other interface is in standby mode.</td>
</tr>
</tbody>
</table>
Chapter 15      Configuring Flex Links and the MAC Address-Table Move Update Feature

Configuring Flex Links and the MAC Address-Table Move Update

To disable the MAC address-table move update feature, use the `no mac address-table move update transmit` interface configuration command. To display the MAC address-table move update information, use the `show mac address-table move update` privileged EXEC command.

This example shows how to configure an access switch to send MAC address-table move update messages:

```
Switch# configure terminal
Switch(conf)# interface gigabitethernet0/1
Switch(conf-if)# switchport backup interface gigabitethernet0/2 mmu primary vlan 2
Switch(conf-if)# exit
Switch(conf)# mac address-table move update transmit
Switch(conf)# end
```

This example shows how to verify the configuration:

```
Switch# show mac-address-table move update
Switch-ID : 010b.4630.1780
Dst mac-address : 0180.c200.0010
Vlans/Macs supported : 1023/8320
Default/Current settings: Rcv Off/On, Xmt Off/On
Max packets per min : Rcv 40, Xmt 60
Rcv packet count : 5
Rcv conforming packet count : 5
Rcv invalid packet count : 0
Rcv packet count this min : 0
Rcv threshold exceed count : 0
Rcv last sequence# this min : 0
Rcv last interface : Po2
Rcv last src-mac-address : 000b.462d.c502
Rcv last switch-ID : 0403.fd6a.8700
Xmt packet count : 0
Xmt packet count this min : 0
Xmt threshold exceed count : 0
Xmt pak buf unavail cnt : 0
Xmt last interface : None
```

Beginning in privileged EXEC mode, follow these steps to configure a switch to get and process MAC address-table move update messages:

```
Command | Purpose
---|---
Step 1 configure terminal | Enter global configuration mode.
Step 2 mac address-table move update receive | Enable the switch to get and process the MAC address-table move updates.
```

---

To disable the MAC address-table move update feature, use the `no mac address-table move update transmit` interface configuration command. To display the MAC address-table move update information, use the `show mac address-table move update` privileged EXEC command.

This example shows how to configure an access switch to send MAC address-table move update messages:

```
Switch# configure terminal
Switch(conf)# interface gigabitethernet0/1
Switch(conf-if)# switchport backup interface gigabitethernet0/2 mmu primary vlan 2
Switch(conf-if)# exit
Switch(conf)# mac address-table move update transmit
Switch(conf)# end
```

This example shows how to verify the configuration:

```
Switch# show mac-address-table move update
Switch-ID : 010b.4630.1780
Dst mac-address : 0180.c200.0010
Vlans/Macs supported : 1023/8320
Default/Current settings: Rcv Off/On, Xmt Off/On
Max packets per min : Rcv 40, Xmt 60
Rcv packet count : 5
Rcv conforming packet count : 5
Rcv invalid packet count : 0
Rcv packet count this min : 0
Rcv threshold exceed count : 0
Rcv last sequence# this min : 0
Rcv last interface : Po2
Rcv last src-mac-address : 000b.462d.c502
Rcv last switch-ID : 0403.fd6a.8700
Xmt packet count : 0
Xmt packet count this min : 0
Xmt threshold exceed count : 0
Xmt pak buf unavail cnt : 0
Xmt last interface : None
```

Beginning in privileged EXEC mode, follow these steps to configure a switch to get and process MAC address-table move update messages:

```
Command | Purpose
---|---
Step 1 configure terminal | Enter global configuration mode.
Step 2 mac address-table move update receive | Enable the switch to get and process the MAC address-table move updates.
```
To disable the MAC address-table move update feature, use the `no mac address-table move update receive` configuration command. To display the MAC address-table move update information, use the `show mac address-table move update` privileged EXEC command.

This example shows how to configure a switch to get and process MAC address-table move update messages:

```
Switch# configure terminal
Switch(config)# mac address-table move update receive
Switch(config)# end
```

## Monitoring Flex Links and the MAC Address-Table Move Update

Table 15-1 shows the privileged EXEC commands for monitoring the Flex Links configuration and the MAC address-table move update information.

### Table 15-1 Flex Links and MAC Address-Table Move Update Monitoring Commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show interface [interface-id] switchport backup</code></td>
<td>Displays the Flex Link backup interface configured for an interface or all the configured Flex Links and the state of each active and backup interface (up or standby mode).</td>
</tr>
<tr>
<td><code>show mac address-table move update</code></td>
<td>Displays the MAC address-table move update information on the switch.</td>
</tr>
</tbody>
</table>
Chapter 15  Configuring Flex Links and the MAC Address-Table Move Update Feature

Monitoring Flex Links and the MAC Address-Table Move Update
This chapter describes how to configure DHCP snooping and the option-82 data insertion features on the switch.

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release, and see the “DHCP Commands” section in the *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services, Release 12.2.*

This chapter consists of these sections:
- Understanding DHCP Features, page 16-1
- Configuring DHCP Features, page 16-5
- Displaying DHCP Snooping Information, page 16-9

### Understanding DHCP Features

DHCP is widely used in LAN environments to dynamically assign host IP addresses from a centralized server, which significantly reduces the overhead of administration of IP addresses. DHCP also helps conserve the limited IP address space because IP addresses no longer need to be permanently assigned to hosts; only those hosts that are connected to the network consume IP addresses.

These sections contain this information:
- DHCP Server, page 16-2
- DHCP Relay Agent, page 16-2
- DHCP Snooping, page 16-2
- Option-82 Data Insertion, page 16-3

For information about the DHCP client, see the “Configuring DHCP” section of the “IP Addressing and Services” section of the *Cisco IOS IP Configuration Guide, Release 12.2.*
DHCP Server

The DHCP server assigns IP addresses from specified address pools on a switch or router to DHCP clients and manages them. If the DHCP server cannot give the DHCP client the requested configuration parameters from its database, it forwards the request to one or more secondary DHCP servers defined by the network administrator.

DHCP Relay Agent

A DHCP relay agent is a Layer 3 device that forwards DHCP packets between clients and servers. Relay agents forward requests and replies between clients and servers when they are not on the same physical subnet. Relay agent forwarding is different from the normal Layer 2 forwarding, in which IP datagrams are switched transparently between networks. Relay agents receive DHCP messages and generate new DHCP messages to send on output interfaces.

DHCP Snooping

DHCP snooping is a DHCP security feature that provides network security by filtering untrusted DHCP messages and by building and maintaining a DHCP snooping binding database, also referred to as a DHCP snooping binding table. For more information about this database, see the “Displaying DHCP Snooping Information” section on page 16-9.

DHCP snooping acts like a firewall between untrusted hosts and DHCP servers. You use DHCP snooping to differentiate between untrusted interfaces connected to the end user and trusted interfaces connected to the DHCP server or another switch.

Note

For DHCP snooping to function properly, all DHCP servers must be connected to the switch through trusted interfaces.

An untrusted DHCP message is a message that is received from outside the network or firewall. When you use DHCP snooping in a service-provider environment, an untrusted message is sent from a device that is not in the service-provider network, such as a customer’s switch. Messages from unknown devices are untrusted because they can be sources of traffic attacks.

The DHCP snooping binding database has the MAC address, the IP address, the lease time, the binding type, the VLAN number, and the interface information that corresponds to the local untrusted interfaces of a switch. It does not have information regarding hosts interconnected with a trusted interface.

In a service-provider network, a trusted interface is connected to a port on a device in the same network. An untrusted interface is connected to an untrusted interface in the network or to an interface on a device that is not in the network.

When a switch receives a packet on an untrusted interface and the interface belongs to a VLAN in which DHCP snooping is enabled, the switch compares the source MAC address and the DHCP client hardware address. If the addresses match (the default), the switch forwards the packet. If the addresses do not match, the switch drops the packet.
The switch drops a DHCP packet when one of these situations occurs:

- A packet from a DHCP server, such as a DHCPOFFER, DHCPACK, DHCPNAK, or DHCPLEASEQUERY packet, is received from outside the network or firewall.

- A packet is received on an untrusted interface, and the source MAC address and the DHCP client hardware address do not match.

- The switch receives a DHCPRELEASE or DHCPDECLINE broadcast message that has a MAC address in the DHCP snooping binding database, but the interface information in the binding database does not match the interface on which the message was received.

- A DHCP relay agent forwards a DHCP packet that includes a relay-agent IP address that is not 0.0.0.0, or the relay agent forwards a packet that includes option-82 information to an untrusted port.

If the switch is an aggregation switch supporting DHCP snooping and is connected to an edge switch that is inserting DHCP option-82 information, the switch drops packets with option-82 information when packets are received on an untrusted interface. If DHCP snooping is enabled and packets are received on a trusted port, the aggregation switch does not learn the DHCP snooping bindings for connected devices and cannot build a complete DHCP snooping binding database.

When an aggregation switch can be connected to an edge switch through an untrusted interface and you enter the `ip dhcp snooping information option allow-untrusted` global configuration command, the aggregation switch accepts packets with option-82 information from the edge switch. The aggregation switch learns the bindings for hosts connected through an untrusted switch interface. The DHCP security features can still be enabled on the aggregation switch while the switch receives packets with option-82 information on untrusted input interfaces to which hosts are connected. The port on the edge switch that connects to the aggregation switch must be configured as a trusted interface.

### Option-82 Data Insertion

In residential, metropolitan Ethernet-access environments, DHCP can centrally manage the IP address assignments for a large number of subscribers. When the DHCP option-82 feature is enabled on the switch, a subscriber device is identified by the switch port through which it connects to the network (in addition to its MAC address). Multiple hosts on the subscriber LAN can be connected to the same port on the access switch and are uniquely identified.

---

**Note**
The DHCP option-82 feature is supported only when DHCP snooping is globally enabled and on the VLANs to which subscriber devices using this feature are assigned.

---

Figure 16-1 on page 16-4 is an example of a metropolitan Ethernet network in which a centralized DHCP server assigns IP addresses to subscribers connected to the switch at the access layer. Because the DHCP clients and their associated DHCP server do not reside on the same IP network or subnet, a DHCP relay agent (the Catalyst switch) is configured with a helper address to enable broadcast forwarding and to transfer DHCP messages between the clients and the server.
When you enable the DHCP snooping information option 82 on the switch, this sequence of events occurs:

- The Blade Server (DHCP client) generates a DHCP request and broadcasts it on the network.
- When the blade switch receives the DHCP request, it adds the option-82 information in the packet. remote-ID suboption is the switch MAC address, and the circuit-ID suboption is the port identifier, `vlan-mod-port`, from which the packet is received.
- If the IP address of the relay agent is configured, the switch adds this IP address in the DHCP packet.
- The blade switch forwards the DHCP request that includes the option-82 field to the DHCP server.
- The DHCP server receives the packet. If the server is option-82-capable, it can use the remote ID, the circuit ID, or both to assign IP addresses and implement policies, such as restricting the number of IP addresses that can be assigned to a single remote ID or circuit ID. Then the DHCP server echoes the option-82 field in the DHCP reply.
- The DHCP server unicasts the reply to the blade switch if the request was relayed to the server by the switch. The switch verifies that it originally inserted the option-82 data by inspecting the remote ID and possibly the circuit ID fields. The switch removes the option-82 field and forwards the packet to the switch port that connects to the DHCP client that sent the DHCP request.

When the described sequence of events occurs, the values in these fields in Figure 16-2 do not change:

- Circuit-ID suboption fields
  - Suboption type
  - Length of the suboption type
  - Circuit-ID type
  - Length of the circuit-ID type
- Remote-ID suboption fields
  - Suboption type
  - Length of the suboption type
  - Remote-ID type
  - Length of the remote-ID type
In the port field of the circuit ID suboption, the port numbers start at 1. For example, on a CGESM switch, which has 24 ports, port 1 is the Gigabit Ethernet 0/1 port, port 2 is the Gigabit Ethernet 0/2 port, port 3 is the Gigabit Ethernet 0/3 port, and so on. Because ports 19, 20, 21, and 22 are small form-factor pluggable (SFP) modules, port 19 is the SFP module slot 0/1, port 20 is the SFP module slot 0/2, port 21 is the SFP module slot 0/3 and port 22 is the SFP module slot 0/4.

Figure 16-2 shows the packet formats for the remote-ID suboption and the circuit-ID suboption. The switch uses the packet formats when you globally enable DHCP snooping and enter the **ip dhcp snooping information option** global configuration command.

**Figure 16-2 Suboption Packet Formats**

**Circuit ID Suboption Frame Format**

<table>
<thead>
<tr>
<th>Suboption type</th>
<th>Circuit ID type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Length</td>
</tr>
<tr>
<td>1 byte</td>
<td>1 byte</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>VLAN Module Port</td>
</tr>
</tbody>
</table>

**Remote ID Suboption Frame Format**

<table>
<thead>
<tr>
<th>Suboption type</th>
<th>Remote ID type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Length</td>
</tr>
<tr>
<td>1 byte</td>
<td>1 byte</td>
</tr>
<tr>
<td>2</td>
<td>1 byte</td>
</tr>
<tr>
<td>6</td>
<td>MAC address</td>
</tr>
</tbody>
</table>

### Configuring DHCP Features

These sections contain this configuration information:

- Default DHCP Configuration, page 16-5
- DHCP Snooping Configuration Guidelines, page 16-6
- Configuring the DHCP Relay Agent, page 16-7
- Enabling DHCP Snooping and Option 82, page 16-7

### Default DHCP Configuration

Table 16-1 shows the default DHCP configuration.
Configuring DHCP Features

DHCP Snooping Configuration Guidelines

These are the configuration guidelines for DHCP snooping.

- You must globally enable DHCP snooping on the switch.
- DHCP snooping is not active until DHCP snooping is enabled on a VLAN.
- Before globally enabling DHCP snooping on the switch, make sure that the devices acting as the DHCP server and the DHCP relay agent are configured and enabled.
- When you globally enable DHCP snooping on the switch, these Cisco IOS commands are not available until snooping is disabled. If you enter these commands, the switch returns an error message, and the configuration is not applied.
  - `ip dhcp relay information check` global configuration command
  - `ip dhcp relay information policy` global configuration command
  - `ip dhcp relay information trust-all` global configuration command
  - `ip dhcp relay information trusted` interface configuration command
- Before configuring the DHCP snooping information option on your switch, be sure to configure the device that is acting as the DHCP server. For example, you must specify the IP addresses that the DHCP server can assign or exclude, or you must configure DHCP options for these devices.
- If the DHCP relay agent is enabled but DHCP snooping is disabled, the DHCP option-82 data insertion feature is not supported.

### Table 16-1 Default DHCP Configuration

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHCP server</td>
<td>Enabled in Cisco IOS software, requires configuration¹</td>
</tr>
<tr>
<td>DHCP relay agent</td>
<td>Enabled²</td>
</tr>
<tr>
<td>DHCP packet forwarding address</td>
<td>None configured</td>
</tr>
<tr>
<td>Checking the relay agent information</td>
<td>Enabled (invalid messages are dropped)²</td>
</tr>
<tr>
<td>DHCP relay agent forwarding policy</td>
<td>Replace the existing relay agent information²</td>
</tr>
<tr>
<td>DHCP snooping enabled globally</td>
<td>Disabled</td>
</tr>
<tr>
<td>DHCP snooping information option</td>
<td>Enabled</td>
</tr>
<tr>
<td>DHCP snooping option to accept packets on untrusted input interfaces³</td>
<td>Disabled</td>
</tr>
<tr>
<td>DHCP snooping limit rate</td>
<td>None configured</td>
</tr>
<tr>
<td>DHCP snooping trust</td>
<td>Untrusted</td>
</tr>
<tr>
<td>DHCP snooping VLAN</td>
<td>Disabled</td>
</tr>
<tr>
<td>DHCP snooping MAC address verification</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

1. The switch responds to DHCP requests only if it is configured as a DHCP server.
2. The switch relays DHCP packets only if the IP address of the DHCP server is configured on the SVI of the DHCP client.
3. Use this feature when the switch is an aggregation switch that receives packets with option-82 information from an edge switch.
- If a switch port is connected to a DHCP server, configure a port as trusted by entering the `ip dhcp snooping trust` interface configuration command.
- If a switch port is connected to a DHCP client, configure a port as untrusted by entering the `no ip dhcp snooping trust` interface configuration command.
- Do not enter the `ip dhcp snooping information option allow-untrusted` command on an aggregation switch to which an untrusted device is connected. If you enter this command, an untrusted device might spoof the option-82 information.
- Starting with Cisco IOS Release 12.2(37)SE, you can display DHCP snooping statistics by entering the `show ip dhcp snooping statistics` user EXEC command, and you can clear the snooping statistics counters by entering the `clear ip dhcp snooping statistics` privileged EXEC command.

### Configuring the DHCP Relay Agent

Beginning in privileged EXEC mode, follow these steps to enable the DHCP relay agent on the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> service dhcp</td>
<td>Enable the DHCP server and relay agent on your switch. By default, this feature is enabled.</td>
</tr>
<tr>
<td><strong>Step 3</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong> show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable the DHCP server and relay agent, use the `no service dhcp` global configuration command.

See the “Configuring DHCP” section of the “IP Addressing and Services” section of the Cisco IOS IP Configuration Guide, Release 12.2 for these procedures:

- Checking (validating) the relay agent information
- Configuring the relay agent forwarding policy

### Enabling DHCP Snooping and Option 82

Beginning in privileged EXEC mode, follow these steps to enable DHCP snooping on the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> ip dhcp snooping</td>
<td>Enable DHCP snooping globally.</td>
</tr>
<tr>
<td><strong>Step 3</strong> ip dhcp snooping vlan vlan-range</td>
<td>Enable DHCP snooping on a VLAN or range of VLANs. The range is 1 to 4094.</td>
</tr>
</tbody>
</table>

You can enter a single VLAN ID identified by VLAN ID number, a series of VLAN IDs separated by commas, a range of VLAN IDs separated by hyphens, or a range of VLAN IDs separated by entering the starting and ending VLAN IDs separated by a space.
Configuring DHCP Features

To disable DHCP snooping, use the `no ip dhcp snooping` global configuration command. To disable DHCP snooping on a VLAN or range of VLANs, use the `no ip dhcp snooping vlan vlan-range` global configuration command. To disable the insertion and removal of the option-82 field, use the `no ip dhcp snooping information option` global configuration command. To configure an aggregation switch to drop incoming DHCP snooping packets with option-82 information from an edge switch, use the `no ip dhcp snooping information option allow-untrusted` global configuration command.

This example shows how to enable DHCP snooping globally and on VLAN 10 and to configure a rate limit of 100 packets per second on a port:

```
Switch(config)# ip dhcp snooping
Switch(config)# ip dhcp snooping vlan 10
Switch(config)# ip dhcp snooping information option
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip dhcp snooping limit rate 100
```
Enabling the Cisco IOS DHCP Server Database

For procedures to enable and configure the Cisco IOS DHCP server database, see the “DHCP Configuration Task List” section in the “Configuring DHCP” chapter of the Cisco IOS IP Configuration Guide, Release 12.2.

Displaying DHCP Snooping Information

To display the DHCP snooping information, use one or more of the privileged EXEC commands in Table 16-2:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show ip dhcp snooping</td>
<td>Displays the DHCP snooping configuration for a switch</td>
</tr>
<tr>
<td>show ip dhcp snooping binding</td>
<td>Displays only the dynamically configured bindings in the DHCP snooping binding database, also referred to as a binding table.</td>
</tr>
<tr>
<td>show ip dhcp snooping statistics</td>
<td>Displays the DHCP snooping statistics in summary or detail form.</td>
</tr>
</tbody>
</table>

**Note** If DHCP snooping is enabled and an interface changes to the down state, the switch does not delete the statically configured bindings.
Displaying DHCP Snooping Information
This chapter describes how to configure Internet Group Management Protocol (IGMP) snooping on the switch, including an application of local IGMP snooping, Multicast VLAN Registration (MVR). It also includes procedures for controlling multicast group membership by using IGMP filtering and procedures for configuring the IGMP throttling action.

Note

For complete syntax and usage information for the commands used in this chapter, see the switch command reference for this release and the “IP Multicast Routing Commands” section in the Cisco IOS IP Command Reference, Volume 3 of 3:Multicast, Release 12.2.

This chapter consists of these sections:

- Understanding IGMP Snooping, page 17-1
- Configuring IGMP Snooping, page 17-6
- Displaying IGMP Snooping Information, page 17-15
- Understanding Multicast VLAN Registration, page 17-17
- Configuring MVR, page 17-19
- Displaying MVR Information, page 17-23
- Configuring IGMP Filtering and Throttling, page 17-23
- Displaying IGMP Filtering and Throttling Configuration, page 17-28

Note

You can either manage IP multicast group addresses through features such as IGMP snooping and MVR, or you can use static IP addresses.

Understanding IGMP Snooping

Layer 2 switches can use IGMP snooping to constrain the flooding of multicast traffic by dynamically configuring Layer 2 interfaces so that multicast traffic is forwarded to only those interfaces associated with IP multicast devices. As the name implies, IGMP snooping requires the LAN switch to snoop on the IGMP transmissions between the host and the router and to keep track of multicast groups and member ports. When the switch receives an IGMP report from a host for a particular multicast group, the switch adds the host port number to the forwarding table entry; when it receives an IGMP Leave Group message from a host, it removes the host port from the table entry. It also periodically deletes entries if it does not receive IGMP membership reports from the multicast clients.
Understanding IGMP Snooping

Note

For more information on IP multicast and IGMP, see RFC 1112 and RFC 2236.

The multicast router sends out periodic general queries to all VLANs. All hosts interested in this multicast traffic send join requests and are added to the forwarding table entry. The switch creates one entry per VLAN in the IGMP snooping IP multicast forwarding table for each group from which it receives an IGMP join request.

The switch supports IP multicast group-based bridging, rather than MAC-addressed based groups. With multicast MAC address-based groups, if an IP address being configured translates (aliases) to a previously configured MAC address or to any reserved multicast MAC addresses (in the range 224.0.0.xxx), the command fails. Because the switch uses IP multicast groups, there are no address aliasing issues.

The IP multicast groups learned through IGMP snooping are dynamic. However, you can statically configure multicast groups by using the `ip igmp snooping vlan vlan-id static ip_address interface interface-id` global configuration command. If you specify group membership for a multicast group address statically, your setting supersedes any automatic manipulation by IGMP snooping. Multicast group membership lists can consist of both user-defined and IGMP snooping-learned settings.

You can configure an IGMP snooping querier to support IGMP snooping in subnets without multicast interfaces because the multicast traffic does not need to be routed. For more information about the IGMP snooping querier, see the “Configuring the IGMP Snooping Querier” section on page 17-13.

If a port spanning-tree, a port group, or a VLAN ID change occurs, the IGMP snooping-learned multicast groups from this port on the VLAN are deleted.

These sections describe IGMP snooping characteristics:

- IGMP Versions, page 17-2
- Joining a Multicast Group, page 17-3
- Leaving a Multicast Group, page 17-5
- Immediate Leave, page 17-5
- IGMP Configurable-Leave Timer, page 17-5
- IGMP Report Suppression, page 17-6

IGMP Versions

The switch supports IGMP Version 1, IGMP Version 2, and IGMP Version 3. These versions are interoperable on the switch. For example, if IGMP snooping is enabled on an IGMPv2 switch and the switch receives an IGMPv3 report from a host, the switch can forward the IGMPv3 report to the multicast router.

Note

The switch supports IGMPv3 snooping based only on the destination multicast MAC address. It does not support snooping based on the source MAC address or on proxy reports.

An IGMPv3 switch supports Basic IGMPv3 Snooping Support (BISS), which includes support for the snooping features on IGMPv1 and IGMPv2 switches and for IGMPv3 membership report messages. BISS constrains the flooding of multicast traffic when your network includes IGMPv3 hosts. It constrains traffic to approximately the same set of ports as the IGMP snooping feature on IGMPv2 or IGMPv1 hosts.
**Note**

IGMPv3 join and leave messages are not supported on switches running IGMP filtering or MVR.

An IGMPv3 switch can receive messages from and forward messages to a device running the Source Specific Multicast (SSM) feature. For more information about source-specific multicast with IGMPv3 and IGMP, see the following URL:

http://www.cisco.com/univercd/cc/td/doc/product/software/ios121/121newft/121t/121t5/dtssm5t.htm

**Joining a Multicast Group**

When a blade server connected to the switch wants to join an IP multicast group and it is an IGMP Version 2 client, it sends an unsolicited IGMP join message, specifying the IP multicast group to join. Alternatively, when the switch receives a general query from the router, it forwards the query to all ports in the VLAN. IGMP Version 1 or Version 2 blade servers wanting to join the multicast group respond by sending a join message to the switch. The switch CPU creates a multicast forwarding-table entry for the group if it is not already present. The CPU also adds the interface where the join message was received to the forwarding-table entry. The blade server associated with that interface receives multicast traffic for that multicast group. See Figure 17-1.

*Figure 17-1  Initial IGMP Join Message*
Router A sends a general query to the switch, which forwards the query to ports 2 through 5, which are all members of the same VLAN. Blade Server 1 wants to join multicast group 224.1.2.3 and multicasts an IGMP membership report (IGMP join message) to the group. The switch CPU uses the information in the IGMP report to set up a forwarding-table entry, as shown in Table 17-1, that includes the port numbers of Blade Server 1 and the router.

**Table 17-1 IGMP Snooping Forwarding Table**

<table>
<thead>
<tr>
<th>Destination Address</th>
<th>Type of Packet</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>224.1.2.3</td>
<td>IGMP</td>
<td>1, 2</td>
</tr>
</tbody>
</table>

The switch hardware can distinguish IGMP information packets from other packets for the multicast group. The information in the table tells the switching engine to send frames addressed to the 224.1.2.3 multicast IP address that are not IGMP packets to the router and to the host that has joined the group.

If another blade server (for example, Blade Server 4) sends an unsolicited IGMP join message for the same group (Figure 17-2), the CPU receives that message and adds the port number of Blade Server 4 to the forwarding table as shown in Table 17-2. Note that because the forwarding table directs IGMP messages only to the CPU, the message is not flooded to other ports on the switch. Any known multicast traffic is forwarded to the group and not to the CPU.

**Figure 17-2 Second Host Joining a Multicast Group**

![Second Host Joining a Multicast Group](image)

**Table 17-2 Updated IGMP Snooping Forwarding Table**

<table>
<thead>
<tr>
<th>Destination Address</th>
<th>Type of Packet</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>224.1.2.3</td>
<td>IGMP</td>
<td>1, 2, 5</td>
</tr>
</tbody>
</table>
Leaving a Multicast Group

The router sends periodic multicast general queries, and the switch forwards these queries through all ports in the VLAN. Interested blade servers respond to the queries. If at least one blade server in the VLAN wishes to receive multicast traffic, the router continues forwarding the multicast traffic to the VLAN. The switch forwards multicast group traffic only to those blade servers listed in the forwarding table for that IP multicast group maintained by IGMP snooping.

When blade servers want to leave a multicast group, they can silently leave, or they can send a leave message. When the switch receives a leave message from a blade server, it sends a group-specific query to learn if any other devices connected to that interface are interested in traffic for the specific multicast group. The switch then updates the forwarding table for that MAC group so that only those blade servers interested in receiving multicast traffic for the group are listed in the forwarding table. If the router receives no reports from a VLAN, it removes the group for the VLAN from its IGMP cache.

Immediate Leave

Immediate Leave is only supported on IGMP Version 2 hosts.

The switch uses IGMP snooping Immediate Leave to remove from the forwarding table an interface that sends a leave message without the switch sending group-specific queries to the interface. The VLAN interface is pruned from the multicast tree for the multicast group specified in the original leave message. Immediate Leave ensures optimal bandwidth management for all blade servers on a switched network, even when multiple multicast groups are simultaneously in use.

Note

You should only use the Immediate Leave feature on VLANs where a single blade server is connected to each port. If Immediate Leave is enabled in VLANs where more than one blade server is connected to a port, some blade servers might inadvertently be dropped.

For configuration steps, see the “Enabling IGMP Immediate Leave” section on page 17-10.

IGMP Configurable-Leave Timer

In Cisco IOS Release 12.2(25)SEA and earlier, the IGMP snooping leave time was fixed at 5 seconds. If membership reports were not received by the switch before the query response time of the query expired, a port was removed from the multicast group membership. However, some applications require a leave latency of less than 5 seconds.

In Cisco IOS Release 12.2(25)SED and later, you can configure the time that the switch waits after sending a group-specific query to determine if hosts are still interested in a specific multicast group. The IGMP leave response time can be configured from 100 to 5000 milliseconds. The timer can be set either globally or on a per-VLAN basis. The VLAN configuration of the leave time overrides the global configuration.

For configuration steps, see the “Configuring the IGMP Leave Timer” section on page 17-11.
IGMP Report Suppression

Note

IGMP report suppression is supported only when the multicast query has IGMPv1 and IGMPv2 reports. This feature is not supported when the query includes IGMPv3 reports.

The switch uses IGMP report suppression to forward only one IGMP report per multicast router query to multicast devices. When IGMP router suppression is enabled (the default), the switch sends the first IGMP report from all blade servers for a group to all the multicast routers. The switch does not send the remaining IGMP reports for the group to the multicast routers. This feature prevents duplicate reports from being sent to the multicast devices.

If the multicast router query includes requests only for IGMPv1 and IGMPv2 reports, the switch forwards only the first IGMPv1 or IGMPv2 report from all blade servers for a group to all the multicast routers.

If the multicast router query also includes requests for IGMPv3 reports, the switch forwards all IGMPv1, IGMPv2, and IGMPv3 reports for a group to the multicast devices.

If you disable IGMP report suppression, all IGMP reports are forwarded to the multicast routers. For configuration steps, see the “Disabling IGMP Report Suppression” section on page 17-15.

Configuring IGMP Snooping

IGMP snooping allows switches to examine IGMP packets and make forwarding decisions based on their content. These sections contain this configuration information:

- Default IGMP Snooping Configuration, page 17-6
- Enabling or Disabling IGMP Snooping, page 17-7
- Setting the Snooping Method, page 17-8
- Configuring a Multicast Router Port, page 17-9
- Configuring a Blade Server Static to Join a Group, page 17-9
- Enabling IGMP Immediate Leave, page 17-10
- Configuring the IGMP Leave Timer, page 17-11
- Configuring TCN-Related Commands, page 17-11
- Configuring the IGMP Snooping Querier, page 17-13
- Disabling IGMP Report Suppression, page 17-15

Default IGMP Snooping Configuration

Table 17-3 shows the default IGMP snooping configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGMP snooping</td>
<td>Enabled globally and per VLAN</td>
</tr>
<tr>
<td>Multicast routers</td>
<td>None configured</td>
</tr>
</tbody>
</table>
Configuring IGMP Snooping and MVR

Chapter 17 Configuring IGMP Snooping and MVR

Configuring IGMP Snooping

Enabling or Disabling IGMP Snooping

By default, IGMP snooping is globally enabled on the switch. When globally enabled or disabled, it is also enabled or disabled in all existing VLAN interfaces. IGMP snooping is by default enabled on all VLANs, but can be enabled and disabled on a per-VLAN basis.

Global IGMP snooping overrides the VLAN IGMP snooping. If global snooping is disabled, you cannot enable VLAN snooping. If global snooping is enabled, you can enable or disable VLAN snooping.

Beginning in privileged EXEC mode, follow these steps to globally enable IGMP snooping on the switch:

To globally disable IGMP snooping on all VLAN interfaces, use the `no ip igmp snooping` global configuration command.

Beginning in privileged EXEC mode, follow these steps to enable IGMP snooping on a VLAN interface:

### Table 17-3 Default IGMP Snooping Configuration (continued)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multicast router learning (snooping) method</td>
<td>PIM-DVMRP</td>
</tr>
<tr>
<td>IGMP snooping Immediate Leave</td>
<td>Disabled</td>
</tr>
<tr>
<td>Static groups</td>
<td>None configured</td>
</tr>
<tr>
<td>TCN(^1) flood query count</td>
<td>2</td>
</tr>
<tr>
<td>TCN query solicitation</td>
<td>Disabled</td>
</tr>
<tr>
<td>IGMP snooping querier</td>
<td>Disabled</td>
</tr>
<tr>
<td>IGMP report suppression</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

1. TCN = Topology Change Notification

### Enabling or Disabling IGMP Snooping

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 ip igmp snooping</td>
<td>Globally enable IGMP snooping in all existing VLAN interfaces.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To globally disable IGMP snooping on all VLAN interfaces, use the `no ip igmp snooping` global configuration command.

Beginning in privileged EXEC mode, follow these steps to enable IGMP snooping on a VLAN interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 ip igmp snooping vlan vlan-id</td>
<td>Enable IGMP snooping on the VLAN interface. The VLAN ID range is 1 to 1001 and 1006 to 4094.</td>
</tr>
</tbody>
</table>

Note: IGMP snooping must be globally enabled before you can enable VLAN snooping.
Chapter 17 Configuring IGMP Snooping and MVR

Configuring IGMP Snooping

To disable IGMP snooping on a VLAN interface, use the `no ip igmp snooping vlan vlan-id` global configuration command for the specified VLAN number.

Setting the Snooping Method

Multicast-capable router ports are added to the forwarding table for every Layer 2 multicast entry. The switch learns of such ports through one of these methods:

- Snooping on IGMP queries, Protocol Independent Multicast (PIM) packets, and Distance Vector Multicast Routing Protocol (DVMRP) packets
- Listening to Cisco Group Management Protocol (CGMP) packets from other routers
- Statically connecting to a multicast router port with the `ip igmp snooping mrouter` global configuration command

You can configure the switch either to snoop on IGMP queries and PIM/DVMRP packets or to listen to CGMP self-join or proxy-join packets. By default, the switch snoops on PIM/DVMRP packets on all VLANs. To learn of multicast router ports through only CGMP packets, use the `ip igmp snooping vlan vlan-id mrouter learn cgmp` global configuration command. When this command is entered, the router listens to only CGMP self-join and CGMP proxy-join packets and to no other CGMP packets. To learn of multicast router ports through only PIM-DVMRP packets, use the `ip igmp snooping vlan vlan-id mrouter learn pim-dvmrp` global configuration command.

**Note**

If you want to use CGMP as the learning method and no multicast routers in the VLAN are CGMP proxy-enabled, you must enter the `ip cgmp router-only` command to dynamically access the router.

Beginning in privileged EXEC mode, follow these steps to alter the method in which a VLAN interface dynamically accesses a multicast router:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong>ip igmp snooping vlan vlan-id mrouter learn {cgmp</td>
<td>pim-dvmrp}</td>
</tr>
<tr>
<td><strong>Step 3</strong>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong>show ip igmp snooping</td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td><strong>Step 5</strong>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
To return to the default learning method, use the `no ip igmp snooping vlan vlan-id mrouter learn cgmp` global configuration command.

This example shows how to configure IGMP snooping to use CGMP packets as the learning method:

```
Switch# configure terminal
Switch(config)# ip igmp snooping vlan 1 mrouter learn cgmp
Switch(config)# end
```

### Configuring a Multicast Router Port

To add a multicast router port (add a static connection to a multicast router), use the `ip igmp snooping vlan mrouter` global configuration command on the switch.

Beginning in privileged EXEC mode, follow these steps to enable a static connection to a multicast router:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>ip igmp snooping vlan vlan-id mrouter interface interface-id</code></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>show ip igmp snooping mrouter [vlan vlan-id]</code></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>copy running-config startup-config</code></td>
</tr>
</tbody>
</table>

To remove a multicast router port from the VLAN, use the `no ip igmp snooping vlan vlan-id mrouter interface interface-id` global configuration command.

This example shows how to enable a static connection to a multicast router:

```
Switch# configure terminal
Switch(config)# ip igmp snooping vlan 200 mrouter interface gigabitethernet0/2
Switch(config)# end
```

### Configuring a Blade Server Statically to Join a Group

Blade servers that are connected to Layer 2 ports normally join multicast groups dynamically. You can also statically configure a Layer 2 port, to which a blade server is connected, so that the port joins a multicast group.
Chapter 17 Configuring IGMP Snooping and MVR

Configuring IGMP Snooping

Beginning in privileged EXEC mode, follow these steps to add a Layer 2 port as a member of a multicast group:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>ip igmp snooping vlan vlan-id static ip_address interface interface-id</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show ip igmp snooping groups</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To remove the Layer 2 port from the multicast group, use the **no ip igmp snooping vlan vlan-id static mac-address interface interface-id** global configuration command.

This example shows how to statically configure a blade server on a port:

Switch# configure terminal
Switch(config)# ip igmp snooping vlan 105 static 224.2.4.12 interface gigabitethernet0/1
Switch(config)# end

Enabling IGMP Immediate Leave

When you enable IGMP Immediate Leave, the switch immediately removes a port when it detects an IGMP Version 2 leave message on that port. You should only use the Immediate-Leave feature when there is a single receiver present on every port in the VLAN.

**Note**

Immediate Leave is supported only on IGMP Version 2 blade servers.

Beginning in privileged EXEC mode, follow these steps to enable IGMP Immediate Leave:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>ip igmp snooping vlan vlan-id immediate-leave</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show ip igmp snooping vlan vlan-id</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>
To disable IGMP Immediate Leave on a VLAN, use the `no ip igmp snooping vlan vlan-id immediate-leave` global configuration command.

This example shows how to enable IGMP Immediate Leave on VLAN 130:

Switch# configure terminal
Switch(config)# ip igmp snooping vlan 130 immediate-leave
Switch(config)# end

**Configuring the IGMP Leave Timer**

Follows these guidelines when configuring the IGMP leave timer:

- You can configure the leave time globally or on a per-VLAN basis.
- Configuring the leave time on a VLAN overrides the global setting.
- The default leave time is 1000 milliseconds.
- The IGMP configurable leave time is only supported on hosts running IGMP Version 2.
- The actual leave latency in the network is usually the configured leave time. However, the leave time might vary around the configured time, depending on real-time CPU load conditions, network delays and the amount of traffic sent through the interface.

Beginning in privileged EXEC mode, follow these steps to enable the IGMP configurable-leave timer:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>ip igmp snooping last-member-query-interval time</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip igmp snooping vlan vlan-id last-member-query-interval time</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show ip igmp snooping</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To globally reset the IGMP leave timer to the default setting, use the `no ip igmp snooping last-member-query-interval` global configuration command.

To remove the configured IGMP leave-time setting from the specified VLAN, use the `no ip igmp snooping vlan vlan-id last-member-query-interval` global configuration command.

**Configuring TCN-Related Commands**

These sections describe how to control flooded multicast traffic during a TCN event:

- Controlling the Multicast Flooding Time After a TCN Event, page 17-12
- Recovering from Flood Mode, page 17-12
- Disabling Multicast Flooding During a TCN Event, page 17-13
Controlling the Multicast Flooding Time After a TCN Event

You can control the time that multicast traffic is flooded after a TCN event by using the `ip igmp snooping tcn flood query count` global configuration command. This command configures the number of general queries for which multicast data traffic is flooded after a TCN event. Some examples of TCN events are when the client changed its location and the receiver is on the same port that was blocked but is now forwarding, and when a port went down without sending a leave message.

If you set the TCN flood query count to 1 by using the `ip igmp snooping tcn flood query count` command, the flooding stops after receiving 1 general query. If you set the count to 7, the flooding until 7 general queries are received. Groups are relearned based on the general queries received during the TCN event.

Beginning in privileged EXEC mode, follow these steps to configure the TCN flood query count:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>ip igmp snooping tcn flood query count count</code></td>
<td>Specify the number of IGMP general queries for which the multicast traffic is flooded. The range is 1 to 10. By default, the flooding query count is 2.</td>
</tr>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><code>show ip igmp snooping</code></td>
<td>Verify the TCN settings.</td>
</tr>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default flooding query count, use the `no ip igmp snooping tcn flood query count` global configuration command.

Recovering from Flood Mode

When a topology change occurs, the spanning-tree root sends a special IGMP leave message (also known as global leave) with the group multicast address 0.0.0.0. However, when you enable the `ip igmp snooping tcn query solicit` global configuration command, the switch sends the global leave message whether or not it is the spanning-tree root. When the router receives this special leave, it immediately sends general queries, which expedite the process of recovering from the flood mode during the TCN event. Leaves are always sent if the switch is the spanning-tree root regardless of this configuration command. By default, query solicitation is disabled.

Beginning in privileged EXEC mode, follow these steps to enable the switch to send the global leave message whether or not it is the spanning-tree root:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>ip igmp snooping tcn query solicit</code></td>
<td>Send an IGMP leave message (global leave) to speed the process of recovering from the flood mode caused during a TCN event. By default, query solicitation is disabled.</td>
</tr>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
Configuring IGMP Snooping

To return to the default query solicitation, use the `no ip igmp snooping tcn query solicit` global configuration command.

Disabling Multicast Flooding During a TCN Event

When the switch receives a TCN, multicast traffic is flooded to all the ports until 2 general queries are received. If the switch has many ports with attached hosts that are subscribed to different multicast groups, this flooding might exceed the capacity of the link and cause packet loss. You can use the `ip igmp snooping tcn flood` interface configuration command to control this behavior.

Beginning in privileged EXEC mode, follow these steps to disable multicast flooding on an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the interface to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 no ip igmp snooping tcn flood</td>
<td>Disable the flooding of multicast traffic during a spanning-tree TCN event. By default, multicast flooding is enabled on an interface.</td>
</tr>
<tr>
<td>Step 4 exit</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show ip igmp snooping</td>
<td>Verify the TCN settings.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To re-enable multicast flooding on an interface, use the `ip igmp snooping tcn flood` interface configuration command.

Configuring the IGMP Snooping Querier

Follow these guidelines when configuring the IGMP snooping querier:

- Configure the VLAN in global configuration mode.
- Configure an IP address on the VLAN interface. When enabled, the IGMP snooping querier uses the IP address as the query source address.
- If there is no IP address configured on the VLAN interface, the IGMP snooping querier tries to use the configured global IP address for the IGMP querier. If there is no global IP address specified, the IGMP querier tries to use the VLAN switch virtual interface (SVI) IP address (if one exists). If there is no SVI IP address, the switch uses the first available IP address configured on the switch. The first IP address available appears in the output of the `show ip interface` privileged EXEC command. The IGMP snooping querier does not generate an IGMP general query if it cannot find an available IP address on the switch.
- The IGMP snooping querier supports IGMP Versions 1 and 2.
When administratively enabled, the IGMP snooping querier moves to the nonquerier state if it detects the presence of a multicast router in the network.

When it is administratively enabled, the IGMP snooping querier moves to the operationally disabled state under these conditions:
  - IGMP snooping is disabled in the VLAN.
  - PIM is enabled on the SVI of the corresponding VLAN.

Beginning in privileged EXEC mode, follow these steps to enable the IGMP snooping querier feature in a VLAN:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>ip igmp snooping querier</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip igmp snooping querier address ip_address</td>
</tr>
<tr>
<td>Step 4</td>
<td>ip igmp snooping querier query-interval interval-count</td>
</tr>
<tr>
<td>Step 5</td>
<td>ip igmp snooping querier tcn query [count count</td>
</tr>
<tr>
<td>Step 6</td>
<td>interval interval]</td>
</tr>
<tr>
<td>Step 7</td>
<td>ip igmp snooping querier timer expiry timeout</td>
</tr>
<tr>
<td>Step 8</td>
<td>ip igmp snooping querier version version</td>
</tr>
<tr>
<td>Step 9</td>
<td>end</td>
</tr>
<tr>
<td>Step 10</td>
<td>show ip igmp snooping vlan vlan-id</td>
</tr>
<tr>
<td>Step 10</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

This example shows how to set the IGMP snooping querier source address to 10.0.0.64:

```
Switch# configure terminal
Switch(config)# ip igmp snooping querier 10.0.0.64
Switch(config)# end
```

This example shows how to set the IGMP snooping querier maximum response time to 25 seconds:

```
Switch# configure terminal
Switch(config)# ip igmp snooping querier query-interval 25
Switch(config)# end
```

This example shows how to set the IGMP snooping querier timeout to 60 seconds:

```
Switch# configure terminal
Switch(config)# ip igmp snooping querier timeout expiry 60
Switch(config)# end
```
This example shows how to set the IGMP snooping querier feature to version 2:

```
Switch# configure terminal
Switch(config)# no ip igmp snooping querier version 2
Switch(config)# end
```

### Disabling IGMP Report Suppression

**Note**

IGMP report suppression is supported only when the multicast query has IGMPv1 and IGMPv2 reports. This feature is not supported when the query includes IGMPv3 reports.

IGMP report suppression is enabled by default. When it is enabled, the switch forwards only one IGMP report per multicast router query. When report suppression is disabled, all IGMP reports are forwarded to the multicast routers.

Beginning in privileged EXEC mode, follow these steps to disable IGMP report suppression:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 no ip igmp snooping report-suppression</td>
<td>Disable IGMP report suppression.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show ip igmp snooping</td>
<td>Verify that IGMP report suppression is disabled.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To re-enable IGMP report suppression, use the `ip igmp snooping report-suppression` global configuration command.

### Displaying IGMP Snooping Information

You can display IGMP snooping information for dynamically learned and statically configured router ports and VLAN interfaces. You can also display MAC address multicast entries for a VLAN configured for IGMP snooping.
To display IGMP snooping information, use one or more of the privileged EXEC commands in Table 17-4.

### Table 17-4 Commands for Displaying IGMP Snooping Information

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show ip igmp snooping [vlan vlan-id]</code></td>
<td>Display the snooping configuration information for all VLANs on the switch or for a specified VLAN. (Optional) Enter <code>vlan vlan-id</code> to display information for a single VLAN. The VLAN ID range is 1 to 1001 and 1006 to 4094.</td>
</tr>
</tbody>
</table>
| `show ip igmp snooping groups [count |dynamic [count] | user [count]]` | Display multicast table information for the switch or about a specific parameter:  
  - **count**—Display the total number of entries for the specified command options instead of the actual entries.  
  - **dynamic**—Display entries learned through IGMP snooping.  
  - **user**—Display only the user-configured multicast entries. |
| `show ip igmp snooping groups vlan vlan-id [ip_address | count | dynamic [count] | user[count]]` | Display multicast table information for a multicast VLAN or about a specific parameter for the VLAN:  
  - **vlan-id**—The VLAN ID range is 1 to 1001 and 1006 to 4094.  
  - **count**—Display the total number of entries for the specified command options instead of the actual entries.  
  - **dynamic**—Display entries learned through IGMP snooping.  
  - **ip_address**—Display characteristics of the multicast group with the specified group IP address.  
  - **user**—Display only the user-configured multicast entries. |
| `show ip igmp snooping mrouter [vlan vlan-id]` | Display information on dynamically learned and manually configured multicast router interfaces. **Note** When you enable IGMP snooping, the switch automatically learns the interface to which a multicast router is connected. These are dynamically learned interfaces. (Optional) Enter `vlan vlan-id` to display information for a single VLAN. |
| `show ip igmp snooping querier [vlan vlan-id]` | Display information about the IP address and receiving port for the most-recently received IGMP query messages in the VLAN. (Optional) Enter `vlan vlan-id` to display information for a single VLAN. |
| `show ip igmp snooping querier [vlan vlan-id] detail` | Display information about the IP address and receiving port of the most-recently received IGMP query message in the VLAN and the configuration and operational state of the IGMP snooping querier in the VLAN. |

For more information about the keywords and options in these commands, see the command reference for this release.
Understanding Multicast VLAN Registration

Multicast VLAN Registration (MVR) is designed for applications using wide-scale deployment of multicast traffic across an Ethernet ring-based service-provider network (for example, the broadcast of multiple television channels over a service-provider network). MVR allows a subscriber on a port to subscribe and unsubscribe to a multicast stream on the network-wide multicast VLAN. It allows the single multicast VLAN to be shared in the network while subscribers remain in separate VLANs. MVR provides the ability to continuously send multicast streams in the multicast VLAN, but to isolate the streams from the subscriber VLANs for bandwidth and security reasons.

MVR assumes that subscriber ports subscribe and unsubscribe (join and leave) these multicast streams by sending out IGMP join and leave messages. These messages can originate from an IGMP Version-2-compatible blade server with an Ethernet connection. Although MVR operates on the underlying mechanism of IGMP snooping, the two features operate independently of each other. One can be enabled or disabled without affecting the behavior of the other feature. However, if IGMP snooping and MVR are both enabled, MVR reacts only to join and leave messages from multicast groups configured under MVR. Join and leave messages from all other multicast groups are managed by IGMP snooping.

The switch CPU identifies the MVR IP multicast streams and their associated IP multicast group in the switch forwarding table, intercepts the IGMP messages, and modifies the forwarding table to include or remove the subscriber as a receiver of the multicast stream, even though the receivers might be in a different VLAN from the source. This forwarding behavior selectively allows traffic to cross between different VLANs.

You can set the switch for compatible or dynamic mode of MVR operation:

- In compatible mode, multicast data received by MVR hosts is forwarded to all MVR data ports, regardless of MVR host membership on those ports. The multicast data is forwarded only to those receiver ports that MVR hosts have joined, either by IGMP reports or by MVR static configuration. IGMP reports received from MVR hosts are never forwarded from MVR data ports that were configured in the blade server.

- In dynamic mode, multicast data received by MVR hosts on the switch is forwarded from only those MVR data and client ports that the MVR hosts have joined, either by IGMP reports or by MVR static configuration. Any IGMP reports received from MVR hosts are also forwarded from all the MVR data ports in the blade server. This eliminates using unnecessary bandwidth on MVR data port links, which occurs when the blade server runs in compatible mode.

Only Layer 2 ports take part in MVR. You must configure ports as MVR receiver ports. Only one MVR multicast VLAN per switch is supported.
Using MVR in a Multicast Television Application

In a multicast television application, a PC or a television with a set-top box can receive the multicast stream. Multiple set-top boxes or PCs can be connected to one subscriber port, which is a switch port configured as an MVR receiver port. Figure 17-3 is an example configuration. DHCP assigns an IP address to the set-top box or the PC. When a subscriber selects a channel, the set-top box or PC sends an IGMP report to Switch A to join the appropriate multicast. If the IGMP report matches one of the configured IP multicast group addresses, the switch CPU modifies the hardware address table to include this receiver port and VLAN as a forwarding destination of the specified multicast stream when it is received from the multicast VLAN. Uplink ports that send and receive multicast data to and from the multicast VLAN are called MVR source ports.

Figure 17-3  Multicast VLAN Registration Example

Note: All source ports belong to the multicast VLAN.
When a subscriber changes channels or turns off the television, the set-top box sends an IGMP leave message for the multicast stream. The switch CPU sends a MAC-based general query through the receiver port VLAN. If there is another set-top box in the VLAN still subscribing to this group, that set-top box must respond within the maximum response time specified in the query. If the CPU does not receive a response, it eliminates the receiver port as a forwarding destination for this group.

Without Immediate Leave, when the switch receives an IGMP leave message from a subscriber on a receiver port, it sends out an IGMP query on that port and waits for IGMP group membership reports. If no reports are received in a configured time period, the receiver port is removed from multicast group membership. With Immediate Leave, an IGMP query is not sent from the receiver port on which the IGMP leave was received. As soon as the leave message is received, the receiver port is removed from multicast group membership, which speeds up leave latency. Enable the Immediate-Leave feature only on receiver ports to which a single receiver device is connected.

MVR eliminates the need to duplicate television-channel multicast traffic for subscribers in each VLAN. Multicast traffic for all channels is only sent around the VLAN trunk once—only on the multicast VLAN. The IGMP leave and join messages are in the VLAN to which the subscriber port is assigned. These messages dynamically register for streams of multicast traffic in the multicast VLAN on the Layer 3 device, Switch B. The access layer switch, Switch A, modifies the forwarding behavior to allow the traffic to be forwarded from the multicast VLAN to the subscriber port in a different VLAN, selectively allowing traffic to cross between two VLANs.

IGMP reports are sent to the same IP multicast group address as the multicast data. The Switch A CPU must capture all IGMP join and leave messages from receiver ports and forward them to the multicast VLAN of the source (uplink) port, based on the MVR mode.

## Configuring MVR

These sections contain this configuration information:

- Default MVR Configuration, page 17-19
- MVR Configuration Guidelines and Limitations, page 17-20
- Configuring MVR Global Parameters, page 17-20
- Configuring MVR Interfaces, page 17-21

### Default MVR Configuration

Table 17-5 shows the default MVR configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVR</td>
<td>Disabled globally and per interface</td>
</tr>
<tr>
<td>Multicast addresses</td>
<td>None configured</td>
</tr>
<tr>
<td>Query response time</td>
<td>0.5 second</td>
</tr>
<tr>
<td>Multicast VLAN</td>
<td>VLAN 1</td>
</tr>
<tr>
<td>Mode</td>
<td>Compatible</td>
</tr>
</tbody>
</table>
Configuring MVR Global Parameters

You do not need to set the optional MVR parameters if you choose to use the default settings. If you do want to change the default parameters (except for the MVR VLAN), you must first enable MVR.

For complete syntax and usage information for the commands used in this section, see the command reference for this release.

Beginning in privileged EXEC mode, follow these steps to configure MVR parameters:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2: mvr</td>
<td>Enable MVR on the switch.</td>
</tr>
<tr>
<td>Step 3: mvr group ip-address [count]</td>
<td>Configure an IP multicast address on the switch or use the count parameter to configure a contiguous series of MVR group addresses (the range for count is 1 to 256; the default is 1). Any multicast data sent to this address is sent to all source ports on the switch and all receiver ports that have elected to receive data on that multicast address. Each multicast address would correspond to one television channel.</td>
</tr>
</tbody>
</table>

Table 17-5  Default MVR Configuration (continued)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface (per port) default</td>
<td>Neither a receiver nor a source port</td>
</tr>
<tr>
<td>Immediate Leave</td>
<td>Disabled on all ports</td>
</tr>
</tbody>
</table>
### Configuring MVR Interfaces

Beginning in privileged EXEC mode, follow these steps to configure Layer 2 MVR interfaces:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 mvr</td>
<td>Enable MVR on the switch.</td>
</tr>
<tr>
<td>Step 3 interface</td>
<td>Specify the Layer 2 port to configure, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>

To return the switch to its default settings, use the `no mvr [mode | group ip-address | querytime | vlan]` global configuration commands.

This example shows how to enable MVR, configure the group address, set the query time to 1 second (10 tenths), specify the MVR multicast VLAN as VLAN 22, and set the MVR mode as dynamic:

```
Switch(config)# mvr
Switch(config)# mvr group 228.1.23.4
Switch(config)# mvr querytime 10
Switch(config)# mvr vlan 22
Switch(config)# mvr mode dynamic
Switch(config)# end
```

You can use the `show mvr members` privileged EXEC command to verify the MVR multicast group addresses on the switch.

### Command Purpose

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 4 <code>mvr querytime value</code></td>
<td>(Optional) Define the maximum time to wait for IGMP report memberships on a receiver port before removing the port from multicast group membership. The value is in units of tenths of a second. The range is 1 to 100, and the default is 5 tenths or one-half second.</td>
</tr>
<tr>
<td>Step 5 <code>mvr vlan vlan-id</code></td>
<td>(Optional) Specify the VLAN in which multicast data is received; all source ports must belong to this VLAN. The VLAN range is 1 to 1001 and 1006 to 4094. The default is VLAN 1.</td>
</tr>
<tr>
<td>Step 6 `mvr mode {dynamic</td>
<td>compatible}`</td>
</tr>
<tr>
<td></td>
<td>dynamic—Allows dynamic MVR membership on source ports.</td>
</tr>
<tr>
<td></td>
<td>compatible—Is compatible with Catalyst 3500 XL and Catalyst 2900 XL switches and does not support IGMP dynamic joins on source ports. The default is compatible mode.</td>
</tr>
<tr>
<td>Step 7 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 8 show mvr or show mvr members</td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td>Step 9 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to enable MVR, configure the group address, set the query time to 1 second (10 tenths), specify the MVR multicast VLAN as VLAN 22, and set the MVR mode as dynamic:

```
Switch(config)# mvr
Switch(config)# mvr group 228.1.23.4
Switch(config)# mvr querytime 10
Switch(config)# mvr vlan 22
Switch(config)# mvr mode dynamic
Switch(config)# end
```

You can use the `show mvr members` privileged EXEC command to verify the MVR multicast group addresses on the switch.
### Chapter 17      Configuring IGMP Snooping and MVR

#### Configuring MVR

To return the interface to its default settings, use the `no mvr [type | immediate | vlan vlan-id | group]` interface configuration commands.

This example shows how to configure a port as a receiver port, statically configure the port to receive multicast traffic sent to the multicast group address, configure Immediate Leave on the port, and verify the results.

```bash
Switch(config)# mvr
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# mvr type receiver
Switch(config-if)# mvr vlan 22 group 228.1.23.4
Switch(config-if)# mvr immediate
Switch(config)# end
Switch# show mvr interface
Port   Type         Status               Immediate Leave
------- ------- -------------- ----------------------------
Gi0/2   RECEIVER   ACTIVE/DOWN       ENABLED
```

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 4** mvr type {source | receiver} | Configure an MVR port as one of these:
|                                | • **source**—Configure uplink ports that receive and send multicast data as source ports. Subscribers cannot be directly connected to source ports. All source ports on a switch belong to the single multicast VLAN.
|                                | • **receiver**—Configure a port as a receiver port if it is a subscriber port and should only receive multicast data. It does not receive data unless it becomes a member of the multicast group, either statically or by using IGMP leave and join messages. Receiver ports cannot belong to the multicast VLAN. The default configuration is as a non-MVR port. If you attempt to configure a non-MVR port with MVR characteristics, the operation fails. |
| **Step 5** mvr vlan vlan-id group [ip-address] | (Optional) Statically configure a port to receive multicast traffic sent to the multicast VLAN and the IP multicast address. A port statically configured as a member of a group remains a member of the group until statically removed. **Note** In compatible mode, this command applies to only receiver ports. In dynamic mode, it applies to receiver ports and source ports. Receiver ports can also dynamically join multicast groups by using IGMP join and leave messages. |
| **Step 6** mvr immediate | (Optional) Enable the Immediate-Leave feature of MVR on the port. **Note** This command applies to only receiver ports and should only be enabled on receiver ports to which a single receiver device is connected. |
| **Step 7** end | Return to privileged EXEC mode. |
| **Step 8** show mvr | Verify the configuration. |
| or show mvr interface | |
| or show mvr members | |
| **Step 9** copy running-config startup-config | (Optional) Save your entries in the configuration file. |

To return the interface to its default settings, use the no mvr [type | immediate | vlan vlan-id | group] interface configuration commands.

This example shows how to configure a port as a receiver port, statically configure the port to receive multicast traffic sent to the multicast group address, configure Immediate Leave on the port, and verify the results.

```bash
Switch(config)# mvr
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# mvr type receiver
Switch(config-if)# mvr vlan 22 group 228.1.23.4
Switch(config-if)# mvr immediate
Switch(config)# end
Switch# show mvr interface
Port   Type         Status               Immediate Leave
------- ------- -------------- ----------------------------
Gi0/2   RECEIVER   ACTIVE/DOWN       ENABLED
```
Displaying MVR Information

You can display MVR information for the switch or for a specified interface. Beginning in privileged EXEC mode, use the commands in Table 17-6 to display MVR configuration:

Table 17-6 Commands for Displaying MVR Information

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show mvr</td>
<td>Displays MVR status and values for the switch—whether MVR is enabled or disabled, the multicast VLAN, the maximum (256) and current (0 through 256) number of multicast groups, the query response time, and the MVR mode.</td>
</tr>
</tbody>
</table>
| show mvr interface [interface-id] [members [vlan vlan-id]] | Displays all MVR interfaces and their MVR configurations. When a specific interface is entered, displays this information:  
- Type—Receiver or Source  
- Status—One of these:  
  - Active means the port is part of a VLAN.  
  - Up/Down means that the port is forwarding or nonforwarding.  
  - Inactive means that the port is not part of any VLAN.  
- Immediate Leave—Enabled or Disabled  
If the members keyword is entered, displays all multicast group members on this port or, if a VLAN identification is entered, all multicast group members on the VLAN. The VLAN ID range is 1 to 1001 and 1006 to 4094. |
| show mvr members [ip-address] | Displays all receiver and source ports that are members of any IP multicast group or the specified IP multicast group IP address. |

Configuring IGMP Filtering and Throttling

In some environments, for example, metropolitan or multiple-dwelling unit (MDU) installations, you might want to control the set of multicast groups to which a user on a switch port can belong. You can control the distribution of multicast services, such as IP/TV, based on some type of subscription or service plan. You might also want to limit the number of multicast groups to which a user on a switch port can belong.

With the IGMP filtering feature, you can filter multicast joins on a per-port basis by configuring IP multicast profiles and associating them with individual switch ports. An IGMP profile can contain one or more multicast groups and specifies whether access to the group is permitted or denied. If an IGMP profile denying access to a multicast group is applied to a switch port, the IGMP join report requesting the stream of IP multicast traffic is dropped, and the port is not allowed to receive IP multicast traffic from that group. If the filtering action permits access to the multicast group, the IGMP report from the port is forwarded for normal processing. You can also set the maximum number of IGMP groups that a Layer 2 interface can join.

IGMP filtering controls only group-specific query and membership reports, including join and leave reports. It does not control general IGMP queries. IGMP filtering has no relationship with the function that directs the forwarding of IP multicast traffic. The filtering feature operates in the same manner whether CGMP or MVR is used to forward the multicast traffic.
IGMP filtering is applicable only to the dynamic learning of IP multicast group addresses, not static configuration.

With the IGMP throttling feature, you can set the maximum number of IGMP groups that a Layer 2 interface can join. If the maximum number of IGMP groups is set, the IGMP snooping forwarding table contains the maximum number of entries, and the interface receives an IGMP join report, you can configure an interface to drop the IGMP report or to replace the randomly selected multicast entry with the received IGMP report.

Note

IGMPv3 join and leave messages are not supported on switches running IGMP filtering.

These sections contain this configuration information:
- Default IGMP Filtering and Throttling Configuration, page 17-24
- Configuring IGMP Profiles, page 17-24 (optional)
- Applying IGMP Profiles, page 17-25 (optional)
- Setting the Maximum Number of IGMP Groups, page 17-26 (optional)
- Configuring the IGMP Throttling Action, page 17-27 (optional)

Default IGMP Filtering and Throttling Configuration

Table 17-7 shows the default IGMP filtering configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGMP filters</td>
<td>None applied</td>
</tr>
<tr>
<td>IGMP maximum number of IGMP groups</td>
<td>No maximum set</td>
</tr>
<tr>
<td>IGMP profiles</td>
<td>None defined</td>
</tr>
<tr>
<td>IGMP profile action</td>
<td>Deny the range addresses</td>
</tr>
</tbody>
</table>

When the maximum number of groups is in forwarding table, the default IGMP throttling action is to deny the IGMP report. For configuration guidelines, see the “Configuring the IGMP Throttling Action” section on page 17-27.

Configuring IGMP Profiles

To configure an IGMP profile, use the `ip igmp profile` global configuration command with a profile number to create an IGMP profile and to enter IGMP profile configuration mode. From this mode, you can specify the parameters of the IGMP profile to be used for filtering IGMP join requests from a port. When you are in IGMP profile configuration mode, you can create the profile by using these commands:

- `deny`: Specifies that matching addresses are denied; this is the default.
- `exit`: Exits from igmp-profile configuration mode.
- `no`: Negates a command or returns to its defaults.
**permit**: Specifies that matching addresses are permitted.

**range**: Specifies a range of IP addresses for the profile. You can enter a single IP address or a range with a start and an end address.

The default is for the switch to have no IGMP profiles configured. When a profile is configured, if neither the **permit** nor **deny** keyword is included, the default is to deny access to the range of IP addresses.

Beginning in privileged EXEC mode, follow these steps to create an IGMP profile:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>ip igmp profile <strong>profile number</strong></td>
<td>Assign a number to the profile you are configuring, and enter IGMP profile configuration mode. The profile number range is 1 to 4294967295.</td>
</tr>
<tr>
<td>3</td>
<td>permit</td>
<td>deny</td>
</tr>
<tr>
<td>4</td>
<td>range <strong>ip multicast address</strong></td>
<td>Enter the IP multicast address or range of IP multicast addresses to which access is being controlled. If entering a range, enter the low IP multicast address, a space, and the high IP multicast address. You can use the <strong>range</strong> command multiple times to enter multiple addresses or ranges of addresses.</td>
</tr>
<tr>
<td>5</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>6</td>
<td>show ip igmp profile <strong>profile number</strong></td>
<td>Verify the profile configuration.</td>
</tr>
<tr>
<td>7</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To delete a profile, use the **no ip igmp profile **profile number** global configuration command.

To delete an IP multicast address or range of IP multicast addresses, use the **no range ip multicast address** IGMP profile configuration command.

This example shows how to create IGMP profile 4 allowing access to the single IP multicast address and how to verify the configuration. If the action was to deny (the default), it would not appear in the **show ip igmp profile** output display.

```plaintext
Switch(config)# ip igmp profile 4
Switch(config-igmp-profile)# permit
Switch(config-igmp-profile)# range 229.9.9.0
Switch(config-igmp-profile)# end
Switch# show ip igmp profile 4
IGMP Profile 4
  permit
  range 229.9.9.0 229.9.9.0
```

### Applying IGMP Profiles

To control access as defined in an IGMP profile, use the **ip igmp filter** interface configuration command to apply the profile to the appropriate interfaces. You can apply IGMP profiles only to Layer 2 access ports. You cannot apply profiles to ports that belong to an EtherChannel port group. You can apply a profile to multiple interfaces, but each interface can have only one profile applied to it.
Beginning in privileged EXEC mode, follow these steps to apply an IGMP profile to a switch port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip igmp filter profile number</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config interface interface-id</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To remove a profile from an interface, use the **no ip igmp filter profile number** interface configuration command.

This example shows how to apply IGMP profile 4 to a port:

Switch(config)# interface gigabitethernet0/2
Switch(config-if)# ip igmp filter 4
Switch(config-if)# end

### Setting the Maximum Number of IGMP Groups

You can set the maximum number of IGMP groups that a Layer 2 interface can join by using the **ip igmp max-groups number** interface configuration command. Use the **no** form of this command to set the maximum back to the default, which is no limit.

You can use this command on a logical EtherChannel interface but cannot use it on ports that belong to an EtherChannel port group.

Beginning in privileged EXEC mode, follow these steps to set the maximum number of IGMP groups in the forwarding table:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip igmp max-groups number</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config interface interface-id</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>
To remove the maximum group limitation and return to the default of no maximum, use the `no ip igmp max-groups` interface configuration command.

This example shows how to limit to 25 the number of IGMP groups that a port can join.

```
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# ip igmp max-groups 25
Switch(config-if)# end
```

### Configuring the IGMP Throttling Action

After you set the maximum number of IGMP groups that a Layer 2 interface can join, you can configure an interface to replace the existing group with the new group for which the IGMP report was received by using the `ip igmp max-groups action replace` interface configuration command. Use the `no` form of this command to return to the default, which is to drop the IGMP join report.

Follow these guidelines when configuring the IGMP throttling action:

- You can use this command on a logical EtherChannel interface but cannot use it on ports that belong to an EtherChannel port group.
- When the maximum group limitation is set to the default (no maximum), entering the `ip igmp max-groups action {deny | replace}` command has no effect.
- If you configure the throttling action and set the maximum group limitation after an interface has added multicast entries to the forwarding table, the forwarding-table entries are either aged out or removed, depending on the throttling action:
  - If you configure the throttling action as `deny`, the entries that were previously in the forwarding table are not removed but are aged out. After these entries are aged out and the maximum number of entries is in the forwarding table, the switch drops the next IGMP report received on the interface.
  - If you configure the throttling action as `replace`, the entries that were previously in the forwarding table are removed. When the maximum number of entries is in the forwarding table, the switch replaces a randomly selected entry with the received IGMP report.

To prevent the switch from removing the forwarding-table entries, you can configure the IGMP throttling action before an interface adds entries to the forwarding table.

Beginning in privileged EXEC mode, follow these steps to configure the throttling action when the maximum number of entries is in the forwarding table:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><code>configure terminal</code></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><code>interface interface-id</code></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>`ip igmp max-groups action {deny</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Displaying IGMP Filtering and Throttling Configuration

You can display IGMP profile characteristics, and you can display the IGMP profile and maximum group configuration for all interfaces on the switch or for a specified interface. You can also display the IGMP throttling configuration for all interfaces on the switch or for a specified interface.

Use the privileged EXEC commands in Table 17-8 to display IGMP filtering and throttling configuration:

**Table 17-8 Commands for Displaying IGMP Filtering and Throttling Configuration**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show ip igmp profile [profile number]</td>
<td>Displays the specified IGMP profile or all the IGMP profiles defined on the switch.</td>
</tr>
<tr>
<td>show running-config [interface interface-id]</td>
<td>Displays the configuration of the specified interface or the configuration of all interfaces on the switch, including (if configured) the maximum number of IGMP groups to which an interface can belong and the IGMP profile applied to the interface.</td>
</tr>
</tbody>
</table>

To return to the default action of dropping the report, use the `no ip igmp max-groups action` interface configuration command.
Configuring Port-Based Traffic Control

This chapter describes how to configure the port-based traffic control features on the switch.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Configuring Storm Control, page 18-1
- Configuring Protected Ports, page 18-5
- Configuring Port Blocking, page 18-6
- Configuring Port Security, page 18-7
- Displaying Port-Based Traffic Control Settings, page 18-17

Configuring Storm Control

These sections contain this conceptual and configuration information:
- Understanding Storm Control, page 18-1
- Default Storm Control Configuration, page 18-3
- Configuring Storm Control and Threshold Levels, page 18-3

Understanding Storm Control

Storm control prevents traffic on a LAN from being disrupted by a broadcast, multicast, or unicast storm on one of the physical interfaces. A LAN storm occurs when packets flood the LAN, creating excessive traffic and degrading network performance. Errors in the protocol-stack implementation, mistakes in network configurations, or users issuing a denial-of-service attack can cause a storm.

Storm control (or traffic suppression) monitors packets passing from an interface to the switching bus and determines if the packet is unicast, multicast, or broadcast. The switch counts the number of packets of a specified type received within the 1-second time interval and compares the measurement with a predefined suppression-level threshold.
Storm control uses one of these methods to measure traffic activity:

- Bandwidth as a percentage of the total available bandwidth of the port that can be used by the broadcast, multicast, or unicast traffic
- Traffic rate in packets per second at which broadcast, multicast, or unicast packets are received (Cisco IOS Release 12.2(25)SE1 or later)
- Traffic rate in bits per second at which broadcast, multicast, or unicast packets are received (Cisco IOS Release 12.2(25)SE1 or later)

With each method, the port blocks traffic when the rising threshold is reached. The port remains blocked until the traffic rate drops below the falling threshold (if one is specified) and then resumes normal forwarding. If the falling suppression level is not specified, the switch blocks all traffic until the traffic rate drops below the rising suppression level. In general, the higher the level, the less effective the protection against broadcast storms.

Note: When the storm control threshold for multicast traffic is reached, all multicast traffic except control traffic, such as bridge protocol data unit (BDPU) and Cisco Discovery Protocol (CDP) frames, are blocked.

The graph in Figure 18-1 shows broadcast traffic patterns on an interface over a given period of time. The example can also be applied to multicast and unicast traffic. In this example, the broadcast traffic being forwarded exceeded the configured threshold between time intervals T1 and T2 and between T4 and T5. When the amount of specified traffic exceeds the threshold, all traffic of that kind is dropped for the next time period. Therefore, broadcast traffic is blocked during the intervals following T2 and T5. At the next time interval (for example, T3), if broadcast traffic does not exceed the threshold, it is again forwarded.

**Figure 18-1  Broadcast Storm Control Example**

The combination of the storm-control suppression level and the 1-second time interval controls the way the storm control algorithm works. A higher threshold allows more packets to pass through. A threshold value of 100 percent means that no limit is placed on the traffic. A value of 0.0 means that all broadcast, multicast, or unicast traffic on that port is blocked.

Note: Because packets do not arrive at uniform intervals, the 1-second time interval during which traffic activity is measured can affect the behavior of storm control.
You use the `storm-control` interface configuration commands to set the threshold value for each traffic type.

**Default Storm Control Configuration**

By default, unicast, broadcast, and multicast storm control are disabled on the switch interfaces; that is, the suppression level is 100 percent.

**Configuring Storm Control and Threshold Levels**

You configure storm control on a port and enter the threshold level that you want to be used for a particular type of traffic.

However, because of hardware limitations and the way in which packets of different sizes are counted, threshold percentages are approximations. Depending on the sizes of the packets making up the incoming traffic, the actual enforced threshold might differ from the configured level by several percentage points.

**Note**

Storm control is supported on physical interfaces. You can also configure storm control on an EtherChannel. When storm control is configured on an EtherChannel, the storm control settings propagate to the EtherChannel physical interfaces.

Beginning in privileged EXEC mode, follow these steps to storm control and threshold levels:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface <code>interface-id</code></td>
<td>Specify the interface to be configured, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
Chapter 18  Configuring Port-Based Traffic Control

Configuring Storm Control

Step 3

```
storm-control (broadcast | multicast | unicast) level (level [level-low] | bps bps [bps-low] | pps pps [pps-low])
```

Configure broadcast, multicast, or unicast storm control. By default, storm control is disabled.

The keywords have these meanings:

- **For level**, specify the rising threshold level for broadcast, multicast, or unicast traffic as a percentage (up to two decimal places) of the bandwidth. The port blocks traffic when the rising threshold is reached. The range is 0.00 to 100.00.

- **(Optional) For level-low**, specify the falling threshold level as a percentage (up to two decimal places) of the bandwidth. This value must be less than or equal to the rising suppression value. The port forwards traffic when traffic drops below this level. If you do not configure a falling suppression level, it is set to the rising suppression level. The range is 0.00 to 100.00.

If you set the threshold to the maximum value (100 percent), no limit is placed on the traffic. If you set the threshold to 0.0, all broadcast, multicast, and unicast traffic on that port is blocked.

- **For bps bps**, specify the rising threshold level for broadcast, multicast, or unicast traffic in bits per second (up to one decimal place). The port blocks traffic when the rising threshold is reached. The range is 0.0 to 1000000000.0.

- **(Optional) For bps-low**, specify the falling threshold level in bits per second (up to one decimal place). It can be less than or equal to the rising threshold level. The port forwards traffic when traffic drops below this level. The range is 0.0 to 1000000000.0.

- **For pps pps**, specify the rising threshold level for broadcast, multicast, or unicast traffic in packets per second (up to one decimal place). The port blocks traffic when the rising threshold is reached. The range is 0.0 to 10000000000.0.

- **(Optional) For pps-low**, specify the falling threshold level in packets per second (up to one decimal place). It can be less than or equal to the rising threshold level. The port forwards traffic when traffic drops below this level. The range is 0.0 to 10000000000.0.

For BPS and PPS settings, you can use metric suffixes such as k, m, and g for large number thresholds.

Step 4

```
storm-control action (shutdown | trap)
```

Specify the action to be taken when a storm is detected. The default is to filter out the traffic and not to send traps.

- Select the **shutdown** keyword to error-disable the port during a storm.

- Select the **trap** keyword to generate an SNMP trap when a storm is detected.

Step 5

```
end
```

Return to privileged EXEC mode.
Configuring Protected Ports

Some applications require that no traffic be forwarded at Layer 2 between ports on the same switch so that one neighbor does not see the traffic generated by another neighbor. In such an environment, the use of protected ports ensures that there is no exchange of unicast, broadcast, or multicast traffic between these ports on the switch.

Protected ports have these features:

- A protected port does not forward any traffic (unicast, multicast, or broadcast) to any other port that is also a protected port. Data traffic cannot be forwarded between protected ports at Layer 2; only control traffic, such as PIM packets, is forwarded because these packets are processed by the CPU and forwarded in software. All data traffic passing between protected ports must be forwarded through a Layer 3 device.

- Forwarding behavior between a protected port and a nonprotected port proceeds as usual.

These sections contain this configuration information:

- Default Protected Port Configuration, page 18-6
- Protected Port Configuration Guidelines, page 18-6
- Configuring a Protected Port, page 18-6

### Step 6

<table>
<thead>
<tr>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>show storm-control [interface-id] [broadcast</td>
</tr>
</tbody>
</table>

Verify the storm control suppression levels set on the interface for the specified traffic type. If you do not enter a traffic type, broadcast storm control settings are displayed.

### Step 7

<table>
<thead>
<tr>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

(Optional) Save your entries in the configuration file.

To disable storm control, use the `no storm-control [broadcast | multicast | unicast] level` command.

This example shows how to enable unicast storm control on a port with an 87-percent rising suppression level and a 65-percent falling suppression level:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# storm-control unicast level 87 65
```

This example shows how to enable broadcast address storm control on a port to a level of 20 percent. When the broadcast traffic exceeds the configured level of 20 percent of the total available bandwidth of the port within the traffic-storm-control interval, the switch drops all broadcast traffic until the end of the traffic-storm-control interval:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# storm-control broadcast level 20
```
Default Protected Port Configuration

The default is to have no protected ports defined.

Protected Port Configuration Guidelines

You can configure protected ports on a physical interface (for example, Gigabit Ethernet port 1) or an EtherChannel group (for example, port-channel 5). When you enable protected ports for a port channel, it is enabled for all ports in the port-channel group.

Configuring a Protected Port

Beginning in privileged EXEC mode, follow these steps to define a port as a protected port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>switchport protected</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show interfaces interface-id switchport</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable protected port, use the `no switchport protected` interface configuration command.

This example shows how to configure a port as a protected port:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport protected
Switch(config-if)# end
```

Configuring Port Blocking

By default, the switch floods packets with unknown destination MAC addresses out of all ports. If unknown unicast and multicast traffic is forwarded to a protected port, there could be security issues. To prevent unknown unicast or multicast traffic from being forwarded from one port to another, you can block a port (protected or nonprotected) from flooding unknown unicast or multicast packets to other ports.

These sections contain this configuration information:

- Default Port Blocking Configuration, page 18-7
- Blocking Flooded Traffic on an Interface, page 18-7
Default Port Blocking Configuration

The default is to not block flooding of unknown multicast and unicast traffic out of a port, but to flood these packets to all ports.

Blocking Flooded Traffic on an Interface

The interface can be a physical interface or an EtherChannel group. When you block multicast or unicast traffic for a port channel, it is blocked on all ports in the port-channel group.

Beginning in privileged EXEC mode, follow these steps to disable the flooding of multicast and unicast packets out of an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1  configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2  interface interface-id</td>
<td>Specify the interface to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3  switchport block multicast</td>
<td>Block unknown multicast forwarding out of the port.</td>
</tr>
<tr>
<td>Step 4  switchport block unicast</td>
<td>Block unknown unicast forwarding out of the port.</td>
</tr>
<tr>
<td>Step 5  end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 6  show interfaces interface-id switchport</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 7  copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the interface to the default condition where no traffic is blocked and normal forwarding occurs on the port, use the no switchport block {multicast | unicast} interface configuration commands.

This example shows how to block unicast and multicast flooding on a port:

```plaintext
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport block multicast
Switch(config-if)# switchport block unicast
Switch(config-if)# end
```

Configuring Port Security

You can use the port security feature to restrict input to an interface by limiting and identifying MAC addresses of the stations allowed to access the port. When you assign secure MAC addresses to a secure port, the port does not forward packets with source addresses outside the group of defined addresses. If you limit the number of secure MAC addresses to one and assign a single secure MAC address, the workstation attached to that port is assured the full bandwidth of the port.

If a port is configured as a secure port and the maximum number of secure MAC addresses is reached, when the MAC address of a station attempting to access the port is different from any of the identified secure MAC addresses, a security violation occurs. Also, if a station with a secure MAC address configured or learned on one secure port attempts to access another secure port, a violation is flagged.
These sections contain this conceptual and configuration information:

- Understanding Port Security, page 18-8
- Default Port Security Configuration, page 18-10
- Port Security Configuration Guidelines, page 18-10
- Enabling and Configuring Port Security, page 18-11
- Enabling and Configuring Port Security Aging, page 18-16

### Understanding Port Security

These sections contain this conceptual information:

- Secure MAC Addresses, page 18-8
- Security Violations, page 18-9

### Secure MAC Addresses

You configure the maximum number of secure addresses allowed on a port by using the `switchport port-security maximum value` interface configuration command.

**Note**

If you try to set the maximum value to a number less than the number of secure addresses already configured on an interface, the command is rejected.

The switch supports these types of secure MAC addresses:

- Static secure MAC addresses—These are manually configured by using the `switchport port-security mac-address mac-address` interface configuration command, stored in the address table, and added to the switch running configuration.
- Dynamic secure MAC addresses—These are dynamically configured, stored only in the address table, and removed when the switch restarts.
- 'Sticky' secure MAC addresses—These can be dynamically learned or manually configured, stored in the address table, and added to the running configuration. If these addresses are saved in the configuration file, when the switch restarts, the interface does not need to dynamically reconfigure them.

You can configure an interface to convert the dynamic MAC addresses to sticky secure MAC addresses and add them to the running configuration by enabling sticky learning. To enable sticky learning, enter the `switchport port-security mac-address sticky` interface configuration command. When you enter this command, the interface converts all the dynamic secure MAC addresses, including those that were dynamically learned before sticky learning was enabled, to sticky secure MAC addresses. All sticky secure MAC addresses are added to the running configuration.

The sticky secure MAC addresses do not automatically become part of the configuration file, which is the startup configuration used each time the switch restarts. If you save the sticky secure MAC addresses in the configuration file, when the switch restarts, the interface does not need to relearn these addresses. If you do not save the sticky secure addresses, they are lost.

If sticky learning is disabled, the sticky secure MAC addresses are converted to dynamic secure addresses and are removed from the running configuration.
The maximum number of secure MAC addresses that you can configure on a switch is set by the maximum number of available MAC addresses allowed in the system. This number is the total of available MAC addresses, including those used for other Layer 2 functions and any other secure MAC addresses configured on interfaces.

Security Violations

It is a security violation when one of these situations occurs:

- The maximum number of secure MAC addresses have been added to the address table, and a station whose MAC address is not in the address table attempts to access the interface.
- An address learned or configured on one secure interface is seen on another secure interface in the same VLAN.

You can configure the interface for one of three violation modes, based on the action to be taken if a violation occurs:

- protect—when the number of secure MAC addresses reaches the maximum limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses to drop below the maximum value or increase the number of maximum allowable addresses. You are not notified that a security violation has occurred.

  Note: We do not recommend configuring the protect violation mode on a trunk port. The protect mode disables learning when any VLAN reaches its maximum limit, even if the port has not reached its maximum limit.

- restrict—when the number of secure MAC addresses reaches the maximum limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses to drop below the maximum value or increase the number of maximum allowable addresses. In this mode, you are notified that a security violation has occurred. An SNMP trap is sent, a syslog message is logged, and the violation counter increments.

- shutdown—a port security violation causes the interface to become error-disabled and to shut down immediately, and the port LED turns off. An SNMP trap is sent, a syslog message is logged, and the violation counter increments. When a secure port is in the error-disabled state, you can bring it out of this state by entering the errdisable recovery cause psecure-violation global configuration command, or you can manually re-enable it by entering the shutdown and no shut down interface configuration commands. This is the default mode.

- shutdown vlan—Use to set the security violation mode per-VLAN. In this mode, the VLAN is error disabled instead of the entire port when a violation occurs.

Table 18-1 shows the violation mode and the actions taken when you configure an interface for port security.

<table>
<thead>
<tr>
<th>Violation Mode</th>
<th>Traffic is forwarded¹</th>
<th>Sends SNMP trap</th>
<th>Sends syslog message</th>
<th>Displays error message²</th>
<th>Violation counter increments</th>
<th>Shuts down port</th>
</tr>
</thead>
<tbody>
<tr>
<td>protect</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>restrict</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 18-1 Security Violation Mode Actions
Table 18-1  Security Violation Mode Actions (continued)

<table>
<thead>
<tr>
<th>Violation Mode</th>
<th>Traffic is forwarded¹</th>
<th>Sends SNMP trap</th>
<th>Sends syslog message</th>
<th>Displays error message²</th>
<th>Violation counter increments</th>
<th>Shuts down port</th>
</tr>
</thead>
<tbody>
<tr>
<td>shutdown</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>shutdown vlan</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No³</td>
</tr>
</tbody>
</table>

1. Packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses.
2. The switch returns an error message if you manually configure an address that would cause a security violation.
3. Shuts down only the VLAN on which the violation occurred.

Default Port Security Configuration

Table 18-2 shows the default port security configuration for an interface.

Table 18-2  Default Port Security Configuration

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port security</td>
<td>Disabled on a port.</td>
</tr>
<tr>
<td>Sticky address learning</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Maximum number of secure MAC addresses per port</td>
<td>1.</td>
</tr>
<tr>
<td>Violation mode</td>
<td>Shutdown. The port shuts down when the maximum number of secure MAC addresses is exceeded.</td>
</tr>
<tr>
<td>Port security aging</td>
<td>Disabled. Aging time is 0.</td>
</tr>
<tr>
<td></td>
<td>Static aging is disabled.</td>
</tr>
<tr>
<td></td>
<td>Type is absolute.</td>
</tr>
</tbody>
</table>

Port Security Configuration Guidelines

Follow these guidelines when configuring port security:

- Port security can only be configured on static access ports or trunk ports. A secure port cannot be a dynamic access port.
- A secure port cannot be a destination port for Switched Port Analyzer (SPAN).
- A secure port cannot belong to a Gigabit EtherChannel port group.

Note: Voice VLAN is only supported on access ports and not on trunk ports, even though the configuration is allowed.

- When you enable port security on an interface that is also configured with a voice VLAN, set the maximum allowed secure addresses on the port to two. When the port is connected to a Cisco IP phone, the IP phone requires one MAC address. The Cisco IP phone address is learned on the voice
VLAN, but is not learned on the access VLAN. If you connect a single PC to the Cisco IP phone, no additional MAC addresses are required. If you connect more than one PC to the Cisco IP phone, you must configure enough secure addresses to allow one for each PC and one for the phone.

- When you enter a maximum secure address value for an interface, and the new value is greater than the previous value, the new value overwrites the previously configured value. If the new value is less than the previous value and the number of configured secure addresses on the interface exceeds the new value, the command is rejected.

- The switch does not support port security aging of sticky secure MAC addresses.

Table 18-3 summarizes port security compatibility with other port-based features.

### Table 18-3  Port Security Compatibility with Other Switch Features

<table>
<thead>
<tr>
<th>Type of Port or Feature on Port</th>
<th>Compatible with Port Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTP1 port2</td>
<td>No</td>
</tr>
<tr>
<td>Trunk port</td>
<td>Yes</td>
</tr>
<tr>
<td>Dynamic-access port3</td>
<td>No</td>
</tr>
<tr>
<td>SPAN source port</td>
<td>Yes</td>
</tr>
<tr>
<td>SPAN destination port</td>
<td>No</td>
</tr>
<tr>
<td>EtherChannel</td>
<td>No</td>
</tr>
<tr>
<td>Protected port</td>
<td>Yes</td>
</tr>
<tr>
<td>IEEE 802.1x port</td>
<td>Yes</td>
</tr>
<tr>
<td>Voice VLAN port4</td>
<td>Yes</td>
</tr>
<tr>
<td>Flex Links</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. DTP = Dynamic Trunking Protocol
2. A port configured with the `switchport mode dynamic` interface configuration command.
3. A VLAN Query Protocol (VQP) port configured with the `switchport access vlan dynamic` interface configuration command.
4. You must set the maximum allowed secure addresses on the port to two plus the maximum number of secure addresses allowed on the access VLAN.

### Enabling and Configuring Port Security

Beginning in privileged EXEC mode, follow these steps to restrict input to an interface by limiting and identifying MAC addresses of the stations allowed to access the port:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>interface interface-id</td>
<td>Specify the interface to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td>3</td>
<td>switchport mode (access</td>
<td>Set the interface switchport mode as access or trunk; an interface in the default mode (dynamic auto) cannot be configured as a secure port.</td>
</tr>
<tr>
<td></td>
<td>trunk)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>switchport voice vlan vlan-id</td>
<td>Enable voice VLAN on a port.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>vlan-id</code>—Specify the VLAN to be used for voice traffic.</td>
</tr>
<tr>
<td>5</td>
<td>switchport port-security</td>
<td>Enable port security on the interface.</td>
</tr>
</tbody>
</table>
### Command

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 6</strong></td>
<td>switchport port-security [maximum value [vlan {vlan-list</td>
</tr>
</tbody>
</table>

(Optional) **vlan**—set a per-VLAN maximum value

Enter one of these options after you enter the `vlan` keyword:

- **vlan-list**—On a trunk port, you can set a per-VLAN maximum value on a range of VLANs separated by a hyphen or a series of VLANs separated by commas. For nonspecified VLANs, the per-VLAN maximum value is used.

- **access**—On an access port, specify the VLAN as an access VLAN.

- **voice**—On an access port, specify the VLAN as a voice VLAN.

**Note**  
The `voice` keyword is available only if a voice VLAN is configured on a port and if that port is not the access VLAN. If an interface is configured for voice VLAN, configure a maximum of two secure MAC addresses.
### Step 7

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>`switchport port-security violation { protect</td>
<td>restrict</td>
</tr>
<tr>
<td>- <strong>protect</strong>—When the number of port secure MAC addresses reaches the maximum limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses to drop below the maximum value or increase the number of maximum allowable addresses. You are not notified that a security violation has occurred.</td>
<td></td>
</tr>
<tr>
<td>- <strong>restrict</strong>—When the number of secure MAC addresses reaches the limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses or increase the number of maximum allowable addresses. An SNMP trap is sent, a syslog message is logged, and the violation counter increments.</td>
<td></td>
</tr>
<tr>
<td>- <strong>shutdown</strong>—The interface is error-disabled when a violation occurs, and the port LED turns off. An SNMP trap is sent, a syslog message is logged, and the violation counter increments.</td>
<td></td>
</tr>
<tr>
<td>- <strong>shutdown vlan</strong>—Use to set the security violation mode per VLAN. In this mode, the VLAN is error disabled instead of the entire port when a violation occurs.</td>
<td></td>
</tr>
</tbody>
</table>

**Note**

- We do not recommend configuring the **protect** mode on a trunk port. The **protect** mode disables learning when any VLAN reaches its maximum limit, even if the port has not reached its maximum limit.
- **restrict**—When the number of secure MAC addresses reaches the limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses or increase the number of maximum allowable addresses. An SNMP trap is sent, a syslog message is logged, and the violation counter increments.
- **shutdown**—The interface is error-disabled when a violation occurs, and the port LED turns off. An SNMP trap is sent, a syslog message is logged, and the violation counter increments.
- **shutdown vlan**—Use to set the security violation mode per VLAN. In this mode, the VLAN is error disabled instead of the entire port when a violation occurs.

**Note**

- When a secure port is in the error-disabled state, you can bring it out of this state by entering the `errdisable recovery cause psecure-violation` global configuration command. You can manually re-enable it by entering the `shutdown` and `no shutdown` interface configuration commands or by using the `clear errdisable interface vlan` privileged EXEC command.
Chapter 18  Configuring Port-Based Traffic Control

### Configuring Port Security

#### Step 8
```
switchport port-security
[mac-address mac-address [vlan
  {vlan-id | {access | voice}]]]
```
(Optional) Enter a secure MAC address for the interface. You can use this command to enter the maximum number of secure MAC addresses. If you configure fewer secure MAC addresses than the maximum, the remaining MAC addresses are dynamically learned.

**Note** If you enable sticky learning after you enter this command, the secure addresses that were dynamically learned are converted to sticky secure MAC addresses and are added to the running configuration.

(Optional) `vlan`—set a per-VLAN maximum value.

Enter one of these options after you enter the `vlan` keyword:

- `vlan-id`—On a trunk port, you can specify the VLAN ID and the MAC address. If you do not specify a VLAN ID, the native VLAN is used.
- `access`—On an access port, specify the VLAN as an access VLAN.
- `voice`—On an access port, specify the VLAN as a voice VLAN.

**Note** The `voice` keyword is available only if a voice VLAN is configured on a port and if that port is not the access VLAN. If an interface is configured for voice VLAN, configure a maximum of two secure MAC addresses.

#### Step 9
```
switchport port-security
mac-address sticky
```
(Optional) Enable sticky learning on the interface.

#### Step 10
```
switchport port-security
mac-address sticky [mac-address [vlan
  {vlan-id | {access | voice}]]]
```
(Optional) Enter a sticky secure MAC address, repeating the command as many times as necessary. If you configure fewer secure MAC addresses than the maximum, the remaining MAC addresses are converted to sticky secure MAC addresses, and are added to the running configuration.

**Note** If you do not enable sticky learning before this command is entered, an error message appears, and you cannot enter a sticky secure MAC address.

(Optional) `vlan`—set a per-VLAN maximum value.

Enter one of these options after you enter the `vlan` keyword:

- `vlan-id`—On a trunk port, you can specify the VLAN ID and the MAC address. If you do not specify a VLAN ID, the native VLAN is used.
- `access`—On an access port, specify the VLAN as an access VLAN.
- `voice`—On an access port, specify the VLAN as a voice VLAN.

**Note** The `voice` keyword is available only if a voice VLAN is configured on a port and if that port is not the access VLAN.

#### Step 11
```
end
```
Return to privileged EXEC mode.

#### Step 12
```
show port-security
```
Verify your entries.

#### Step 13
```
copy running-config
startup-config
```
(Optional) Save your entries in the configuration file.
To return the interface to the default condition as not a secure port, use the `no switchport port-security` interface configuration command. If you enter this command when sticky learning is enabled, the sticky secure addresses remain part of the running configuration but are removed from the address table. All addresses are now dynamically learned.

To return the interface to the default number of secure MAC addresses, use the `no switchport port-security maximum value` interface configuration command. To return the violation mode to the default condition (shutdown mode), use the `no switchport port-security violation {protocol | restrict}` interface configuration command.

To disable sticky learning on an interface, use the `no switchport port-security mac-address sticky` interface configuration command. The interface converts the sticky secure MAC addresses to dynamic secure addresses. However, if you have previously saved the configuration with the sticky MAC addresses, you should save the configuration again after entering the `no switchport port-security mac-address sticky` command, or the sticky addresses will be restored if the switch reboots.

Use the `clear port-security {all | configured | dynamic | sticky}` privileged EXEC command to delete from the MAC address table all secure addresses or all secure addresses of a specific type (configured, dynamic, or sticky) on the switch or on an interface.

To delete a specific secure MAC address from the address table, use the `no switchport port-security mac-address mac-address` interface configuration command. To delete all dynamic secure addresses on an interface from the address table, enter the `no switchport port-security` interface configuration command followed by the `switchport port-security` command (to re-enable port security on the interface). If you use the `no switchport port-security mac-address sticky` interface configuration command to convert sticky secure MAC addresses to dynamic secure MAC addresses before entering the `no switchport port-security` command, all secure addresses on the interface except those that were manually configured are deleted.

You must specifically delete configured secure MAC addresses from the address table by using the `no switchport port-security mac-address mac-address` interface configuration command.

This example shows how to enable port security on a port and to set the maximum number of secure addresses to 50. The violation mode is the default, no static secure MAC addresses are configured, and sticky learning is enabled.

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport port-security
Switch(config-if)# switchport port-security maximum 50
Switch(config-if)# switchport port-security mac-address sticky
```

This example shows how to configure a static secure MAC address on VLAN 3 on a port:

```
Switch(config)# interface gigabitethernet0/11
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport port-security
Switch(config-if)# switchport port-security mac-address 0000.02000.0004 vlan 3
```

This example shows how to enable sticky port security on a port, to manually configure MAC addresses for data VLAN and voice VLAN, and to set the total maximum number of secure addresses to 20 (10 for data VLAN and 10 for voice VLAN).

```
Switch(config)# interface fastethernet0/1
Switch(config-if)# switchport access vlan 21
Switch(config-if)# switchport mode access
Switch(config-if)# switchport voice vlan 22
Switch(config-if)# switchport port-security
Switch(config-if)# switchport port-security violation restrict
Switch(config-if)# switchport port-security mac-address sticky 0000.0000.0002
```
Configuring Port Security

Switch(config-if)# switchport port-security mac-address 0000.0000.0003
Switch(config-if)# switchport port-security mac-address sticky 0000.0000.0001 vlan voice
Switch(config-if)# switchport port-security mac-address 0000.0000.0004 vlan voice
Switch(config-if)# switchport port-security maximum 10 vlan access
Switch(config-if)# switchport port-security maximum 10 vlan voice

Enabling and Configuring Port Security Aging

You can use port security aging to set the aging time for all secure addresses on a port. Two types of aging are supported per port:

- Absolute—The secure addresses on the port are deleted after the specified aging time.
- Inactivity—The secure addresses on the port are deleted only if the secure addresses are inactive for the specified aging time.

Use this feature to remove and add devices on a secure port without manually deleting the existing secure MAC addresses and to still limit the number of secure addresses on a port. You can enable or disable the aging of secure addresses on a per-port basis.

Beginning in privileged EXEC mode, follow these steps to configure port security aging:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td></td>
<td>Specify the interface to be configured, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>switchport port-security aging {static</td>
</tr>
<tr>
<td></td>
<td>Enable or disable static aging for the secure port, or set the aging time or type.</td>
</tr>
<tr>
<td></td>
<td><strong>Note</strong> The switch does not support port security aging of sticky secure addresses. Enter static to enable aging for statically configured secure addresses on this port. For time, specify the aging time for this port. The valid range is from 0 to 1440 minutes. For type, select one of these keywords:</td>
</tr>
<tr>
<td></td>
<td>- <strong>absolute</strong>—Sets the aging type as absolute aging. All the secure addresses on this port age out exactly after the time (minutes) specified lapses and are removed from the secure address list.</td>
</tr>
<tr>
<td></td>
<td>- <strong>inactivity</strong>—Sets the aging type as inactivity aging. The secure addresses on this port age out only if there is no data traffic from the secure source addresses for the specified time period.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show port-security [interface interface-id] [address]</td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td><em>(Optional)</em> Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
To disable port security aging for all secure addresses on a port, use the `no switchport port-security aging time` interface configuration command. To disable aging for only statically configured secure addresses, use the `no switchport port-security aging static` interface configuration command.

This example shows how to set the aging time as 2 hours for the secure addresses on a port:

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport port-security aging time 120
```

This example shows how to set the aging time as 2 minutes for the inactivity aging type with aging enabled for the configured secure addresses on the interface:

```
Switch(config-if)# switchport port-security aging time 2
Switch(config-if)# switchport port-security aging type inactivity
Switch(config-if)# switchport port-security aging static
```

You can verify the previous commands by entering the `show port-security interface interface-id` privileged EXEC command.

### Displaying Port-Based Traffic Control Settings

The `show interfaces interface-id switchport` privileged EXEC command displays (among other characteristics) the interface traffic suppression and control configuration. The `show storm-control` and `show port-security` privileged EXEC commands display those storm control and port security settings.

To display traffic control information, use one or more of the privileged EXEC commands in Table 18-4.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show interfaces [interface-id] switchport</code></td>
<td>Displays the administrative and operational status of all switching (nonrouting) ports or the specified port, including port blocking and port protection settings.</td>
</tr>
<tr>
<td>`show storm-control [interface-id] [broadcast</td>
<td>multicast</td>
</tr>
<tr>
<td><code>show port-security [interface interface-id]</code></td>
<td>Displays port security settings for the switch or for the specified interface, including the maximum allowed number of secure MAC addresses for each interface, the number of secure MAC addresses on the interface, the number of security violations that have occurred, and the violation mode.</td>
</tr>
<tr>
<td><code>show port-security [interface interface-id] address</code></td>
<td>Displays all secure MAC addresses configured on all switch interfaces or on a specified interface with aging information for each address.</td>
</tr>
<tr>
<td><code>show port-security interface interface-id vlan</code></td>
<td>Displays the number of secure MAC addresses configured per VLAN on the specified interface.</td>
</tr>
</tbody>
</table>
Configuring CDP

This chapter describes how to configure Cisco Discovery Protocol (CDP) on the switch.

Note

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release and the “System Management Commands” section in the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

This chapter consists of these sections:

- Understanding CDP, page 19-1
- Configuring CDP, page 19-2
- Monitoring and Maintaining CDP, page 19-5

Understanding CDP

CDP is a device discovery protocol that runs over Layer 2 (the data link layer) on all Cisco-manufactured devices (routers, bridges, access servers, and switches) and allows network management applications to discover Cisco devices that are neighbors of already known devices. With CDP, network management applications can learn the device type and the Simple Network Management Protocol (SNMP) agent address of neighboring devices running lower-layer, transparent protocols. This feature enables applications to send SNMP queries to neighboring devices.

CDP runs on all media that support Subnetwork Access Protocol (SNAP). Because CDP runs over the data-link layer only, two systems that support different network-layer protocols can learn about each other.

Each CDP-configured device sends periodic messages to a multicast address, advertising at least one address at which it can receive SNMP messages. The advertisements also contain time-to-live, or holdtime information, which is the length of time a receiving device holds CDP information before discarding it. Each device also listens to the messages sent by other devices to learn about neighboring devices.

On the switch, CDP enables CiscoView to display a graphical view of the network. The switch uses CDP to find cluster candidates and maintain information about cluster members and other devices up to three cluster-enabled devices away from the command switch by default.

The switch supports CDP Version 2.
Configuring CDP

These sections contain this configuration information:
- Default CDP Configuration, page 19-2
- Configuring the CDP Characteristics, page 19-2
- Disabling and Enabling CDP, page 19-3
- Disabling and Enabling CDP on an Interface, page 19-4

Default CDP Configuration

Table 19-1 shows the default CDP configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDP global state</td>
<td>Enabled</td>
</tr>
<tr>
<td>CDP interface state</td>
<td>Enabled</td>
</tr>
<tr>
<td>CDP timer (packet update frequency)</td>
<td>60 seconds</td>
</tr>
<tr>
<td>CDP holdtime (before discarding)</td>
<td>180 seconds</td>
</tr>
<tr>
<td>CDP Version-2 advertisements</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

Configuring the CDP Characteristics

You can configure the frequency of CDP updates, the amount of time to hold the information before discarding it, and whether or not to send Version-2 advertisements.

Beginning in privileged EXEC mode, follow these steps to configure the CDP timer, holdtime, and advertisement type.

**Note**
Steps 2 through 4 are all optional and can be performed in any order.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>cdp timer seconds</td>
</tr>
<tr>
<td></td>
<td>(Optional) Set the transmission frequency of CDP updates in seconds.</td>
</tr>
<tr>
<td></td>
<td>The range is 5 to 254; the default is 60 seconds.</td>
</tr>
<tr>
<td>Step 3</td>
<td>cdp holdtime seconds</td>
</tr>
<tr>
<td></td>
<td>(Optional) Specify the amount of time a receiving device should hold</td>
</tr>
<tr>
<td></td>
<td>the information sent by your device before discarding it.</td>
</tr>
<tr>
<td></td>
<td>The range is 10 to 255 seconds; the default is 180 seconds.</td>
</tr>
<tr>
<td>Step 4</td>
<td>cdp advertise-v2</td>
</tr>
<tr>
<td></td>
<td>(Optional) Configure CDP to send Version-2 advertisements.</td>
</tr>
<tr>
<td></td>
<td>This is the default state.</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
Chapter 19  Configuring CDP

Configuring CDP

Use the `no` form of the CDP commands to return to the default settings.

This example shows how to configure CDP characteristics.

```
Switch# configure terminal
Switch(config)# cdp timer 50
Switch(config)# cdp holdtime 120
Switch(config)# cdp advertise-v2
Switch(config)# end
```

For additional CDP `show` commands, see the “Monitoring and Maintaining CDP” section on page 19-5.

Disabling and Enabling CDP

CDP is enabled by default.

**Note**

Switch clusters and other Cisco devices (such as Cisco IP Phones) regularly exchange CDP messages. Disabling CDP can interrupt cluster discovery and device connectivity. For more information, see Chapter 6, “Clustering Switches” and see *Getting Started with Cisco Network Assistant*, available on Cisco.com.

Beginning in privileged EXEC mode, follow these steps to disable the CDP device discovery capability:

```
Step 1 configure terminal
Step 2 no cdp run
Step 3 end
```

Beginning in privileged EXEC mode, follow these steps to enable CDP when it has been disabled:

```
Step 1 configure terminal
Step 2 cdp run
Step 3 end
```

This example shows how to enable CDP if it has been disabled.

```
Switch# configure terminal
Switch(config)# cdp run
Switch(config)# end
```
Disabling and Enabling CDP on an Interface

CDP is enabled by default on all supported interfaces to send and to receive CDP information. Beginning in privileged EXEC mode, follow these steps to disable CDP on a port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the interface on which you are disabling CDP, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 no cdp enable</td>
<td>Disable CDP on the interface.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Beginning in privileged EXEC mode, follow these steps to enable CDP on a port when it has been disabled:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the interface on which you are enabling CDP, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3 cdp enable</td>
<td>Enable CDP on the interface after disabling it.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to enable CDP on a port when it has been disabled.

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# cdp enable
Switch(config-if)# end
```
Monitoring and Maintaining CDP

To monitor and maintain CDP on your device, perform one or more of these tasks, beginning in privileged EXEC mode.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear cdp counters</td>
<td>Reset the traffic counters to zero.</td>
</tr>
<tr>
<td>clear cdp table</td>
<td>Delete the CDP table of information about neighbors.</td>
</tr>
<tr>
<td>show cdp</td>
<td>Display global information, such as frequency of transmissions and the holdtime for packets being sent.</td>
</tr>
<tr>
<td>show cdp entry entry-name [protocol</td>
<td>Display information about a specific neighbor. You can enter an asterisk (*) to display all CDP neighbors, or you can enter the name of the neighbor about which you want information. You can also limit the display to information about the protocols enabled on the specified neighbor or information about the version of software running on the device.</td>
</tr>
<tr>
<td>show cdp interface [interface-id]</td>
<td>Display information about interfaces where CDP is enabled. You can limit the display to the interface about which you want information.</td>
</tr>
<tr>
<td>show cdp neighbors [interface-id]</td>
<td>Display information about neighbors, including device type, interface type and number, holdtime settings, capabilities, platform, and port ID. You can limit the display to neighbors of a specific interface or expand the display to provide more detailed information.</td>
</tr>
<tr>
<td>show cdp traffic</td>
<td>Display CDP counters, including the number of packets sent and received and checksum errors.</td>
</tr>
</tbody>
</table>
Configuring LLDP and LLDP-MED

This chapter describes how to configure the Link Layer Discovery Protocol (LLDP) and LLDP Media Endpoint Discovery (LLDP-MED) on the switch.

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release and the “System Management Commands” section in the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

This chapter consists of these sections:
- Understanding LLDP and LLDP-MED, page 20-1
- Configuring LLDP and LLDP-MED, page 20-3
- Monitoring and Maintaining LLDP and LLDP-MED, page 20-7

Understanding LLDP and LLDP-MED

This section contains this conceptual information:
- Understanding LLDP, page 20-1
- Understanding LLDP-MED, page 20-2

Understanding LLDP

The Cisco Discovery Protocol (CDP) is a device discovery protocol that runs over Layer 2 (the data link layer) on all Cisco-manufactured devices (routers, bridges, access servers, and switches). CDP allows network management applications to automatically discover and learn about other Cisco devices connected to the network.

To support non-Cisco devices and to allow for interoperability between other devices, the switch supports the IEEE 802.1AB Link Layer Discovery Protocol (LLDP). LLDP is a neighbor discovery protocol that is used for network devices to advertise information about themselves to other devices on the network. This protocol runs over the data-link layer, which allows two systems running different network layer protocols to learn about each other.

LLDP supports a set of attributes that it uses to discover neighbor devices. These attributes contain type, length, and value descriptions and are referred to as TLVs. LLDP supported devices can use TLVs to receive and send information to their neighbors. Details such as configuration information, device capabilities, and device identity can be advertised using this protocol.

The switch supports these basic management TLVs. These are mandatory LLDP TLVs.
Chapter 20 Configuring LLDP and LLDP-MED

Understanding LLDP and LLDP-MED

- Port description TLV
- System name TLV
- System description
- System capabilities TLV
- Management address TLV

These organizationally specific LLDP TLVs are also advertised to support LLDP-MED.

- Port VLAN ID TLV (IEEE 802.1 organizationally specific TLVs)
- MAC/PHY configuration/status TLV (IEEE 802.3 organizationally specific TLVs)

A switch stack appears as a single switch in the network. Therefore, LLDP discovers the switch stack, not the individual stack members.

Understanding LLDP-MED

LLDP for Media Endpoint Devices (LLDP-MED) is an extension to LLDP that operates between endpoint devices such as IP phones and network devices such as switches. It specifically provides support for voice over IP (VoIP) applications and provides additional TLVs for capabilities discovery, network policy, Power over Ethernet, and inventory management.

LLDP-MED supports these TLVs:

- LLDP-MED capabilities TLV
  Allows LLDP-MED endpoints to determine the capabilities that the connected device supports and what capabilities the device has enabled.

- Network policy TLV
  Allows both network connectivity devices and endpoints to advertise VLAN configurations and associated Layer 2 and Layer 3 attributes for the specific application on that port. For example, the switch can notify a phone of the VLAN number that it should use. The phone can connect into any switch, obtain its VLAN number, and then start communicating with the call control.

- Power management TLV
  Enables advanced power management between LLDP-MED endpoint and network connectivity devices. Allows switches and phones to convey power information, such as how the device is powered, power priority, and how much power the device needs.

- Inventory management TLV
  Allows an endpoint to transmit detailed inventory information about itself to the switch, including information hardware revision, firmware version, software version, serial number, manufacturer name, model name, and asset ID TLV.

Note
LLDP and LLDP-MED cannot operate simultaneously in a network. By default, a network device sends only LLDP packets until it receives LLDP-MED packets from an endpoint device. The network device then sends out LLDP-MED packets until it receives LLDP-only packets.
Configuring LLDP and LLDP-MED

This section contains this configuration information:

- Default LLDP Configuration, page 20-3
- Configuring LLDP Characteristics, page 20-3
- Disabling and Enabling LLDP Globally, page 20-4
- Disabling and Enabling LLDP on an Interface, page 20-5
- Configuring LLDP-MED TLVs, page 20-6

Default LLDP Configuration

Table 20-1 shows the default LLDP configuration. To change the default settings, use the LLDP global configuration and LLDP interface configuration commands.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLDP global state</td>
<td>Enabled</td>
</tr>
<tr>
<td>LLDP holdtime (before discarding)</td>
<td>120 seconds</td>
</tr>
<tr>
<td>LLDP timer (packet update frequency)</td>
<td>30 seconds</td>
</tr>
<tr>
<td>LLDP reinitialization delay</td>
<td>2 seconds</td>
</tr>
<tr>
<td>LLDP tlv-select</td>
<td>Enabled to send and receive all TLVs.</td>
</tr>
<tr>
<td>LLDP interface state</td>
<td>Enabled</td>
</tr>
<tr>
<td>LLDP receive</td>
<td>Enabled</td>
</tr>
<tr>
<td>LLDP transmit</td>
<td>Enabled</td>
</tr>
<tr>
<td>LLDP med-tlv-select</td>
<td>Enabled to send all LLDP-MED TLVs</td>
</tr>
</tbody>
</table>

Configuring LLDP Characteristics

You can configure the frequency of LLDP updates, the amount of time to hold the information before discarding it, and the initialization delay time. You can also select the LLDP and LLDP-MED TLVs to be sent and received.

Beginning in privileged EXEC mode, follow these steps to configure these characteristics:

Note: Steps 2 through 5 are all optional and can be performed in any order.
Chapter 20  Configuring LLDP and LLDP-MED

Configuring LLDP and LLDP-MED

Use the no form of each of the LLDP commands to return to the default setting.

This example shows how to configure LLDP characteristics.

```
Switch# configure terminal
Switch(config)# lldp holdtime 120
Switch(config)# lldp reinit 2
Switch(config)# lldp timer 30
Switch(config)# end
```

For additional LLDP show commands, see the “Monitoring and Maintaining LLDP and LLDP-MED” section on page 20-7.

Disabling and Enabling LLDP Globally

LLDP is enabled by default.

Beginning in privileged EXEC mode, follow these steps to disable LLDP:

```
Step 1  configure terminal
Step 2  no lldp run
Step 3  end
```

Beginning in privileged EXEC mode, follow these steps to enable LLDP-MED when it has been disabled:

```
Step 1  configure terminal
Step 2  lldp run
Step 3  end
```
Chapter 20 Configuring LLDP and LLDP-MED

Configuring LLDP and LLDP-MED

This example shows how to disable LLDP.

Switch# configure terminal
Switch(config)# no lldp run
Switch(config)# end

This example shows how to enable LLDP.

Switch# configure terminal
Switch(config)# lldp run
Switch(config)# end

Disabling and Enabling LLDP on an Interface

LLDP is enabled by default on all supported interfaces to send and to receive LLDP information.

Beginning in privileged EXEC mode, follow these steps to disable LLDP on an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>no lldp transmit</strong></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>no lldp receive</strong></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>

Beginning in privileged EXEC mode, follow these steps to enable LLDP-MED on an interface when it has been disabled:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>lldp transmit</strong></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>lldp receive</strong></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>

This example shows how to enable LLDP on an interface.

Switch# configure terminal
Switch(config)# interface GigabitEthernet1/0/1
Switch(config-if)# lldp transmit
Switch(config-if)# lldp receive
Switch(config-if)# end
**Configuring LLDP-MED TLVs**

By default, the switch only sends LLDP packets until it receives LLDP-MED packets from the end device. The device continues to send LLDP-MED packets until it receives LLDP packets only.

Using the `lldp` interface command, you can configure the interface not to send the following TLVs:

Table 20-2  **LLDP-MED TLVs**

<table>
<thead>
<tr>
<th>LLDP-MED TLV</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>inventory-management</td>
<td>LLDP-MED inventory management TLV</td>
</tr>
<tr>
<td>network-policy</td>
<td>LLDP-MED network policy TLV</td>
</tr>
<tr>
<td>power-management</td>
<td>LLDP-MED power management TLV</td>
</tr>
</tbody>
</table>

Beginning in privileged EXEC mode, follow these steps to disable a TLV on an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1  <code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2  <code>interface interface-id</code></td>
<td>Specify the interface on which you are configuring a LLDP-MED TLV, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3  <code>no lldp med-tlv-select tlv</code></td>
<td>Specify the TLV to disable.</td>
</tr>
<tr>
<td>Step 4  <code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5  <code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Beginning in privileged EXEC mode, follow these steps to enable a TLV on an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1  <code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2  <code>interface interface-id</code></td>
<td>Specify the interface on which you are configuring an LLDP-MED TLV, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3  <code>lldp med-tlv-select tlv</code></td>
<td>Specify the TLV to enable.</td>
</tr>
<tr>
<td>Step 4  <code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5  <code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to enable a TLV on an interface when it has been disabled.

```
Switch# configure terminal
Switch(config)# interface GigabitEthernet1/0/1
Switch(config-if)# lldp med-tlv-select inventory management
Switch(config-if)# end
```
## Monitoring and Maintaining LLDP and LLDP-MED

To monitor and maintain LLDP and LLDP-MED on your device, perform one or more of these tasks, beginning in privileged EXEC mode.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear lldp counters</td>
<td>Reset the traffic counters to zero.</td>
</tr>
<tr>
<td>clear lldp table</td>
<td>Delete the LLDP table of information about neighbors.</td>
</tr>
<tr>
<td>show lldp</td>
<td>Display global information, such as frequency of transmissions, the holdtime for packets being sent, and the delay time for LLDP to initialize on an interface.</td>
</tr>
<tr>
<td>show lldp entry <em>entry-name</em></td>
<td>Display information about a specific neighbor. You can enter an asterisk (*) to display all neighbors, or you can enter the name of the neighbor about which you want information.</td>
</tr>
<tr>
<td>show lldp interface [interface-id]</td>
<td>Display information about interfaces where LLDP is enabled. You can limit the display to the interface about which you want information.</td>
</tr>
<tr>
<td>show lldp neighbors [interface-id] [detail]</td>
<td>Display information about neighbors, including device type, interface type and number, holdtime settings, capabilities, and port ID. You can limit the display to neighbors of a specific interface or expand the display to provide more detailed information.</td>
</tr>
<tr>
<td>show lldp traffic</td>
<td>Display LLDP counters, including the number of packets sent and received, number of packets discarded, and number of unrecognized TLVs.</td>
</tr>
</tbody>
</table>
CHAPTER 21

Configuring UDLD

This chapter describes how to configure the UniDirectional Link Detection (UDLD) protocol on the switch.

**Note**
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Understanding UDLD, page 21-1
- Configuring UDLD, page 21-3
- Displaying UDLD Status, page 21-6

**Understanding UDLD**

UDLD is a Layer 2 protocol that enables devices connected through fiber-optic or twisted-pair Ethernet cables to monitor the physical configuration of the cables and detect when a unidirectional link exists. All connected devices must support UDLD for the protocol to successfully identify and disable unidirectional links. When UDLD detects a unidirectional link, it disables the affected port and alerts you. Unidirectional links can cause a variety of problems, including spanning-tree topology loops.

**Modes of Operation**

UDLD supports two modes of operation: normal (the default) and aggressive. In normal mode, UDLD can detect unidirectional links due to misconnected ports on fiber-optic connections. In aggressive mode, UDLD can also detect unidirectional links due to one-way traffic on fiber-optic and twisted-pair links and to misconnected ports on fiber-optic links.

In normal and aggressive modes, UDLD works with the Layer 1 mechanisms to learn the physical status of a link. At Layer 1, autonegotiation takes care of physical signaling and fault detection. UDLD performs tasks that autonegotiation cannot perform, such as detecting the identities of neighbors and shutting down misconnected ports. When you enable both autonegotiation and UDLD, the Layer 1 and Layer 2 detections work together to prevent physical and logical unidirectional connections and the malfunctioning of other protocols.

A unidirectional link occurs whenever traffic sent by a local device is received by its neighbor but traffic from the neighbor is not received by the local device.
In normal mode, UDLD detects a unidirectional link when fiber strands in a fiber-optic port are misconnected and the Layer 1 mechanisms do not detect this misconnection. If the ports are connected correctly but the traffic is one way, UDLD does not detect the unidirectional link because the Layer 1 mechanism, which is supposed to detect this condition, does not do so. In this case, the logical link is considered undetermined, and UDLD does not disable the port.

When UDLD is in normal mode, if one of the fiber strands in a pair is disconnected and autonegotiation is active, the link does not stay up because the Layer 1 mechanisms did not detect a physical problem with the link. In this case, UDLD does not take any action, and the logical link is considered undetermined.

In aggressive mode, UDLD detects a unidirectional link by using the previous detection methods. UDLD in aggressive mode can also detect a unidirectional link on a point-to-point link on which no failure between the two devices is allowed. It can also detect a unidirectional link when one of these problems exists:

- On fiber-optic or twisted-pair links, one of the ports cannot send or receive traffic.
- On fiber-optic or twisted-pair links, one of the ports is down while the other is up.
- One of the fiber strands in the cable is disconnected.

In these cases, UDLD disables the affected port.

In a point-to-point link, UDLD hello packets can be considered as a heart beat whose presence guarantees the health of the link. Conversely, the loss of the heart beat means that the link must be shut down if it is not possible to re-establish a bidirectional link.

If both fiber strands in a cable are working normally from a Layer 1 perspective, UDLD in aggressive mode detects whether those fiber strands are connected correctly and whether traffic is flowing bidirectionally between the correct neighbors. This check cannot be performed by autonegotiation because autonegotiation operates at Layer 1.

### Methods to Detect Unidirectional Links

UDLD operates by using two mechanisms:

- **Neighbor database maintenance**
  
  UDLD learns about other UDLD-capable neighbors by periodically sending a hello packet (also called an advertisement or probe) on every active port to keep each device informed about its neighbors.

  When the switch receives a hello message, it caches the information until the age time (hold time or time-to-live) expires. If the switch receives a new hello message before an older cache entry ages, the switch replaces the older entry with the new one.

  Whenever a port is disabled and UDLD is running, whenever UDLD is disabled on a port, or whenever the switch is reset, UDLD clears all existing cache entries for the ports affected by the configuration change. UDLD sends at least one message to inform the neighbors to flush the part of their caches affected by the status change. The message is intended to keep the caches synchronized.

- **Event-driven detection and echoing**
  
  UDLD relies on echoing as its detection mechanism. Whenever a UDLD device learns about a new neighbor or receives a resynchronization request from an out-of-sync neighbor, it restarts the detection window on its side of the connection and sends echo messages in reply. Because this behavior is the same on all UDLD neighbors, the sender of the echoes expects to receive an echo in reply.
If the detection window ends and no valid reply message is received, the link might shut down, depending on the UDLD mode. When UDLD is in normal mode, the link might be considered undetermined and might not be shut down. When UDLD is in aggressive mode, the link is considered unidirectional, and the port is disabled.

If UDLD in normal mode is in the advertisement or in the detection phase and all the neighbor cache entries are aged out, UDLD restarts the link-up sequence to resynchronize with any potentially out-of-sync neighbors.

If you enable aggressive mode when all the neighbors of a port have aged out either in the advertisement or in the detection phase, UDLD restarts the link-up sequence to resynchronize with any potentially out-of-sync neighbor. UDLD shuts down the port if, after the fast train of messages, the link state is still undetermined.

Figure 21-1 shows an example of a unidirectional link condition.

**Figure 21-1  UDLD Detection of a Unidirectional Link**

Switch B successfully receives traffic from Switch A on this port. However, Switch A does not receive traffic from Switch B on the same port. If UDLD is in aggressive mode, it detects the problem and disables the port. If UDLD is in normal mode, the logical link is considered undetermined, and UDLD does not disable the interface.

**Configuring UDLD**

These sections contain this configuration information:

- Default UDLD Configuration, page 21-4
- Configuration Guidelines, page 21-4
- Enabling UDLD Globally, page 21-5
- Enabling UDLD on an Interface, page 21-5
- Resetting an Interface Disabled by UDLD, page 21-6
Default UDLD Configuration

Table 21-1 shows the default UDLD configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDLD global enable state</td>
<td>Globally disabled</td>
</tr>
<tr>
<td>UDLD per-port enable state for fiber-optic media</td>
<td>Disabled on all Ethernet fiber-optic ports</td>
</tr>
<tr>
<td>UDLD per-port enable state for twisted-pair (copper) media</td>
<td>Disabled on all Ethernet 10/100 and 1000BASE ports</td>
</tr>
<tr>
<td>UDLD aggressive mode</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

Configuration Guidelines

These are the UDLD configuration guidelines:

- UDLD is not supported on ATM ports.
- A UDLD-capable port cannot detect a unidirectional link if it is connected to a UDLD-incapable port of another switch.
- When configuring the mode (normal or aggressive), make sure that the same mode is configured on both sides of the link.

⚠️ **Caution**

Loop guard works only on point-to-point links. We recommend that each end of the link has a directly connected device that is running STP.
Enabling UDLD Globally

Beginning in privileged EXEC mode, follow these steps to enable UDLD in the aggressive or normal mode and to set the configurable message timer on all fiber-optic ports on the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>udld {aggressive</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>This command affects fiber-optic ports only. Use the <strong>udld</strong> interface configuration command to enable UDLD on other port types. For more information, see the “Enabling UDLD on an Interface” section on page 21-5.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show udl</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable UDLD globally, use the **no udld enable** global configuration command to disable normal mode UDLD on all fiber-optic ports. Use the **no udld aggressive** global configuration command to disable aggressive mode UDLD on all fiber-optic ports.

Enabling UDLD on an Interface

Beginning in privileged EXEC mode, follow these steps either to enable UDLD in the aggressive or normal mode or to disable UDLD on a port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
</tbody>
</table>
Resetting an Interface Disabled by UDLD

Beginning in privileged EXEC mode, follow these steps to reset all ports disabled by UDLD:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>udld reset</td>
</tr>
<tr>
<td>Step 2</td>
<td>show udld interface-id</td>
</tr>
</tbody>
</table>

You can also bring up the port by using these commands:

- The `shutdown` interface configuration command followed by the `no shutdown` interface configuration command restarts the disabled port.
- The `no udld {aggressive | enable}` global configuration command followed by the `udld {aggressive | enable}` global configuration command re-enables the disabled ports.
- The `no udld port` interface configuration command followed by the `udld port [aggressive]` interface configuration command re-enables the disabled fiber-optic port.
- The `errdisable recovery cause udld` global configuration command enables the timer to automatically recover from the UDLD error-disabled state, and the `errdisable recovery interval interval` global configuration command specifies the time to recover from the UDLD error-disabled state.

Displaying UDLD Status

To display the UDLD status for the specified port or for all ports, use the `show udld [interface-id]` privileged EXEC command.

For detailed information about the fields in the command output, see the command reference for this release.
Configuring SPAN and RSPAN

This chapter describes how to configure Switched Port Analyzer (SPAN) and Remote SPAN (RSPAN) on the switch.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Understanding SPAN and RSPAN, page 22-1
- Configuring SPAN and RSPAN, page 22-9
- Displaying SPAN and RSPAN Status, page 22-23

Understanding SPAN and RSPAN

You can analyze network traffic passing through ports or VLANs by using SPAN or RSPAN to send a copy of the traffic to another port on the switch or on another switch that has been connected to a network analyzer or other monitoring or security device. SPAN copies (or mirrors) traffic received or sent (or both) on source ports or source VLANs to a destination port for analysis. SPAN does not affect the switching of network traffic on the source ports or VLANs. You must dedicate the destination port for SPAN use. Except for traffic that is required for the SPAN or RSPAN session, destination ports do not receive or forward traffic.

Only traffic that enters or leaves source ports or traffic that enters or leaves source VLANs can be monitored by using SPAN; traffic routed to a source VLAN cannot be monitored. For example, if incoming traffic is being monitored, traffic that gets routed from another VLAN to the source VLAN cannot be monitored; however, traffic that is received on the source VLAN and routed to another VLAN can be monitored.

You can use the SPAN or RSPAN destination port to inject traffic from a network security device. For example, if you connect a Cisco Intrusion Detection System (IDS) sensor appliance to a destination port, the IDS device can send TCP reset packets to close down the TCP session of a suspected attacker.
These sections contain this conceptual information:

- Local SPAN, page 22-2
- Remote SPAN, page 22-2
- SPAN and RSPAN Concepts and Terminology, page 22-3
- SPAN and RSPAN Interaction with Other Features, page 22-8

Local SPAN

Local SPAN supports a SPAN session entirely within one switch; all source ports or source VLANs and destination ports are in the same switch. Local SPAN copies traffic from one or more source ports in any VLAN or from one or more VLANs to a destination port for analysis. For example, in Figure 22-1, all traffic on port 5 (the source port) is mirrored to port 17 (the destination port). A network analyzer on port 17 receives all network traffic from port 5 without being physically attached to port 5.

Remote SPAN

RSPAN supports source ports, source VLANs, and destination ports on different switches, enabling remote monitoring of multiple switches across your network. Figure 22-2 shows source ports on Switch A and Switch B. The traffic for each RSPAN session is carried over a user-specified RSPAN VLAN that is dedicated for that RSPAN session in all participating switches. The RSPAN traffic from the source ports or VLANs is copied into the RSPAN VLAN and forwarded over trunk ports carrying the RSPAN VLAN to a destination session monitoring the RSPAN VLAN. Each RSPAN source switch must have either ports or VLANs as RSPAN sources. The destination is always a physical port, as shown on Switch C in the figure.
SPAN and RSPAN Concepts and Terminology

This section describes concepts and terminology associated with SPAN and RSPAN configuration.

SPAN Sessions

SPAN sessions (local or remote) allow you to monitor traffic on one or more ports, or one or more VLANs, and send the monitored traffic to one or more destination ports.

A local SPAN session is an association of a destination port with source ports or source VLANs, all on a single network device. Local SPAN does not have separate source and destination sessions. Local SPAN sessions gather a set of ingress and egress packets specified by the user and form them into a stream of SPAN data, which is directed to the destination port.

RSPAN consists of at least one RSPAN source session, an RSPAN VLAN, and at least one RSPAN destination session. You separately configure RSPAN source sessions and RSPAN destination sessions on different network devices. To configure an RSPAN source session on a device, you associate a set of source ports or source VLANs with an RSPAN VLAN. The output of this session is the stream of SPAN packets that are sent to the RSPAN VLAN. To configure an RSPAN destination session on another device, you associate the destination port with the RSPAN VLAN. The destination session collects all RSPAN VLAN traffic and sends it out the RSPAN destination port.
An RSPAN source session is very similar to a local SPAN session, except for where the packet stream is directed. In an RSPAN source session, SPAN packets are relabeled with the RSPAN VLAN ID and directed over normal trunk ports to the destination switch.

An RSPAN destination session takes all packets received on the RSPAN VLAN, strips off the VLAN tagging, and presents them on the destination port. Its purpose is to present a copy of all RSPAN VLAN packets (except Layer 2 control packets) to the user for analysis.

There can be more than one source session and more than one destination session active in the same RSPAN VLAN. There can also be intermediate switches separating the RSPAN source and destination sessions. These switches need not be capable of running RSPAN, but they must respond to the requirements of the RSPAN VLAN (see the “RSPAN VLAN” section on page 22-7).

Traffic monitoring in a SPAN session has these restrictions:

- Sources can be ports or VLANs, but you cannot mix source ports and source VLANs in the same session.
- The switch supports up to two source sessions (local SPAN and RSPAN source sessions). You can run both a local SPAN and an RSPAN source session in the same switch. The switch supports a total of 66 source and RSPAN destination sessions.
- You can have multiple destination ports in a SPAN session, but no more than 64 destination ports.
- You can configure two separate SPAN or RSPAN source sessions with separate or overlapping sets of SPAN source ports and VLANs.
- SPAN sessions do not interfere with the normal operation of the switch. However, an oversubscribed SPAN destination, for example, a 10-Mb/s port monitoring a 100-Mb/s port, can result in dropped or lost packets.
- When RSPAN is enabled, each packet being monitored is transmitted twice, once as normal traffic and once as a monitored packet. Therefore monitoring a large number of ports or VLANs could potentially generate large amounts of network traffic.
- You can configure SPAN sessions on disabled ports; however, a SPAN session does not become active unless you enable the destination port and at least one source port or VLAN for that session.
- The switch does not support a combination of local SPAN and RSPAN in a single session. That is, an RSPAN source session cannot have a local destination port, an RSPAN destination session cannot have a local source port, and an RSPAN destination session and an RSPAN source session that are using the same RSPAN VLAN cannot run on the same switch.

Monitored Traffic

SPAN sessions can monitor these traffic types:

- Receive (Rx) SPAN—The goal of receive (or ingress) SPAN is to monitor as much as possible all the packets received by the source interface or VLAN before any modification or processing is performed by the switch. A copy of each packet received by the source is sent to the destination port for that SPAN session.

Packets that are modified because of routing or quality of service (QoS)—for example, modified Differentiated Services Code Point (DSCP)—are copied before modification.

Features that can cause a packet to be dropped during receive processing have no effect on ingress SPAN; the destination port receives a copy of the packet even if the actual incoming packet is dropped. These features include IP standard and extended input access control lists (ACLs), ingress QoS policing, VLAN ACLs, and egress QoS policing.
Transmit (Tx) SPAN—The goal of transmit (or egress) SPAN is to monitor as much as possible all the packets sent by the source interface after all modification and processing is performed by the switch. A copy of each packet sent by the source is sent to the destination port for that SPAN session. The copy is provided after the packet is modified.

Features that can cause a packet to be dropped during transmit processing also affect the duplicated copy for SPAN. These features include IP standard and extended output ACLs and egress QoS policing.

Both—In a SPAN session, you can also monitor a port or VLAN for both received and sent packets. This is the default.

The default configuration for local SPAN session ports is to send all packets untagged. SPAN also does not normally monitor bridge protocol data unit (BPDU) packets and Layer 2 protocols, such as Cisco Discovery Protocol (CDP), VLAN Trunk Protocol (VTP), Dynamic Trunking Protocol (DTP), Spanning Tree Protocol (STP), and Port Aggregation Protocol (PAgP). However, when you enter the encapsulation replicate keywords when configuring a destination port, these changes occur:

- Packets are sent on the destination port with the same encapsulation—untagged, Inter-Switch Link (ISL), or IEEE 802.1Q—that they had on the source port.
- Packets of all types, including BPDU and Layer 2 protocol packets, are monitored.

Therefore, a local SPAN session with encapsulation replicate enabled can have a mixture of untagged, ISL, and IEEE 802.1Q tagged packets appear on the destination port.

Switch congestion can cause packets to be dropped at ingress source ports, egress source ports, or SPAN destination ports. In general, these characteristics are independent of one another. For example:

- A packet might be forwarded normally but dropped from monitoring due to an oversubscribed SPAN destination port.
- An ingress packet might be dropped from normal forwarding, but still appear on the SPAN destination port.
- An egress packet dropped because of switch congestion is also dropped from egress SPAN.

In some SPAN configurations, multiple copies of the same source packet are sent to the SPAN destination port. For example, a bidirectional (both Rx and Tx) SPAN session is configured for the Rx monitor on port A and Tx monitor on port B. If a packet enters the switch through port A and is switched to port B, both incoming and outgoing packets are sent to the destination port. Both packets are the same.

Source Ports

A source port (also called a monitored port) is a switched port that you monitor for network traffic analysis. In a local SPAN session or RSPAN source session, you can monitor source ports or VLANs for traffic in one or both directions. The switch supports any number of source ports (up to the maximum number of available ports on the switch) and any number of source VLANs (up to the maximum number of VLANs supported). However, the switch supports a maximum of two sessions (local or RSPAN) with source ports or VLANs, and you cannot mix ports and VLANs in a single session.

A source port has these characteristics:

- It can be monitored in multiple SPAN sessions.
- Each source port can be configured with a direction (ingress, egress, or both) to monitor.
- It can be any port type (for example, EtherChannel, Gigabit Ethernet, and so forth).
- For EtherChannel sources, you can monitor traffic for the entire EtherChannel or individually on a physical port as it participates in the port channel.
Understanding SPAN and RSPAN

- It can be an access port, trunk port, or voice VLAN port.
- It cannot be a destination port.
- Source ports can be in the same or different VLANs.
- You can monitor multiple source ports in a single session.

Source VLANs

VLAN-based SPAN (VSPAN) is the monitoring of the network traffic in one or more VLANs. The SPAN or RSPAN source interface in VSPAN is a VLAN ID, and traffic is monitored on all the ports for that VLAN.

VSPAN has these characteristics:
- All active ports in the source VLAN are included as source ports and can be monitored in either or both directions.
- On a given port, only traffic on the monitored VLAN is sent to the destination port.
- If a destination port belongs to a source VLAN, it is excluded from the source list and is not monitored.
- If ports are added to or removed from the source VLANs, the traffic on the source VLAN received by those ports is added to or removed from the sources being monitored.
- You cannot use filter VLANs in the same session with VLAN sources.
- You can monitor only Ethernet VLANs.

VLAN Filtering

When you monitor a trunk port as a source port, by default, all VLANs active on the trunk are monitored. You can limit SPAN traffic monitoring on trunk source ports to specific VLANs by using VLAN filtering.
- VLAN filtering applies only to trunk ports or to voice VLAN ports.
- VLAN filtering applies only to port-based sessions and is not allowed in sessions with VLAN sources.
- When a VLAN filter list is specified, only those VLANs in the list are monitored on trunk ports or on voice VLAN access ports.
- SPAN traffic coming from other port types is not affected by VLAN filtering; that is, all VLANs are allowed on other ports.
- VLAN filtering affects only traffic forwarded to the destination SPAN port and does not affect the switching of normal traffic.

Destination Port

Each local SPAN session or RSPAN destination session must have a destination port (also called a monitoring port) that receives a copy of traffic from the source ports or VLANs and sends the SPAN packets to the user, usually a network analyzer.
A destination port has these characteristics:

- For a local SPAN session, the destination port must reside on the same switch as the source port. For an RSPAN session, it is located on the switch containing the RSPAN destination session. There is no destination port on a switch running only an RSPAN source session.
- When a port is configured as a SPAN destination port, the configuration overwrites the original port configuration. When the SPAN destination configuration is removed, the port reverts to its previous configuration. If a configuration change is made to the port while it is acting as a SPAN destination port, the change does not take effect until the SPAN destination configuration had been removed.
- If the port was in an EtherChannel group, it is removed from the group while it is a destination port.
- It can be any Ethernet physical port.
- It cannot be a secure port.
- It cannot be a source port.
- It cannot be an EtherChannel group or a VLAN.
- It can participate in only one SPAN session at a time (a destination port in one SPAN session cannot be a destination port for a second SPAN session).
- When it is active, incoming traffic is disabled. The port does not transmit any traffic except that required for the SPAN session. Incoming traffic is never learned or forwarded on a destination port.
- If ingress traffic forwarding is enabled for a network security device, the destination port forwards traffic at Layer 2.
- It does not participate in any of the Layer 2 protocols (STP, VTP, CDP, DTP, PagP).
- A destination port that belongs to a source VLAN of any SPAN session is excluded from the source list and is not monitored.
- The maximum number of destination ports in a switch is 64.

Local SPAN and RSPAN destination ports behave differently regarding VLAN tagging and encapsulation:

- For local SPAN, if the `encapsulation replicate` keywords are specified for the destination port, these packets appear with the original encapsulation (untagged, ISL, or IEEE 802.1Q). If these keywords are not specified, packets appear in the untagged format. Therefore, the output of a local SPAN session with `encapsulation replicate` enabled can contain a mixture of untagged, ISL, or IEEE 802.1Q-tagged packets.
- For RSPAN, the original VLAN ID is lost because it is overwritten by the RSPAN VLAN identification. Therefore, all packets appear on the destination port as untagged.

## RSPAN VLAN

The RSPAN VLAN carries SPAN traffic between RSPAN source and destination sessions. It has these special characteristics:

- All traffic in the RSPAN VLAN is always flooded.
- No MAC address learning occurs on the RSPAN VLAN.
- RSPAN VLAN traffic only flows on trunk ports.
- RSPAN VLANs must be configured in VLAN configuration mode by using the `remote-span` VLAN configuration mode command.
- STP can run on RSPAN VLAN trunks but not on SPAN destination ports.
For VLANs 1 to 1005 that are visible to VLAN Trunking Protocol (VTP), the VLAN ID and its associated RSPAN characteristic are propagated by VTP. If you assign an RSPAN VLAN ID in the extended VLAN range (1006 to 4094), you must manually configure all intermediate switches.

It is normal to have multiple RSPAN VLANs in a network at the same time with each RSPAN VLAN defining a network-wide RSPAN session. That is, multiple RSPAN source sessions anywhere in the network can contribute packets to the RSPAN session. It is also possible to have multiple RSPAN destination sessions throughout the network, monitoring the same RSPAN VLAN and presenting traffic to the user. The RSPAN VLAN ID separates the sessions.

**SPAN and RSPAN Interaction with Other Features**

SPAN interacts with these features:

- **STP**—A destination port does not participate in STP while its SPAN or RSPAN session is active. The destination port can participate in STP after the SPAN or RSPAN session is disabled. On a source port, SPAN does not affect the STP status. STP can be active on trunk ports carrying an RSPAN VLAN.

- **CDP**—A SPAN destination port does not participate in CDP while the SPAN session is active. After the SPAN session is disabled, the port again participates in CDP.

- **VTP**—You can use VTP to prune an RSPAN VLAN between switches.

- **VLAN and trunking**—You can modify VLAN membership or trunk settings for source or destination ports at any time. However, changes in VLAN membership or trunk settings for a destination port do not take effect until you remove the SPAN destination configuration. Changes in VLAN membership or trunk settings for a source port immediately take effect, and the respective SPAN sessions automatically adjust accordingly.

- **EtherChannel**—You can configure an EtherChannel group as a source port but not as a SPAN destination port. When a group is configured as a SPAN source, the entire group is monitored. If a physical port is added to a monitored EtherChannel group, the new port is added to the SPAN source port list. If a port is removed from a monitored EtherChannel group, it is automatically removed from the source port list.

A physical port that belongs to an EtherChannel group can be configured as a SPAN source port and still be a part of the EtherChannel. In this case, data from the physical port is monitored as it participates in the EtherChannel. However, if a physical port that belongs to an EtherChannel group is configured as a SPAN destination, it is removed from the group. After the port is removed from the SPAN session, it rejoins the EtherChannel group. Ports removed from an EtherChannel group remain members of the group, but they are in the **inactive** or **suspended** state.

If a physical port that belongs to an EtherChannel group is a destination port and the EtherChannel group is a source, the port is removed from the EtherChannel group and from the list of monitored ports.

- **Multicast traffic** can be monitored. For egress and ingress port monitoring, only a single unedited packet is sent to the SPAN destination port. It does not reflect the number of times the multicast packet is sent.
• A secure port cannot be a SPAN destination port.

For SPAN sessions, do not enable port security on ports with monitored egress when ingress forwarding is enabled on the destination port. For RSPAN source sessions, do not enable port security on any ports with monitored egress.

• An IEEE 802.1x port can be a SPAN source port. You can enable IEEE 802.1x on a port that is a SPAN destination port; however, IEEE 802.1x is disabled until the port is removed as a SPAN destination.

For SPAN sessions, do not enable IEEE 802.1x on ports with monitored egress when ingress forwarding is enabled on the destination port. For RSPAN source sessions, do not enable IEEE 802.1x on any ports that are egress monitored.

### Configuring SPAN and RSPAN

These sections contain this configuration information:

- Default SPAN and RSPAN Configuration, page 22-9
- Configuring Local SPAN, page 22-9
- Configuring RSPAN, page 22-15

### Default SPAN and RSPAN Configuration

Table 22-1 shows the default SPAN and RSPAN configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPAN state (SPAN and RSPAN)</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Source port traffic to monitor</td>
<td>Both received and sent traffic (<strong>both</strong>).</td>
</tr>
<tr>
<td>Encapsulation type (destination port)</td>
<td>Native form (untagged packets).</td>
</tr>
<tr>
<td>Ingress forwarding (destination port)</td>
<td>Disabled</td>
</tr>
<tr>
<td>VLAN filtering</td>
<td>On a trunk interface used as a source port, all VLANs are monitored.</td>
</tr>
<tr>
<td>RSPAN VLANs</td>
<td>None configured.</td>
</tr>
</tbody>
</table>

### Configuring Local SPAN

These sections contain this configuration information:

- SPAN Configuration Guidelines, page 22-10
- Creating a Local SPAN Session, page 22-10
- Creating a Local SPAN Session and Configuring Incoming Traffic, page 22-13
- Specifying VLANs to Filter, page 22-14
SPAN Configuration Guidelines

Follow these guidelines when configuring SPAN:

- For SPAN sources, you can monitor traffic for a single port or VLAN or a series or range of ports or VLANs for each session. You cannot mix source ports and source VLANs within a single SPAN session.
- The destination port cannot be a source port; a source port cannot be a destination port.
- You cannot have two SPAN sessions using the same destination port.
- When you configure a switch port as a SPAN destination port, it is no longer a normal switch port; only monitored traffic passes through the SPAN destination port.
- Entering SPAN configuration commands does not remove previously configured SPAN parameters. You must enter the `no monitor session {session_number | all | local | remote}` global configuration command to delete configured SPAN parameters.
- For local SPAN, outgoing packets through the SPAN destination port carry the original encapsulation headers—untagged, ISL, or IEEE 802.1Q—if the `encapsulation replicate` keywords are specified. If the keywords are not specified, the packets are sent in native form. For RSPAN destination ports, outgoing packets are not tagged.
- You can configure a disabled port to be a source or destination port, but the SPAN function does not start until the destination port and at least one source port or source VLAN are enabled.
- You can limit SPAN traffic to specific VLANs by using the `filter vlan` keyword. If a trunk port is being monitored, only traffic on the VLANs specified with this keyword is monitored. By default, all VLANs are monitored on a trunk port.
- You cannot mix source VLANs and filter VLANs within a single SPAN session.
- Egress SPAN routed packets (both unicast and multicast) show the incorrect source MAC address. For local SPAN packets with native encapsulation on the destination port, the packet shows the MAC address of VLAN 1. This problem does not appear with local SPAN when the encapsulation replicate option is used. This limitation does not apply to bridged packets. The workaround is to use the `encapsulate replicate` keywords in the `monitor session` global configuration command.

Creating a Local SPAN Session

Beginning in privileged EXEC mode, follow these steps to create a SPAN session and specify the source (monitored) ports or VLANs and the destination (monitoring) ports:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>no monitor session `{session_number</td>
</tr>
<tr>
<td>Step</td>
<td>Command</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
</tr>
</tbody>
</table>
| 3    | monitor session session_number source {interface interface-id | vlan vlan-id} [, | -] [both | rx | tx] | Specify the SPAN session and the source port (monitored port). For session_number, the range is 1 to 66. For interface-id, specify the source port or source VLAN to monitor.  
  - For source interface-id, specify the source port to monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (port-channel port-channel-number). Valid port-channel numbers are 1 to 48.  
  - For vlan-id, specify the source VLAN to monitor. The range is 1 to 4094 (excluding the RSPAN VLAN).  
  Note A single session can include multiple sources (ports or VLANs), defined in a series of commands, but you cannot combine source ports and source VLANs in one session.  
(Optional) [, | -] Specify a series or range of interfaces. Enter a space before and after the comma; enter a space before and after the hyphen.  
(Optional) Specify the direction of traffic to monitor. If you do not specify a traffic direction, the SPAN monitors both sent and received traffic.  
  - both—Monitor both received and sent traffic. This is the default.  
  - rx—Monitor received traffic.  
  - tx—Monitor sent traffic.  
  Note You can use the monitor session session_number source command multiple times to configure multiple source ports. |
| 4    | monitor session session_number destination {interface interface-id [, | -] [encapsulation replicate]} | Specify the SPAN session and the destination port (monitoring port). For session_number, specify the session number entered in step 3.  
Note For local SPAN, you must use the same session number for the source and destination interfaces.  
For interface-id, specify the destination port. The destination interface must be a physical port; it cannot be an EtherChannel, and it cannot be a VLAN.  
(Optional) [, | -] Specify a series or range of interfaces. Enter a space before and after the comma; enter a space before and after the hyphen.  
(Optional) Enter encapsulation replicate to specify that the destination interface replicates the source interface encapsulation method. If not selected, the default is to send packets in native form (untagged).  
Note You can use monitor session session_number destination command multiple times to configure multiple destination ports. |
| 5    | end     | Return to privileged EXEC mode. |
To delete a SPAN session, use the `no monitor session session_number` global configuration command. To remove a source or destination port or VLAN from the SPAN session, use the `no monitor session session_number source {interface interface-id | vlan vlan-id}` global configuration command or the `no monitor session session_number destination interface interface-id` global configuration command. For destination interfaces, the encapsulation options are ignored with the `no` form of the command.

This example shows how to set up SPAN session 1 for monitoring source port traffic to a destination port. First, any existing SPAN configuration for session 1 is deleted, and then bidirectional traffic is mirrored from source Gigabit Ethernet port 1 to destination Gigabit Ethernet port 2, retaining the encapsulation method.

```
Switch(config)# no monitor session 1
Switch(config)# monitor session 1 source interface gigabitethernet0/1
Switch(config)# monitor session 1 destination interface gigabitethernet0/2
Switch(config)# encapsulation replicate
Switch(config)# end
```

This example shows how to remove port 1 as a SPAN source for SPAN session 1:

```
Switch(config)# no monitor session 1 source interface gigabitethernet0/1
Switch(config)# end
```

This example shows how to disable received traffic monitoring on port 1, which was configured for bidirectional monitoring:

```
Switch(config)# no monitor session 1 source interface gigabitethernet0/1 rx
```

The monitoring of traffic received on port 1 is disabled, but traffic sent from this port continues to be monitored.

This example shows how to remove any existing configuration on SPAN session 2, configure SPAN session 2 to monitor received traffic on all ports belonging to VLANs 1 through 3, and send it to destination Gigabit Ethernet port 2. The configuration is then modified to also monitor all traffic on all ports belonging to VLAN 10.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source vlan 1 - 3 rx
Switch(config)# monitor session 2 destination interface gigabitethernet0/2
Switch(config)# monitor session 2 source vlan 10
Switch(config)# end
```
Creating a Local SPAN Session and Configuring Incoming Traffic

Beginning in privileged EXEC mode, follow these steps to create a SPAN session, to specify the source ports or VLANs and the destination ports, and to enable incoming traffic on the destination port for a network security device (such as a Cisco IDS Sensor Appliance).

For details about the keywords not related to incoming traffic, see the “Creating a Local SPAN Session” section on page 22-10.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>no monitor session {session_number</td>
</tr>
<tr>
<td></td>
<td>Remove any existing SPAN configuration for the session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>monitor session session_number source {interface interface-id</td>
</tr>
<tr>
<td></td>
<td>Specify the SPAN session and the source port (monitored port).</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>monitor session session_number destination {interface interface-id [,</td>
</tr>
<tr>
<td></td>
<td>Specify the SPAN session, the destination port, the packet encapsulation, and the ingress VLAN and encapsulation.</td>
</tr>
<tr>
<td></td>
<td>For session_number, specify the session number entered in Step 3.</td>
</tr>
<tr>
<td></td>
<td>For interface-id, specify the destination port. The destination interface must be a physical port; it cannot be an EtherChannel, and it cannot be a VLAN.</td>
</tr>
<tr>
<td></td>
<td>(Optional) [,</td>
</tr>
<tr>
<td></td>
<td>(Optional) Enter encapsulation replicate to specify that the destination interface replicates the source interface encapsulation method. If not selected, the default is to send packets in native form (untagged).</td>
</tr>
<tr>
<td></td>
<td>Enter ingress with keywords to enable forwarding of incoming traffic on the destination port and to specify the encapsulation type:</td>
</tr>
<tr>
<td></td>
<td>• dot1q vlan vlan-id—Accept incoming packets with IEEE 802.1Q encapsulation with the specified VLAN as the default VLAN.</td>
</tr>
<tr>
<td></td>
<td>• isl—Forward ingress packets with ISL encapsulation.</td>
</tr>
<tr>
<td></td>
<td>• untagged vlan vlan-id or vlan vlan-id—Accept incoming packets with untagged encapsulation type with the specified VLAN as the default VLAN.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>end</td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>show monitor [session session_number] show running-config</td>
</tr>
<tr>
<td></td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>copy running-config startup-config</td>
</tr>
<tr>
<td></td>
<td>(Optional) Save the configuration in the configuration file.</td>
</tr>
</tbody>
</table>
To delete a SPAN session, use the `no monitor session session_number` global configuration command. To remove a source or destination port or VLAN from the SPAN session, use the `no monitor session session_number source {interface interface-id | vlan vlan-id}` global configuration command or the `no monitor session session_number destination interface interface-id` global configuration command. For destination interfaces, the encapsulation and ingress options are ignored with the `no` form of the command.

This example shows how to remove any existing configuration on SPAN session 2, configure SPAN session 2 to monitor received traffic on Gigabit Ethernet source port 1, and send it to destination Gigabit Ethernet port 2 with the same egress encapsulation type as the source port, and to enable ingress forwarding with IEEE 802.1Q encapsulation and VLAN 6 as the default ingress VLAN.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source gigabitethernet0/1 rx
Switch(config)# monitor session 2 destination interface gigabitethernet0/2 encapsulation replicate ingress dot1q vlan 6
Switch(config)# end
```

### Specifying VLANs to Filter

Beginning in privileged EXEC mode, follow these steps to limit SPAN source traffic to specific VLANs:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>no monitor session {session_number</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>monitor session session_number source interface interface-id</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>monitor session session_number filter vlan vlan-id [, 1 -]</td>
</tr>
</tbody>
</table>
Chapter 22      Configuring SPAN and RSPAN

Configuring SPAN and RSPAN

To monitor all VLANs on the trunk port, use the `no monitor session session_number filter` global configuration command.

This example shows how to remove any existing configuration on SPAN session 2, configure SPAN session 2 to monitor traffic received on Gigabit Ethernet trunk port 2, and send traffic for only VLANs 1 through 5 and VLAN 9 to destination Gigabit Ethernet port 1.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source interface gigabitethernet0/2 rx
Switch(config)# monitor session 2 filter vlan 1 - 5, 9
Switch(config)# monitor session 2 destination interface gigabitethernet0/1
Switch(config)# end
```

To monitor all VLANs on the trunk port, use the `no monitor session session_number filter` global configuration command.

This example shows how to remove any existing configuration on SPAN session 2, configure SPAN session 2 to monitor traffic received on Gigabit Ethernet trunk port 2, and send traffic for only VLANs 1 through 5 and VLAN 9 to destination Gigabit Ethernet port 1.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source interface gigabitethernet0/2 rx
Switch(config)# monitor session 2 filter vlan 1 - 5, 9
Switch(config)# monitor session 2 destination interface gigabitethernet0/1
Switch(config)# end
```

### Configuring RSPAN

These sections contain this configuration information:

- RSPAN Configuration Guidelines, page 22-15
- Configuring a VLAN as an RSPAN VLAN, page 22-16
- Creating an RSPAN Source Session, page 22-17
- Creating an RSPAN Destination Session, page 22-19
- Creating an RSPAN Destination Session and Configuring Incoming Traffic, page 22-20
- Specifying VLANs to Filter, page 22-22

### RSPAN Configuration Guidelines

Follow these guidelines when configuring RSPAN:

- All the items in the “SPAN Configuration Guidelines” section on page 22-10 apply to RSPAN.
- As RSPAN VLANs have special properties, you should reserve a few VLANs across your network for use as RSPAN VLANs; do not assign access ports to these VLANs.
You can apply an output ACL to RSPAN traffic to selectively filter or monitor specific packets. Specify these ACLs on the RSPAN VLAN in the RSPAN source switches.

For RSPAN configuration, you can distribute the source ports and the destination ports across multiple switches in your network.

RSPAN does not support BPDU packet monitoring or other Layer 2 switch protocols.

The RSPAN VLAN is configured only on trunk ports and not on access ports. To avoid unwanted traffic in RSPAN VLANs, make sure that the VLAN remote-span feature is supported in all the participating switches.

Access ports (including voice VLAN ports) on the RSPAN VLAN are put in the inactive state.

RSPAN VLANs are included as sources for port-based RSPAN sessions when source trunk ports have active RSPAN VLANs. RSPAN VLANs can also be sources in SPAN sessions. However, since the switch does not monitor spanned traffic, it does not support egress spanning of packets on any RSPAN VLAN identified as the destination of an RSPAN source session on the switch.

You can configure any VLAN as an RSPAN VLAN as long as these conditions are met:
- The same RSPAN VLAN is used for an RSPAN session in all the switches.
- All participating switches support RSPAN.

We recommend that you configure an RSPAN VLAN before you configure an RSPAN source or a destination session.

If you enable VTP and VTP pruning, RSPAN traffic is pruned in the trunks to prevent the unwanted flooding of RSPAN traffic across the network for VLAN IDs that are lower than 1005.

These are the hardware limitations related to RSPAN:
- Egress SPAN routed packets (both unicast and multicast) show the incorrect source MAC address. For remote SPAN packets, the source MAC address should be the MAC address of the egress VLAN, but instead the packet shows the MAC address of the RSPAN VLAN. There is no workaround.
- During periods of very high traffic, when two RSPAN source sessions are configured, the VLAN ID of packets in one RSPAN session might overwrite the VLAN ID of the other RSPAN session. If this occurs, packets intended for one RSPAN VLAN are incorrectly sent to the other RSPAN VLAN. This problem does not affect RSPAN destination sessions. The workaround is to configure only one RSPAN source session.

### Configuring a VLAN as an RSPAN VLAN

First create a new VLAN to be the RSPAN VLAN for the RSPAN session. You must create the RSPAN VLAN in all switches that will participate in RSPAN. If the RSPAN VLAN-ID is in the normal range (lower than 1005) and VTP is enabled in the network, you can create the RSPAN VLAN in one switch, and VTP propagates it to the other switches in the VTP domain. For extended-range VLANs (greater than 1005), you must configure RSPAN VLAN on both source and destination switches and any intermediate switches.

Use VTP pruning to get an efficient flow of RSPAN traffic, or manually delete the RSPAN VLAN from all trunks that do not need to carry the RSPAN traffic.
Beginning in privileged EXEC mode, follow these steps to create an RSPAN VLAN:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 vlan vlan-id</td>
<td>Enter a VLAN ID to create a VLAN, or enter the VLAN ID of an existing VLAN, and enter VLAN configuration mode. The range is 2 to 1001 and 1006 to 4094. The RSPAN VLAN cannot be VLAN 1 (the default VLAN) or VLAN IDs 1002 through 1005 (reserved for Token Ring and FDDI VLANs).</td>
</tr>
<tr>
<td>Step 3 remote-span</td>
<td>Configure the VLAN as an RSPAN VLAN.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save the configuration in the configuration file.</td>
</tr>
</tbody>
</table>

To remove the remote SPAN characteristic from a VLAN and convert it back to a normal VLAN, use the no remote-span VLAN configuration command.

This example shows how to create RSPAN VLAN 901.

```
Switch(config)# vlan 901
Switch(config-vlan)# remote span
Switch(config-vlan)# end
```

Creating an RSPAN Source Session

Beginning in privileged EXEC mode, follow these steps to start an RSPAN source session and to specify the monitored source and the destination RSPAN VLAN:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 no monitor session {session_number</td>
<td>all</td>
</tr>
</tbody>
</table>
### Configuring SPAN and RSPAN

#### Step 3

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **monitor session session_number source** [interface interface-id | vlan vlan-id] [,,] [both | rx | tx] | Specify the RSPAN session and the source port (monitored port). For **session_number**, the range is 1 to 66. Enter a source port or source VLAN for the RSPAN session:  
  - For **interface-id**, specify the source port to monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel port-channel-number**). Valid port-channel numbers are 1 to 48.  
  - For **vlan-id**, specify the source VLAN to monitor. The range is 1 to 4094 (excluding the RSPAN VLAN). A single session can include multiple sources (ports or VLANs), defined in a series of commands, but you cannot combine source ports and source VLANs in one session.  
  (Optional) [,,] Specify a series or range of interfaces. Enter a space before and after the comma; enter a space before and after the hyphen.  
  (Optional) Specify the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both sent and received traffic.  
    - **both**—Monitor both received and sent traffic.  
    - **rx**—Monitor received traffic.  
    - **tx**—Monitor sent traffic. |

#### Step 4

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>monitor session session_number destination remote vlan vlan-id</strong></td>
<td>Specify the RSPAN session and the destination RSPAN VLAN. For <strong>session_number</strong>, enter the number defined in Step 3. For <strong>vlan-id</strong>, specify the source RSPAN VLAN to monitor.</td>
</tr>
</tbody>
</table>

#### Step 5

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>end</strong></td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

#### Step 6

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>show monitor [session session_number]</strong></td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td><strong>show running-config</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### Step 7

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>copy running-config startup-config</strong></td>
<td>(Optional) Save the configuration in the configuration file.</td>
</tr>
</tbody>
</table>

To delete a SPAN session, use the **no monitor session session_number** global configuration command. To remove a source port or VLAN from the SPAN session, use the **no monitor session session_number source** [interface interface-id | vlan vlan-id] global configuration command. To remove the RSPAN VLAN from the session, use the **no monitor session session_number destination remote vlan vlan-id**.

This example shows how to remove any existing RSPAN configuration for session 1, configure RSPAN session 1 to monitor multiple source interfaces, and configure the destination as RSPAN VLAN 901.

```
Switch(config)# no monitor session 1
Switch(config)# monitor session 1 source interface gigabitethernet0/1 tx
Switch(config)# monitor session 1 source interface gigabitethernet0/2 rx
Switch(config)# monitor session 1 source interface port-channel 2
Switch(config)# monitor session 1 destination remote vlan 901
Switch(config)# end
```
Chapter 22 Configuring SPAN and RSPAN

Configuring SPAN and RSPAN

Creating an RSPAN Destination Session

You configure the RSPAN destination session on a different switch; that is, not the switch on which the source session was configured.

Beginning in privileged EXEC mode, follow these steps to define the RSPAN VLAN on that switch, to create an RSPAN destination session, and to specify the source RSPAN VLAN and the destination port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 vlan vlan-id</td>
<td>Enter the VLAN ID of the RSPAN VLAN created from the source switch, and enter VLAN configuration mode. If both switches are participating in VTP and the RSPAN VLAN ID is from 2 to 1005, Steps 2 through 4 are not required because the RSPAN VLAN ID is propagated through the VTP network.</td>
</tr>
<tr>
<td>Step 3 remote-span</td>
<td>Identify the VLAN as the RSPAN VLAN.</td>
</tr>
<tr>
<td>Step 4 exit</td>
<td>Return to global configuration mode.</td>
</tr>
<tr>
<td>Step 5 no monitor session</td>
<td>Remove any existing RSPAN configuration for the session. No session_number, the range is 1 to 66. Specify all to remove all RSPAN sessions, local to remove all local sessions, or remote to remove all remote SPAN sessions.</td>
</tr>
<tr>
<td>Step 6 monitor session session_number source remote vlan vlan-id</td>
<td>Specify the RSPAN session and the source RSPAN VLAN. For session_number, the range is 1 to 66. For vlan-id, specify the source RSPAN VLAN to monitor.</td>
</tr>
<tr>
<td>Step 7 monitor session session_number destination interface interface-id</td>
<td>Specify the RSPAN session and the destination interface. For session_number, enter the number defined in Step 6. In an RSPAN destination session, you must use the same session number for the source RSPAN VLAN and the destination port. For interface-id, specify the destination interface. The destination interface must be a physical interface. Though visible in the command-line help string, encapsulation replicate is not supported for RSPAN. The original VLAN ID is overwritten by the RSPAN VLAN ID, and all packets appear on the destination port as untagged.</td>
</tr>
<tr>
<td>Step 8 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 9 show monitor [session session_number]</td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td>show running-config</td>
<td></td>
</tr>
<tr>
<td>Step 10 copy running-config startup-config</td>
<td>(Optional) Save the configuration in the configuration file.</td>
</tr>
</tbody>
</table>

To delete a SPAN session, use the no monitor session session_number global configuration command. To remove a destination port from the SPAN session, use the no monitor session session_number destination interface interface-id global configuration command. To remove the RSPAN VLAN from the session, use the no monitor session session_number source remote vlan vlan-id.
This example shows how to configure VLAN 901 as the source remote VLAN and port 1 as the destination interface:

```
Switch(config)# monitor session 1 source remote vlan 901
Switch(config)# monitor session 1 destination interface gigabitethernet0/1
Switch(config)# end
```

### Creating an RSPAN Destination Session and Configuring Incoming Traffic

Beginning in privileged EXEC mode, follow these steps to create an RSPAN destination session, to specify the source RSPAN VLAN and the destination port, and to enable incoming traffic on the destination port for a network security device (such as a Cisco IDS Sensor Appliance).

For details about the keywords not related to incoming traffic, see the “Creating an RSPAN Destination Session” section on page 22-19. This procedure assumes that the RSPAN VLAN has already been configured.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>Step 2</strong></td>
</tr>
<tr>
<td>configure terminal</td>
<td>no monitor session {session_number</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>Step 4</strong></td>
</tr>
<tr>
<td>monitor session session_number source remote vlan vlan-id</td>
<td>Specify the RSPAN session and the source RSPAN VLAN.  For session_number, the range is 1 to 66.  For vlan-id, specify the source RSPAN VLAN to monitor.</td>
</tr>
</tbody>
</table>
## Configuring SPAN and RSPAN

### Step 4

**monitor session session_number destination {interface interface-id [, | -] [ingress [dot1q vlan vlan-id | isl | untagged vlan vlan-id | vlan vlan-id]}}**

Specify the SPAN session, the destination port, the packet encapsulation, and the incoming VLAN and encapsulation. For `session_number`, enter the number defined in Step 4.

In an RSPAN destination session, you must use the same session number for the source RSPAN VLAN and the destination port.

For `interface-id`, specify the destination interface. The destination interface must be a physical interface.

Though visible in the command-line help string, `encapsulation replicate` is not supported for RSPAN. The original VLAN ID is overwritten by the RSPAN VLAN ID, and all packets appear on the destination port as untagged.

(Optional) `[, | -]` Specify a series or range of interfaces. Enter a space before and after the comma; enter a space before and after the hyphen.

Enter `ingress` with additional keywords to enable forwarding of incoming traffic on the destination port and to specify the encapsulation type:

- **dot1q vlan vlan-id**—Forward incoming packets with IEEE 802.1Q encapsulation with the specified VLAN as the default VLAN.
- **isl**—Forward ingress packets with ISL encapsulation.
- **untagged vlan vlan-id** or **vlan vlan-id**—Forward incoming packets with untagged encapsulation type with the specified VLAN as the default VLAN.

### Step 5

**end**

Return to privileged EXEC mode.

### Step 6

**show monitor [session session_number]**

**show running-config**

Verify the configuration.

### Step 7

**copy running-config startup-config**

(Optional) Save the configuration in the configuration file.

---

To delete an RSPAN session, use the `no monitor session session_number` global configuration command. To remove a destination port from the RSPAN session, use the `no monitor session session_number destination interface interface-id` global configuration command. The ingress options are ignored with the `no` form of the command.

This example shows how to configure VLAN 901 as the source remote VLAN in RSPAN session 2, to configure Gigabit Ethernet source port 2 as the destination interface, and to enable forwarding of incoming traffic on the interface with VLAN 6 as the default receiving VLAN.

```
Switch(config)# monitor session 2 source remote vlan 901
Switch(config)# monitor session 2 destination interface gigabitethernet0/2 ingress vlan 6
Switch(config)# end
```
## Specifying VLANs to Filter

Beginning in privileged EXEC mode, follow these steps to configure the RSPAN source session to limit RSPAN source traffic to specific VLANs:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>**no monitor session {session_number</td>
</tr>
<tr>
<td></td>
<td>Remove any existing SPAN configuration for the session.</td>
</tr>
<tr>
<td></td>
<td>For <strong>session_number</strong>, the range is 1 to 66.</td>
</tr>
<tr>
<td></td>
<td>Specify <strong>all</strong> to remove all SPAN sessions, <strong>local</strong> to remove all local sessions, or <strong>remote</strong> to remove all remote SPAN sessions.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>monitor session session_number source interface interface-id</strong></td>
</tr>
<tr>
<td></td>
<td>Specify the characteristics of the source port (monitored port) and SPAN session.</td>
</tr>
<tr>
<td></td>
<td>For <strong>session_number</strong>, the range is 1 to 66.</td>
</tr>
<tr>
<td></td>
<td>For <strong>interface-id</strong>, specify the source port to monitor. The interface specified must already be configured as a trunk port.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>monitor session session_number filter vlan vlan-id [, 1 - ]</strong></td>
</tr>
<tr>
<td></td>
<td>Limit the SPAN source traffic to specific VLANs.</td>
</tr>
<tr>
<td></td>
<td>For <strong>session_number</strong>, enter the session number specified in step 3.</td>
</tr>
<tr>
<td></td>
<td>For <strong>vlan-id</strong>, the range is 1 to 4094.</td>
</tr>
<tr>
<td></td>
<td>(Optional) Use a comma (,) to specify a series of VLANs or use a hyphen (-) to specify a range of VLANs. Enter a space before and after the comma; enter a space before and after the hyphen.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>monitor session session_number destination remote vlan vlan-id</strong></td>
</tr>
<tr>
<td></td>
<td>Specify the RSPAN session and the destination remote VLAN (RSPAN VLAN).</td>
</tr>
<tr>
<td></td>
<td>For <strong>session_number</strong>, enter the session number specified in step 3.</td>
</tr>
<tr>
<td></td>
<td>For <strong>vlan-id</strong>, specify the RSPAN VLAN to carry the monitored traffic to the destination port.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><strong>show monitor [session session_number]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>show running-config</strong></td>
</tr>
<tr>
<td></td>
<td>Verify the configuration.</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
<tr>
<td></td>
<td>(Optional) Save the configuration in the configuration file.</td>
</tr>
</tbody>
</table>

To monitor all VLANs on the trunk port, use the **no monitor session session_number filter vlan** global configuration command.

This example shows how to remove any existing configuration on RSPAN session 2, configure RSPAN session 2 to monitor traffic received on trunk port 2, and send traffic for only VLANs 1 through 5 and 9 to destination RSPAN VLAN 902.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source interface gigabitethernet0/2 rx
Switch(config)# monitor session 2 filter vlan 1 - 5, 9
Switch(config)# monitor session 2 destination remote vlan 902
Switch(config)# end
```
Displaying SPAN and RSPAN Status

To display the current SPAN or RSPAN configuration, use the `show monitor` user EXEC command. You can also use the `show running-config` privileged EXEC command to display configured SPAN or RSPAN sessions.
Configuring RMON

This chapter describes how to configure Remote Network Monitoring (RMON) on the switch. RMON is a standard monitoring specification that defines a set of statistics and functions that can be exchanged between RMON-compliant console systems and network probes. RMON provides you with comprehensive network-fault diagnosis, planning, and performance-tuning information.

For complete syntax and usage information for the commands used in this chapter, see the “System Management Commands” section in the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

This chapter consists of these sections:

- Understanding RMON, page 23-1
- Configuring RMON, page 23-2
- Displaying RMON Status, page 23-6

Understanding RMON

RMON is an Internet Engineering Task Force (IETF) standard monitoring specification that allows various network agents and console systems to exchange network monitoring data. You can use the RMON feature with the Simple Network Management Protocol (SNMP) agent in the switch to monitor all the traffic flowing among switches on all connected LAN segments as shown in Figure 23-1.
The switch supports these RMON groups (defined in RFC 1757):

- Statistics (RMON group 1)—Collects Ethernet statistics (including Fast Ethernet and Gigabit Ethernet statistics, depending on the switch type and supported interfaces) on an interface.
- History (RMON group 2)—Collects a history group of statistics on Ethernet ports (including Fast Ethernet and Gigabit Ethernet statistics, depending on the switch type and supported interfaces) for a specified polling interval.
- Alarm (RMON group 3)—Monitors a specific management information base (MIB) object for a specified interval, triggers an alarm at a specified value (rising threshold), and resets the alarm at another value (falling threshold). Alarms can be used with events; the alarm triggers an event, which can generate a log entry or an SNMP trap.
- Event (RMON group 9)—Specifies the action to take when an event is triggered by an alarm. The action can be to generate a log entry or an SNMP trap.

Because switches supported by this software release use hardware counters for RMON data processing, the monitoring is more efficient, and little processing power is required.

**Configuring RMON**

These sections contain this configuration information:

- Default RMON Configuration, page 23-3
- Configuring RMON Alarms and Events, page 23-3 (required)
- Collecting Group History Statistics on an Interface, page 23-5 (optional)
- Collecting Group Ethernet Statistics on an Interface, page 23-5 (optional)
Default RMON Configuration

RMON is disabled by default; no alarms or events are configured.

Configuring RMON Alarms and Events

You can configure your switch for RMON by using the command-line interface (CLI) or an SNMP-compatible network management station. We recommend that you use a generic RMON console application on the network management station (NMS) to take advantage of the RMON network management capabilities. You must also configure SNMP on the switch to access RMON MIB objects. For more information, see Chapter 25, “Configuring SNMP.”

Beginning in privileged EXEC mode, follow these steps to enable RMON alarms and events. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>rmon alarm number variable interval [absolute</td>
</tr>
</tbody>
</table>

- For *number*, specify the alarm number. The range is 1 to 65535.
- For *variable*, specify the MIB object to monitor.
- For *interval*, specify the time in seconds the alarm monitors the MIB variable. The range is 1 to 4294967295 seconds.
- Specify the *absolute* keyword to test each MIB variable directly. Specify the *delta* keyword to test the change between samples of a MIB variable.
- For *value*, specify a number at which the alarm is triggered and one for when the alarm is reset. The range for the rising threshold and falling threshold values is -2147483648 to 2147483647.
- (Optional) For *event-number*, specify the event number to trigger when the rising or falling threshold exceeds its limit.
- (Optional) For *owner string*, specify the owner of the alarm.
To disable an alarm, use the `no rmon alarm number` global configuration command on each alarm you configured. You cannot disable at once all the alarms that you configured. To disable an event, use the `no rmon event number` global configuration command. To learn more about alarms and events and how they interact with each other, see RFC 1757.

You can set an alarm on any MIB object. The following example configures RMON alarm number 10 by using the `rmon alarm` command. The alarm monitors the MIB variable `ifEntry.20.1` once every 20 seconds until the alarm is disabled and checks the change in the variable’s rise or fall. If the `ifEntry.20.1` value shows a MIB counter increase of 15 or more, such as from 100000 to 100015, the alarm is triggered. The alarm in turn triggers event number 1, which is configured with the `rmon event` command. Possible events can include a log entry or an SNMP trap. If the `ifEntry.20.1` value changes by 0, the alarm is reset and can be triggered again.

```plaintext
Switch(config)# rmon alarm 10 ifEntry.20.1 20 delta rising-threshold 15 1 falling-threshold 0 owner jjohnson
```

The following example creates RMON event number 1 by using the `rmon event` command. The event is defined as `High ifOutErrors` and generates a log entry when the event is triggered by the alarm. The user `jjones` owns the row that is created in the event table by this command. This example also generates an SNMP trap when the event is triggered.

```plaintext
Switch(config)# rmon event 1 log trap eventtrap description "High ifOutErrors" owner jjones
```
Collecting Group History Statistics on an Interface

You must first configure RMON alarms and events to display collection information.
Beginning in privileged EXEC mode, follow these steps to collect group history statistics on an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>rmon collection history index [buckets bucket-number] [interval seconds] [owner ownername]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>show rmon history</td>
</tr>
<tr>
<td>Step 7</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To disable history collection, use the no rmon collection history index interface configuration command.

Collecting Group Ethernet Statistics on an Interface

Beginning in privileged EXEC mode, follow these steps to collect group Ethernet statistics on an interface. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
</tbody>
</table>
Displaying RMON Status

To display the RMON status, use one or more of the privileged EXEC commands in Table 23-1:

Table 23-1 Commands for Displaying RMON Status

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show rmon</td>
<td>Displays general RMON statistics.</td>
</tr>
<tr>
<td>show rmon alarms</td>
<td>Displays the RMON alarm table.</td>
</tr>
<tr>
<td>show rmon events</td>
<td>Displays the RMON event table.</td>
</tr>
<tr>
<td>show rmon history</td>
<td>Displays the RMON history table.</td>
</tr>
<tr>
<td>show rmon statistics</td>
<td>Displays the RMON statistics table.</td>
</tr>
</tbody>
</table>

For information about the fields in these displays, see the “System Management Commands” section in the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.
CHAPTER 24

Configuring System Message Logging

This chapter describes how to configure system message logging on the switch.

For complete syntax and usage information for the commands used in this chapter, see the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

This chapter consists of these sections:

- Understanding System Message Logging, page 24-1
- Configuring System Message Logging, page 24-2
- Displaying the Logging Configuration, page 24-12

Understanding System Message Logging

By default, a switch sends the output from system messages and debug privileged EXEC commands to a logging process. The logging process controls the distribution of logging messages to various destinations, such as the logging buffer, terminal lines, or a UNIX syslog server, depending on your configuration. The process also sends messages to the console.

Note

The syslog format is compatible with 4.3 BSD UNIX.

When the logging process is disabled, messages are sent only to the console. The messages are sent as they are generated, so message and debug output are interspersed with prompts or output from other commands. Messages appear on the console after the process that generated them has finished.

You can set the severity level of the messages to control the type of messages displayed on the consoles and each of the destinations. You can time-stamp log messages or set the syslog source address to enhance real-time debugging and management. For information on possible messages, see the system message guide for this release.

You can remotely monitor system messages by viewing the logs on a syslog server or by accessing the switch through Telnet or through the console port.
Configuring System Message Logging

These sections contain this configuration information:

- System Log Message Format, page 24-2
- Default System Message Logging Configuration, page 24-3
- Disabling Message Logging, page 24-3 (optional)
- Setting the Message Display Destination Device, page 24-4 (optional)
- Synchronizing Log Messages, page 24-5 (optional)
- Enabling and Disabling Time Stamps on Log Messages, page 24-7 (optional)
- Enabling and Disabling Sequence Numbers in Log Messages, page 24-7 (optional)
- Defining the Message Severity Level, page 24-8 (optional)
- Limiting Syslog Messages Sent to the History Table and to SNMP, page 24-9 (optional)
- Configuring UNIX Syslog Servers, page 24-10 (optional)

System Log Message Format

System log messages can contain up to 80 characters and a percent sign (%), which follows the optional sequence number or time-stamp information, if configured. Messages appear in this format:

seq no:timestamp: %facility-severity-MNEMONIC:description

The part of the message preceding the percent sign depends on the setting of the service sequence-numbers, service timestamps log datetime, service timestamps log datetime [localtime] [msec] [show-timezone], or service timestamps log uptime global configuration command.

Table 24-1 describes the elements of syslog messages.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>seq no:</td>
<td>Stamps log messages with a sequence number only if the service sequence-numbers global configuration command is configured. For more information, see the “Enabling and Disabling Sequence Numbers in Log Messages” section on page 24-7.</td>
</tr>
<tr>
<td>timestamp formats:</td>
<td>Date and time of the message or event. This information appears only if the service timestamps log [datetime</td>
</tr>
<tr>
<td>mm/dd hh:mm:ss or hh:mm:ss (short uptime) or d h (long uptime)</td>
<td></td>
</tr>
<tr>
<td>facility</td>
<td>The facility to which the message refers (for example, SNMP, SYS, and so forth). For a list of supported facilities, see Table 24-4 on page 24-11.</td>
</tr>
<tr>
<td>severity</td>
<td>Single-digit code from 0 to 7 that is the severity of the message. For a description of the severity levels, see Table 24-3 on page 24-9.</td>
</tr>
</tbody>
</table>
Table 24-1 System Log Message Elements (continued)

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNEMONIC</td>
<td>Text string that uniquely describes the message.</td>
</tr>
<tr>
<td>description</td>
<td>Text string containing detailed information about the event being reported.</td>
</tr>
</tbody>
</table>

This example shows a partial switch system message:

```
00:00:46: %LINK-3-UPDOWN: Interface Port-channel1, changed state to up
00:00:47: %LINK-3-UPDOWN: Interface GigabitEthernet0/1, changed state to up
00:00:47: %LINK-3-UPDOWN: Interface GigabitEthernet0/2, changed state to up
00:00:48: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to down
00:00:48: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to down
*Mar 1 18:46:11: %SYS-5-CONFIG_I: Configured from console by vty2 (10.34.195.36)
18:47:02: %SYS-5-CONFIG_I: Configured from console by vty2 (10.34.195.36)
*Mar 1 18:48:50.483 UTC: %SYS-5-CONFIG_I: Configured from console by vty2 (10.34.195.36)
```

Default System Message Logging Configuration

Table 24-2 shows the default system message logging configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>System message logging to the console</td>
<td>Enabled.</td>
</tr>
<tr>
<td>Console severity</td>
<td>Debugging (and numerically lower levels; see Table 24-3 on page 24-9).</td>
</tr>
<tr>
<td>Logging file configuration</td>
<td>No filename specified.</td>
</tr>
<tr>
<td>Logging buffer size</td>
<td>4096 bytes.</td>
</tr>
<tr>
<td>Logging history size</td>
<td>1 message.</td>
</tr>
<tr>
<td>Time stamps</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Synchronous logging</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Logging server</td>
<td>Disabled.</td>
</tr>
<tr>
<td>Syslog server IPv4 address</td>
<td>None configured.</td>
</tr>
<tr>
<td>Server facility</td>
<td>Local7 (see Table 24-4 on page 24-11).</td>
</tr>
<tr>
<td>Server severity</td>
<td>Informational (and numerically lower levels; see Table 24-3 on page 24-9).</td>
</tr>
</tbody>
</table>

Disabling Message Logging

Message logging is enabled by default. It must be enabled to send messages to any destination other than the console. When enabled, log messages are sent to a logging process, which logs messages to designated locations asynchronously to the processes that generated the messages.
Beginning in privileged EXEC mode, follow these steps to disable message logging. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> no logging console</td>
<td>Disable message logging.</td>
</tr>
<tr>
<td><strong>Step 3</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong> show running-config or show logging</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Disabling the logging process can slow down the switch because a process must wait until the messages are written to the console before continuing. When the logging process is disabled, messages appear on the console as soon as they are produced, often appearing in the middle of command output.

The logging synchronous global configuration command also affects the display of messages to the console. When this command is enabled, messages appear only after you press Return. For more information, see the “Synchronizing Log Messages” section on page 24-5.

To re-enable message logging after it has been disabled, use the logging on global configuration command.

### Setting the Message Display Destination Device

If message logging is enabled, you can send messages to specific locations in addition to the console. Beginning in privileged EXEC mode, use one or more of the following commands to specify the locations that receive messages. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> logging buffered [size]</td>
<td>Log messages to an internal buffer on the switch. The range is 4096 to 2147483647 bytes. The default buffer size is 4096 bytes. If the switch fails, the log file is lost unless you had previously saved it to flash memory. See Step 4.</td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td>Do not make the buffer size too large because the switch could run out of memory for other tasks. Use the show memory privileged EXEC command to view the free processor memory on the switch. However, this value is the maximum available, and the buffer size should not be set to this amount.</td>
</tr>
</tbody>
</table>
Configuring System Message Logging

Chapter 24

Configuring System Message Logging

The **logging buffered** global configuration command copies logging messages to an internal buffer. The buffer is circular, so newer messages overwrite older messages after the buffer is full. To display the messages that are logged in the buffer, use the **show logging** privileged EXEC command. The first message displayed is the oldest message in the buffer. To clear the contents of the buffer, use the **clear logging** privileged EXEC command.

To disable logging to the console, use the **no logging console** global configuration command. To disable logging to a file, use the **no logging file [severity-level-number | type]** global configuration command.

**Synchronizing Log Messages**

You can synchronize unsolicited messages and **debug** privileged EXEC command output with solicited device output and prompts for a specific console port line or virtual terminal line. You can identify the types of messages to be output asynchronously based on the level of severity. You can also configure the maximum number of buffers for storing asynchronous messages for the terminal after which messages are dropped.

When synchronous logging of unsolicited messages and **debug** command output is enabled, unsolicited device output appears on the console or printed after solicited device output appears or is printed. Unsolicited messages and **debug** command output appears on the console after the prompt for user input.

---

### Command Table

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td><strong>logging host</strong></td>
<td>Log messages to a UNIX syslog server host. For <em>host</em>, specify the name or IP address of the host to be used as the syslog server. To build a list of syslog servers that receive logging messages, enter this command more than once. For complete syslog server configuration steps, see the “Configuring UNIX Syslog Servers” section on page 24-10.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• For <em>filename</em>, enter the log message filename.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For <em>max-file-size</em>, specify the maximum logging file size. The range is 4096 to 2147483647. The default is 4096 bytes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For <em>min-file-size</em>, specify the minimum logging file size. The range is 1024 to 2147483647. The default is 2048 bytes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Optional) For *severity-level-number</td>
</tr>
<tr>
<td>5</td>
<td><strong>end</strong></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>6</td>
<td><strong>terminal monitor</strong></td>
<td>Log messages to a nonconsole terminal during the current session. Terminal parameter-setting commands are set locally and do not remain in effect after the session has ended. You must perform this step for each session to see the debugging messages.</td>
</tr>
<tr>
<td>7</td>
<td><strong>show running-config</strong></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>8</td>
<td><strong>copy running-config startup-config</strong></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
is returned. Therefore, unsolicited messages and **debug** command output are not interspersed with solicited device output and prompts. After the unsolicited messages appear, the console again displays the user prompt.

Beginning in privileged EXEC mode, follow these steps to configure synchronous logging. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> line [console</td>
<td>vty] line-number [ending-line-number]</td>
</tr>
<tr>
<td></td>
<td>• Use the console keyword for configurations that occur through the switch console port.</td>
</tr>
<tr>
<td></td>
<td>• Use the line vty line-number command to specify which vty lines are to have synchronous logging enabled. You use a vty connection for configurations that occur through a Telnet session. The range of line numbers is from 0 to 15.</td>
</tr>
<tr>
<td></td>
<td>You can change the setting of all 16 vty lines at once by entering:</td>
</tr>
<tr>
<td></td>
<td>line vty 0 15</td>
</tr>
<tr>
<td></td>
<td>Or you can change the setting of the single vty line being used for your current connection. For example, to change the setting for vty line 2, enter:</td>
</tr>
<tr>
<td></td>
<td>line vty 2</td>
</tr>
<tr>
<td></td>
<td>When you enter this command, the mode changes to line configuration.</td>
</tr>
<tr>
<td><strong>Step 3</strong> logging synchronous [level [severity-level</td>
<td>all]</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For level severity-level, specify the message severity level. Messages with a severity level equal to or higher than this value are printed asynchronously. Low numbers mean greater severity and high numbers mean lesser severity. The default is 2.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) Specifying level all means that all messages are printed asynchronously regardless of the severity level.</td>
</tr>
<tr>
<td></td>
<td>• (Optional) For limit number-of-buffers, specify the number of buffers to be queued for the terminal after which new messages are dropped. The range is 0 to 2147483647. The default is 20.</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable synchronization of unsolicited messages and debug output, use the `no logging synchronous [level severity-level | all] [limit number-of-buffers]` line configuration command.
Enabling and Disabling Time Stamps on Log Messages

By default, log messages are not time-stamped. Beginning in privileged EXEC mode, follow these steps to enable time-stamping of log messages. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 service timestamps log uptime</td>
<td>Enable log time stamps.</td>
</tr>
<tr>
<td>or</td>
<td>The first command enables time stamps on log messages,</td>
</tr>
<tr>
<td>or</td>
<td>showing the time since the system was rebooted.</td>
</tr>
<tr>
<td>service timestamps log datetime [msec] [localtime] [show-timezone]</td>
<td>The second command enables time stamps on log messages.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable time stamps for both debug and log messages, use the `no service timestamps` global configuration command.

This example shows part of a logging display with the `service timestamps log datetime` global configuration command enabled:

```
*Mar 1 18:46:11: %SYS-5-CONFIG_I: Configured from console by vty2 (10.34.195.36)
```

This example shows part of a logging display with the `service timestamps log uptime` global configuration command enabled:

```
00:00:46: %LINK-3-UPDOWN: Interface Port-channel1, changed state to up
```

Enabling and Disabling Sequence Numbers in Log Messages

Because there is a chance that more than one log message can have the same time stamp, you can display messages with sequence numbers so that you can unambiguously see a single message. By default, sequence numbers in log messages are not displayed.

Beginning in privileged EXEC mode, follow these steps to enable sequence numbers in log messages. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 service sequence-numbers</td>
<td>Enable sequence numbers.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>
Chapter 24    Configuring System Message Logging

Configuring System Message Logging

To disable sequence numbers, use the `no service sequence-numbers` global configuration command.

This example shows part of a logging display with sequence numbers enabled:

```
000019: %SYS-5-CONFIG_I: Configured from console by vty2 (10.34.195.36)
```

Defining the Message Severity Level

You can limit messages displayed to the selected device by specifying the severity level of the message, which are described in Table 24-3.

Beginning in privileged EXEC mode, follow these steps to define the message severity level. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>logging console level</code></td>
</tr>
<tr>
<td></td>
<td>Limit messages logged to the console.</td>
</tr>
<tr>
<td></td>
<td>By default, the console receives debugging messages and numerically</td>
</tr>
<tr>
<td></td>
<td>lower levels (see Table 24-3 on page 24-9).</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>logging monitor level</code></td>
</tr>
<tr>
<td></td>
<td>Limit messages logged to the terminal lines.</td>
</tr>
<tr>
<td></td>
<td>By default, the terminal receives debugging messages and numerically</td>
</tr>
<tr>
<td></td>
<td>lower levels (see Table 24-3 on page 24-9).</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>logging trap level</code></td>
</tr>
<tr>
<td></td>
<td>Limit messages logged to the syslog servers.</td>
</tr>
<tr>
<td></td>
<td>By default, syslog servers receive informational messages and</td>
</tr>
<tr>
<td></td>
<td>numerically lower levels (see Table 24-3 on page 24-9).</td>
</tr>
<tr>
<td></td>
<td>For complete syslog server configuration steps, see the “Configuring</td>
</tr>
<tr>
<td></td>
<td>UNIX Syslog Servers” section on page 24-10.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>end</code></td>
</tr>
<tr>
<td></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>show running-config</code> or <code>show logging</code></td>
</tr>
<tr>
<td></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 7</td>
<td><code>copy running-config startup-config</code> (Optional) Save your entries in the</td>
</tr>
<tr>
<td></td>
<td>configuration file.</td>
</tr>
</tbody>
</table>

**Note**

Specifying a `level` causes messages at that level and numerically lower levels to appear at the destination.

To disable logging to the console, use the `no logging console` global configuration command. To disable logging to a terminal other than the console, use the `no logging monitor` global configuration command. To disable logging to syslog servers, use the `no logging trap` global configuration command.
Chapter 24 Configuring System Message Logging

Table 24-3 describes the level keywords. It also lists the corresponding UNIX syslog definitions from the most severe level to the least severe level.

### Table 24-3 Message Logging Level Keywords

<table>
<thead>
<tr>
<th>Level Keyword</th>
<th>Level</th>
<th>Description</th>
<th>Syslog Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>emergencies</td>
<td>0</td>
<td>System unstable</td>
<td>LOG_EMERG</td>
</tr>
<tr>
<td>alerts</td>
<td>1</td>
<td>Immediate action needed</td>
<td>LOG_ALERT</td>
</tr>
<tr>
<td>critical</td>
<td>2</td>
<td>Critical conditions</td>
<td>LOG_CRIT</td>
</tr>
<tr>
<td>errors</td>
<td>3</td>
<td>Error conditions</td>
<td>LOG_ERR</td>
</tr>
<tr>
<td>warnings</td>
<td>4</td>
<td>Warning conditions</td>
<td>LOG_WARNING</td>
</tr>
<tr>
<td>notifications</td>
<td>5</td>
<td>Normal but significant condition</td>
<td>LOG_NOTICE</td>
</tr>
<tr>
<td>informational</td>
<td>6</td>
<td>Informational messages only</td>
<td>LOG_INFO</td>
</tr>
<tr>
<td>debugging</td>
<td>7</td>
<td>Debugging messages</td>
<td>LOG_DEBUG</td>
</tr>
</tbody>
</table>

The software generates four other categories of messages:

- Error messages about software or hardware malfunctions, displayed at levels warnings through emergencies. These types of messages mean that the functionality of the switch is affected. For information on how to recover from these malfunctions, see the system message guide for this release.
- Output from the debug commands, displayed at the debugging level. Debug commands are typically used only by the Technical Assistance Center.
- Interface up or down transitions and system restart messages, displayed at the notifications level. This message is only for information; switch functionality is not affected.

### Limiting Syslog Messages Sent to the History Table and to SNMP

If you enabled syslog message traps to be sent to an SNMP network management station by using the `snmp-server enable trap` global configuration command, you can change the level of messages sent and stored in the switch history table. You also can change the number of messages that are stored in the history table.

Messages are stored in the history table because SNMP traps are not guaranteed to reach their destination. By default, one message of the level `warning` and numerically lower levels (see Table 24-3 on page 24-9) are stored in the history table even if syslog traps are not enabled.

Beginning in privileged EXEC mode, follow these steps to change the level and history table size defaults. This procedure is optional.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>
| Step 2     | logging history `level` | Change the default level of syslog messages stored in the history file and sent to the SNMP server.  
See Table 24-3 on page 24-9 for a list of `level` keywords.  
By default, `warnings`, `errors`, `critical`, `alerts`, and `emergencies` messages are sent. |
Configuring System Message Logging

When the history table is full (it contains the maximum number of message entries specified with the `logging history size` global configuration command), the oldest message entry is deleted from the table to allow the new message entry to be stored.

To return the logging of syslog messages to the default level, use the `no logging history` global configuration command. To return the number of messages in the history table to the default value, use the `no logging history size` global configuration command.

**Configuring UNIX Syslog Servers**

The next sections describe how to configure the UNIX server syslog daemon and how to define the UNIX system logging facility.

**Logging Messages to a UNIX Syslog Daemon**

Before you can send system log messages to a UNIX syslog server, you must configure the syslog daemon on a UNIX server. This procedure is optional.

Log in as root, and perform these steps:

1. **Step 1** Add a line such as the following to the file `/etc/syslog.conf`:

   ```
   local7.debug /usr/adm/logs/cisco.log
   ```

   The `local7` keyword specifies the logging facility to be used; see Table 24-3 on page 24-11 for information on the facilities. The `debug` keyword specifies the syslog level; see Table 24-3 on page 24-9 for information on the severity levels. The syslog daemon sends messages at this level or at a more severe level to the file specified in the next field. The file must already exist, and the syslog daemon must have permission to write to it.

2. **Step 2** Create the log file by entering these commands at the UNIX shell prompt:

   ```
   $ touch /var/log/cisco.log
   $ chmod 666 /var/log/cisco.log
   ```

---

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>logging history size number</code></td>
<td>Specify the number of syslog messages that can be stored in the history table.</td>
</tr>
<tr>
<td></td>
<td>The default is to store one message. The range is 0 to 500 messages.</td>
</tr>
<tr>
<td><code>end</code></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><code>show running-config</code></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

1. Table 24-3 lists the level keywords and severity level. For SNMP usage, the severity level values increase by 1. For example, *emergencies* equal 1, not 0, and *critical* equals 3, not 2.
Step 3  Make sure the syslog daemon reads the new changes:

```
$ kill -HUP `cat /etc/syslog.pid`
```

For more information, see the `man syslog.conf` and `man syslogd` commands on your UNIX system.

### Configuring the UNIX System Logging Facility

When sending system log messages to an external device, you can cause the switch to identify its messages as originating from any of the UNIX syslog facilities.

Beginning in privileged EXEC mode, follow these steps to configure UNIX system facility message logging. This procedure is optional.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>logging host</td>
<td>Log messages to a UNIX syslog server host by entering its IP address. To build a list of syslog servers that receive logging messages, enter this command more than once.</td>
</tr>
<tr>
<td>3</td>
<td>logging trap level</td>
<td>Limit messages logged to the syslog servers. Be default, syslog servers receive informational messages and lower. See Table 24-3 on page 24-9 for level keywords.</td>
</tr>
<tr>
<td>4</td>
<td>logging facility facility-type</td>
<td>Configure the syslog facility. See Table 24-4 on page 24-11 for facility-type keywords. The default is <code>local7</code>.</td>
</tr>
<tr>
<td>5</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>6</td>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>7</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove a syslog server, use the `no logging host` global configuration command, and specify the syslog server IP address. To disable logging to syslog servers, enter the `no logging trap` global configuration command.

Table 24-4 lists the UNIX system facilities supported by the software. For more information about these facilities, consult the operator’s manual for your UNIX operating system.

### Table 24-4  Logging Facility-Type Keywords

<table>
<thead>
<tr>
<th>Facility Type Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>auth</td>
<td>Authorization system</td>
</tr>
<tr>
<td>cron</td>
<td>Cron facility</td>
</tr>
<tr>
<td>daemon</td>
<td>System daemon</td>
</tr>
<tr>
<td>kern</td>
<td>Kernel</td>
</tr>
<tr>
<td>local0-7</td>
<td>Locally defined messages</td>
</tr>
<tr>
<td>lpr</td>
<td>Line printer system</td>
</tr>
</tbody>
</table>
To display the logging configuration and the contents of the log buffer, use the `show logging` privileged EXEC command. For information about the fields in this display, see the *Cisco IOS Configuration Fundamentals Command Reference, Release 12.2*.

### Displaying the Logging Configuration

<table>
<thead>
<tr>
<th>Facility Type Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mail</td>
<td>Mail system</td>
</tr>
<tr>
<td>news</td>
<td>USENET news</td>
</tr>
<tr>
<td>sys9-14</td>
<td>System use</td>
</tr>
<tr>
<td>syslog</td>
<td>System log</td>
</tr>
<tr>
<td>user</td>
<td>User process</td>
</tr>
<tr>
<td>uucp</td>
<td>UNIX-to-UNIX copy system</td>
</tr>
</tbody>
</table>
Configuring SNMP

This chapter describes how to configure the Simple Network Management Protocol (SNMP) on the switch.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release and the *Cisco IOS Configuration Fundamentals Command Reference, Release 12.2*.

This chapter consists of these sections:
- Understanding SNMP, page 25-1
- Configuring SNMP, page 25-6
- Displaying SNMP Status, page 25-17

**Understanding SNMP**

SNMP is an application-layer protocol that provides a message format for communication between managers and agents. The SNMP system consists of an SNMP manager, an SNMP agent, and a MIB. The SNMP manager can be part of a network management system (NMS) such as CiscoWorks. The agent and MIB reside on the switch. To configure SNMP on the switch, you define the relationship between the manager and the agent.

The SNMP agent contains MIB variables whose values the SNMP manager can request or change. A manager can get a value from an agent or store a value into the agent. The agent gathers data from the MIB, the repository for information about device parameters and network data. The agent can also respond to a manager’s requests to get or set data.

An agent can send unsolicited traps to the manager. Traps are messages alerting the SNMP manager to a condition on the network. Traps can mean improper user authentication, restarts, link status (up or down), MAC address tracking, closing of a TCP connection, loss of connection to a neighbor, or other significant events.

These sections contain this conceptual information:
- SNMP Versions, page 25-2
- SNMP Manager Functions, page 25-3
- SNMP Agent Functions, page 25-4
- SNMP Community Strings, page 25-4
SNMP Versions

This software release supports these SNMP versions:

- **SNMPv1**—The Simple Network Management Protocol, a Full Internet Standard, defined in RFC 1157.
- **SNMPv2C** replaces the Party-based Administrative and Security Framework of SNMPv2Classic with the community-string-based Administrative Framework of SNMPv2C while retaining the bulk retrieval and improved error handling of SNMPv2Classic. It has these features:
  - **SNMPv2**—Version 2 of the Simple Network Management Protocol, a Draft Internet Standard, defined in RFCs 1902 through 1907.
  - **SNMPv2C**—The community-string-based Administrative Framework for SNMPv2, an Experimental Internet Protocol defined in RFC 1901.
- **SNMPv3**—Version 3 of the SNMP is an interoperable standards-based protocol defined in RFCs 2273 to 2275. SNMPv3 provides secure access to devices by authenticating and encrypting packets over the network and includes these security features:
  - Message integrity—ensuring that a packet was not tampered with in transit
  - Authentication—determining that the message is from a valid source
  - Encryption—mixing the contents of a package to prevent it from being read by an unauthorized source.

Note: To select encryption, enter the **priv** keyword. This keyword is available only when the cryptographic (encrypted) software image is installed.

Both SNMPv1 and SNMPv2C use a community-based form of security. The community of managers able to access the agent’s MIB is defined by an IP address access control list and password.

SNMPv2C includes a bulk retrieval mechanism and more detailed error message reporting to management stations. The bulk retrieval mechanism retrieves tables and large quantities of information, minimizing the number of round-trips required. The SNMPv2C improved error-handling includes expanded error codes that distinguish different kinds of error conditions; these conditions are reported through a single error code in SNMPv1. Error return codes in SNMPv2C report the error type.

SNMPv3 provides for both security models and security levels. A security model is an authentication strategy set up for a user and the group within which the user resides. A security level is the permitted level of security within a security model. A combination of the security level and the security model determine which security mechanism is used when handling an SNMP packet. Available security models are SNMPv1, SNMPv2C, and SNMPv3.
Table 25-1 identifies the characteristics of the different combinations of security models and levels.

<table>
<thead>
<tr>
<th>Model</th>
<th>Level</th>
<th>Authentication</th>
<th>Encryption</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNMPv1</td>
<td>noAuthNoPriv</td>
<td>Community string</td>
<td>No</td>
<td>Uses a community string match for authentication.</td>
</tr>
<tr>
<td>SNMPv2C</td>
<td>noAuthNoPriv</td>
<td>Community string</td>
<td>No</td>
<td>Uses a community string match for authentication.</td>
</tr>
<tr>
<td>SNMPv3</td>
<td>noAuthNoPriv</td>
<td>Username</td>
<td>No</td>
<td>Uses a username match for authentication.</td>
</tr>
<tr>
<td>SNMPv3</td>
<td>authNoPriv</td>
<td>MD5 or SHA</td>
<td>No</td>
<td>Provides authentication based on the HMAC-MD5 or HMAC-SHA algorithms.</td>
</tr>
<tr>
<td>SNMPv3</td>
<td>authPriv</td>
<td>MD5 or SHA</td>
<td>DES</td>
<td>Provides authentication based on the HMAC-MD5 or HMAC-SHA algorithms.</td>
</tr>
</tbody>
</table>

You must configure the SNMP agent to use the SNMP version supported by the management station. Because an agent can communicate with multiple managers, you can configure the software to support communications using SNMPv1, SNMPv2C, or SNMPv3.

### SNMP Manager Functions

The SNMP manager uses information in the MIB to perform the operations described in Table 25-2.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>get-request</td>
<td>Retrieves a value from a specific variable.</td>
</tr>
<tr>
<td>get-next-request</td>
<td>Retrieves a value from a variable within a table.¹</td>
</tr>
<tr>
<td>get-bulk-request</td>
<td>Retrieves large blocks of data, such as multiple rows in a table, that would otherwise require the transmission of many small blocks of data.</td>
</tr>
<tr>
<td>get-response</td>
<td>Replies to a get-request, get-next-request, and set-request sent by an NMS.</td>
</tr>
<tr>
<td>set-request</td>
<td>Stores a value in a specific variable.</td>
</tr>
<tr>
<td>trap</td>
<td>An unsolicited message sent by an SNMP agent to an SNMP manager when some event has occurred.</td>
</tr>
</tbody>
</table>

¹. With this operation, an SNMP manager does not need to know the exact variable name. A sequential search is performed to find the needed variable from within a table.

². The **get-bulk** command only works with SNMPv2 or later.
SNMP Agent Functions

The SNMP agent responds to SNMP manager requests as follows:

- Get a MIB variable—The SNMP agent begins this function in response to a request from the NMS. The agent retrieves the value of the requested MIB variable and responds to the NMS with that value.
- Set a MIB variable—The SNMP agent begins this function in response to a message from the NMS. The SNMP agent changes the value of the MIB variable to the value requested by the NMS.

The SNMP agent also sends unsolicited trap messages to notify an NMS that a significant event has occurred on the agent. Examples of trap conditions include, but are not limited to, when a port or module goes up or down, when spanning-tree topology changes occur, and when authentication failures occur.

SNMP Community Strings

SNMP community strings authenticate access to MIB objects and function as embedded passwords. In order for the NMS to access the switch, the community string definitions on the NMS must match at least one of the three community string definitions on the switch.

A community string can have one of these attributes:

- Read-only (RO)—Gives read access to authorized management stations to all objects in the MIB except the community strings, but does not allow write access
- Read-write (RW)—Gives read and write access to authorized management stations to all objects in the MIB, but does not allow access to the community strings
- When a cluster is created, the command switch manages the exchange of messages among member switches and the SNMP application. The Network Assistant software appends the member switch number (@esN, where N is the switch number) to the first configured RW and RO community strings on the command switch and propagates them to the member switches. For more information, see Chapter 6, “Clustering Switches” and see Getting Started with Cisco Network Assistant, available on Cisco.com.

Using SNMP to Access MIB Variables

An example of an NMS is the CiscoWorks network management software. CiscoWorks 2000 software uses the switch MIB variables to set device variables and to poll devices on the network for specific information. The results of a poll can be displayed as a graph and analyzed to troubleshoot internetworking problems, increase network performance, verify the configuration of devices, monitor traffic loads, and more.
As shown in Figure 25-1, the SNMP agent gathers data from the MIB. The agent can send traps, or notification of certain events, to the SNMP manager, which receives and processes the traps. Traps alert the SNMP manager to a condition on the network such as improper user authentication, restarts, link status (up or down), MAC address tracking, and so forth. The SNMP agent also responds to MIB-related queries sent by the SNMP manager in get-request, get-next-request, and set-request format.

For information on supported MIBs and how to access them, see Appendix A, “Supported MIBs.”

**SNMP Notifications**

SNMP allows the switch to send notifications to SNMP managers when particular events occur. SNMP notifications can be sent as traps or inform requests. In command syntax, unless there is an option in the command to select either traps or informs, the keyword traps refers to either traps or informs, or both. Use the snmp-server host command to specify whether to send SNMP notifications as traps or informs.

Note

SNMPv1 does not support informs.

Traps are unreliable because the receiver does not send an acknowledgment when it receives a trap, and the sender cannot determine if the trap was received. When an SNMP manager receives an inform request, it acknowledges the message with an SNMP response protocol data unit (PDU). If the sender does not receive a response, the inform request can be sent again. Because they can be re-sent, informs are more likely than traps to reach their intended destination.

The characteristics that make informs more reliable than traps also consume more resources in the switch and in the network. Unlike a trap, which is discarded as soon as it is sent, an inform request is held in memory until a response is received or the request times out. Traps are sent only once, but an inform might be re-sent or retried several times. The retries increase traffic and contribute to a higher overhead on the network. Therefore, traps and informs require a trade-off between reliability and resources. If it is important that the SNMP manager receive every notification, use inform requests. If traffic on the network or memory in the switch is a concern and notification is not required, use traps.
SNMP ifIndex MIB Object Values

In an NMS, the IF-MIB generates and assigns an interface index (ifIndex) object value that is a unique number greater than zero to identify a physical or a logical interface. When the switch reboots or the switch software is upgraded, the switch uses this same value for the interface. For example, if the switch assigns a port 2 an ifIndex value of 10003, this value is the same after the switch reboots.

The switch uses one of the values in Table 25-3 to assign an ifIndex value to an interface:

<table>
<thead>
<tr>
<th>Interface Type</th>
<th>ifIndex Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVI(^1)</td>
<td>1–4999</td>
</tr>
<tr>
<td>EtherChannel</td>
<td>5000–5012</td>
</tr>
<tr>
<td>Loopback</td>
<td>5013–5077</td>
</tr>
<tr>
<td>Tunnel</td>
<td>5078–5142</td>
</tr>
<tr>
<td>Physical (such as Gigabit Ethernet or SFP(^2)-module interfaces)</td>
<td>10000–14500</td>
</tr>
<tr>
<td>Null</td>
<td>14501</td>
</tr>
</tbody>
</table>

1. SVI = switch virtual interface
2. SFP = small form-factor pluggable

The switch might not use sequential values within a range.

Configuring SNMP

These sections contain this configuration information:

- Default SNMP Configuration, page 25-7
- SNMP Configuration Guidelines, page 25-7
- Disabling the SNMP Agent, page 25-8
- Configuring Community Strings, page 25-8
- Configuring SNMP Groups and Users, page 25-10
- Configuring SNMP Notifications, page 25-12
- Setting the Agent Contact and Location Information, page 25-15
- Limiting TFTP Servers Used Through SNMP, page 25-16
- SNMP Examples, page 25-16
Default SNMP Configuration

Table 25-4 shows the default SNMP configuration.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNMP agent</td>
<td>Disabled&lt;sup&gt;1&lt;/sup&gt;.</td>
</tr>
<tr>
<td>SNMP trap receiver</td>
<td>None configured.</td>
</tr>
<tr>
<td>SNMP traps</td>
<td>None enabled except the trap for TCP connections (tty).</td>
</tr>
<tr>
<td>SNMP version</td>
<td>If no version keyword is present, the default is Version 1.</td>
</tr>
<tr>
<td>SNMPv3 authentication</td>
<td>If no keyword is entered, the default is the noauth (noAuthNoPriv) security level.</td>
</tr>
<tr>
<td>SNMP notification type</td>
<td>If no type is specified, all notifications are sent.</td>
</tr>
</tbody>
</table>

<sup>1</sup> This is the default when the switch starts and the startup configuration does not have any snmp-server global configuration commands.

SNMP Configuration Guidelines

If the switch starts and the switch startup configuration has at least one snmp-server global configuration command, the SNMP agent is enabled.

An SNMP group is a table that maps SNMP users to SNMP views. An SNMP user is a member of an SNMP group. An SNMP host is the recipient of an SNMP trap operation. An SNMP engine ID is a name for the local or remote SNMP engine.

When configuring SNMP, follow these guidelines:

- When configuring an SNMP group, do not specify a notify view. The snmp-server host global configuration command autogenerates a notify view for the user and then adds it to the group associated with that user. Modifying the group's notify view affects all users associated with that group. See the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2 for information about when you should configure notify views.

- To configure a remote user, specify the IP address or port number for the remote SNMP agent of the device where the user resides.

- Before you configure remote users for a particular agent, configure the SNMP engine ID, using the snmp-server engineID global configuration with the remote option. The remote agent's SNMP engine ID and user password are used to compute the authentication and privacy digests. If you do not configure the remote engine ID first, the configuration command fails.

- When configuring SNMP informs, you need to configure the SNMP engine ID for the remote agent in the SNMP database before you can send proxy requests or informs to it.

- If a local user is not associated with a remote host, the switch does not send informs for the auth (authNoPriv) and the priv (authPriv) authentication levels.

- Changing the value of the SNMP engine ID has important side effects. A user's password (entered on the command line) is converted to an MD5 or SHA security digest based on the password and the local engine ID. The command-line password is then destroyed, as required by RFC 2274. Because of this deletion, if the value of the engine ID changes, the security digests of SNMPv3 users become
invalid, and you need to reconfigure SNMP users by using the `snmp-server user username` global configuration command. Similar restrictions require the reconfiguration of community strings when the engine ID changes.

**Disabling the SNMP Agent**

Beginning in privileged EXEC mode, follow these steps to disable the SNMP agent:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 no snmp-server</td>
<td>Disable the SNMP agent operation.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

The `no snmp-server` global configuration command disables all running versions (Version 1, Version 2C, and Version 3) on the device. No specific Cisco IOS command exists to enable SNMP. The first `snmp-server` global configuration command that you enter enables all versions of SNMP.

**Configuring Community Strings**

You use the SNMP community string to define the relationship between the SNMP manager and the agent. The community string acts like a password to permit access to the agent on the switch. Optionally, you can specify one or more of these characteristics associated with the string:

- An access list of IP addresses of the SNMP managers that are permitted to use the community string to gain access to the agent
- A MIB view, which defines the subset of all MIB objects accessible to the given community
- Read and write or read-only permission for the MIB objects accessible to the community
Beginning in privileged EXEC mode, follow these steps to configure a community string on the switch:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>
| 2    | snmp-server community string [view view-name] [ro | rw] [access-list-number] | Configure the community string.  
  - For `string`, specify a string that acts like a password and permits access to the SNMP protocol. You can configure one or more community strings of any length.  
  - (Optional) For `view`, specify the view record accessible to the community.  
  - (Optional) Specify either read-only (`ro`) if you want authorized management stations to retrieve MIB objects, or specify read-write (`rw`) if you want authorized management stations to retrieve and modify MIB objects. By default, the community string permits read-only access to all objects.  
  - (Optional) For `access-list-number`, enter an IP standard access list number from 1 to 99 and 1300 to 1999. |
| 3    | access-list access-list-number [deny | permit] source [source-wildcard] | (Optional) If you specified an IP standard access list number in Step 2, then create the list, repeating the command as many times as necessary.  
  - For `access-list-number`, enter the access list number specified in Step 2.  
  - The `deny` keyword denies access if the conditions are matched. The `permit` keyword permits access if the conditions are matched.  
  - For `source`, enter the IP address of the SNMP managers that are permitted to use the community string to gain access to the agent.  
  - (Optional) For `source-wildcard`, enter the wildcard bits in dotted decimal notation to be applied to the source. Place ones in the bit positions that you want to ignore.  
  Recall that the access list is always terminated by an implicit deny statement for everything. |
| 4    | end | Return to privileged EXEC mode. |
| 5    | show running-config | Verify your entries. |
| 6    | copy running-config startup-config | (Optional) Save your entries in the configuration file. |

**Note**  
To disable access for an SNMP community, set the community string for that community to the null string (do not enter a value for the community string).  
To remove a specific community string, use the `no snmp-server community string` global configuration command.
This example shows how to assign the string *comaccess* to SNMP, to allow read-only access, and to specify that IP access list 4 can use the community string to gain access to the switch SNMP agent:

```
Switch(config)# snmp-server community comaccess ro 4
```

### Configuring SNMP Groups and Users

You can specify an identification name (engine ID) for the local or remote SNMP server engine on the switch. You can configure an SNMP server group that maps SNMP users to SNMP views, and you can add new users to the SNMP group.

Beginning in privileged EXEC mode, follow these steps to configure SNMP on the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 snmp-server engineID [local engineid-string</td>
<td>Configure a name for either the local or remote copy of SNMP.</td>
</tr>
<tr>
<td>remote ip-address [udp-port port-number]   ]</td>
<td></td>
</tr>
</tbody>
</table>
|                                             | - The *engineid-string* is a 24-character ID string with the name of the copy of SNMP. You need not specify the entire 24-character engine ID if it has trailing zeros. Specify only the portion of the engine ID up to the point where only zeros remain in the value. For example, to configure an engine ID of 123400000000000000000000, you can enter this: *snmp-server engineID local 1234*  
|                                             | - If you select *remote*, specify the *ip-address* of the device that contains the remote copy of SNMP and the optional User Datagram Protocol (UDP) port on the remote device. The default is 162. |
### Step 3

**Command**
```
snmp-server group groupname { v1 | v2c | v3
    { auth | noauth | priv } } [ read readview ]
    [ write writeview ] [ notify notifyview ] [ access
        access-list ]
```

**Purpose**

Configure a new SNMP group on the remote device.

- For `groupname`, specify the name of the group.
- Specify a security model:
  - **v1** is the least secure of the possible security models.
  - **v2c** is the second least secure model. It allows transmission of informs and integers twice the normal width.
  - **v3**, the most secure, requires you to select an authentication level:
    - **auth**—Enables the Message Digest 5 (MD5) and the Secure Hash Algorithm (SHA) packet authentication.
    - **noauth**—Enables the noAuthNoPriv security level. This is the default if no keyword is specified.
    - **priv**—Enables Data Encryption Standard (DES) packet encryption (also called privacy).

**Note**
The `priv` keyword is available only when the cryptographic software image is installed.

- (Optional) Enter `read readview` with a string (not to exceed 64 characters) that is the name of the view in which you can only view the contents of the agent.
- (Optional) Enter `write writeview` with a string (not to exceed 64 characters) that is the name of the view in which you enter data and configure the contents of the agent.
- (Optional) Enter `notify notifyview` with a string (not to exceed 64 characters) that is the name of the view in which you specify a notify, inform, or trap.
- (Optional) Enter `access access-list` with a string (not to exceed 64 characters) that is the name of the access list.
Chapter 25        Configuring SNMP

Configuring SNMP

Configuring SNMP Notifications

A trap manager is a management station that receives and processes traps. Traps are system alerts that the switch generates when certain events occur. By default, no trap manager is defined, and no traps are sent. Switches running this Cisco IOS release can have an unlimited number of trap managers.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>snmp-server user username groupname [remote host [udp-port port]] [v1 [access access-list]</td>
<td>v2c [access access-list]</td>
</tr>
<tr>
<td></td>
<td>• The <strong>username</strong> is the name of the user on the host that connects to the agent.</td>
</tr>
<tr>
<td></td>
<td>• The <strong>groupname</strong> is the name of the group to which the user is associated.</td>
</tr>
<tr>
<td></td>
<td>• Enter <strong>remote</strong> to specify a remote SNMP entity to which the user belongs and the hostname or IP address of that entity with the optional UDP port number. The default is 162.</td>
</tr>
<tr>
<td></td>
<td>• Enter the SNMP version number (<strong>v1</strong>, <strong>v2c</strong>, or <strong>v3</strong>). If you enter <strong>v3</strong>, you have these additional options:</td>
</tr>
<tr>
<td></td>
<td>- <strong>encrypted</strong> specifies that the password appears in encrypted format. This keyword is available only when the <strong>v3</strong> keyword is specified.</td>
</tr>
<tr>
<td></td>
<td>- <strong>auth</strong> is an authentication level setting session that can be either the HMAC-MD5-96 (<strong>md5</strong>) or the HMAC-SHA-96 (<strong>sha</strong>) authentication level and requires a password string (not to exceed 64 characters).</td>
</tr>
<tr>
<td></td>
<td>• (Optional) Enter <strong>access access-list</strong> with a string (not to exceed 64 characters) that is the name of the access list.</td>
</tr>
</tbody>
</table>

Step 4

| Step 5 | end | Return to privileged EXEC mode. |
| Step 6 | show running-config | Verify your entries. |
| Step 7 | copy running-config startup-config | (Optional) Save your entries in the configuration file. |

Table 25-5 describes the supported switch traps (notification types). You can enable any or all of these traps and configure a trap manager to receive them.

<table>
<thead>
<tr>
<th>Table 25-5 Switch Notification Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notification Type</td>
</tr>
<tr>
<td>bgp</td>
</tr>
<tr>
<td>bridge</td>
</tr>
</tbody>
</table>
### Table 25-5 Switch Notification Types (continued)

<table>
<thead>
<tr>
<th>Notification Type Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cluster</td>
<td>Generates a trap when the cluster configuration changes.</td>
</tr>
<tr>
<td>config</td>
<td>Generates a trap for SNMP configuration changes.</td>
</tr>
<tr>
<td>copy-config</td>
<td>Generates a trap for SNMP copy configuration changes.</td>
</tr>
<tr>
<td>entity</td>
<td>Generates a trap for SNMP entity changes.</td>
</tr>
<tr>
<td>envmon</td>
<td>Generates environmental monitor traps. You can enable any or all of these environmental traps: fan, shutdown, status, supply, temperature.</td>
</tr>
<tr>
<td>flash</td>
<td>Generates SNMP FLASH notifications.</td>
</tr>
<tr>
<td>hsrp</td>
<td>Generates a trap for Hot Standby Router Protocol (HSRP) changes.</td>
</tr>
<tr>
<td>ipmulticast</td>
<td>Generates a trap for IP multicast routing changes.</td>
</tr>
<tr>
<td>mac-notification</td>
<td>Generates a trap for MAC address notifications.</td>
</tr>
<tr>
<td>msdp</td>
<td>Generates a trap for Multicast Source Discovery Protocol (MSDP) changes.</td>
</tr>
<tr>
<td>ospf</td>
<td>Generates a trap for Open Shortest Path First (OSPF) changes. You can enable any or all of these traps: Cisco specific, errors, link-state advertisement, rate limit, retransmit, and state changes.</td>
</tr>
<tr>
<td>pim</td>
<td>Generates a trap for Protocol-Independent Multicast (PIM) changes. You can enable any or all of these traps: invalid PIM messages, neighbor changes, and rendezvous point (RP)-mapping changes.</td>
</tr>
<tr>
<td>port-security</td>
<td>Generates SNMP port security traps. You can also set a maximum trap rate per second. The range is from 0 to 1000; the default is 0, which means that there is no rate limit.</td>
</tr>
<tr>
<td>rtr</td>
<td>Generates a trap for the SNMP Response Time Reporter (RTR).</td>
</tr>
<tr>
<td>snmp</td>
<td>Generates a trap for SNMP-type notifications for authentication, cold start, warm start, link up or link down.</td>
</tr>
<tr>
<td>storm-control</td>
<td>Generates a trap for SNMP storm-control. You can also set a maximum trap rate per second. The range is from 0 to 1000; the default is 0 (no limit is imposed; a trap is sent at every occurrence).</td>
</tr>
<tr>
<td>stpx</td>
<td>Generates SNMP STP Extended MIB traps.</td>
</tr>
<tr>
<td>syslog</td>
<td>Generates SNMP syslog traps.</td>
</tr>
<tr>
<td>tty</td>
<td>Generates a trap for TCP connections. This trap is enabled by default.</td>
</tr>
<tr>
<td>vlan-membership</td>
<td>Generates a trap for SNMP VLAN membership changes.</td>
</tr>
<tr>
<td>vlancreate</td>
<td>Generates SNMP VLAN created traps.</td>
</tr>
<tr>
<td>vlansite</td>
<td>Generates SNMP VLAN deleted traps.</td>
</tr>
<tr>
<td>vtp</td>
<td>Generates a trap for VLAN Trunking Protocol (VTP) changes.</td>
</tr>
</tbody>
</table>

**Note**

To enable the sending of SNMP inform notifications, use the `snmp-server enable traps` global configuration command combined with the `snmp-server host host-addr informs` global configuration command.
You can use the `snmp-server host` global configuration command to a specific host to receive the notification types listed in Table 25-5.

Beginning in privileged EXEC mode, follow these steps to configure the switch to send traps or informs to a host:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 snmp-server engineID remote</td>
<td>Specify the engine ID for the remote host.</td>
</tr>
<tr>
<td>ip-address engineid-string</td>
<td></td>
</tr>
<tr>
<td>Step 3 snmp-server user username</td>
<td>Configure an SNMP user to be associated with the remote host created in</td>
</tr>
<tr>
<td>groupname {remote host [udp-port port]}</td>
<td>Step 2.</td>
</tr>
<tr>
<td>} v1 [access access-list]</td>
<td>v2c [access access-list]</td>
</tr>
<tr>
<td>community-string [notification-type]</td>
<td>Specify the recipient of an SNMP trap operation.</td>
</tr>
<tr>
<td>{ informs</td>
<td>traps} [version {1</td>
</tr>
<tr>
<td>[interface-id]</td>
<td>(Optional) Enter informs to send SNMP informs to the host.</td>
</tr>
<tr>
<td>Step 4 snmp-server group groupname</td>
<td>(Optional) Enter traps (the default) to send SNMP traps to the host.</td>
</tr>
<tr>
<td>} v1</td>
<td>v2c</td>
</tr>
<tr>
<td>Step 5 snmp-server enable traps</td>
<td>Enable the switch to send traps or informs and specify the type of</td>
</tr>
<tr>
<td>notification-types</td>
<td>notifications to be sent. For a list of notification types, see Table 25-5 on page 25-12.</td>
</tr>
<tr>
<td>Step 6 snmp-server trap-source interface-id</td>
<td>(Optional) Specify the source interface, which provides the IP address for the trap message. This command also sets the source IP address for informs.</td>
</tr>
<tr>
<td>Step 7</td>
<td></td>
</tr>
</tbody>
</table>

Note: The `priv` keyword is available only when the cryptographic software image is installed.

For `community-string`, when `version 1` or `version 2c` is specified, enter the password-like community string sent with the notification operation. When `version 3` is specified, enter the SNMPv3 username.

To enable multiple types of traps, you must enter a separate `snmp-server enable traps` command for each trap type.
Configuring SNMP

## Configuring SNMP

The `snmp-server host` command specifies which hosts receive the notifications. The `snmp-server enable trap` command globally enables the mechanism for the specified notification (for traps and informs). To enable a host to receive an inform, you must configure an `snmp-server host informs` command for the host and globally enable informs by using the `snmp-server enable traps` command.

To remove the specified host from receiving traps, use the `no snmp-server host host` global configuration command. The `no snmp-server host` command with no keywords disables traps, but not informs, to the host. To disable informs, use the `no snmp-server host informs` global configuration command. To disable a specific trap type, use the `no snmp-server enable traps notification-types` global configuration command.

### Setting the Agent Contact and Location Information

Beginning in privileged EXEC mode, follow these steps to set the system contact and location of the SNMP agent so that these descriptions can be accessed through the configuration file:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><code>snmp-server contact text</code></td>
<td>Set the system contact string.</td>
</tr>
</tbody>
</table>
|                                             | For example:
|                                             | `snmp-server contact Dial System Operator at beeper 21555`.             |
| `snmp-server location text`                  | Set the system location string.                                         |
|                                             | For example:
|                                             | `snmp-server location Building 3/Room 222`.                            |
| `end`                                        | Return to privileged EXEC mode.                                         |
| `show running-config`                        | Verify your entries.                                                   |
| `copy running-config startup-config`         | (Optional) Save your entries in the configuration file.                 |

The `snmp-server host` command specifies which hosts receive the notifications. The `snmp-server enable trap` command globally enables the mechanism for the specified notification (for traps and informs). To enable a host to receive an inform, you must configure an `snmp-server host informs` command for the host and globally enable informs by using the `snmp-server enable traps` command.
Limiting TFTP Servers Used Through SNMP

Beginning in privileged EXEC mode, follow these steps to limit the TFTP servers used for saving and loading configuration files through SNMP to the servers specified in an access list:

**Command** | **Purpose**
--- | ---
Step 1 | configure terminal
Enter global configuration mode.
Step 2 | snmp-server tftp-server-list
access-list-number
Limit TFTP servers used for configuration file copies through SNMP to the servers in the access list.
For access-list-number, enter an IP standard access list numbered from 1 to 99 and 1300 to 1999.
Step 3 | access-list access-list-number {deny | permit} source [source-wildcard]
Create a standard access list, repeating the command as many times as necessary.
• For access-list-number, enter the access list number specified in Step 2.
• The **deny** keyword denies access if the conditions are matched. The **permit** keyword permits access if the conditions are matched.
• For source, enter the IP address of the TFTP servers that can access the switch.
  • (Optional) For source-wildcard, enter the wildcard bits, in dotted decimal notation, to be applied to the source. Place ones in the bit positions that you want to ignore.
  Recall that the access list is always terminated by an implicit deny statement for everything.
Step 4 | end
Return to privileged EXEC mode.
Step 5 | show running-config
Verify your entries.
Step 6 | copy running-config startup-config
(Optional) Save your entries in the configuration file.

**SNMP Examples**

This example shows how to enable all versions of SNMP. The configuration permits any SNMP manager to access all objects with read-only permissions using the community string **public**. This configuration does not cause the switch to send any traps.

```plaintext
Switch(config)# snmp-server community public
```

This example shows how to permit any SNMP manager to access all objects with read-only permission using the community string **public**. The switch also sends VTP traps to the hosts 192.180.1.111 and 192.180.1.33 using SNMPv1 and to the host 192.180.1.27 using SNMPv2C. The community string **public** is sent with the traps.

```plaintext
Switch(config)# snmp-server community public
Switch(config)# snmp-server enable traps vtp
Switch(config)# snmp-server host 192.180.1.27 version 2c public
Switch(config)# snmp-server host 192.180.1.111 version 1 public
Switch(config)# snmp-server host 192.180.1.33 public
```
This example shows how to allow read-only access for all objects to members of access list 4 that use the comaccess community string. No other SNMP managers have access to any objects. SNMP Authentication Failure traps are sent by SNMPv2C to the host cisco.com using the community string public.

Switch(config)# snmp-server community comaccess ro 4
Switch(config)# snmp-server enable traps snmp authentication
Switch(config)# snmp-server host cisco.com version 2c public

This example shows how to send Entity MIB traps to the host cisco.com. The community string is restricted. The first line enables the switch to send Entity MIB traps in addition to any traps previously enabled. The second line specifies the destination of these traps and overwrites any previous snmp-server host commands for the host cisco.com.

Switch(config)# snmp-server enable traps entity
Switch(config)# snmp-server host cisco.com restricted entity

This example shows how to enable the switch to send all traps to the host myhost.cisco.com using the community string public:

Switch(config)# snmp-server enable traps
Switch(config)# snmp-server host myhost.cisco.com public

This example shows how to associate a user with a remote host and to send auth (authNoPriv) authentication-level informs when the user enters global configuration mode:

Switch(config)# snmp-server engineID remote 192.180.1.27 00000063000100a1c0b4011b
Switch(config)# snmp-server group authgroup v3 auth
Switch(config)# snmp-server user authuser authgroup v3 auth md5 mypassword
Switch(config)# snmp-server host 192.180.1.27 informs version 3 auth authuser config
Switch(config)# snmp-server enable traps
Switch(config)# snmp-server inform retries 0

### Displaying SNMP Status

To display SNMP input and output statistics, including the number of illegal community string entries, errors, and requested variables, use the `show snmp` privileged EXEC command. You also can use the other privileged EXEC commands in Table 25-6 to display SNMP information. For information about the fields in the displays, see the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

#### Table 25-6 Commands for Displaying SNMP Information

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>show snmp</td>
<td>Displays SNMP statistics.</td>
</tr>
<tr>
<td>show snmp engineID</td>
<td>Displays information on the local SNMP engine and all remote engines that have been configured on the device.</td>
</tr>
<tr>
<td>show snmp group</td>
<td>Displays information on each SNMP group on the network.</td>
</tr>
<tr>
<td>show snmp pending</td>
<td>Displays information on pending SNMP requests.</td>
</tr>
<tr>
<td>show snmp sessions</td>
<td>Displays information on the current SNMP sessions.</td>
</tr>
<tr>
<td>show snmp user</td>
<td>Displays information on each SNMP user name in the SNMP users table.</td>
</tr>
</tbody>
</table>
Displaying SNMP Status
Configuring Network Security with ACLs

This chapter describes how to configure network security on the switch by using access control lists (ACLs), which in commands and tables are also referred to as access lists.

Note

Information in this chapter about IP ACLs is specific to IP Version 4 (IPv4).

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release, see the “Configuring IP Services” section in the “IP Addressing and Services” chapter of the Cisco IOS IP Configuration Guide, Release 12.2, and the Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services, Release 12.2.

This chapter consists of these sections:

- Understanding ACLs, page 26-1
- Configuring IPv4 ACLs, page 26-5
- Creating Named MAC Extended ACLs, page 26-20
- Configuring VLAN Maps, page 26-22
- Displaying IPv4 ACL Configuration, page 26-29

Understanding ACLs

Packet filtering can help limit network traffic and restrict network use by certain users or devices. ACLs filter traffic as it passes through a switch and permit or deny packets crossing specified interfaces or VLANs. An ACL is a sequential collection of permit and deny conditions that apply to packets. When a packet is received on an interface, the switch compares the fields in the packet against any applied ACLs to verify that the packet has the required permissions to be forwarded, based on the criteria specified in the access lists. One by one, it tests packets against the conditions in an access list. The first match decides whether the switch accepts or rejects the packets. Because the switch stops testing after the first match, the order of conditions in the list is critical. If no conditions match, the switch rejects the packet. If there are no restrictions, the switch forwards the packet; otherwise, the switch drops the packet. The switch can use ACLs on all packets it forwards, including packets bridged within a VLAN.

You configure access lists on a switch to provide basic security for your network. If you do not configure ACLs, all packets passing through the switch could be allowed onto all parts of the network. You can use ACLs to control which hosts can access different parts of a network or to decide which types of traffic are forwarded or blocked. For example, you can allow e-mail traffic to be forwarded but not Telnet traffic.
Understanding ACLs

An ACL contains an ordered list of access control entries (ACEs). Each ACE specifies permit or deny and a set of conditions the packet must satisfy in order to match the ACE. The meaning of permit or deny depends on the context in which the ACL is used.

The switch supports IP ACLs and Ethernet (MAC) ACLs:

- IP ACLs filter IPv4 traffic, including TCP, User Datagram Protocol (UDP), Internet Group Management Protocol (IGMP), and Internet Control Message Protocol (ICMP).
- Ethernet ACLs filter non-IP traffic.

This switch also supports quality of service (QoS) classification ACLs. For more information, see the “Classification Based on QoS ACLs” section on page 27-7.

These sections contain this conceptual information:

- Supported ACLs, page 26-2
- Handling Fragmented and Unfragmented Traffic, page 26-4

Supported ACLs

The switch supports two applications of ACLs to filter traffic:

- Port ACLs access-control traffic entering a Layer 2 interface. The switch does not support port ACLs in the outbound direction. You can apply only one IP access list and one MAC access list to a Layer 2 interface. For more information, see the “Port ACLs” section on page 26-2.
- VLAN ACLs or VLAN maps access-control all packets (bridged and routed). You can use VLAN maps to filter traffic between devices in the same VLAN. VLAN maps are configured to provide access control based on Layer 3 addresses for IPv4. Unsupported protocols are access-controlled through MAC addresses using Ethernet ACEs. After a VLAN map is applied to a VLAN, all packets (routed or bridged) entering the VLAN are checked against the VLAN map. Packets can either enter the VLAN through a switch port or through a routed port after being routed. For more information, see the “VLAN Maps” section on page 26-3.

You can use input port ACLs and VLAN maps on the same switch. However, a port ACL takes precedence over a VLAN map. When an input port ACL is applied to an interface that belongs to a VLAN that has a VLAN map applied, incoming packets received at the interface are filtered by the port ACL. Other packets are filtered by the VLAN map.

Port ACLs

Port ACLs are ACLs that are applied to Layer 2 interfaces on a switch. Port ACLs are supported only on physical interfaces and not on EtherChannel interfaces and can be applied only on interfaces in the inbound direction. These access lists are supported:

- Standard IP access lists using source addresses
- Extended IP access lists using source and destination addresses and optional protocol type information
- MAC extended access lists using source and destination MAC addresses and optional protocol type information

The switch examines ACLs associated with all inbound features configured on a given interface and permits or denies packet forwarding based on how the packet matches the entries in the ACL. In this way, ACLs control access to a network or to part of a network. Figure 26-1 is an example of using port ACLs to control access to a network when all servers are in the same VLAN. ACLs applied at the Layer
2 input would allow Blade Server A to access the Human Resources network, but prevent Blade Server B from accessing the same network. Port ACLs can only be applied to Layer 2 interfaces in the inbound direction.

Figure 26-1 Using ACLs to Control Traffic to a Network

When you apply a port ACL to a trunk port, the ACL filters traffic on all VLANs present on the trunk port. When you apply a port ACL to a port with voice VLAN, the ACL filters traffic on both data and voice VLANs.

With port ACLs, you can filter IP traffic by using IP access lists and non-IP traffic by using MAC addresses. You can filter both IP and non-IP traffic on the same Layer 2 interface by applying both an IP access list and a MAC access list to the interface.

Note

You cannot apply more than one IP access list and one MAC access list to a Layer 2 interface. If an IP access list or MAC access list is already configured on a Layer 2 interface and you apply a new IP access list or MAC access list to the interface, the new ACL replaces the previously configured one.

VLAN Maps

You use VLAN ACLs or VLAN maps to filter traffic between devices in the same VLAN. When a VLAN map is applied to a VLAN, all packets being forwarded in the VLAN are checked against the VLAN map.

Use VLAN maps for security packet filtering. VLAN maps are not defined by direction (input or output). You can configure VLAN maps to match Layer 3 addresses for IPv4 traffic.

All non-IP protocols are access-controlled through MAC addresses and Ethertype using MAC VLAN maps. (IP traffic is not access controlled by MAC VLAN maps.) You can enforce VLAN maps only on packets going through the switch; you cannot enforce VLAN maps on traffic between hosts on a hub or on another switch connected to this switch.
Understanding ACLs

With VLAN maps, forwarding of packets is permitted or denied, based on the action specified in the map. Figure 26-2 shows how a VLAN map is applied to prevent a specific type of traffic from Host A in VLAN 10 from being forwarded. You can apply only one VLAN map to a VLAN.

**Handling Fragmented and Unfragmented Traffic**

IP packets can be fragmented as they cross the network. When this happens, only the fragment containing the beginning of the packet contains the Layer 4 information, such as TCP or UDP port numbers, ICMP type and code, and so on. All other fragments are missing this information.

Some ACEs do not check Layer 4 information and therefore can be applied to all packet fragments. ACEs that do test Layer 4 information cannot be applied in the standard manner to most of the fragments in a fragmented IP packet. When the fragment contains no Layer 4 information and the ACE tests some Layer 4 information, the matching rules are modified:

- Permit ACEs that check the Layer 3 information in the fragment (including protocol type, such as TCP, UDP, and so on) are considered to match the fragment regardless of what the missing Layer 4 information might have been.
- Deny ACEs that check Layer 4 information never match a fragment unless the fragment contains Layer 4 information.

Consider access list 102, configured with these commands, applied to three fragmented packets:

```
Switch(config)# access-list 102 permit tcp any host 10.1.1.1 eq smtp
Switch(config)# access-list 102 deny tcp any host 10.1.1.2 eq telnet
Switch(config)# access-list 102 permit tcp any host 10.1.1.2
Switch(config)# access-list 102 deny tcp any any
```

In the first and second ACEs in the examples, the *eq* keyword after the destination address means to test for the TCP-destination-port well-known numbers equaling Simple Mail Transfer Protocol (SMTP) and Telnet, respectively.

- Packet A is a TCP packet from host 10.2.2.2., port 65000, going to host 10.1.1.1 on the SMTP port. If this packet is fragmented, the first fragment matches the first ACE (a permit) as if it were a complete packet because all Layer 4 information is present. The remaining fragments also match the first ACE, even though they do not contain the SMTP port information, because the first ACE only checks Layer 3 information when applied to fragments. The information in this example is that the packet is TCP and that the destination is 10.1.1.1.
• Packet B is from host 10.2.2.2, port 65001, going to host 10.1.1.2 on the Telnet port. If this packet is fragmented, the first fragment matches the second ACE (a deny) because all Layer 3 and Layer 4 information is present. The remaining fragments in the packet do not match the second ACE because they are missing Layer 4 information. Instead, they match the third ACE (a permit).

Because the first fragment was denied, host 10.1.1.2 cannot reassemble a complete packet, so packet B is effectively denied. However, the later fragments that are permitted will consume bandwidth on the network and resources of host 10.1.1.2 as it tries to reassemble the packet.

• Fragmented packet C is from host 10.2.2.2, port 65001, going to host 10.1.1.3, port ftp. If this packet is fragmented, the first fragment matches the fourth ACE (a deny). All other fragments also match the fourth ACE because that ACE does not check any Layer 4 information and because Layer 3 information in all fragments shows that they are being sent to host 10.1.1.3, and the earlier permit ACEs were checking different hosts.

Configuring IPv4 ACLs

Configuring IPv4 ACLs on the switch is the same as configuring IPv4 ACLs on other Cisco switches and routers. The process is briefly described here. For more detailed information on configuring ACLs, see the “Configuring IP Services” section in the “IP Addressing and Services” chapter of the Cisco IOS IP Configuration Guide, Release 12.2. For detailed information about the commands, see the Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services, Release 12.2.

The switch does not support these Cisco IOS router ACL-related features:

• Non-IP protocol ACLs (see Table 26-1 on page 26-6) or bridge-group ACLs
• IP accounting
• Inbound and outbound rate limiting (except with QoS ACLs)
• Reflexive ACLs or dynamic ACLs (except for some specialized dynamic ACLs used by the switch clustering feature)
• ACL logging

These are the steps to use IP ACLs on the switch:

**Step 1**
Create an ACL by specifying an access list number or name and the access conditions.

**Step 2**
Apply the ACL to interfaces or terminal lines. You can also apply standard and extended IP ACLs to VLAN maps.

These sections contain this configuration information:

• Creating Standard and Extended IPv4 ACLs, page 26-6
• Applying an IPv4 ACL to a Terminal Line, page 26-16
• Applying an IPv4 ACL to an Interface, page 26-17
• Hardware and Software Treatment of IP ACLs, page 26-18
• IPv4 ACL Configuration Examples, page 26-18
Creating Standard and Extended IPv4 ACLs

This section describes IP ACLs. An ACL is a sequential collection of permit and deny conditions. One by one, the switch tests packets against the conditions in an access list. The first match determines whether the switch accepts or rejects the packet. Because the switch stops testing after the first match, the order of the conditions is critical. If no conditions match, the switch denies the packet.

The software supports these types of ACLs or access lists for IPv4:

- Standard IP access lists use source addresses for matching operations.
- Extended IP access lists use source and destination addresses for matching operations and optional protocol-type information for finer granularity of control.

These sections describe access lists and how to create them:

- Access List Numbers, page 26-6
- Creating a Numbered Standard ACL, page 26-7
- Creating a Numbered Extended ACL, page 26-8
- Resequencing ACEs in an ACL, page 26-12
- Creating Named Standard and Extended ACLs, page 26-12
- Using Time Ranges with ACLs, page 26-14
- Including Comments in ACLs, page 26-16

Access List Numbers

The number you use to denote your ACL shows the type of access list that you are creating. Table 26-1 lists the access-list number and corresponding access list type and shows whether or not they are supported in the switch. The switch supports IPv4 standard and extended access lists, numbers 1 to 199 and 1300 to 2699.

<table>
<thead>
<tr>
<th>Access List Number</th>
<th>Type</th>
<th>Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–99</td>
<td>IP standard access list</td>
<td>Yes</td>
</tr>
<tr>
<td>100–199</td>
<td>IP extended access list</td>
<td>Yes</td>
</tr>
<tr>
<td>200–299</td>
<td>Protocol type-code access list</td>
<td>No</td>
</tr>
<tr>
<td>300–399</td>
<td>DECN net access list</td>
<td>No</td>
</tr>
<tr>
<td>400–499</td>
<td>XNS standard access list</td>
<td>No</td>
</tr>
<tr>
<td>500–599</td>
<td>XNS extended access list</td>
<td>No</td>
</tr>
<tr>
<td>600–699</td>
<td>AppleTalk access list</td>
<td>No</td>
</tr>
<tr>
<td>700–799</td>
<td>48-bit MAC address access list</td>
<td>No</td>
</tr>
<tr>
<td>800–899</td>
<td>IPX standard access list</td>
<td>No</td>
</tr>
<tr>
<td>900–999</td>
<td>IPX extended access list</td>
<td>No</td>
</tr>
<tr>
<td>1000–1099</td>
<td>IPX SAP access list</td>
<td>No</td>
</tr>
<tr>
<td>1100–1199</td>
<td>Extended 48-bit MAC address access list</td>
<td>No</td>
</tr>
<tr>
<td>1200–1299</td>
<td>IPX summary address access list</td>
<td>No</td>
</tr>
</tbody>
</table>
Chapter 26 Configuring Network Security with ACLs

Table 26-1 Access List Numbers (continued)

<table>
<thead>
<tr>
<th>Access List Number</th>
<th>Type</th>
<th>Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300–1999</td>
<td>IP standard access list (expanded range)</td>
<td>Yes</td>
</tr>
<tr>
<td>2000–2699</td>
<td>IP extended access list (expanded range)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note

In addition to numbered standard and extended ACLs, you can also create standard and extended named IP ACLs by using the supported numbers. That is, the name of a standard IP ACL can be 1 to 99; the name of an extended IP ACL can be 100 to 199. The advantage of using named ACLs instead of numbered lists is that you can delete individual entries from a named list.

Creating a Numbered Standard ACL

Beginning in privileged EXEC mode, follow these steps to create a numbered standard ACL:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 access-list access-list-number {deny</td>
<td>Define a standard IPv4 access list by using a source address and</td>
</tr>
<tr>
<td>permit} source [source-wildcard]</td>
<td>wildcard.</td>
</tr>
<tr>
<td></td>
<td>The access-list-number is a decimal number from 1 to 99 or 1300 to</td>
</tr>
<tr>
<td></td>
<td>1999.</td>
</tr>
<tr>
<td></td>
<td>Enter deny or permit to specify whether to deny or permit access</td>
</tr>
<tr>
<td></td>
<td>if conditions are matched.</td>
</tr>
<tr>
<td></td>
<td>The source is the source address of the network or host from which</td>
</tr>
<tr>
<td></td>
<td>the packet is being sent specified as:</td>
</tr>
<tr>
<td></td>
<td>• The 32-bit quantity in dotted-decimal format.</td>
</tr>
<tr>
<td></td>
<td>• The keyword any as an abbreviation for source and Source-</td>
</tr>
<tr>
<td></td>
<td>wildcard of 0.0.0.0 255.255.255.255. You do not need to enter a</td>
</tr>
<tr>
<td></td>
<td>source-wildcard.</td>
</tr>
<tr>
<td></td>
<td>• The keyword host as an abbreviation for source and Source- wildcard</td>
</tr>
<tr>
<td></td>
<td>of source 0.0.0.0.</td>
</tr>
<tr>
<td></td>
<td>(Optional) The source-wildcard applies wildcard bits to the source.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show access-lists [number</td>
<td>name]</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Use the no access-list access-list-number global configuration command to delete the entire ACL. You cannot delete individual ACEs from numbered access lists.
When creating an ACL, remember that, by default, the end of the ACL contains an implicit deny statement for all packets that it did not find a match for before reaching the end. With standard access lists, if you omit the mask from an associated IP host address ACL specification, 0.0.0.0 is assumed to be the mask.

This example shows how to create a standard ACL to deny access to IP host 171.69.198.102, permit access to any others, and display the results.

```
Switch (config)# access-list 2 deny host 171.69.198.102
Switch (config)# access-list 2 permit any
Switch(config)# end
Switch# show access-lists
Standard IP access list 2
  10 deny 171.69.198.102
  20 permit any
```

The switch always rewrites the order of standard access lists so that entries with host matches and entries with matches having a don’t care mask of 0.0.0.0 are moved to the top of the list, above any entries with non-zero don’t care masks. Therefore, in show command output and in the configuration file, the ACEs do not necessarily appear in the order in which they were entered.

After creating a numbered standard IPv4 ACL, you can apply it to terminal lines (see the “Applying an IPv4 ACL to a Terminal Line” section on page 26-16), to interfaces (see the “Applying an IPv4 ACL to an Interface” section on page 26-17), or to VLANs (see the “Configuring VLAN Maps” section on page 26-22).

Creating a Numbered Extended ACL

Although standard ACLs use only source addresses for matching, you can use extended ACL source and destination addresses for matching operations and optional protocol type information for finer granularity of control. When you are creating ACEs in numbered extended access lists, remember that after you create the ACL, any additions are placed at the end of the list. You cannot reorder the list or selectively add or remove ACEs from a numbered list.

Some protocols also have specific parameters and keywords that apply to that protocol.

These IP protocols are supported (protocol keywords are in parentheses in bold):
- Authentication Header Protocol (**ahp**), Enhanced Interior Gateway Routing Protocol (**eigrp**),

**Note** ICMP echo-reply cannot be filtered. All other ICMP codes or types can be filtered.

For more details on the specific keywords for each protocol, see these command references:

- *Cisco IOS IP Command Reference, Volume 1 of 3: Addressing and Services, Release 12.2*
- *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast, Release 12.2*
Chapter 26 Configuring Network Security with ACLs

Configuring IPv4 ACLs

Note
The switch does not support dynamic or reflexive access lists. It also does not support filtering based on the type of service (ToS) minimize-monetary-cost bit.

Supported parameters can be grouped into these categories: TCP, UDP, ICMP, IGMP, or other IP.

Beginning in privileged EXEC mode, follow these steps to create an extended ACL:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2a access-list access-list-number</td>
<td>Define an extended IPv4 access list and the access conditions.</td>
</tr>
<tr>
<td>deny protocol source source-wildcard</td>
<td>The access-list-number is a decimal number from 100 to 199 or 2000 to 2699. Enter deny or permit to specify whether to deny or permit the packet if conditions are matched. If you enter a dscp value, you cannot enter tos or precedence. You can enter both a tos and a precedence value with no dscp.</td>
</tr>
<tr>
<td>permit</td>
<td></td>
</tr>
<tr>
<td>[precedence precedence] [tos tos] [fragments]</td>
<td></td>
</tr>
<tr>
<td>[time-range time-range-name] [dscp dscp]</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td></td>
</tr>
</tbody>
</table>

The source is the network or host from which the packet is sent. The source-wildcard applies wildcard bits to the source.
The destination is the network or host number to which the packet is sent. The destination-wildcard applies wildcard bits to the destination.

Source, source-wildcard, destination, and destination-wildcard can be specified as:

- The 32-bit quantity in dotted-decimal format.
- The keyword any for 0.0.0.0 255.255.255.255 (any host).
- The keyword host for a single host 0.0.0.0.

The other keywords are optional and have these meanings:

- precedence—Enter to match packets with a precedence level specified as a number from 0 to 7 or by name: routine (0), priority (1), immediate (2), flash (3), flash-override (4), critical (5), internet (6), network (7).
- fragments—Enter to check non-initial fragments.
- tos—Enter to match by type of service level, specified by a number from 0 to 15 or a name: normal (0), max-reliability (2), max-throughput (4), min-delay (8).
- time-range—for an explanation of this keyword, see the “Using Time Ranges with ACLs” section on page 26-14.
- dscp—Enter to match packets with the DSCP value specified by a number from 0 to 63, or use the question mark (?) to see a list of available values.
### Command

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>access-list access-list-number</code> {deny</td>
<td>permit} protocol any any [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp]</td>
</tr>
<tr>
<td>or <code>access-list access-list-number</code> [deny</td>
<td>permit] protocol host source destination [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp]</td>
</tr>
<tr>
<td>Step 2b <code>access-list access-list-number</code> {deny</td>
<td>permit} tcp source source-wildcard [operator port] destination destination-wildcard [operator port] [established] [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp] [flag]</td>
</tr>
<tr>
<td>Step 2c <code>access-list access-list-number</code> {deny</td>
<td>permit} udp source source-wildcard [operator port] destination destination-wildcard [operator port] [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp]</td>
</tr>
</tbody>
</table>
### Chapter 26      Configuring Network Security with ACLs

#### Configuring IPv4 ACLs

Use the `no access-list access-list-number` global configuration command to delete the entire access list. You cannot delete individual ACEs from numbered access lists.

This example shows how to create and display an extended access list to deny Telnet access from any host in network 171.69.198.0 to any host in network 172.20.52.0 and to permit any others. (The `eq` keyword after the destination address means to test for the TCP destination port number equaling Telnet.)

```
Switch(config)# access-list 102 deny tcp 171.69.198.0 0.0.0.255 172.20.52.0 0.0.0.255 eq telnet
Switch(config)# access-list 102 permit tcp any any
Switch(config)# end
```

After an ACL is created, any additions (possibly entered from the terminal) are placed at the end of the list. You cannot selectively add or remove access list entries from a numbered access list.

**Note** When you are creating an ACL, remember that, by default, the end of the access list contains an implicit deny statement for all packets if it did not find a match before reaching the end.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 2d</strong></td>
<td></td>
</tr>
</tbody>
</table>
| `access-list access-list-number [deny | permit] icmp source source-wildcard destination destination-wildcard [icmp-type | [icmp-type icmp-code] | [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp]` | (Optional) Define an extended ICMP access list and the access conditions. Enter `icmp` for Internet Control Message Protocol. The ICMP parameters are the same as those described for most IP protocols in Step 2a, with the addition of the ICMP message type and code parameters. These optional keywords have these meanings:
  - `icmp-type`—Enter to filter by ICMP message type, a number from 0 to 255.
  - `icmp-code`—Enter to filter ICMP packets that are filtered by the ICMP message type code type, a number from 0 to 255.
  - `icmp-message`—Enter to filter ICMP packets by the ICMP message type name or the ICMP message type and code name. To see a list of ICMP message type names and code names, use the `?`, or see the “Configuring IP Services” section of the *Cisco IOS IP Configuration Guide, Release 12.2*.
| **Step 2e**              |                                                                                                                                                        |
| `access-list access-list-number [deny | permit] igmp source source-wildcard destination destination-wildcard [igmp-type] [precedence precedence] [tos tos] [fragments] [time-range time-range-name] [dscp dscp]` | (Optional) Define an extended IGMP access list and the access conditions. Enter `igmp` for Internet Group Management Protocol. The IGMP parameters are the same as those described for most IP protocols in Step 2a, with this optional parameter.
  - `igmp-type`—To match IGMP message type, enter a number from 0 to 15, or enter the message name (`dvmrp`, `host-query`, `host-report`, `pim`, or `trace`).
| **Step 3**               | Return to privileged EXEC mode.                                                                      |
| **Step 4**               | Verify the access list configuration.                                                                |
| **Step 5**               | (Optional) Save your entries in the configuration file.                                              |
Configuring IPv4 ACLs

Chapter 26 Configuring Network Security with ACLs

After creating a numbered extended ACL, you can apply it to terminal lines (see the “Applying an IPv4 ACL to a Terminal Line” section on page 26-16), to interfaces (see the “Applying an IPv4 ACL to an Interface” section on page 26-17), or to VLANs (see the “Configuring VLAN Maps” section on page 26-22).

Resequencing ACEs in an ACL

In Cisco IOS Release 12.2(18)SE and later, sequence numbers for the entries in an access list are automatically generated when you create a new ACL. You can use the `ip access-list resequence` global configuration command to edit the sequence numbers in an ACL and change the order in which ACEs are applied. For example, if you add a new ACE to an ACL, it is placed at the bottom of the list. By changing the sequence number, you can move the ACE to a different position in the ACL.

For more information about the `ip access-list resequence` command, see this URL:

Creating Named Standard and Extended ACLs

You can identify IPv4 ACLs with an alphanumeric string (a name) rather than a number. You can use named ACLs to configure more IPv4 access lists in a router than if you were to use numbered access lists. If you identify your access list with a name rather than a number, the mode and command syntax are slightly different. However, not all commands that use IP access lists accept a named access list.

Note

The name you give to a standard or extended ACL can also be a number in the supported range of access list numbers. That is, the name of a standard IP ACL can be 1 to 99; the name of an extended IP ACL can be 100 to 199. The advantage of using named ACLs instead of numbered lists is that you can delete individual entries from a named list.

Consider these guidelines and limitations before configuring named ACLs:

- Not all commands that accept a numbered ACL accept a named ACL. ACLs for packet filters and route filters on interfaces can use a name. VLAN maps also accept a name.
- A standard ACL and an extended ACL cannot have the same name.
- Numbered ACLs are also available, as described in the “Creating Standard and Extended IPv4 ACLs” section on page 26-6.
- You can use standard and extended ACLs (named or numbered) in VLAN maps.

Beginning in privileged EXEC mode, follow these steps to create a standard ACL using names:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>ip access-list standard name</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 26  Configuring Network Security with ACLs

Configuring IPv4 ACLs

To remove a named standard ACL, use the `no ip access-list standard name` global configuration command.

Beginning in privileged EXEC mode, follow these steps to create an extended ACL using names:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 ip access-list extended name</td>
<td>Define an extended IPv4 access list using a name, and enter access-list configuration mode. The name can be a number from 100 to 199.</td>
</tr>
<tr>
<td>Step 3 {deny</td>
<td>permit} protocol [source [source-wildcard]</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show access-lists [number</td>
<td>name]</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove a named extended ACL, use the `no ip access-list extended name` global configuration command.

When you are creating standard extended ACLs, remember that, by default, the end of the ACL contains an implicit deny statement for everything if it did not find a match before reaching the end. For standard ACLs, if you omit the mask from an associated IP host address access list specification, 0.0.0.0 is assumed to be the mask.
After you create an ACL, any additions are placed at the end of the list. You cannot selectively add ACL entries to a specific ACL. However, you can use no permit and no deny access-list configuration mode commands to remove entries from a named ACL. This example shows how you can delete individual ACEs from the named access list border-list:

```
Switch(config)# ip access-list extended border-list
Switch(config-ext-nacl)# no permit ip host 10.1.1.3 any
```

Being able to selectively remove lines from a named ACL is one reason you might use named ACLs instead of numbered ACLs.

After creating a named ACL, you can apply it to interfaces (see the “Applying an IPv4 ACL to an Interface” section on page 26-17) or to VLANs (see the “Configuring VLAN Maps” section on page 26-22).

### Using Time Ranges with ACLs

You can selectively apply extended ACLs based on the time of day and the week by using the time-range global configuration command. First, define a time-range name and set the times and the dates or the days of the week in the time range. Then enter the time-range name when applying an ACL to set restrictions to the access list. You can use the time range to define when the permit or deny statements in the ACL are in effect, for example, during a specified time period or on specified days of the week. The time-range keyword and argument are referenced in the named and numbered extended ACL task tables in the previous sections, the “Creating Standard and Extended IPv4 ACLs” section on page 26-6, and the “Creating Named Standard and Extended ACLs” section on page 26-12.

Time-based access lists trigger CPU activity because the new configuration of the access list must be merged with other features and the combined configuration loaded into the TCAM. For this reason, you should be careful not to have several access lists configured to take affect in close succession (within a small number of minutes of each other.)

The time range relies on the switch system clock; therefore, you need a reliable clock source. We recommend that you use Network Time Protocol (NTP) to synchronize the switch clock. For more information, see the “Managing the System Time and Date” section on page 4-1.

Beginning in privileged EXEC mode, follow these steps to configure a time-range parameter for an ACL:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>time-range time-range-name</td>
</tr>
</tbody>
</table>
| Step 3  | absolute [start time date] [end time date] or periodic day-of-the-week hh:mm to [day-of-the-week] hh:mm or periodic {weekdays | weekend | daily} hh:mm to hh:mm | Specify when the function it will be applied to is operational.  
  - You can use only one absolute statement in the time range. If you configure more than one absolute statement, only the one configured last is executed.  
  - You can enter multiple periodic statements. For example, you could configure different hours for weekdays and weekends.  
  See the example configurations. |
Chapter 26  Configuring Network Security with ACLs

Configuring IPv4 ACLs

Repeat the steps if you have multiple items that you want in effect at different times.

To remove a configured time-range limitation, use the `no time-range time-range-name` global configuration command.

This example shows how to configure time ranges for `workhours` and to configure January 1, 2006, as a company holiday and to verify your configuration.

```
Switch(config)# time-range workhours
Switch(config-time-range)# periodic weekdays 8:00 to 12:00
Switch(config-time-range)# periodic weekdays 13:00 to 17:00
Switch(config-time-range)# exit
Switch(config)# time-range new_year_day_2006
Switch(config-time-range)# absolute start 00:00 1 Jan 2006 end 23:59 1 Jan 2006
Switch(config-time-range)# end
Switch# show time-range
  time-range entry: new_year_day_2006 (inactive)  
  absolute start 00:00 01 January 2006 end 23:59 01 January 2006
  time-range entry: workhours (inactive)  
  periodic weekdays 8:00 to 12:00
  periodic weekdays 13:00 to 17:00
```

To apply a time range, enter the time-range name in an extended ACL that can implement time ranges.

This example shows how to create and verify extended access list 188 that denies TCP traffic from any source to any destination during the defined holiday times and permits all TCP traffic during work hours.

```
Switch(config)# access-list 188 deny tcp any any time-range new_year_day_2006
Switch(config)# access-list 188 permit tcp any any time-range workhours
Switch(config)# end
Switch# show access-lists
  Extended IP access list 188
  10 deny tcp any any time-range new_year_day_2006 (inactive)
  20 permit tcp any any time-range workhours (inactive)
```

This example uses named ACLs to permit and deny the same traffic.

```
Switch(config)# ip access-list extended deny_access
Switch(config-ext-nacl)# deny tcp any any time-range new_year_day_2006
Switch(config-ext-nacl)# exit
Switch(config)# ip access-list extended may_access
Switch(config-ext-nacl)# permit tcp any any time-range workhours
Switch(config-ext-nacl)# end
Switch# show ip access-lists
  Extended IP access list lpip_default
  10 permit ip any
  Extended IP access list deny_access
  10 deny tcp any any time-range new_year_day_2006 (inactive)
  Extended IP access list may_access
  10 permit tcp any any time-range workhours (inactive)
```
Including Comments in ACLs

You can use the remark keyword to include comments (remarks) about entries in any IP standard or extended ACL. The remarks make the ACL easier for you to understand and scan. Each remark line is limited to 100 characters.

The remark can go before or after a permit or deny statement. You should be consistent about where you put the remark so that it is clear which remark describes which permit or deny statement. For example, it would be confusing to have some remarks before the associated permit or deny statements and some remarks after the associated statements.

To include a comment for IP numbered standard or extended ACLs, use the access-list access-list number remark remark global configuration command. To remove the remark, use the no form of this command.

In this example, the server that belongs to Jones is allowed access, and the workstation that belongs to Smith is not allowed access:

```
Switch(config)# access-list 1 remark Permit only Jones server through
Switch(config)# access-list 1 permit 171.69.2.88
Switch(config)# access-list 1 remark Do not allow Smith server through
Switch(config)# access-list 1 deny 171.69.3.13
```

For an entry in a named IP ACL, use the remark access-list configuration command. To remove the remark, use the no form of this command.

In this example, the Jones subnet is not allowed to use outbound Telnet:

```
Switch(config)# ip access-list extended telnetting
Switch(config-ext-nacl)# remark Do not allow Jones subnet to telnet out
Switch(config-ext-nacl)# deny tcp host 171.69.2.88 any eq telnet
```

Applying an IPv4 ACL to a Terminal Line

You can use numbered ACLs to control access to one or more terminal lines. You cannot apply named ACLs to lines. You must set identical restrictions on all the virtual terminal lines because a user can attempt to connect to any of them.

For procedures for applying ACLs to interfaces, see the “Applying an IPv4 ACL to an Interface” section on page 26-17. For applying ACLs to VLANs, see the “Configuring VLAN Maps” section on page 26-22.

Beginning in privileged EXEC mode, follow these steps to restrict incoming and outgoing connections between a virtual terminal line and the addresses in an ACL:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td>line [console</td>
<td>vty] line-number</td>
</tr>
<tr>
<td>• console—Specify the console terminal line. The console port is DCE.</td>
<td></td>
</tr>
<tr>
<td>• vty—Specify a virtual terminal for remote console access.</td>
<td></td>
</tr>
<tr>
<td>The line-number is the first line number in a contiguous group that you want to configure when the line type is specified. The range is from 0 to 16.</td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>access-class access-list-number [in</td>
<td>out]</td>
</tr>
</tbody>
</table>
Configuring IPv4 ACLs

To remove an ACL from a terminal line, use the `no access-class access-list-number {in | out}` line configuration command.

Applying an IPv4 ACL to an Interface

This section describes how to apply IPv4 ACLs to network interfaces. Note these guidelines:

- Apply an ACL only to inbound Layer 2 interfaces.
- When controlling access to an interface, you can use a named or numbered ACL.
- If you apply an ACL to a Layer 2 interface that is a member of a VLAN, the Layer 2 (port) ACL takes precedence over a VLAN map applied to the VLAN. Incoming packets received on the Layer 2 port are always filtered by the port ACL.

Beginning in privileged EXEC mode, follow these steps to control access to an interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>ip access-group {access-list-number</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To remove the specified access group, use the `no ip access-group {access-list-number | name} {in}` interface configuration command.

This example shows how to apply access list 2 to a port to filter packets entering the port:

```
Switch(config)# interface gigabitethernet0/1
Router(config-if)# ip access-group 2 in
```

For inbound ACLs, after receiving a packet, the switch checks the packet against the ACL. If the ACL permits the packet, the switch continues to process the packet. If the ACL rejects the packet, the switch discards the packet.

When you apply an undefined ACL to an interface, the switch acts as if the ACL has not been applied to the interface and permits all packets. Remember this behavior if you use undefined ACLs for network security.
Hardware and Software Treatment of IP ACLs

ACL processing is primarily accomplished in hardware, but requires forwarding of some traffic flows to the CPU for software processing. If the hardware reaches its capacity to store ACL configurations, packets are sent to the CPU for forwarding. The forwarding rate for software-forwarded traffic is substantially less than for hardware-forwarded traffic.

If ACLs cause large numbers of packets to be sent to the CPU, the switch performance can be negatively affected.

When you enter the `show ip access-lists` privileged EXEC command, the match count displayed does not account for packets that are access controlled in hardware. Use the `show access-lists hardware counters` privileged EXEC command to obtain some basic hardware ACL statistics for switched packets.

IPv4 ACL Configuration Examples

This section provides examples of configuring and applying IPv4 ACLs. For detailed information about compiling ACLs, see the Cisco IOS Security Configuration Guide, Release 12.2 and to the Configuring IP Services” section in the “IP Addressing and Services” chapter of the Cisco IOS IP Configuration Guide, Release 12.2.

This example uses a standard ACL to allow a port access to a specific Internet host with the address 172.20.128.64.

```
Switch(config)# access-list 6 permit 172.20.128.64 0.0.0.0
Switch(config)# end
Switch(config)# show access-lists
Standard IP access list 6
  10 permit 172.20.128.64 wildcard bits 0.0.0.0
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group 6 in
```

This example uses an extended ACL to deny to a port traffic coming from port 80 (HTTP). It permits all other types of traffic.

```
Switch(config)# access-list 106 deny tcp any any eq 80
Switch(config)# access-list 106 permit ip any any
Switch(config)# end
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group 106 in
```

Numbered ACLs

This ACL accepts addresses on network 36.0.0.0 subnets and denies all packets coming from 56.0.0.0 subnets. The ACL is applied to packets entering a port.

```
Switch(config)# access-list 2 permit 36.0.0.0 0.255.255.255
Switch(config)# access-list 2 deny 56.0.0.0 0.255.255.255
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group 2 in
```

Extended ACLs

In this example, suppose that you have a network connected to the Internet, and you want any host on the network to be able to form TCP connections to any host on the Internet. However, you do not want IP hosts to be able to form TCP connections to hosts on your network, except to the mail (SMTP) port of a dedicated mail host.

```
Switch(config)# access-list 1 permit tcp any any eq 25
Switch(config)# access-list 1 permit tcp any any eq 110
Switch(config)# access-list 1 permit tcp any any eq 143
Switch(config)# access-list 1 deny tcp any any eq 110
Switch(config)# access-list 1 deny tcp any any eq 143
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group 1 in
```
SMTP uses TCP port 25 on one end of the connection and a random port number on the other end. The same port numbers are used throughout the life of the connection. Mail packets coming in from the Internet have a destination port of 25. Because the secure system of the network always accepts mail connections on port 25, the incoming services are controlled.

```
Switch(config)# access-list 102 permit tcp any 128.88.0.0 0.0.255.255 eq 23
Switch(config)# access-list 102 permit tcp any 128.88.0.0 0.0.255.255 eq 25
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group 102 in
```

**Named ACLs**

This example creates an extended ACL named *marketing_group*. The *marketing_group* ACL allows any TCP Telnet traffic to the destination address and wildcard 171.69.0.0 0.0.255.255 and denies any other TCP traffic. It permits any other IP traffic.

```
Switch(config)# ip access-list extended marketing_group
Switch(config-ext-nacl)# permit tcp any 171.69.0.0 0.0.255.255 eq telnet
Switch(config-ext-nacl)# deny tcp any any
Switch(config-ext-nacl)# permit ip any any
Switch(config-ext-nacl)# exit
```

The *marketing_group* ACL is applied to incoming traffic on a port.

```
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# ip access-group marketing_group in
```

**Time Range Applied to an IP ACL**

This example denies HTTP traffic on IP on Monday through Friday between the hours of 8:00 a.m. and 6:00 p.m (18:00). The example allows UDP traffic only on Saturday and Sunday from noon to 8:00 p.m. (20:00).

```
Switch(config)# time-range no-http
Switch(config)# periodic weekdays 8:00 to 18:00
!
Switch(config)# time-range udp-yes
Switch(config)# periodic weekend 12:00 to 20:00
!
Switch(config)# ip access-list extended strict
Switch(config-ext-nacl)# deny tcp any any eq www time-range no-http
Switch(config-ext-nacl)# permit udp any any time-range udp-yes
!
Switch(config-ext-nacl)# exit
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# ip access-group strict in
```

**Commented IP ACL Entries**

In this example of a numbered ACL, the server that belongs to Jones is allowed access, and the workstation that belongs to Smith is not allowed access:

```
Switch(config)# access-list 1 remark Permit only Jones server through
Switch(config)# access-list 1 permit 171.69.2.88
Switch(config)# access-list 1 remark Do not allow Smith server through
Switch(config)# access-list 1 deny 171.69.3.13
```
In this example of a numbered ACL, the Winter and Smith servers are not allowed to browse the web:

```
Switch(config)# access-list 100 remark Do not allow Winter to browse the web
Switch(config)# access-list 100 deny host 171.69.3.85 any eq www
Switch(config)# access-list 100 remark Do not allow Smith to browse the web
Switch(config)# access-list 100 deny host 171.69.3.13 any eq www
```

In this example of a named ACL, the Jones subnet is not allowed access:

```
Switch(config)# ip access-list standard prevention
Switch(config-std-nacl)# remark Do not allow Jones subnet through
Switch(config-std-nacl)# deny 171.69.0.0 0.0.255.255
```

In this example of a named ACL, the Jones subnet is not allowed to use outbound Telnet:

```
Switch(config)# ip access-list extended telnetting
Switch(config-ext-nacl)# remark Do not allow Jones subnet to telnet out
Switch(config-ext-nacl)# deny tcp 171.69.0.0 0.0.255.255 any eq telnet
```

### Creating Named MAC Extended ACLs

You can filter non-IPv4 traffic on a VLAN or on a Layer 2 interface by using MAC addresses and named MAC extended ACLs. The procedure is similar to that of configuring other extended named ACLs.

For more information about the supported non-IP protocols in the `mac access-list extended` command, see the command reference for this release.

**Note**

Though visible in the command-line help strings, `appletalk` is not supported as a matching condition for the `deny` and `permit` MAC access-list configuration mode commands.

Beginning in privileged EXEC mode, follow these steps to create a named MAC extended ACL:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td><code>mac access-list extended name</code></td>
<td>Define an extended MAC access list using a name.</td>
</tr>
</tbody>
</table>
Chapter 26      Configuring Network Security with ACLs

Creating Named MAC Extended ACLs

### Step 3

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| {deny | permit} {any | host source MAC address | source MAC address mask} {any | host destination MAC address | destination MAC address mask} {type mask | lsap lsap mask | aarp | amber | dec-spanning | decnet-iv | diagnostic | etype | etype-6000 | etype-8042 | lat | lace-sca | mop-console | mop-dump | msdos | mumps | netbios | vines-echo | vines-ip | xns-idp | 0-65535} {cos | cos} | In extended MAC access-list configuration mode, specify to permit or deny source MAC address, a source MAC address with a mask, or a specific host MAC address and any destination MAC address, destination MAC address with a mask, or a specific destination MAC address. (Optional) You can also enter these options:

- type mask—An arbitrary EtherType number of a packet with Ethernet II or SNAP encapsulation in decimal, hexadecimal, or octal with optional mask of don’t care bits applied to the EtherType before testing for a match.
- lsap lsap mask—An LSAP number of a packet with IEEE 802.2 encapsulation in decimal, hexadecimal, or octal with optional mask of don’t care bits.
- cos cos—An IEEE 802.1Q cost of service number from 0 to 7 used to set priority. |

### Step 4

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

### Step 5

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show access-lists [number</td>
<td>name]</td>
</tr>
</tbody>
</table>

### Step 6

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Use the no mac access-list extended name global configuration command to delete the entire ACL. You can also delete individual ACEs from named MAC extended ACLs.

This example shows how to create and display an access list named mac1, denying only EtherType DECnet Phase IV traffic, but permitting all other types of traffic.

```
Switch(config)# mac access-list extended mac1
Switch(config-ext-macl)# deny any any decnet-iv
Switch(config-ext-macl)# permit any any
Switch(config-ext-macl)# end
Switch # show access-lists
Extended MAC access list mac1
  10 deny any any decnet-iv
  20 permit any any
```

### Applying a MAC ACL to a Layer 2 Interface

After you create a MAC ACL, you can apply it to a Layer 2 interface to filter non-IP traffic coming in that interface. When you apply the MAC ACL, consider these guidelines:

- If you apply an ACL to a Layer 2 interface that is a member of a VLAN, the Layer 2 (port) ACL takes precedence over a VLAN map applied to the VLAN. Incoming packets received on the Layer 2 port are always filtered by the port ACL.
- You can apply no more than one IP access list and one MAC access list to the same Layer 2 interface. The IP access list filters only IP packets, and the MAC access list filters non-IP packets.
A Layer 2 interface can have only one MAC access list. If you apply a MAC access list to a Layer 2 interface that has a MAC ACL configured, the new ACL replaces the previously configured one.

Beginning in privileged EXEC mode, follow these steps to apply a MAC access list to control access to a Layer 2 interface:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Identify a specific interface, and enter interface configuration mode. The interface must be a physical Layer 2 interface (port ACL).</td>
</tr>
<tr>
<td>Step 3 mac access-group {name} {in}</td>
<td>Control access to the specified interface by using the MAC access list. Port ACLs are supported only in the inbound direction.</td>
</tr>
<tr>
<td>Step 4 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5 show mac access-group [interface interface-id]</td>
<td>Display the MAC access list applied to the interface or all Layer 2 interfaces.</td>
</tr>
<tr>
<td>Step 6 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove the specified access group, use the no mac access-group {name} interface configuration command.

This example shows how to apply MAC access list mac1 to a port to filter packets entering the port:

Switch(config)# interface gigabitethernet0/2
Router(config-if)# mac access-group mac1 in

**Note**

The mac access-group interface configuration command is only valid when applied to a physical Layer 2 interface. You cannot use the command on EtherChannel port channels.

After receiving a packet, the switch checks it against the inbound ACL. If the ACL permits it, the switch continues to process the packet. If the ACL rejects the packet, the switch discards it. When you apply an undefined ACL to an interface, the switch acts as if the ACL has not been applied and permits all packets. Remember this behavior if you use undefined ACLs for network security.

### Configuring VLAN Maps

This section describes how to configure VLAN maps, which is the only way to control filtering within a VLAN. VLAN maps have no direction. To filter traffic in a specific direction by using a VLAN map, you need to include an ACL with specific source or destination addresses. If there is a match clause for that type of packet (IP or MAC) in the VLAN map, the default action is to drop the packet if the packet does not match any of the entries within the map. If there is no match clause for that type of packet, the default is to forward the packet.

For complete syntax and usage information for the commands used in this section, see the command reference for this release.
To create a VLAN map and apply it to one or more VLANs, perform these steps:

**Step 1** Create the standard or extended IPv4 ACLs or named MAC extended ACLs that you want to apply to the VLAN. See the “Creating Standard and Extended IPv4 ACLs” section on page 26-6 and the “Creating a VLAN Map” section on page 26-24.

**Step 2** Enter the `vlan access-map` global configuration command to create a VLAN ACL map entry.

**Step 3** In access-map configuration mode, optionally enter an `action—forward` (the default) or `drop`—and enter the `match` command to specify an IP packet or a non-IP packet (with only a known MAC address) and to match the packet against one or more ACLs (standard or extended).

**Note** If the VLAN map is configured with a match clause for a type of packet (IP or MAC) and the map action is drop, all packets that match the type are dropped. If the VLAN map has no match clause, and the configured action is drop, all IP and Layer 2 packets are dropped.

**Step 4** Use the `vlan filter` global configuration command to apply a VLAN map to one or more VLANs.

These sections contain this configuration information:

- VLAN Map Configuration Guidelines, page 26-23
- Creating a VLAN Map, page 26-24
- Applying a VLAN Map to a VLAN, page 26-26
- Using VLAN Maps in Your Network, page 26-27

**VLAN Map Configuration Guidelines**

Follow these guidelines when configuring VLAN maps:

- If there is no ACL configured to deny traffic on an interface and no VLAN map is configured, all traffic is permitted.
- Each VLAN map consists of a series of entries. The order of entries in an VLAN map is important. A packet that comes into the switch is tested against the first entry in the VLAN map. If it matches, the action specified for that part of the VLAN map is taken. If there is no match, the packet is tested against the next entry in the map.
- If the VLAN map has at least one match clause for the type of packet (IP or MAC) and the packet does not match any of these match clauses, the default is to drop the packet. If there is no match clause for that type of packet in the VLAN map, the default is to forward the packet.
- The system might take longer to boot up if you have configured a very large number of ACLs.
- Logging is not supported for VLAN maps.
- If VLAN map configuration cannot be applied in hardware, all packets in that VLAN must be forwarded by software.
- When a switch has an IP access list or MAC access list applied to a Layer 2 interface, and you apply a VLAN map to a VLAN that the port belongs to, the port ACL takes precedence over the VLAN map.

For configuration examples, see the “Using VLAN Maps in Your Network” section on page 26-27.
**Creating a VLAN Map**

Each VLAN map consists of an ordered series of entries. Beginning in privileged EXEC mode, follow these steps to create, add to, or delete a VLAN map entry:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>vlan access-map name [number]</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>**action [drop</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>**match {ip</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>show running-config</strong></td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>

Use the `no vlan access-map name` global configuration command to delete a map. Use the `no vlan access-map name number` global configuration command to delete a single sequence entry from within the map.

Use the `no action` access-map configuration command to enforce the default action, which is to forward. VLAN maps do not use the specific permit or deny keywords. To deny a packet by using VLAN maps, create an ACL that would match the packet, and set the action to drop. A permit in the ACL counts as a match. A deny in the ACL means no match.

**Examples of ACLs and VLAN Maps**

These examples show how to create ACLs and VLAN maps that for specific purposes.

**Example 1**

This example shows how to create an ACL and a VLAN map to deny a packet. In the first map, any packets that match the `ipl` ACL (TCP packets) would be dropped. You first create the `ipl` ACL to permit any TCP packet and no other packets. Because there is a match clause for IP packets in the VLAN map, the default action is to drop any IP packet that does not match any of the match clauses.

```
Switch(config)# ip access-list extended ipl
Switch(config-ext-nacl)# permit tcp any any
Switch(config-ext-nacl)# exit
Switch(config)# vlan access-map map_1 10
Switch(config-access-map)# match ip address ipl
Switch(config-access-map)# action drop
```
Chapter 26  Configuring Network Security with ACLs

Configuring VLAN Maps

This example shows how to create a VLAN map to permit a packet. ACL ip2 permits UDP packets and any packets that match the ip2 ACL are forwarded. In this map, any IP packets that did not match any of the previous ACLs (that is, packets that are not TCP packets or UDP packets) would get dropped.

```
Switch(config)# ip access-list extended ip2
Switch(config-ext-nacl)# permit udp any any
Switch(config-ext-nacl)# exit
Switch(config)# vlan access-map map_1 20
Switch(config-access-map)# match ip address ip2
Switch(config-access-map)# action forward
```

Example 2

In this example, the VLAN map has a default action of drop for IP packets and a default action of forward for MAC packets. Used with standard ACL 101 and extended named access lists igmp-match and tcp-match, the map will have the following results:

- Forward all UDP packets
- Drop all IGMP packets
- Forward all TCP packets
- Drop all other IP packets
- Forward all non-IP packets

```
Switch(config)# access-list 101 permit udp any any
Switch(config)# ip access-list extended igmp-match
Switch(config-ext-nacl)# permit igmp any any
Switch(config)# ip access-list extended tcp-match
Switch(config-ext-nacl)# permit tcp any any
Switch(config-ext-nacl)# exit
Switch(config)# vlan access-map drop-ip-default 10
Switch(config-access-map)# match ip address 101
Switch(config-access-map)# action forward
Switch(config-access-map)# exit
Switch(config)# vlan access-map drop-ip-default 20
Switch(config-access-map)# match ip address igmp-match
Switch(config-access-map)# action drop
Switch(config-access-map)# exit
Switch(config)# vlan access-map drop-ip-default 30
Switch(config-access-map)# match ip address tcp-match
Switch(config-access-map)# action forward
```

Example 3

In this example, the VLAN map has a default action of drop for MAC packets and a default action of forward for IP packets. Used with MAC extended access lists good-hosts and good-protocols, the map will have the following results:

- Forward MAC packets from hosts 0000.0c00.0111 and 0000.0c00.0211
- Forward MAC packets with decnet-iv or vines-ip protocols
- Drop all other non-IP packets
- Forward all IP packets

```
Switch(config)# mac access-list extended good-hosts
Switch(config-ext-macl)# permit host 000.0c00.0111 any
Switch(config-ext-macl)# permit host 000.0c00.0211 any
Switch(config-ext-macl)# exit
Switch(config)# mac access-list extended good-protocols
Switch(config-ext-macl)# permit any any decnet-ip
```
Configuring VLAN Maps

Example 4

In this example, the VLAN map has a default action of drop for all packets (IP and non-IP). Used with access lists *tcp-match* and *good-hosts* from Examples 2 and 3, the map will have the following results:

- Forward all TCP packets
- Forward MAC packets from hosts 0000.0c00.0111 and 0000.0c00.0211
- Drop all other IP packets
- Drop all other MAC packets

```
Switch(config)# vlan access-map drop-all-default 10
Switch(config-access-map)# match ip address tcp-match
Switch(config-access-map)# action forward
Switch(config-access-map)# exit
Switch(config)# vlan access-map drop-all-default 20
Switch(config-access-map)# match mac address good-hosts
Switch(config-access-map)# action forward
```

Applying a VLAN Map to a VLAN

Beginning in privileged EXEC mode, follow these steps to apply a VLAN map to one or more VLANs:

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>vlan filter mapname vlan-list list</td>
<td>Apply the VLAN map to one or more VLAN IDs. The list can be a single VLAN ID (22), a consecutive list (10-22), or a string of VLAN IDs (12, 22, 30). Spaces around the comma and hyphen are optional.</td>
</tr>
<tr>
<td>3</td>
<td>show running-config</td>
<td>Display the access list configuration.</td>
</tr>
<tr>
<td>4</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove the VLAN map, use the `no vlan filter mapname vlan-list list` global configuration command.

This example shows how to apply VLAN map 1 to VLANs 20 through 22:

```
Switch(config)# vlan filter map 1 vlan-list 20-22
```
Using VLAN Maps in Your Network

These sections describes some typical uses for VLAN maps:

- Wiring Closet Configuration, page 26-27
- Denying Access to a Server on a VLAN, page 26-28

Wiring Closet Configuration

In a wiring closet configuration, the switch can support a VLAN map and a QoS classification ACL. In Figure 26-3, assume that Host X and Host Y are in different VLANs and are connected to wiring closet switches A and C. Traffic from Host X to Host Y is eventually being routed by Switch B, a Layer 3 switch with routing enabled. Traffic from Host X to Host Y can be access-controlled at the traffic entry point, Switch A.

Figure 26-3  Wiring Closet Configuration

If you do not want HTTP traffic switched from Host X to Host Y, you can configure a VLAN map on Switch A to drop all HTTP traffic from Host X (IP address 10.1.1.32) to Host Y (IP address 10.1.1.34) at Switch A and not bridge it to Switch B.

First, define the IP access list http that permits (matches) any TCP traffic on the HTTP port.

```
Switch(config)# ip access-list extended http
Switch(config-ext-nacl)# permit tcp host 10.1.1.32 host 10.1.1.34 eq www
Switch(config-ext-nacl)# exit
```
Next, create VLAN access map *map2* so that traffic that matches the *http* access list is dropped and all other IP traffic is forwarded.

```bash
Switch(config)# vlan access-map map2 10
Switch(config-access-map)# match ip address http
Switch(config-access-map)# action drop
Switch(config)# exit
Switch(config)# ip access-list extended match_all
Switch(config-ext-nacl)# permit ip any any
Switch(config-ext-nacl)# exit
Switch(config)# vlan access-map map2 20
Switch(config-access-map)# match ip address match_all
Switch(config-access-map)# action forward
```

Then, apply VLAN access map *map2* to VLAN 1.

```bash
Switch(config)# vlan filter map2 vlan 1
```

**Denying Access to a Server on a VLAN**

You can restrict access to a server on a VLAN. For example, server 10.1.1.100 in VLAN 10 needs to have access denied to hosts 10.1.1.4 and 10.1.1.8 (see Figure 26-4):

**Figure 26-4  Deny Access to a Server on a VLAN**

![Deny Access to a Server on a VLAN](image)

This example shows how to deny access to a server on another VLAN by creating the VLAN map SERVER1 that denies access to hosts in subnet 10.1.2.0/8, host 10.1.1.4, and host 10.1.1.8 and permits other IP traffic. The final step is to apply the map SERVER1 to VLAN 10.

**Step 1** Define the IP ACL that will match the correct packets.

```bash
Switch(config)# ip access-list extended SERVER1_ACL
Switch(config-ext-nacl)# permit ip host 10.1.1.4 host 10.1.1.100
Switch(config-ext-nacl)# permit ip host 10.1.1.8 host 10.1.1.100
Switch(config-ext-nacl)# exit
```

**Step 2** Define a VLAN map using this ACL that will drop IP packets that match SERVER1_ACL and forward IP packets that do not match the ACL.

```bash
Switch(config)# vlan access-map SERVER1_MAP
Switch(config-access-map)# match ip address SERVER1_ACL
Switch(config-access-map)# action drop
```
Switch(config)# vlan access-map SERVER1_MAP 20
Switch(config-access-map)# action forward
Switch(config-access-map)# exit

**Step 3** Apply the VLAN map to VLAN 10.
Switch(config)# vlan filter SERVER1_MAP vlan-list 10.

### Displaying IPv4 ACL Configuration

You can display the ACLs that are configured on the switch, and you can display the ACLs that have been applied to interfaces and VLANs.

When you use the `ip access-group` interface configuration command to apply ACLs to a Layer 2 interface, you can display the access groups on the interface. You can also display the MAC ACLs applied to a Layer 2 interface. You can use the privileged EXEC commands as described in Table 26-2 to display this information.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show access-lists [number \ name]</code></td>
<td>Display the contents of one or all current IP and MAC address access lists or a specific access list (numbered or named).</td>
</tr>
<tr>
<td><code>show ip access-lists [number \ name]</code></td>
<td>Display the contents of all current IP access lists or a specific IP access list (numbered or named).</td>
</tr>
<tr>
<td><code>show running-config [interface interface-id]</code></td>
<td>Displays the contents of the configuration file for the switch or the specified interface, including all configured MAC and IP access lists and which access groups are applied to an interface.</td>
</tr>
<tr>
<td><code>show mac access-group [interface interface-id]</code></td>
<td>Displays MAC access lists applied to all Layer 2 interfaces or the specified Layer 2 interface.</td>
</tr>
</tbody>
</table>

You can also display information about VLAN access maps or VLAN filters. Use the privileged EXEC commands in Table 26-3 to display VLAN map information.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>show vlan access-map [mapname]</code></td>
<td>Show information about all VLAN access maps or the specified access map.</td>
</tr>
<tr>
<td><code>show vlan filter [access-map name \ vlan vlan-id]</code></td>
<td>Show information about all VLAN filters or about a specified VLAN or VLAN access map.</td>
</tr>
</tbody>
</table>
Configuring QoS

This chapter describes how to configure quality of service (QoS) by using automatic QoS (auto-QoS) commands or by using standard QoS commands on the switch. With QoS, you can provide preferential treatment to certain types of traffic at the expense of others. Without QoS, the switch offers best-effort service to each packet, regardless of the packet contents or size. It sends the packets without any assurance of reliability, delay bounds, or throughput.

You can configure QoS on physical ports and on switch virtual interfaces (SVIs). Other than to apply policy maps, you configure the QoS settings, such as classification, queueing, and scheduling, the same way on physical ports and SVIs. When configuring QoS on a physical port, you apply a nonhierarchical policy map. When configuring QoS on an SVI, you apply a nonhierarchical or a hierarchical policy map.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference this release.

This chapter consists of these sections:

- Understanding QoS, page 27-1
- Configuring Auto-QoS, page 27-20
- Displaying Auto-QoS Information, page 27-29
- Configuring Standard QoS, page 27-29
- Displaying Standard QoS Information, page 27-75

The switch supports some of the modular QoS CLI (MQC) commands. For more information about the MQC commands, see the “Modular Quality of Service Command-Line Interface Overview” at this site:

Understanding QoS

Typically, networks operate on a best-effort delivery basis, which means that all traffic has equal priority and an equal chance of being delivered in a timely manner. When congestion occurs, all traffic has an equal chance of being dropped.

When you configure the QoS feature, you can select specific network traffic, prioritize it according to its relative importance, and use congestion-management and congestion-avoidance techniques to provide preferential treatment. Implementing QoS in your network makes network performance more predictable and bandwidth utilization more effective.
The QoS implementation is based on the Differentiated Services (Diff-Serv) architecture, an emerging standard from the Internet Engineering Task Force (IETF). This architecture specifies that each packet is classified upon entry into the network.

The classification is carried in the IP packet header, using 6 bits from the deprecated IP type of service (ToS) field to carry the classification \((\text{class})\) information. Classification can also be carried in the Layer 2 frame. These special bits in the Layer 2 frame or a Layer 3 packet are described here and shown in Figure 27-1:

- **Prioritization bits in Layer 2 frames:**
  
  Layer 2 Inter-Switch Link (ISL) frame headers have a 1-byte User field that carries an IEEE 802.1p class of service (CoS) value in the three least-significant bits. On ports configured as Layer 2 ISL trunks, all traffic is in ISL frames.

  Layer 2 802.1Q frame headers have a 2-byte Tag Control Information field that carries the CoS value in the three most-significant bits, which are called the User Priority bits. On ports configured as Layer 2 802.1Q trunks, all traffic is in 802.1Q frames except for traffic in the native VLAN. Other frame types cannot carry Layer 2 CoS values.

  Layer 2 CoS values range from 0 for low priority to 7 for high priority.

- **Prioritization bits in Layer 3 packets:**

  Layer 3 IP packets can carry either an IP precedence value or a Differentiated Services Code Point (DSCP) value. QoS supports the use of either value because DSCP values are backward-compatible with IP precedence values.

  IP precedence values range from 0 to 7.

  DSCP values range from 0 to 63.

---

**Note**  
IPv6 QoS is not supported in this release.
### Understanding QoS

All switches and routers that access the Internet rely on the class information to provide the same forwarding treatment to packets with the same class information and different treatment to packets with different class information. The class information in the packet can be assigned by end hosts or by switches or routers along the way, based on a configured policy, detailed examination of the packet, or both. Detailed examination of the packet is expected to happen closer to the edge of the network so that the core switches and routers are not overloaded with this task.

Switches and routers along the path can use the class information to limit the amount of resources allocated per traffic class. The behavior of an individual device when handling traffic in the DiffServ architecture is called per-hop behavior. If all devices along a path provide a consistent per-hop behavior, you can construct an end-to-end QoS solution.

Implementing QoS in your network can be a simple or complex task and depends on the QoS features offered by your internetworking devices, the traffic types and patterns in your network, and the granularity of control that you need over incoming and outgoing traffic.

### Basic QoS Model

To implement QoS, the switch must distinguish packets or flow from one another (classify), assign a label to indicate the given quality of service as the packets move through the switch, make the packets comply with the configured resource usage limits (police and mark), and provide different treatment (queue and schedule) in all situations where resource contention exists. The switch also needs to ensure that traffic sent from it meets a specific traffic profile (shape).
Figure 27-2 shows the basic QoS model. Actions at the ingress port include classifying traffic, policing, marking, queueing, and scheduling:

- Classifying a distinct path for a packet by associating it with a QoS label. The switch maps the CoS or DSCP in the packet to a QoS label to distinguish one kind of traffic from another. The QoS label that is generated identifies all future QoS actions to be performed on this packet. For more information, see the “Classification” section on page 27-5.

- Policing determines whether a packet is in or out of profile by comparing the rate of the incoming traffic to the configured policer. The policer limits the bandwidth consumed by a flow of traffic. The result is passed to the marker. For more information, see the “Policing and Marking” section on page 27-8.

- Marking evaluates the policer and configuration information for the action to be taken when a packet is out of profile and determines what to do with the packet (pass through a packet without modification, mark down the QoS label in the packet, or drop the packet). For more information, see the “Policing and Marking” section on page 27-8.

- Queueing evaluates the QoS label and the corresponding DSCP or CoS value to select into which of the two ingress queues to place a packet. Queueing is enhanced with the weighted tail-drop (WTD) algorithm, a congestion-avoidance mechanism. If the threshold is exceeded, the packet is dropped. For more information, see the “Queueing and Scheduling Overview” section on page 27-13.

- Scheduling services the queues based on their configured shaped round robin (SRR) weights. One of the ingress queues is the priority queue, and SRR services it for its configured share before servicing the other queue. For more information, see the “SRR Shaping and Sharing” section on page 27-14.

Actions at the egress port include queueing and scheduling:

- Queueing evaluates the QoS packet label and the corresponding DSCP or CoS value before selecting which of the four egress queues to use. Because congestion can occur when multiple ingress ports simultaneously send data to an egress port, WTD differentiates traffic classes and subjects the packets to different thresholds based on the QoS label. If the threshold is exceeded, the packet is dropped. For more information, see the “Queueing and Scheduling Overview” section on page 27-13.

- Scheduling services the four egress queues based on their configured SRR shared or shaped weights. One of the queues (queue 1) can be the expedited queue, which is serviced until empty before the other queues are serviced.

---

Figure 27-2  Basic QoS Model

---
Classification

Classification is the process of distinguishing one kind of traffic from another by examining the fields in the packet. Classification is enabled only if QoS is globally enabled on the switch. By default, QoS is globally disabled, so no classification occurs.

During classification, the switch performs a lookup and assigns a QoS label to the packet. The QoS label identifies all QoS actions to be performed on the packet and from which queue the packet is sent.

The QoS label is based on the DSCP or the CoS value in the packet and decides the queueing and scheduling actions to perform on the packet. The label is mapped according to the trust setting and the packet type as shown in Figure 27-3 on page 27-6.

You specify which fields in the frame or packet that you want to use to classify incoming traffic. For non-IP traffic, you have these classification options as shown in Figure 27-3:

- Trust the CoS value in the incoming frame (configure the port to trust CoS). Then use the configurable CoS-to-DSCP map to generate a DSCP value for the packet. Layer 2 ISL frame headers carry the CoS value in the 3 least-significant bits of the 1-byte User field. Layer 2 802.1Q frame headers carry the CoS value in the 3 most-significant bits of the Tag Control Information field. CoS values range from 0 for low priority to 7 for high priority.
- Trust the DSCP or trust IP precedence value in the incoming frame. These configurations are meaningless for non-IP traffic. If you configure a port with either of these options and non-IP traffic is received, the switch assigns a CoS value and generates an internal DSCP value from the CoS-to-DSCP map. The switch uses the internal DSCP value to generate a CoS value representing the priority of the traffic.
- Perform the classification based on a configured Layer 2 MAC access control list (ACL), which can examine the MAC source address, the MAC destination address, and other fields. If no ACL is configured, the packet is assigned 0 as the DSCP and CoS values, which means best-effort traffic. Otherwise, the policy-map action specifies a DSCP or CoS value to assign to the incoming frame.

For IP traffic, you have these classification options as shown in Figure 27-3:

- Trust the DSCP value in the incoming packet (configure the port to trust DSCP), and assign the same DSCP value to the packet. The IETF defines the 6 most-significant bits of the 1-byte ToS field as the DSCP. The priority represented by a particular DSCP value is configurable. DSCP values range from 0 to 63.
- For ports that are on the boundary between two QoS administrative domains, you can modify the DSCP to another value by using the configurable DSCP-to-DSCP-mutation map.
- Trust the IP precedence value in the incoming packet (configure the port to trust IP precedence), and generate a DSCP value for the packet by using the configurable IP-precedence-to-DSCP map. The IP Version 4 specification defines the 3 most-significant bits of the 1-byte ToS field as the IP precedence. IP precedence values range from 0 for low priority to 7 for high priority.
- Trust the CoS value (if present) in the incoming packet, and generate a DSCP value for the packet by using the CoS-to-DSCP map. If the CoS value is not present, use the default port CoS value.
- Perform the classification based on a configured IP standard or an extended ACL, which examines various fields in the IP header. If no ACL is configured, the packet is assigned 0 as the DSCP and CoS values, which means best-effort traffic. Otherwise, the policy-map action specifies a DSCP or CoS value to assign to the incoming frame.

For information on the maps described in this section, see the “Mapping Tables” section on page 27-12. For configuration information on port trust states, see the “Configuring Classification Using Port Trust States” section on page 27-35.
After classification, the packet is sent to the policing, marking, and the ingress queueing and scheduling stages.

**Figure 27-3 Classification Flowchart**
Classification Based on QoS ACLs

You can use IP standard, IP extended, or Layer 2 MAC ACLs to define a group of packets with the same characteristics (class). In the QoS context, the permit and deny actions in the access control entries (ACEs) have different meanings than with security ACLs:

- If a match with a permit action is encountered (first-match principle), the specified QoS-related action is taken.
- If a match with a deny action is encountered, the ACL being processed is skipped, and the next ACL is processed.
- If no match with a permit action is encountered and all the ACEs have been examined, no QoS processing occurs on the packet, and the switch offers best-effort service to the packet.
- If multiple ACLs are configured on a port, the lookup stops after the packet matches the first ACL with a permit action, and QoS processing begins.

**Note**

When creating an access list, remember that, by default, the end of the access list contains an implicit deny statement for everything if it did not find a match before reaching the end.

After a traffic class has been defined with the ACL, you can attach a policy to it. A policy might contain multiple classes with actions specified for each one of them. A policy might include commands to classify the class as a particular aggregate (for example, assign a DSCP) or rate-limit the class. This policy is then attached to a particular port on which it becomes effective.

You implement IP ACLs to classify IP traffic by using the `access-list` global configuration command; you implement Layer 2 MAC ACLs to classify non-IP traffic by using the `mac access-list extended` global configuration command. For configuration information, see the “Configuring a QoS Policy” section on page 27-41.

Classification Based on Class Maps and Policy Maps

A class map is a mechanism that you use to name a specific traffic flow (or class) and to isolate it from all other traffic. The class map defines the criteria used to match against a specific traffic flow to further classify it. The criteria can include matching the access group defined by the ACL or matching a specific list of DSCP or IP precedence values. If you have more than one type of traffic that you want to classify, you can create another class map and use a different name. After a packet is matched against the class-map criteria, you further classify it through the use of a policy map.

A policy map specifies which traffic class to act on. Actions can include trusting the CoS, DSCP, or IP precedence values in the traffic class; setting a specific DSCP or IP precedence value in the traffic class; or specifying the traffic bandwidth limitations and the action to take when the traffic is out of profile. Before a policy map can be effective, you must attach it to a port.

You create a class map by using the `class-map` global configuration command or the `class` policy-map configuration command. You should use the `class-map` command when the map is shared among many ports. When you enter the `class-map` command, the switch enters the class-map configuration mode. In this mode, you define the match criterion for the traffic by using the `match` class-map configuration command.

You create and name a policy map by using the `policy-map` global configuration command. When you enter this command, the switch enters the policy-map configuration mode. In this mode, you specify the actions to take on a specific traffic class by using the `class`, `trust`, or `set` policy-map configuration and policy-map class configuration commands.
The policy map can contain the **police** and **police aggregate** policy-map class configuration commands, which define the policer, the bandwidth limitations of the traffic, and the action to take if the limits are exceeded.

To enable the policy map, you attach it to a port by using the **service-policy** interface configuration command.

You can apply a nonhierarchical policy map to a physical port or an SVI. However, a hierarchical policy map can only be applied to an SVI. A hierarchical policy map contains two levels. The first level, the VLAN level, specifies the actions to be taken against a traffic flow on the SVI. The second level, the interface level, specifies the actions to be taken against the traffic on the physical ports that belong to the SVI. The interface-level actions are specified in the interface-level policy map.

For more information, see the “Policing and Marking” section on page 27-8. For configuration information, see the “Configuring a QoS Policy” section on page 27-41.

### Policing and Marking

After a packet is classified and has a DSCP-based or CoS-based QoS label assigned to it, the policing and marking process can begin as shown in Figure 27-4.

Policing involves creating a policer that specifies the bandwidth limits for the traffic. Packets that exceed the limits are *out of profile or nonconforming*. Each policer decides on a packet-by-packet basis whether the packet is in or out of profile and specifies the actions on the packet. These actions, carried out by the marker, include passing through the packet without modification, dropping the packet, or modifying (marking down) the assigned DSCP of the packet and allowing the packet to pass through. The configurable policed-DSCP map provides the packet with a new DSCP-based QoS label. For information on the policed-DSCP map, see the “Mapping Tables” section on page 27-12. Marked-down packets use the same queues as the original QoS label to prevent packets in a flow from getting out of order.

---

**Note**

All traffic, regardless of whether it is bridged or routed, is subjected to a policer, if one is configured. As a result, bridged packets might be dropped or might have their DSCP or CoS fields modified when they are policed and marked.

You can configure policing on a physical port or an SVI. For more information about configuring policing on physical ports, see the “Policing on Physical Ports” section on page 27-9. When you configure policy maps on an SVI, you can create a hierarchical policy map and can define an individual policer only in the secondary interface-level policy map. For more information, see the “Policing on SVIs” section on page 27-10.

After you configure the policy map and policing actions, attach the policy to an ingress port or SVI by using the **service-policy** interface configuration command. For configuration information, see the “Classifying, Policing, and Marking Traffic on Physical Ports by Using Policy Maps” section on page 27-47, the “Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps” section on page 27-50, and the “Classifying, Policing, and Marking Traffic by Using Aggregate Policers” section on page 27-55.
Policing on Physical Ports

In policy maps on physical ports, you can create these types of policers:

- **Individual**—QoS applies the bandwidth limits specified in the policer separately to each matched traffic class. You configure this type of policer within a policy map by using the `police` policy-map class configuration command.

- **Aggregate**—QoS applies the bandwidth limits specified in an aggregate policer cumulatively to all matched traffic flows. You configure this type of policer by specifying the aggregate policer name within a policy map by using the `police aggregate` policy-map class configuration command. You specify the bandwidth limits of the policer by using the `mls qos aggregate-policer` global configuration command. In this way, the aggregate policer is shared by multiple classes of traffic within a policy map.

Policing uses a token-bucket algorithm. As each frame is received by the switch, a token is added to the bucket. The bucket has a hole in it and leaks at a rate that you specify as the average traffic rate in bits per second. Each time a token is added to the bucket, the switch verifies that there is enough room in the bucket. If there is not enough room, the packet is marked as nonconforming, and the specified policer action is taken (dropped or marked down).

How quickly the bucket fills is a function of the bucket depth (burst-byte), the rate at which the tokens are removed (rate-bps), and the duration of the burst above the average rate. The size of the bucket imposes an upper limit on the burst length and limits the number of frames that can be transmitted back-to-back. If the burst is short, the bucket does not overflow, and no action is taken against the traffic flow. However, if a burst is long and at a higher rate, the bucket overflows, and the policing actions are taken against the frames in that burst.

You configure the bucket depth (the maximum burst that is tolerated before the bucket overflows) by using the `burst-byte` option of the `police` policy-map class configuration command or the `mls qos aggregate-policer` global configuration command. You configure how fast (the average rate) that the tokens are removed from the bucket by using the `rate-bps` option of the `police` policy-map class configuration command or the `mls qos aggregate-policer` global configuration command.

Figure 27-4 shows the policing and marking process when these types of policy maps are configured:

- A nonhierarchical policy map on a physical port.
- The interface level of a hierarchical policy map attached to an SVI. The physical ports are specified in this secondary policy map.
Policing on SVIs

Before configuring a hierarchical policy map with individual policers on an SVI, you must enable VLAN-based QoS on the physical ports that belong to the SVI. Though a policy map is attached to the SVI, the individual policers only affect traffic on the physical ports specified in the secondary interface level of the hierarchical policy map.

A hierarchical policy map has two levels. The first level, the VLAN level, specifies the actions to be taken against a traffic flow on an SVI. The second level, the interface level, specifies the actions to be taken against the traffic on the physical ports that belong to the SVI and are specified in the interface-level policy map.
When configuring policing on an SVI, you can create and configure a hierarchical policy map with these two levels:

- **VLAN level**—Create this primary level by configuring class maps and classes that specify the port trust state or set a new DSCP or IP precedence value in the packet. The VLAN-level policy map applies only to the VLAN in an SVI and does not support policers.

- **Interface level**—Create this secondary level by configuring class maps and classes that specify the individual policers on physical ports the belong to the SVI. The interface-level policy map only supports individual policers and does not support aggregate policers. Beginning with Cisco IOS Release 12.2(25)SED, you can configure different interface-level policy maps for each class defined in the VLAN-level policy map.

See the “Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps” section on page 27-50 for an example of a hierarchical policy map.

Figure 27-5 shows the policing and marking process when hierarchical policy maps on an SVI.

**Figure 27-5  Policing and Marking Flowchart on SVIs**

- Start
- Get the VLAN and interface-level classification results for the packet.
- Is an interface-level policer configured for this packet?
  - No
  - Yes
    - Check if the packet is in the profile by querying the policer.
      - No
        - Drop packet.
      - Yes
        - Pass through
          - Check out-of-profile action configured for this policer.
            - Drop
            - Mark
              - Modify DSCP according to the policed-DSCP map. Generate a new QoS label.
                - Done
Mapping Tables

During QoS processing, the switch represents the priority of all traffic (including non-IP traffic) with an QoS label based on the DSCP or CoS value from the classification stage:

- During classification, QoS uses configurable mapping tables to derive a corresponding DSCP or CoS value from a received CoS, DSCP, or IP precedence value. These maps include the CoS-to-DSCP map and the IP-precedence-to-DSCP map. You configure these maps by using the `mls qos map cos-dscp` and the `mls qos map ip-prec-dscp` global configuration commands.

On an ingress port configured in the DSCP-trusted state, if the DSCP values are different between the QoS domains, you can apply the configurable DSCP-to-DSCP-mutation map to the port that is on the boundary between the two QoS domains. You configure this map by using the `mls qos map dscp-mutation` global configuration command.

- During policing, QoS can assign another DSCP value to an IP or a non-IP packet (if the packet is out of profile and the policer specifies a marked-down value). This configurable map is called the policed-DSCP map. You configure this map by using the `mls qos map policed-dscp` global configuration command.

- Before the traffic reaches the scheduling stage, QoS stores the packet in an ingress and an egress queue according to the QoS label. The QoS label is based on the DSCP or the CoS value in the packet and selects the queue through the DSCP input and output queue threshold maps or through the CoS input and output queue threshold maps. You configure these maps by using the `mls qos srr-queue {input | output} dscp-map` and the `mls qos srr-queue {input | output} cos-map` global configuration commands.

The CoS-to-DSCP, DSCP-to-CoS, and the IP-precedence-to-DSCP maps have default values that might or might not be appropriate for your network.

The default DSCP-to-DSCP-mutation map and the default policed-DSCP map are null maps; they map an incoming DSCP value to the same DSCP value. The DSCP-to-DSCP-mutation map is the only map you apply to a specific port. All other maps apply to the entire switch.

For configuration information, see the “Configuring DSCP Maps” section on page 27-57.

For information about the DSCP and CoS input queue threshold maps, see the “Queueing and Scheduling on Ingress Queues” section on page 27-15. For information about the DSCP and CoS output queue threshold maps, see the “Queueing and Scheduling on Egress Queues” section on page 27-17.
Queueing and Scheduling Overview

The switch has queues at specific points to help prevent congestion as shown in Figure 27-6.

**Figure 27-6  Ingress and Egress Queue Location**

Because the total inbound bandwidth of all ports can exceed the bandwidth of the internal ring, ingress queues are located after the packet is classified, policed, and marked and before packets are forwarded into the switch fabric. Because multiple ingress ports can simultaneously send packets to an egress port and cause congestion, outbound queues are located after the internal ring.

Weighted Tail Drop

Both the ingress and egress queues use an enhanced version of the tail-drop congestion-avoidance mechanism called weighted tail drop (WTD). WTD is implemented on queues to manage the queue lengths and to provide drop precedences for different traffic classifications.

As a frame is enqueued to a particular queue, WTD uses the frame’s assigned QoS label to subject it to different thresholds. If the threshold is exceeded for that QoS label (the space available in the destination queue is less than the size of the frame), the switch drops the frame.

**Figure 27-7** shows an example of WTD operating on a queue whose size is 1000 frames. Three drop percentages are configured: 40 percent (400 frames), 60 percent (600 frames), and 100 percent (1000 frames). These percentages mean that up to 400 frames can be queued at the 40-percent threshold, up to 600 frames at the 60-percent threshold, and up to 1000 frames at the 100-percent threshold.

In this example, CoS values 6 and 7 have a greater importance than the other CoS values, and they are assigned to the 100-percent drop threshold (queue-full state). CoS values 4 and 5 are assigned to the 60-percent threshold, and CoS values 0 to 3 are assigned to the 40-percent threshold.

Suppose the queue is already filled with 600 frames, and a new frame arrives. It contains CoS values 4 and 5 and is subjected to the 60-percent threshold. If this frame is added to the queue, the threshold will be exceeded, so the switch drops it.
Chapter 27  Configuring QoS

Understanding QoS

Figure 27-7  WTD and Queue Operation

For more information, see the “Mapping DSCP or CoS Values to an Ingress Queue and Setting WTD Thresholds” section on page 27-64, the “Allocating Buffer Space to and Setting WTD Thresholds for an Egress Queue-Set” section on page 27-68, and the “Mapping DSCP or CoS Values to an Egress Queue and to a Threshold ID” section on page 27-70.

SRR Shaping and Sharing

Both the ingress and egress queues are serviced by SRR, which controls the rate at which packets are sent. On the ingress queues, SRR sends packets to the internal ring. On the egress queues, SRR sends packets to the egress port.

You can configure SRR on egress queues for sharing or for shaping. However, for ingress queues, sharing is the default mode, and it is the only mode supported.

In shaped mode, the egress queues are guaranteed a percentage of the bandwidth, and they are rate-limited to that amount. Shaped traffic does not use more than the allocated bandwidth even if the link is idle. Shaping provides a more even flow of traffic over time and reduces the peaks and valleys of bursty traffic. With shaping, the absolute value of each weight is used to compute the bandwidth available for the queues.

In shared mode, the queues share the bandwidth among them according to the configured weights. The bandwidth is guaranteed at this level but not limited to it. For example, if a queue is empty and no longer requires a share of the link, the remaining queues can expand into the unused bandwidth and share it among them. With sharing, the ratio of the weights controls the frequency of dequeuing; the absolute values are meaningless.

For more information, see the “Allocating Bandwidth Between the Ingress Queues” section on page 27-65, the “Configuring SRR Shaped Weights on Egress Queues” section on page 27-72, and the “Configuring SRR Shared Weights on Egress Queues” section on page 27-73.
Queueing and Scheduling on Ingress Queues

Figure 27-8 shows the queueing and scheduling flowchart for ingress ports.

**Figure 27-8  Queueing and Scheduling Flowchart for Ingress Ports**

1. Start
2. Read QoS label (DSCP or CoS value).
3. Determine ingress queue number, buffer allocation, and WTD thresholds.
4. Are thresholds being exceeded?
   - Yes
     - Drop packet.
   - No
5. Queue the packet. Service the queue according to the SRR weights.
6. Send packet to the internal ring.

**Note**
SRR services the priority queue for its configured share before servicing the other queue.

The switch supports two configurable ingress queues, which are serviced by SRR in shared mode only. Table 27-1 describes the queues.

<table>
<thead>
<tr>
<th>Queue Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>User traffic that is considered to be normal priority. You can configure three different thresholds to differentiate among the flows. You can use the <code>mls qos srr-queue input threshold</code>, the <code>mls qos srr-queue input dscp-map</code>, and the <code>mls qos srr-queue input cos-map</code> global configuration commands.</td>
</tr>
<tr>
<td>Expedite</td>
<td>High-priority user traffic such as differentiated services (DF) expedited forwarding or voice traffic. You can configure the bandwidth required for this traffic as a percentage of the total traffic by using the <code>mls qos srr-queue input priority-queue</code> global configuration command. The expedite queue has guaranteed bandwidth.</td>
</tr>
</tbody>
</table>

1. The switch uses two nonconfigurable queues for traffic that is essential for proper network operation.
You assign each packet that flows through the switch to a queue and to a threshold. Specifically, you map DSCP or CoS values to an ingress queue and map DSCP or CoS values to a threshold ID. You use the `mls qos srr-queue input dscp-map queue queue-id {dscp1...dscp8 | threshold threshold-id dscp1...dscp8}` or the `mls qos srr-queue input cos-map queue queue-id {cos1...cos8 | threshold threshold-id cos1...cos8}` global configuration command. You can display the DSCP input queue threshold map and the CoS input queue threshold map by using the `show mls qos maps` privileged EXEC command.

**WTD Thresholds**

The queues use WTD to support distinct drop percentages for different traffic classes. Each queue has three drop thresholds: two configurable (explicit) WTD thresholds and one nonconfigurable (implicit) threshold preset to the queue-full state. You assign the two explicit WTD threshold percentages for threshold ID 1 and ID 2 to the ingress queues by using the `mls qos srr-queue input threshold queue-id threshold-percentage1 threshold-percentage2` global configuration command. Each threshold value is a percentage of the total number of allocated buffers for the queue. The drop threshold for threshold ID 3 is preset to the queue-full state, and you cannot modify it. For more information about how WTD works, see the “Weighted Tail Drop” section on page 27-13.

**Buffer and Bandwidth Allocation**

You define the ratio (allocate the amount of space) with which to divide the ingress buffers between the two queues by using the `mls qos srr-queue input buffers percentage1 percentage2` global configuration command. The buffer allocation together with the bandwidth allocation control how much data can be buffered and sent before packets are dropped. You allocate bandwidth as a percentage by using the `mls qos srr-queue input bandwidth weight1 weight2` global configuration command. The ratio of the weights is the ratio of the frequency in which the SRR scheduler sends packets from each queue.

**Priority Queueing**

You can configure one ingress queue as the priority queue by using the `mls qos srr-queue input priority-queue queue-id bandwidth weight` global configuration command. The priority queue should be used for traffic (such as voice) that requires guaranteed delivery because this queue is guaranteed part of the bandwidth regardless of the load on the internal ring.

SRR services the priority queue for its configured weight as specified by the `bandwidth` keyword in the `mls qos srr-queue input priority-queue queue-id bandwidth weight` global configuration command. Then, SRR shares the remaining bandwidth with both ingress queues and services them as specified by the weights configured with the `mls qos srr-queue input bandwidth weight1 weight2` global configuration command.

You can combine the commands described in this section to prioritize traffic by placing packets with particular DSCPs or CoSs into certain queues, by allocating a large queue size or by servicing the queue more frequently, and by adjusting queue thresholds so that packets with lower priorities are dropped. For configuration information, see the “Configuring Ingress Queue Characteristics” section on page 27-63.
Queueing and Scheduling on Egress Queues

Figure 27-9 shows the queueing and scheduling flowchart for egress ports.

Note
If the expedite queue is enabled, SRR services it until it is empty before servicing the other three queues.

Each port supports four egress queues, one of which (queue 1) can be the egress expedite queue. These queues are assigned to a queue-set. All traffic exiting the switch flows through one of these four queues and is subjected to a threshold based on the QoS label assigned to the packet.
Chapter 27 Configuring QoS

Figure 27-10 shows the egress queue buffer. The buffer space is divided between the common pool and the reserved pool. The switch uses a buffer allocation scheme to reserve a minimum amount of buffers for each egress queue, to prevent any queue or port from consuming all the buffers and depriving other queues, and to control whether to grant buffer space to a requesting queue. The switch detects whether the target queue has not consumed more buffers than its reserved amount (under-limit), whether it has consumed all of its maximum buffers (over limit), and whether the common pool is empty (no free buffers) or not empty (free buffers). If the queue is not over-limit, the switch can allocate buffer space from the reserved pool or from the common pool (if it is not empty). If there are no free buffers in the common pool or if the queue is over-limit, the switch drops the frame.

**Figure 27-10  Egress Queue Buffer Allocation**

<table>
<thead>
<tr>
<th>Port 1 queue 1</th>
<th>Port 1 queue 2</th>
<th>Port 1 queue 3</th>
<th>Port 1 queue 4</th>
<th>Port 2 queue 1</th>
<th>Port 2 queue 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Common pool

Reserved pool

Buffer and Memory Allocation

You guarantee the availability of buffers, set drop thresholds, and configure the maximum memory allocation for a queue-set by using the **mls qos queue-set output qset-id threshold queue-id drop-threshold1 drop-threshold2 reserved-threshold maximum-threshold** global configuration command. Each threshold value is a percentage of the queue’s allocated memory, which you specify by using the **mls qos queue-set output qset-id buffers allocation1 ... allocation4** global configuration command. The sum of all the allocated buffers represents the reserved pool, and the remaining buffers are part of the common pool.

Through buffer allocation, you can ensure that high-priority traffic is buffered. For example, if the buffer space is 400, you can allocate 70 percent of it to queue 1 and 10 percent to queues 2 through 4. Queue 1 then has 280 buffers allocated to it, and queues 2 through 4 each have 40 buffers allocated to them.

You can guarantee that the allocated buffers are reserved for a specific queue in a queue-set. For example, if there are 100 buffers for a queue, you can reserve 50 percent (50 buffers). The switch returns the remaining 50 buffers to the common pool. You also can enable a queue in the full condition to obtain more buffers than are reserved for it by setting a maximum threshold. The switch can allocate the needed buffers from the common pool if the common pool is not empty.
WTD Thresholds

You can assign each packet that flows through the switch to a queue and to a threshold. Specifically, you map DSCP or CoS values to an egress queue and map DSCP or CoS values to a threshold ID. You use the `mls qos srr-queue output dscp-map queue queue-id {dscp1...dscp8 | threshold threshold-id dscp1...dscp8}` or the `mls qos srr-queue output cos-map queue queue-id {cos1...cos8 | threshold threshold-id cos1...cos8}` global configuration command. You can display the DSCP output queue threshold map and the CoS output queue threshold map by using the `show mls qos maps` privileged EXEC command.

The queues use WTD to support distinct drop percentages for different traffic classes. Each queue has three drop thresholds: two configurable (explicit) WTD thresholds and one nonconfigurable (implicit) threshold preset to the queue-full state. You assign the two WTD threshold percentages for threshold ID 1 and ID 2. The drop threshold for threshold ID 3 is preset to the queue-full state, and you cannot modify it. For more information about how WTD works, see the “Weighted Tail Drop” section on page 27-13.

Shaped or Shared Mode

SRR services each queue-set in shared or shaped mode. You map a port to a queue-set by using the `queue-set qset-id` interface configuration command. You assign shared or shaped weights to the port by using the `srr-queue bandwidth share weight1 weight2 weight3 weight4` or the `srr-queue bandwidth shape weight1 weight2 weight3 weight4` interface configuration command. For an explanation of the differences between shaping and sharing, see the “SRR Shaping and Sharing” section on page 27-14.

The buffer allocation together with the SRR weight ratios control how much data can be buffered and sent before packets are dropped. The weight ratio is the ratio of the frequency in which the SRR scheduler sends packets from each queue.

All four queues participate in the SRR unless the expedite queue is enabled, in which case the first bandwidth weight is ignored and is not used in the ratio calculation. The expedite queue is a priority queue, and it is serviced until empty before the other queues are serviced. You enable the expedite queue by using the `priority-queue out` interface configuration command.

You can combine the commands described in this section to prioritize traffic by placing packets with particular DSCPs or CoSs into certain queues, by allocating a large queue size or by servicing the queue more frequently, and by adjusting queue thresholds so that packets with lower priorities are dropped. For configuration information, see the “Configuring Egress Queue Characteristics” section on page 27-67.

**Note**
The egress queue default settings are suitable for most situations. You should change them only when you have a thorough understanding of the egress queues and if these settings do not meet your QoS solution.

Packet Modification

A packet is classified, policed, and queued to provide QoS. Packet modifications can occur during this process:

- For IP and non-IP packets, classification involves assigning a QoS label to a packet based on the DSCP or CoS of the received packet. However, the packet is not modified at this stage; only an indication of the assigned DSCP or CoS value is carried along. The reason for this is that QoS classification and forwarding lookups occur in parallel, and it is possible that the packet is forwarded with its original DSCP to the CPU where it is again processed through software.
During policing, IP and non-IP packets can have another DSCP assigned to them (if they are out of profile and the policer specifies a markdown DSCP). Once again, the DSCP in the packet is not modified, but an indication of the marked-down value is carried along. For IP packets, the packet modification occurs at a later stage; for non-IP packets the DSCP is converted to CoS and used for queueing and scheduling decisions.

Depending on the QoS label assigned to a frame and the mutation chosen, the DSCP and CoS values of the frame are rewritten. If you do not configure the mutation map and if you configure the port to trust the DSCP of the incoming frame, the DSCP value in the frame is not changed, but the CoS is rewritten according to the DSCP-to-CoS map. If you configure the port to trust the CoS of the incoming frame and it is an IP packet, the CoS value in the frame is not changed, but the DSCP might be changed according to the CoS-to-DSCP map.

The input mutation causes the DSCP to be rewritten depending on the new value of DSCP chosen. The set action in a policy map also causes the DSCP to be rewritten.

**Configuring Auto-QoS**

You can use the auto-QoS feature to simplify the deployment of existing QoS features. Auto-QoS makes assumptions about the network design, and as a result, the switch can prioritize different traffic flows and appropriately use the ingress and egress queues instead of using the default QoS behavior. (The default is that QoS is disabled. The switch then offers best-effort service to each packet, regardless of the packet contents or size, and sends it from a single queue.)

When you enable auto-QoS, it automatically classifies traffic based on the traffic type and ingress packet label. The switch uses the resulting classification to choose the appropriate egress queue.

You use auto-QoS commands to identify ports connected to Cisco IP Phones and to devices running the Cisco SoftPhone application. You also use the commands to identify ports that receive trusted traffic through an uplink. Auto-QoS then performs these functions:

- Detects the presence or absence of Cisco IP Phones
- Configures QoS classification
- Configures egress queues

These sections contain this configuration information:

- Generated Auto-QoS Configuration, page 27-21
- Effects of Auto-QoS on the Configuration, page 27-25
- Auto-QoS Configuration Guidelines, page 27-25
- Enabling Auto-QoS for VoIP, page 27-26
- Auto-QoS Configuration Example, page 27-27
Generated Auto-QoS Configuration

By default, auto-QoS is disabled on all ports.

When auto-QoS is enabled, it uses the ingress packet label to categorize traffic, to assign packet labels, and to configure the ingress and egress queues as shown in Table 27-2.

### Table 27-2 Traffic Types, Packet Labels, and Queues

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>VoIP Traffic</th>
<th>VoIP Control Traffic</th>
<th>Routing Protocol Traffic</th>
<th>STP BPDU Traffic</th>
<th>Real-Time Video Traffic</th>
<th>All Other Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSCP</td>
<td>46</td>
<td>24, 26</td>
<td>48</td>
<td>56</td>
<td>34</td>
<td>–</td>
</tr>
<tr>
<td>CoS</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>–</td>
</tr>
<tr>
<td>CoS-to-Ingress Queue Map</td>
<td>2, 3, 4, 5, 6, 7 (queue 2)</td>
<td></td>
<td></td>
<td></td>
<td>0, 1 (queue 1)</td>
<td></td>
</tr>
<tr>
<td>CoS-to-Egress Queue Map</td>
<td>5 (queue 1)</td>
<td>3, 6, 7 (queue 2)</td>
<td>4 (queue 3)</td>
<td>2 (queue 3)</td>
<td>0, 1 (queue 4)</td>
<td></td>
</tr>
</tbody>
</table>

1. VoIP = voice over IP

Table 27-3 shows the generated auto-QoS configuration for the ingress queues.

### Table 27-3 Auto-QoS Configuration for the Ingress Queues

<table>
<thead>
<tr>
<th>Ingress Queue</th>
<th>Queue Number</th>
<th>CoS-to-Queue Map</th>
<th>Queue Weight (Bandwidth)</th>
<th>Queue (Buffer) Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRR shared</td>
<td>1</td>
<td>0, 1</td>
<td>81 percent</td>
<td>67 percent</td>
</tr>
<tr>
<td>Priority</td>
<td>2</td>
<td>2, 3, 4, 5, 6, 7</td>
<td>19 percent</td>
<td>33 percent</td>
</tr>
</tbody>
</table>

Table 27-4 shows the generated auto-QoS configuration for the egress queues.

### Table 27-4 Auto-QoS Configuration for the Egress Queues

<table>
<thead>
<tr>
<th>Egress Queue</th>
<th>Queue Number</th>
<th>CoS-to-Queue Map</th>
<th>Queue Weight (Bandwidth)</th>
<th>Queue (Buffer) Size for Gigabit-Capable Ports</th>
<th>Queue (Buffer) Size for 10/100 Ethernet Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority (shaped)</td>
<td>1</td>
<td>5</td>
<td>10 percent</td>
<td>16 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>SRR shared</td>
<td>2</td>
<td>3, 6, 7</td>
<td>10 percent</td>
<td>6 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>SRR shared</td>
<td>3</td>
<td>2, 4</td>
<td>60 percent</td>
<td>17 percent</td>
<td>26 percent</td>
</tr>
<tr>
<td>SRR shared</td>
<td>4</td>
<td>0, 1</td>
<td>20 percent</td>
<td>61 percent</td>
<td>54 percent</td>
</tr>
</tbody>
</table>

When you enable the auto-QoS feature on the first port, these automatic actions occur:

- QoS is globally enabled (`mls qos` global configuration command), and other global configuration commands are added.
- When you enter the `auto qos voip cisco-phone` interface configuration command on a port at the edge of the network that is connected to a Cisco IP Phone, the switch enables the trusted boundary feature. The switch uses the Cisco Discovery Protocol (CDP) to detect the presence or absence of a Cisco IP Phone. When a Cisco IP Phone is detected, the ingress classification on the port is set to...
trust the QoS label received in the packet. When a Cisco IP Phone is absent, the ingress classification is set to not trust the QoS label in the packet. The switch configures ingress and egress queues on the port according to the settings in Table 27-3 and Table 27-4.

- When you enter the `auto qos voip cisco-softphone` interface configuration command on a port at the edge of the network that is connected to a device running the Cisco SoftPhone, the switch uses policing to determine whether a packet is in or out of profile and to specify the action on the packet. If the packet does not have a DSCP value of 24, 26, or 46 or is out of profile, the switch changes the DSCP value to 0. The switch configures ingress and egress queues on the port according to the settings in Table 27-3 and Table 27-4.

- When you enter the `auto qos voip trust` interface configuration command on a port connected to the interior of the network, the switch trusts the CoS value for nonrouted ports in ingress packets (the assumption is that traffic has already been classified by other edge devices). The switch configures the ingress and egress queues on the port according to the settings in Table 27-3 and Table 27-4.

For information about the trusted boundary feature, see the “Configuring a Trusted Boundary to Ensure Port Security” section on page 27-37.

When you enable auto-QoS by using the `auto qos voip cisco-phone`, the `auto qos voip cisco-softphone`, or the `auto qos voip trust` interface configuration command, the switch automatically generates a QoS configuration based on the traffic type and ingress packet label and applies the commands listed in Table 27-5 to the port.

### Table 27-5  Generated Auto-QoS Configuration

<table>
<thead>
<tr>
<th>Description</th>
<th>Automatically Generated Command</th>
</tr>
</thead>
</table>
| The switch automatically enables standard QoS and configures the CoS-to-DSCP map (maps CoS values in incoming packets to a DSCP value). | Switch(config)# mls qos  
Switch(config)# mls qos map cos-dscp 0 8 16 26 32 46 48 56 |
| The switch automatically maps CoS values to an ingress queue and to a threshold ID. | Switch(config)# no mls srr-queue input cos-map  
Switch(config)# mls srr-queue input cos-map queue 1 threshold 3 0  
Switch(config)# mls srr-queue input cos-map queue 1 threshold 2 1  
Switch(config)# mls srr-queue input cos-map queue 2 threshold 1 2  
Switch(config)# mls srr-queue input cos-map queue 2 threshold 2 4 6 7  
Switch(config)# mls srr-queue input cos-map queue 3 threshold 3 3 6 7  
Switch(config)# mls srr-queue input cos-map queue 4 threshold 3 3 5 |
| The switch automatically maps CoS values to an egress queue and to a threshold ID. | Switch(config)# no mls srr-queue output cos-map  
Switch(config)# mls srr-queue output cos-map queue 1 threshold 3 5  
Switch(config)# mls srr-queue output cos-map queue 2 threshold 3 3 6 7  
Switch(config)# mls srr-queue output cos-map queue 3 threshold 3 2 4  
Switch(config)# mls srr-queue output cos-map queue 4 threshold 2 1  
Switch(config)# mls srr-queue output cos-map queue 4 threshold 3 0 |
Table 27-5  Generated Auto-QoS Configuration (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Automatically Generated Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>The switch automatically maps DSCP values to an ingress queue and to a threshold ID.</td>
<td>Switch(config)# no mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 1 threshold 2 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 1 threshold 3 0 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 1 threshold 3 32</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 1 16 17 18 19 20 21 22 23</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 2 33 34 35 36 37 38 39 48</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 2 49 50 51 52 53 54 55 56</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 2 57 58 59 60 61 62 63</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 3 24 25 26 27 28 29 30 31</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 3 40 41 42 43 44 45 46 47</td>
</tr>
<tr>
<td>The switch automatically maps DSCP values to an egress queue and to a threshold ID.</td>
<td>Switch(config)# no mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 1 threshold 3 40 41 42 43 44 45 46 47</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 3 24 25 26 27 28 29 30 31</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 2 49 50 51 52 53 54 55 56</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 2 threshold 2 57 58 59 60 61 62 63</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 3 threshold 3 16 17 18 19 20 21 22 23</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 3 threshold 3 32 33 34 35 36 37 38 39</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 4 threshold 1 8</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 4 threshold 2 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue output dscp-map</td>
</tr>
<tr>
<td></td>
<td>queue 4 threshold 3 0 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>The switch automatically sets up the ingress queues, with queue 2 as the priority queue and queue 1 in shared mode. The switch also configures the bandwidth and buffer size for the ingress queues.</td>
<td>Switch(config)# no mls qos srr-queue input priority-queue 1</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# no mls qos srr-queue input priority-queue 2</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input bandwidth 90 10</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input threshold 1 8 16</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input threshold 2 34 66</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos srr-queue input buffers 67 33</td>
</tr>
</tbody>
</table>
Configuring Auto-QoS

The switch automatically configures the egress queue buffer sizes. It configures the bandwidth and the SRR mode (shaped or shared) on the egress queues mapped to the port.

Switch(config)# mls qos queue-set output 1 threshold 1 138 138 92 138
Switch(config)# mls qos queue-set output 1 threshold 2 138 138 92 400
Switch(config)# mls qos queue-set output 1 threshold 3 36 77 100 318
Switch(config)# mls qos queue-set output 1 threshold 4 20 50 67 400
Switch(config)# mls qos queue-set output 2 threshold 1 149 149 100 149
Switch(config)# mls qos queue-set output 2 threshold 2 118 118 100 235
Switch(config)# mls qos queue-set output 2 threshold 3 41 68 100 272
Switch(config)# mls qos queue-set output 2 threshold 4 42 72 100 242
Switch(config-if)# srr-queue bandwidth shape 10 0 0
Switch(config-if)# srr-queue bandwidth share 10 10

If you entered the `auto qos voip trust` command, the switch automatically sets the ingress classification to trust the CoS value received in the packet on a nonrouted port by using the `mls qos trust cos` command.

Switch(config-if)# mls qos trust cos
Switch(config-if)# mls qos trust dscp

If you entered the `auto qos voip cisco-phone` command, the switch automatically enables the trusted boundary feature, which uses the CDP to detect the presence or absence of a Cisco IP Phone.

Switch(config-if)# mls qos trust device cisco-phone

If you entered the `auto qos voip cisco-softphone` command, the switch automatically creates class maps and policy maps.

Switch(config)# mls qos map policed-dscp 24 26 46 to 0
Switch(config)# class-map match-all AutoQoS-VoIP-RTP-Trust
Switch(config-cmap)# match ip dscp ef
Switch(config)# class-map match-all AutoQoS-VoIP-Control-Trust
Switch(config-cmap)# match ip dscp cs3 af31
Switch(config)# policy-map AutoQoS-Police-SoftPhone
Switch(config-pmap)# class AutoQoS-VoIP-RTP-Trust
Switch(config-pmap-c)# set dscp ef
Switch(config-pmap-c)# police 320000 8000
exceed-action policed-dscp-transmit
Switch(config-pmap-c)# class AutoQoS-VoIP-Control-Trust
Switch(config-pmap-c)# set dscp cs3
Switch(config-pmap-c)# police 320000 8000
exceed-action policed-dscp-transmit

After creating the class maps and policy maps, the switch automatically applies the policy map called `AutoQoS-Police-SoftPhone` to an ingress interface on which auto-QoS with the Cisco SoftPhone feature is enabled.

Switch(config-if)# service-policy input AutoQoS-Police-SoftPhone

Table 27-5  Generated Auto-QoS Configuration (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Automatically Generated Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>The switch automatically configures the egress queue buffer sizes. It configures the bandwidth and the SRR mode (shaped or shared) on the egress queues mapped to the port.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 1 threshold 1 138 138 92 138</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 1 threshold 2 138 138 92 400</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 1 threshold 3 36 77 100 318</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 1 threshold 4 20 50 67 400</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 2 threshold 1 149 149 100 149</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 2 threshold 2 118 118 100 235</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 2 threshold 3 41 68 100 272</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos queue-set output 2 threshold 4 42 72 100 242</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# srr-queue bandwidth shape 10 0 0</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# srr-queue bandwidth share 10 10</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# mls qos trust cos</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# mls qos trust dscp</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# mls qos trust device cisco-phone</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# mls qos map policed-dscp 24 26 46 to 0</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# class-map match-all AutoQoS-VoIP-RTP-Trust</td>
</tr>
<tr>
<td></td>
<td>Switch(config-cmap)# match ip dscp ef</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# class-map match-all AutoQoS-VoIP-Control-Trust</td>
</tr>
<tr>
<td></td>
<td>Switch(config-cmap)# match ip dscp cs3 af31</td>
</tr>
<tr>
<td></td>
<td>Switch(config)# policy-map AutoQoS-Police-SoftPhone</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap)# class AutoQoS-VoIP-RTP-Trust</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# set dscp ef</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# police 320000 8000</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# exceed-action policed-dscp-transmit</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# class AutoQoS-VoIP-Control-Trust</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# set dscp cs3</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# police 320000 8000</td>
</tr>
<tr>
<td></td>
<td>Switch(config-pmap-c)# exceed-action policed-dscp-transmit</td>
</tr>
<tr>
<td></td>
<td>Switch(config-if)# service-policy input AutoQoS-Police-SoftPhone</td>
</tr>
</tbody>
</table>
Effects of Auto-QoS on the Configuration

When auto-QoS is enabled, the `auto qos voip` interface configuration command and the generated configuration are added to the running configuration.

The switch applies the auto-QoS-generated commands as if the commands were entered from the CLI. An existing user configuration can cause the application of the generated commands to fail or to be overridden by the generated commands. These actions occur without warning. If all the generated commands are successfully applied, any user-entered configuration that was not overridden remains in the running configuration. Any user-entered configuration that was overridden can be retrieved by reloading the switch without saving the current configuration to memory. If the generated commands fail to be applied, the previous running configuration is restored.

Auto-QoS Configuration Guidelines

Before configuring auto-QoS, you should be aware of this information:

- Auto-QoS configures the switch for VoIP with Cisco IP Phones on nonrouted and routed ports. Auto-QoS also configures the switch for VoIP with devices running the Cisco SoftPhone application.

  **Note** When a device running Cisco SoftPhone is connected to a nonrouted or routed port, the switch supports only one Cisco SoftPhone application per port.

  - To take advantage of the auto-QoS defaults, you should enable auto-QoS before you configure other QoS commands. If necessary, you can fine-tune the QoS configuration, but we recommend that you do so only after the auto-QoS configuration is completed. For more information, see the “Effects of Auto-QoS on the Configuration” section on page 27-25.
  
  - After auto-QoS is enabled, do not modify a policy map or aggregate policer that includes `AutoQoS` in its name. If you need to modify the policy map or aggregate policer, make a copy of it, and change the copied policy map or policer. To use this new policy map instead of the generated one, remove the generated policy map from the interface, and apply the new policy map to the interface.
  
  - You can enable auto-QoS on static, dynamic-access, voice VLAN access, and trunk ports.
  
  - By default, the CDP is enabled on all ports. For auto-QoS to function properly, do not disable the CDP.
  
  - When enabling auto-QoS with a Cisco IP Phone on a routed port, you must assign a static IP address to the IP phone.
  
  - This release supports only Cisco IP SoftPhone Version 1.3(3) or later.
  
  - Connected devices must use Cisco Call Manager Version 4 or later.
Enabling Auto-QoS for VoIP

Beginning in privileged EXEC mode, follow these steps to enable auto-QoS for VoIP within a QoS domain:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong>&lt;br&gt;configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong>&lt;br&gt;interface interface-id</td>
<td>Specify the port that is connected to a Cisco IP Phone, the port that is connected to a device running the Cisco SoftPhone feature, or the uplink port that is connected to another trusted switch or router in the interior of the network, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong>&lt;br&gt;auto qos voip [cisco-phone</td>
<td>Enabling Auto-QoS.</td>
</tr>
<tr>
<td></td>
<td>cisco-softphone</td>
</tr>
<tr>
<td></td>
<td>trust]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong>&lt;br&gt;end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong>&lt;br&gt;show auto qos interface interface-id</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td>This command displays the auto-QoS command on the interface on which auto-QoS was enabled. You can use the show running-config privileged EXEC command to display the auto-QoS configuration and the user modifications.</td>
</tr>
</tbody>
</table>

To display the QoS commands that are automatically generated when auto-QoS is enabled or disabled, enter the `debug auto qos` privileged EXEC command before enabling auto-QoS. For more information, see the `debug autoqos` command in the command reference or this release.

To disable auto-QoS on a port, use the `no auto qos voip` interface configuration command. Only the auto-QoS-generated interface configuration commands for this port are removed. If this is the last port on which auto-QoS is enabled and you enter the `no auto qos voip` command, auto-QoS is considered disabled even though the auto-QoS-generated global configuration commands remain (to avoid disrupting traffic on other ports affected by the global configuration).

You can use the `no mls qos` global configuration command to disable the auto-QoS-generated global configuration commands. With QoS disabled, there is no concept of trusted or untrusted ports because the packets are not modified (the CoS, DSCP, and IP precedence values in the packet are not changed). Traffic is switched in pass-through mode (packets are switched without any rewrites and classified as best effort without any policing).

This example shows how to enable auto-QoS and to trust the QoS labels received in incoming packets when the switch or router connected to a port is a trusted device:

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# auto qos voip trust
```
Auto-QoS Configuration Example

This section describes how you could implement auto-QoS in a network, as shown in Figure 27-11. For optimum QoS performance, enable auto-QoS on all the devices in the network.

Figure 27-11  Auto-QoS Configuration Example Network

Figure 27-11 shows a network in which the VoIP traffic is prioritized over all other traffic. Auto-QoS is enabled on the switches in the wiring closets at the edge of the QoS domain.
You should not configure any standard QoS commands before entering the auto-QoS commands. You can fine-tune the QoS configuration, but we recommend that you do so only after the auto-QoS configuration is completed.

Beginning in privileged EXEC mode, follow these steps to configure the switch at the edge of the QoS domain to prioritize the VoIP traffic over all other traffic:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>debug auto qos</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>cdp enable</strong></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>auto qos voip cisco-phone</strong></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><strong>exit</strong></td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td><strong>interface interface-id</strong></td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td><strong>auto qos voip trust</strong></td>
</tr>
<tr>
<td><strong>Step 10</strong></td>
<td><strong>end</strong></td>
</tr>
<tr>
<td><strong>Step 11</strong></td>
<td><strong>show auto qos</strong></td>
</tr>
<tr>
<td><strong>Step 12</strong></td>
<td><strong>copy running-config startup-config</strong></td>
</tr>
</tbody>
</table>
Displaying Auto-QoS Information

To display the initial auto-QoS configuration, use the `show auto qos [interface [interface-id]]` privileged EXEC command. To display any user changes to that configuration, use the `show running-config` privileged EXEC command. You can compare the `show auto qos` and the `show running-config` command output to identify the user-defined QoS settings.

To display information about the QoS configuration that might be affected by auto-QoS, use one of these commands:

- `show mls qos`  
- `show mls qos maps cos-dscp`  
- `show mls qos interface [interface-id] [buffers | queueing]`  
- `show mls qos maps [cos-dscp | cos-input-q | cos-output-q | dscp-cos | dscp-input-q | dscp-output-q]`  
- `show mls qos input-queue`  
- `show running-config`

For more information about these commands, see the command reference for this release.

Configuring Standard QoS

Before configuring standard QoS, you must have a thorough understanding of these items:

- The types of applications used and the traffic patterns on your network.
- Traffic characteristics and needs of your network. Is the traffic bursty? Do you need to reserve bandwidth for voice and video streams?
- Bandwidth requirements and speed of the network.
- Location of congestion points in the network.

These sections contain this configuration information:

- Default Standard QoS Configuration, page 27-30
- Standard QoS Configuration Guidelines, page 27-32
- Enabling QoS Globally, page 27-34 (required)
- Enabling VLAN-Based QoS on Physical Ports, page 27-34 (optional)
- Configuring Classification Using Port Trust States, page 27-35 (required)
- Configuring a QoS Policy, page 27-41 (required)
- Configuring DSCP Maps, page 27-57 (optional, unless you need to use the DSCP-to-DSCP-mutation map or the policed-DSCP map)
- Configuring Ingress Queue Characteristics, page 27-63 (optional)
- Configuring Egress Queue Characteristics, page 27-67 (optional)
Default Standard QoS Configuration

QoS is disabled. There is no concept of trusted or untrusted ports because the packets are not modified (the CoS, DSCP, and IP precedence values in the packet are not changed). Traffic is switched in pass-through mode (packets are switched without any rewrites and classified as best effort without any policing).

When QoS is enabled with the `mls qos` global configuration command and all other QoS settings are at their defaults, traffic is classified as best effort (the DSCP and CoS value is set to 0) without any policing. No policy maps are configured. The default port trust state on all ports is untrusted. The default ingress and egress queue settings are described in the “Default Ingress Queue Configuration” section on page 27-30 and the “Default Egress Queue Configuration” section on page 27-31.

Default Ingress Queue Configuration

Table 27-6 shows the default ingress queue configuration when QoS is enabled.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Queue 1</th>
<th>Queue 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer allocation</td>
<td>90 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>Bandwidth allocation (^1)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Priority queue bandwidth (^2)</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>WTD drop threshold 1</td>
<td>100 percent</td>
<td>100 percent</td>
</tr>
<tr>
<td>WTD drop threshold 2</td>
<td>100 percent</td>
<td>100 percent</td>
</tr>
</tbody>
</table>

1. The bandwidth is equally shared between the queues. SRR sends packets in shared mode only.
2. Queue 2 is the priority queue. SRR services the priority queue for its configured share before servicing the other queue.

Table 27-7 shows the default CoS input queue threshold map when QoS is enabled.

<table>
<thead>
<tr>
<th>CoS Value</th>
<th>Queue ID–Threshold ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–4</td>
<td>1–1</td>
</tr>
<tr>
<td>5</td>
<td>2–1</td>
</tr>
<tr>
<td>6, 7</td>
<td>1–1</td>
</tr>
</tbody>
</table>

Table 27-8 shows the default DSCP input queue threshold map when QoS is enabled.

<table>
<thead>
<tr>
<th>DSCP Value</th>
<th>Queue ID–Threshold ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–39</td>
<td>1–1</td>
</tr>
<tr>
<td>40–47</td>
<td>2–1</td>
</tr>
<tr>
<td>48–63</td>
<td>1–1</td>
</tr>
</tbody>
</table>
Default Egress Queue Configuration

Table 27-9 shows the default egress queue configuration for each queue-set when QoS is enabled. All ports are mapped to queue-set 1. The port bandwidth limit is set to 100 percent and rate unlimited.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Queue 1</th>
<th>Queue 2</th>
<th>Queue 3</th>
<th>Queue 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer allocation</td>
<td>25 percent</td>
<td>25 percent</td>
<td>25 percent</td>
<td>25 percent</td>
</tr>
<tr>
<td>WTD drop threshold 1</td>
<td>100 percent</td>
<td>200 percent</td>
<td>100 percent</td>
<td>100 percent</td>
</tr>
<tr>
<td>WTD drop threshold 2</td>
<td>100 percent</td>
<td>200 percent</td>
<td>100 percent</td>
<td>100 percent</td>
</tr>
<tr>
<td>Reserved threshold</td>
<td>50 percent</td>
<td>50 percent</td>
<td>50 percent</td>
<td>50 percent</td>
</tr>
<tr>
<td>Maximum threshold</td>
<td>400 percent</td>
<td>400 percent</td>
<td>400 percent</td>
<td>400 percent</td>
</tr>
<tr>
<td>SRR shaped weights (absolute) (^1)</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SRR shared weights (^2)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

1. A shaped weight of zero means that this queue is operating in shared mode.
2. One quarter of the bandwidth is allocated to each queue.

Table 27-10 shows the default CoS output queue threshold map when QoS is enabled.

<table>
<thead>
<tr>
<th>CoS Value</th>
<th>Queue ID–Threshold ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 1</td>
<td>2–1</td>
</tr>
<tr>
<td>2, 3</td>
<td>3–1</td>
</tr>
<tr>
<td>4</td>
<td>4–1</td>
</tr>
<tr>
<td>5</td>
<td>1–1</td>
</tr>
<tr>
<td>6, 7</td>
<td>4–1</td>
</tr>
</tbody>
</table>

Table 27-11 shows the default DSCP output queue threshold map when QoS is enabled.

<table>
<thead>
<tr>
<th>DSCP Value</th>
<th>Queue ID–Threshold ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–15</td>
<td>2–1</td>
</tr>
<tr>
<td>16–31</td>
<td>3–1</td>
</tr>
<tr>
<td>32–39</td>
<td>4–1</td>
</tr>
<tr>
<td>40–47</td>
<td>1–1</td>
</tr>
<tr>
<td>48–63</td>
<td>4–1</td>
</tr>
</tbody>
</table>
Configuring Standard QoS

Default Mapping Table Configuration

The default CoS-to-DSCP map is shown in Table 27-12 on page 27-58.
The default IP-precedence-to-DSCP map is shown in Table 27-13 on page 27-59.
The default DSCP-to-CoS map is shown in Table 27-14 on page 27-61.
The default DSCP-to-DSCP-mutation map is a null map, which maps an incoming DSCP value to the same DSCP value.
The default policed-DSCP map is a null map, which maps an incoming DSCP value to the same DSCP value (no markdown).

Standard QoS Configuration Guidelines

Before beginning the QoS configuration, you should be aware of this information in these sections:

- “QoS ACL Guidelines” section on page 27-32
- “Applying QoS on Interfaces” section on page 27-32
- “Policing Guidelines” section on page 27-33
- “General QoS Guidelines” section on page 27-33

QoS ACL Guidelines

These are the guidelines for configuring QoS with access control lists (ACLs):

- It is not possible to match IP fragments against configured IP extended ACLs to enforce QoS. IP fragments are sent as best-effort. IP fragments are denoted by fields in the IP header.
- Only one ACL per class map and only one match class-map configuration command per class map are supported. The ACL can have multiple ACEs, which match fields against the contents of the packet.
- A trust statement in a policy map requires multiple TCAM entries per ACL line. If an input service policy map contains a trust statement in an ACL, the access-list might be too large to fit into the available QoS TCAM and an error can occur when you apply the policy map to a port. Whenever possible, you should minimize the number of lines in a QoS ACL.

Applying QoS on Interfaces

These are the guidelines for configuring QoS on physical ports:

- You can configure QoS on physical ports and SVIs. When configuring QoS on physical ports, you create and apply nonhierarchical policy maps. When configuring QoS on SVIs, you can create and apply nonhierarchical and hierarchical policy maps.
- Incoming traffic is classified, policed, and marked down (if configured) regardless of whether the traffic is bridged, routed, or sent to the CPU. It is possible for bridged frames to be dropped or to have their DSCP and CoS values modified.
Follow these guidelines when configuring policy maps on physical ports or SVIs:

- You cannot apply the same policy map to a physical port and to an SVI.
- If VLAN-based QoS is configured on a physical port, the switch removes all the port-based policy maps on the port. The traffic on this physical port is now affected by the policy map attached to the SVI to which the physical port belongs.
- In a hierarchical policy map attached to an SVI, you can only configure an individual policer at the interface level on a physical port to specify the bandwidth limits for the traffic on the port. The ingress port must be configured as a trunk or as a static-access port. You cannot configure policers at the VLAN level of the hierarchical policy map.
- The switch does not support aggregate policers in hierarchical policy maps.
- After the hierarchical policy map is attached to an SVI, the interface-level policy map cannot be modified or removed from the hierarchical policy map. A new interface-level policy map also cannot be added to the hierarchical policy map. If you want these changes to occur, the hierarchical policy map must first be removed from the SVI. You also cannot add or remove a class map specified in the hierarchical policy map.

**Policing Guidelines**

These are the policing guidelines:

- The port ASIC device, which controls more than one physical port, supports 256 policers (255 user-configurable policers plus 1 policer reserved for system internal use). The maximum number of user-configurable policers supported per port is 63. Policers are allocated on demand by the software and are constrained by the hardware and ASIC boundaries. You cannot reserve policers per port; there is no guarantee that a port will be assigned to any policer.
- Only one policer is applied to a packet on an ingress port. Only the average rate and committed burst parameters are configurable.
- You can create an aggregate policer that is shared by multiple traffic classes within the same nonhierarchical policy map. However, you cannot use the aggregate policer across different policy maps.
- On a port configured for QoS, all traffic received through the port is classified, policed, and marked according to the policy map attached to the port. On a trunk port configured for QoS, traffic in all VLANs received through the port is classified, policed, and marked according to the policy map attached to the port.
- If you have EtherChannel ports configured on your switch, you must configure QoS classification, policing, mapping, and queueing on the individual physical ports that comprise the EtherChannel. You must decide whether the QoS configuration should match on all ports in the EtherChannel.

**General QoS Guidelines**

These are general QoS guidelines:

- Control traffic (such as spanning-tree bridge protocol data units [BPDUs] and routing update packets) received by the switch are subject to all ingress QoS processing.
- You are likely to lose data when you change queue settings; therefore, try to make changes when traffic is at a minimum.
Enabling QoS Globally

By default, QoS is disabled on the switch.

Beginning in privileged EXEC mode, follow these steps to enable QoS. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> mls qos</td>
<td>Enable QoS globally. QoS runs with the default settings described in the “Default Standard QoS Configuration” section on page 27-30, the “Queueing and Scheduling on Ingress Queues” section on page 27-15, and the “Queueing and Scheduling on Egress Queues” section on page 27-17.</td>
</tr>
<tr>
<td><strong>Step 3</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong> show mls qos</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 5</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable QoS, use the **no mls qos** global configuration command.

Enabling VLAN-Based QoS on Physical Ports

By default, VLAN-based QoS is disabled on all physical switch ports. The switch applies QoS, including class maps and policy maps, only on a physical-port basis. You can enable VLAN-based QoS on a switch port.

Beginning in privileged EXEC mode, follow these steps to enable VLAN-based QoS. This procedure is required on physical ports that are specified in the interface level of a hierarchical policy map on an SVI.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> interface interface-id</td>
<td>Specify the physical port, and enter interface configuration mode.</td>
</tr>
<tr>
<td><strong>Step 3</strong> mls qos vlan-based</td>
<td>Enable VLAN-based QoS on the port.</td>
</tr>
<tr>
<td><strong>Step 4</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong> show mls qos interface interface-id</td>
<td>Verify if VLAN-based QoS is enabled on the physical port.</td>
</tr>
<tr>
<td><strong>Step 6</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Use the **no mls qos vlan-based** interface configuration command to disable VLAN-based QoS on the physical port.
Configuring Classification Using Port Trust States

These sections describe how to classify incoming traffic by using port trust states. Depending on your network configuration, you must perform one or more of these tasks or one or more of the tasks in the “Configuring a QoS Policy” section on page 27-41:

- Configuring the Trust State on Ports within the QoS Domain, page 27-35
- Configuring the CoS Value for an Interface, page 27-37
- Configuring a Trusted Boundary to Ensure Port Security, page 27-37
- Enabling DSCP Transparency Mode, page 27-39
- Configuring the DSCP Trust State on a Port Bordering Another QoS Domain, page 27-39

Configuring the Trust State on Ports within the QoS Domain

Packets entering a QoS domain are classified at the edge of the QoS domain. When the packets are classified at the edge, the switch port within the QoS domain can be configured to one of the trusted states because there is no need to classify the packets at every switch within the QoS domain. Figure 27-12 shows a sample network topology.
Beginning in privileged EXEC mode, follow these steps to configure the port to trust the classification of the traffic that it receives:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td><strong>configure terminal</strong></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
</tr>
<tr>
<td><strong>interface interface-id</strong></td>
<td>Specify the port to be trusted, and enter interface configuration mode. Valid interfaces include physical ports.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>**mls qos trust [cos</td>
<td>dscp</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>cos</strong>—Classifies an ingress packet by using the packet CoS value. For an untagged packet, the port default CoS value is used. The default port CoS value is 0.</td>
</tr>
<tr>
<td></td>
<td>• <strong>dscp</strong>—Classifies an ingress packet by using the packet DSCP value. For a non-IP packet, the packet CoS value is used if the packet is tagged; for an untagged packet, the default port CoS is used. Internally, the switch maps the CoS value to a DSCP value by using the CoS-to-DSCP map.</td>
</tr>
<tr>
<td></td>
<td>• <strong>ip-precedence</strong>—Classifies an ingress packet by using the packet IP-precedence value. For a non-IP packet, the packet CoS value is used if the packet is tagged; for an untagged packet, the default port CoS is used. Internally, the switch maps the CoS value to a DSCP value by using the CoS-to-DSCP map.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td></td>
</tr>
<tr>
<td><strong>end</strong></td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td></td>
</tr>
<tr>
<td><strong>show mls qos interface</strong></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td></td>
</tr>
<tr>
<td><strong>copy running-config startup-config</strong></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return a port to its untrusted state, use the **no mls qos trust** interface configuration command.

For information on how to change the default CoS value, see the “Configuring the CoS Value for an Interface” section on page 27-37. For information on how to configure the CoS-to-DSCP map, see the “Configuring the CoS-to-DSCP Map” section on page 27-58.
Configuring the CoS Value for an Interface

QoS assigns the CoS value specified with the `mls qos cos` interface configuration command to untagged frames received on trusted and untrusted ports.

Beginning in privileged EXEC mode, follow these steps to define the default CoS value of a port or to assign the default CoS to all incoming packets on the port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>mls qos cos {default-cos</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show mls qos interface</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no mls qos cos {default-cos | override}` interface configuration command.

Configuring a Trusted Boundary to Ensure Port Security

In a typical network, you connect a Cisco IP Phone to a switch port, as shown in Figure 27-12 on page 27-35, and cascade devices that generate data packets from the back of the telephone. The Cisco IP Phone guarantees the voice quality through a shared data link by marking the CoS level of the voice packets as high priority (CoS = 5) and by marking the data packets as low priority (CoS = 0). Traffic sent from the telephone to the switch is typically marked with a tag that uses the 802.1Q header. The header contains the VLAN information and the class of service (CoS) 3-bit field, which is the priority of the packet.

For most Cisco IP Phone configurations, the traffic sent from the telephone to the switch should be trusted to ensure that voice traffic is properly prioritized over other types of traffic in the network. By using the `mls qos trust cos` interface configuration command, you configure the switch port to which
the telephone is connected to trust the CoS labels of all traffic received on that port. Use the `mls qos trust dscp` interface configuration command to configure a routed port to which the telephone is connected to trust the DSCP labels of all traffic received on that port.

With the trusted setting, you also can use the trusted boundary feature to prevent misuse of a high-priority queue if a user bypasses the telephone and connects the PC directly to the switch. Without trusted boundary, the CoS labels generated by the PC are trusted by the switch (because of the trusted CoS setting). By contrast, trusted boundary uses CDP to detect the presence of a Cisco IP Phone (such as the Cisco IP Phone 7910, 7935, 7940, and 7960) on a switch port. If the telephone is not detected, the trusted boundary feature disables the trusted setting on the switch port and prevents misuse of a high-priority queue. Note that the trusted boundary feature is not effective if the PC and Cisco IP Phone are connected to a hub that is connected to the switch.

In some situations, you can prevent a PC connected to the Cisco IP Phone from taking advantage of a high-priority data queue. You can use the `switchport priority extend cos` interface configuration command to configure the telephone through the switch CLI to override the priority of the traffic received from the PC.

Beginning in privileged EXEC mode, follow these steps to enable trusted boundary on a port:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><code>configure terminal</code> Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>cdp run</code> Enable CDP globally. By default, CDP is enabled.</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>interface interface-id</code> Specify the port connected to the Cisco IP Phone, and enter interface configuration mode. Valid interfaces include physical ports.</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>cdp enable</code> Enable CDP on the port. By default, CDP is enabled.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>mls qos trust cos</code> Configure the switch port to trust the CoS value in traffic received from the Cisco IP Phone. Or <code>mls qos trust dscp</code> Configure the routed port to trust the DSCP value in traffic received from the Cisco IP Phone. By default, the port is not trusted.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>mls qos trust device cisco-phone</code> Specify that the Cisco IP Phone is a trusted device. You cannot enable both trusted boundary and auto-QoS (<code>auto qos voip</code> interface configuration command) at the same time; they are mutually exclusive.</td>
</tr>
<tr>
<td>Step 7</td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 8</td>
<td><code>show mls qos interface</code> Verify your entries.</td>
</tr>
<tr>
<td>Step 9</td>
<td><code>copy running-config startup-config</code> (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable the trusted boundary feature, use the `no mls qos trust device` interface configuration command.
Enabling DSCP Transparency Mode

The switch supports the DSCP transparency feature. It affects only the DSCP field of a packet at egress. By default, DSCP transparency is disabled. The switch modifies the DSCP field in an incoming packet, and the DSCP field in the outgoing packet is based on the quality of service (QoS) configuration, including the port trust setting, policing and marking, and the DSCP-to-DSCP mutation map.

If DSCP transparency is enabled by using the `no mls qos rewrite ip dscp` command, the switch does not modify the DSCP field in the incoming packet, and the DSCP field in the outgoing packet is the same as that in the incoming packet.

Regardless of the DSCP transparency configuration, the switch modifies the internal DSCP value of the packet, which the switch uses to generate a class of service (CoS) value that represents the priority of the traffic. The switch also uses the internal DSCP value to select an egress queue and threshold.

Beginning in privileged EXEC mode, follow these steps to enable DSCP transparency on a switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>mls qos</td>
</tr>
<tr>
<td>Step 3</td>
<td>no mls qos rewrite ip dscp</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show mls qos interface [interface-id]</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To configure the switch to modify the DSCP value based on the trust setting or on an ACL by disabling DSCP transparency, use the `mls qos rewrite ip dscp` global configuration command.

If you disable QoS by using the `no mls qos` global configuration command, the CoS and DSCP values are not changed (the default QoS setting).

If you enter the `no mls qos rewrite ip dscp` global configuration command to enable DSCP transparency and then enter the `mls qos trust [cos | dscp]` interface configuration command, DSCP transparency is still enabled.

Configuring the DSCP Trust State on a Port Bordering Another QoS Domain

If you are administering two separate QoS domains between which you want to implement QoS features for IP traffic, you can configure the switch ports bordering the domains to a DSCP-trusted state as shown in Figure 27-13. Then the receiving port accepts the DSCP-trusted value and avoids the classification stage of QoS. If the two domains use different DSCP values, you can configure the DSCP-to-DSCP-mutation map to translate a set of DSCP values to match the definition in the other domain.
Beginning in privileged EXEC mode, follow these steps to configure the DSCP-trusted state on a port and modify the DSCP-to-DSCP-mutation map. To ensure a consistent mapping strategy across both QoS domains, you must perform this procedure on the ports in both domains:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>mls qos map dscp-mutation</td>
</tr>
<tr>
<td></td>
<td>dscp-mutation-name in-dscp to out-dscp</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>mls qos trust dscp</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>mls qos dscp-mutation</td>
</tr>
<tr>
<td></td>
<td>dscp-mutation-name</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>show mls qos maps dscp-mutation</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>
To return a port to its non-trusted state, use the `no mls qos trust` interface configuration command. To return to the default DSCP-to-DSCP-mutation map values, use the `no mls qos map dscp-mutation dscp-mutation-name` global configuration command.

This example shows how to configure a port to the DSCP-trusted state and to modify the DSCP-to-DSCP-mutation map (named `gi0/2-mutation`) so that incoming DSCP values 10 to 13 are mapped to DSCP 30:

```
Switch(config)# mls qos map dscp-mutation gi0/2-mutation 10 11 12 13 to 30
Switch(config)# interface gigabitethernet0/2
Switch(config-if)# mls qos trust dscp
Switch(config-if)# mls qos dscp-mutation gi0/2-mutation
Switch(config-if)# end
```

**Configuring a QoS Policy**

Configuring a QoS policy typically requires classifying traffic into classes, configuring policies applied to those traffic classes, and attaching policies to ports.

For background information, see the “Classification” section on page 27-5 and the “Policing and Marking” section on page 27-8. For configuration guidelines, see the “Standard QoS Configuration Guidelines” section on page 27-32.

These sections describe how to classify, police, and mark traffic. Depending on your network configuration, you must perform one or more of these tasks:

- Classifying Traffic by Using ACLs, page 27-42
- Classifying Traffic by Using Class Maps, page 27-45
- Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps, page 27-50
- Classifying, Policing, and Marking Traffic by Using Aggregate Policers, page 27-55
Classifying Traffic by Using ACLs

You can classify IP traffic by using IP standard or IP extended ACLs; you can classify non-IP traffic by using Layer 2 MAC ACLs.

Beginning in privileged EXEC mode, follow these steps to create an IP standard ACL for IP traffic:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>access-list access-list-number [deny</td>
</tr>
<tr>
<td></td>
<td>permit] source [source-wildcard]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>show access-lists</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To delete an access list, use the **no access-list access-list-number** global configuration command.

This example shows how to allow access for only those hosts on the three specified networks. The wildcard bits apply to the host portions of the network addresses. Any host with a source address that does not match the access list statements is rejected.

```
Switch(config)# access-list 1 permit 192.5.255.0 0.0.0.255
Switch(config)# access-list 1 permit 128.88.0.0 0.0.255.255
Switch(config)# access-list 1 permit 36.0.0.0 0.0.0.255
! (Note: all other access implicitly denied)
```
Beginning in privileged EXEC mode, follow these steps to create an IP extended ACL for IP traffic:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>access-list access-list-number {deny</td>
<td>permit} protocol source source-wildcard destination destination-wildcard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For access-list-number, enter the access list number. The range is 100 to 199 and 2000 to 2699.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use the permit keyword to permit a certain type of traffic if the conditions are matched. Use the deny keyword to deny a certain type of traffic if conditions are matched.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For protocol, enter the name or number of an IP protocol. Use the question mark (?) to see a list of available protocol keywords.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For source, enter the network or host from which the packet is being sent. You specify this by using dotted decimal notation, by using the any keyword as an abbreviation for source 0.0.0.0 source-wildcard 255.255.255.255, or by using the host keyword for source 0.0.0.0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For source-wildcard, enter the wildcard bits by placing ones in the bit positions that you want to ignore. You specify the wildcard by using dotted decimal notation, by using the any keyword as an abbreviation for source 0.0.0.0 source-wildcard 255.255.255.255, or by using the host keyword for source 0.0.0.0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For destination, enter the network or host to which the packet is being sent. You have the same options for specifying the destination and destination-wildcard as those described by source and source-wildcard.</td>
</tr>
</tbody>
</table>

| Note | When creating an access list, remember that, by default, the end of the access list contains an implicit deny statement for everything if it did not find a match before reaching the end. |

<table>
<thead>
<tr>
<th>Step 3</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>show access-lists</td>
<td>Verify your entries.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 5</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To delete an access list, use the no access-list access-list-number global configuration command.

This example shows how to create an ACL that permits IP traffic from any source to any destination that has the DSCP value set to 32:

```
Switch(config)# access-list 100 permit ip any any dscp 32
```

This example shows how to create an ACL that permits IP traffic from a source host at 10.1.1.1 to a destination host at 10.1.1.2 with a precedence value of 5:

```
Switch(config)# access-list 100 permit ip host 10.1.1.1 host 10.1.1.2 precedence 5
```

This example shows how to create an ACL that permits PIM traffic from any source to a destination group address of 224.0.0.2 with a DSCP set to 32:

```
Switch(config)# access-list 102 permit pim any 224.0.0.2 dscp 32
```
Beginning in privileged EXEC mode, follow these steps to create a Layer 2 MAC ACL for non-IP traffic:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>mac access-list extended name</td>
</tr>
<tr>
<td>Step 3</td>
<td>{permit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show access-lists [access-list-number</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To delete an access list, use the no mac access-list extended access-list-name global configuration command.

This example shows how to create a Layer 2 MAC ACL with two permit statements. The first statement allows traffic from the host with MAC address 0001.0000.0001 to the host with MAC address 0002.0000.0001. The second statement allows only Ethertype XNS-IDP traffic from the host with MAC address 0001.0000.0002 to the host with MAC address 0002.0000.0002.

```
Switch(config)# mac access-list extended maclist1
Switch(config-ext-macl)# permit 0001.0000.0001 0.0.0 0002.0000.0001 0.0.0
Switch(config-ext-macl)# permit 0001.0000.0002 0.0.0 0002.0000.0002 0.0.0 xns-idp
! (Note: all other access implicitly denied)
```
Classifying Traffic by Using Class Maps

You use the class-map global configuration command to name and to isolate a specific traffic flow (or class) from all other traffic. The class map defines the criteria to use to match against a specific traffic flow to further classify it. Match statements can include criteria such as an ACL, IP precedence values, or DSCP values. The match criterion is defined with one match statement entered within the class-map configuration mode.

Note
You can also create class-maps during policy map creation by using the class policy-map configuration command. For more information, see the “Classifying, Policing, and Marking Traffic on Physical Ports by Using Policy Maps” section on page 27-47 and the “Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps” section on page 27-50.

Beginning in privileged EXEC mode, follow these steps to create a class map and to define the match criterion to classify traffic:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
</tbody>
</table>

| Step 2                        | access-list access-list-number {deny | Create an IP standard or extended ACL for IP traffic or a Layer 2 MAC ACL for non-IP traffic, repeating the command as many times as necessary. For more information, see the “Classifying Traffic by Using ACLs” section on page 27-42. |
|                               | permit} source [source-wildcard]  |                                                                         |
|                               | or                              |                                                                         |
|                               | access-list access-list-number {deny |                                                                         |
|                               | permit} protocol source          |                                                                         |
|                               | [source-wildcard] destination    |                                                                         |
|                               | [destination-wildcard]           |                                                                         |
|                               | or                              |                                                                         |
|                               | mac access-list extended name    |                                                                         |
|                               | {permit | deny} {host src-MAC-addr mask |                                                                         |
|                               | | any | host dst-MAC-addr | dst-MAC-addr mask} [type mask] |                                                                         |

| Step 3                        | class-map [match-all | match-any] class-map-name | Create a class map, and enter class-map configuration mode. By default, no class maps are defined. |
|                               | |                           | • (Optional) Use the match-all keyword to perform a logical-AND of all matching statements under this class map. All match criteria in the class map must be matched. |
|                               | |                           | • (Optional) Use the match-any keyword to perform a logical-OR of all matching statements under this class map. One or more match criteria must be matched. |
|                               | |                           | • For class-map-name, specify the name of the class map. If neither the match-all or match-any keyword is specified, the default is match-all. |
|                               | |                           | Note Because only one match command per class map is supported, the match-all and match-any keywords function the same. |
Chapter 27 Configuring QoS

Configuring Standard QoS

To delete an existing policy map, use the `no policy-map policy-map-name` global configuration command. To delete an existing class map, use the `no class-map [match-all | match-any] class-map-name` global configuration command. To remove a match criterion, use the `no match {access-group acl-index-or-name | ip dscp dscp-list | ip precedence ip-precedence-list}` class-map configuration command.

This example shows how to configure the class map called `class1`. The `class1` has one match criterion, which is access list 103. It permits traffic from any host to any destination that matches a DSCP value of 10.

```
Switch(config)# access-list 103 permit any any dscp 10
Switch(config)# class-map class1
Switch(config-cmap)# match access-group 103
Switch(config-cmap)# end
Switch#
```

This example shows how to create a class map called `class2`, which matches incoming traffic with DSCP values of 10, 11, and 12.

```
Switch(config)# class-map class2
Switch(config-cmap)# match ip dscp 10 11 12
Switch(config-cmap)# end
Switch#
```

This example shows how to create a class map called `class3`, which matches incoming traffic with IP-precedence values of 5, 6, and 7:

```
Switch(config)# class-map class3
Switch(config-cmap)# match ip precedence 5 6 7
Switch(config-cmap)# end
Switch#
```
Classifying, Policing, and Marking Traffic on Physical Ports by Using Policy Maps

You can configure a nonhierarchical policy map on a physical port that specifies which traffic class to act on. Actions can include trusting the CoS, DSCP, or IP precedence values in the traffic class; setting a specific DSCP or IP precedence value in the traffic class; and specifying the traffic bandwidth limitations for each matched traffic class (policer) and the action to take when the traffic is out of profile (marking).

A policy map also has these characteristics:

- A policy map can contain multiple class statements, each with different match criteria and policers.
- A separate policy-map class can exist for each type of traffic received through a port.
- A policy-map trust state and a port trust state are mutually exclusive, and whichever is configured last takes affect.

Follow these guidelines when configuring policy maps on physical ports:

- You can attach only one policy map per ingress port.
- If you configure the IP-precedence-to-DSCP map by using the `mls qos map ip-prec-dscp dscp1...dscp8` global configuration command, the settings only affect packets on ingress interfaces that are configured to trust the IP precedence value. In a policy map, if you set the packet IP precedence value to a new value by using the `set ip precedence new-precedence` policy-map class configuration command, the egress DSCP value is not affected by the IP-precedence-to-DSCP map. If you want the egress DSCP value to be different than the ingress value, use the `set dscp new-dscp` policy-map class configuration command.
- If you enter or have used the `set ip dscp` command, the switch changes this command to `set dscp` in its configuration.
- In Cisco IOS Release 12.2(25)SED or later, you can use the `set ip precedence` or the `set precedence` policy-map class configuration command to change the packet IP precedence value. This setting appears as `set ip precedence` in the switch configuration.

Beginning in privileged EXEC mode, follow these steps to create a nonhierarchical policy map:

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>class-map [match-all</td>
<td>Create a class map, and enter class-map configuration mode.</td>
</tr>
<tr>
<td></td>
<td>match-any]</td>
<td>By default, no class maps are defined.</td>
</tr>
<tr>
<td></td>
<td>class-map-name</td>
<td>(Optional) Use the <code>match-all</code> keyword to perform a logical-AND of all matching statements under this class map. All match criteria in the class map must be matched.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Optional) Use the <code>match-any</code> keyword to perform a logical-OR of all matching statements under this class map. One or more match criteria must be matched.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For <code>class-map-name</code>, specify the name of the class map.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If neither the <code>match-all</code> or <code>match-any</code> keyword is specified, the default is <code>match-all</code>.</td>
</tr>
<tr>
<td>Note</td>
<td>Because only one <code>match</code> command per class map is supported, the <code>match-all</code> and <code>match-any</code> keywords function the same.</td>
<td></td>
</tr>
</tbody>
</table>
**Chapter 27 Configuring QoS**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
</tr>
<tr>
<td>policy-map <strong>policy-map-name</strong></td>
<td>Create a policy map by entering the policy map name, and enter policy-map configuration mode. By default, no policy maps are defined. The default behavior of a policy map is to set the DSCP to 0 if the packet is an IP packet and to set the CoS to 0 if the packet is tagged. No policing is performed.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td></td>
</tr>
<tr>
<td>class <strong>class-map-name</strong></td>
<td>Define a traffic classification, and enter policy-map class configuration mode. By default, no policy map class-maps are defined. If a traffic class has already been defined by using the class-map global configuration command, specify its name for class-map-name in this command.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td></td>
</tr>
</tbody>
</table>
| trust [cos | dscp | ip-precedence] | Configure the trust state, which QoS uses to generate a CoS-based or DSCP-based QoS label. **Note** This command is mutually exclusive with the set command within the same policy map. If you enter the trust command, go to Step 6. By default, the port is not trusted. If no keyword is specified when the command is entered, the default is dscp. The keywords have these meanings:  
  • **cos**—QoS derives the DSCP value by using the received or default port CoS value and the CoS-to-DSCP map.  
  • **dscp**—QoS derives the DSCP value by using the DSCP value from the ingress packet. For non-IP packets that are tagged, QoS derives the DSCP value by using the received CoS value; for non-IP packets that are untagged, QoS derives the DSCP value by using the default port CoS value. In either case, the DSCP value is derived from the CoS-to-DSCP map.  
  • **ip-precedence**—QoS derives the DSCP value by using the IP precedence value from the ingress packet and the IP-precedence-to-DSCP map. For non-IP packets that are tagged, QoS derives the DSCP value by using the received CoS value; for non-IP packets that are untagged, QoS derives the DSCP value by using the default port CoS value. In either case, the DSCP value is derived from the CoS-to-DSCP map. For more information, see the “Configuring the CoS-to-DSCP Map” section on page 27-58. |
| **Step 6**          |                                                                          |
| set {dscp new-dscp | ip precedence new-precedence} | Classify IP traffic by setting a new value in the packet.  
  • For **dscp new-dscp**, enter a new DSCP value to be assigned to the classified traffic. The range is 0 to 63.  
  • For **ip precedence new-precedence**, enter a new IP-precedence value to be assigned to the classified traffic. The range is 0 to 7. |
To delete an existing policy map, use the **no policy-map** global configuration command. To delete an existing class map, use the **no class class-map-name** policy-map configuration command. To return to the untrusted state, use the **no trust** policy-map configuration command. To remove an assigned DSCP or IP precedence value, use the **no set {dscp new-dscp | ip precedence new-precedence}** policy-map configuration command. To remove an existing policer, use the **no police rate-bps burst-byte [exceed-action {drop | policed-dscp-transmit}]** policy-map configuration command. To remove the policy map and port association, use the **no service-policy input policy-map-name interface** configuration command.

This example shows how to create a policy map and attach it to an ingress port. In the configuration, the IP standard ACL permits traffic from network 10.1.0.0. For traffic matching this classification, the DSCP value in the incoming packet is trusted. If the matched traffic exceeds an average traffic rate of 48000 b/s and a normal burst size of 8000 bytes, its DSCP is marked down (based on the policed-DSCP map) and sent:

```
Switch(config)# access-list 1 permit 10.1.0.0 0.0.255.255
Switch(config)# class-map ipclass1
Switch(config-cmap)# match access-group 1
Switch(config-cmap)# exit
Switch(config)# policy-map flow1t
Switch(config-pmap)# class ipclass1
Switch(config-pmap-c)# trust dscp
```
Chapter 27      Configuring QoS

Configuring Standard QoS

Switch(config-pmap-c)# police 1000000 8000 exceed-action policed-dscp-transmit
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# service-policy input flow1

This example shows how to create a Layer 2 MAC ACL with two permit statements and attach it to an ingress port. The first permit statement allows traffic from the host with MAC address 0001.0000.0001 destined for the host with MAC address 0002.0000.0001. The second permit statement allows only Ethertype XNS-IDP traffic from the host with MAC address 0001.0000.0002 destined for the host with MAC address 0002.0000.0002.

Switch(config)# mac access-list extended maclist1
Switch(config-ext-mac)# permit 0001.0000.0001 0.0.0 0002.0000.0001 0.0.0
Switch(config-ext-mac)# exit
Switch(config)# mac access-list extended maclist2
Switch(config-ext-mac)# permit 0001.0000.0003 0.0.0 0002.0000.0003 0.0.0
Switch(config-ext-mac)# exit
Switch(config)# class-map macclass1
Switch(config-cmap)# match access-group maclist1
Switch(config-cmap)# exit
Switch(config)# policy-map macpolicy1
Switch(config-pmap)# class macclass1
Switch(config-pmap-c)# set dscp 63
Switch(config-pmap-c)# exit
Switch(config-pmap-c)# class macclass2 maclist2
Switch(config-pmap-c)# set dscp 45
Switch(config-pmap-c)# exit
Switch(config-pmap-c)# exit
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# mls qos trust cos
Switch(config-if)# service-policy input macpolicy1

Classifying, Policing, and Marking Traffic on SVIs by Using Hierarchical Policy Maps

You can configure hierarchical policy maps on SVIs, but not on other types of interfaces. Hierarchical policing combines the VLAN- and interface-level policy maps to create a single policy map.

On an SVI, the VLAN-level policy map specifies which traffic class to act on. Actions can include trusting the CoS, DSCP, or IP precedence values or setting a specific DSCP or IP precedence value in the traffic class. Use the interface-level policy map to specify the physical ports that are affected by individual policers.

Follow these guidelines when configuring hierarchical policy maps:

- Before configuring a hierarchical policy map, you must enable VLAN-based QoS on the physical ports that are to be specified at the interface level of the policy map.
- You can attach only one policy map per ingress port or SVI.
- A policy map can contain multiple class statements, each with different match criteria and actions.
- A separate policy-map class can exist for each type of traffic received on the SVI.
- A policy-map trust state and a port trust state are mutually exclusive, and whichever is configured last takes affect.
- If you configure the IP-precedence-to-DSCP map by using the mls qos map ip-prec-dscp dscp1...dscp8 global configuration command, the settings only affect packets on ingress interfaces that are configured to trust the IP precedence value. In a policy map, if you set the packet IP
precedence value to a new value by using the `set ip precedence new-precedence` policy-map class configuration command, the egress DSCP value is not affected by the IP-precedence-to-DSCP map. If you want the egress DSCP value to be different than the ingress value, use the `set dscp new-dscp` policy-map class configuration command.

- If you enter or have used the `set ip dscp` command, the switch changes this command to `set dscp` in its configuration. If you enter the `set ip dscp` command, this setting appears as `set dscp` in the switch configuration.

- You can use the `set ip precedence` or the `set precedence` policy-map class configuration command to change the packet IP precedence value. This setting appears as `set ip precedence` in the switch configuration.

- If VLAN-based QoS is enabled, the hierarchical policy map supersedes the previously configured port-based policy map.

- The hierarchical policy map is attached to the SVI and affects all traffic belonging to the VLAN. The actions specified in the VLAN-level policy map affect the traffic belonging to the SVI. The police action on the port-level policy map affects the ingress traffic on the affected physical interfaces.

- When configuring a hierarchical policy map on trunk ports, the VLAN ranges must not overlap. If the ranges overlap, the actions specified in the policy map affect the incoming and outgoing traffic on the overlapped VLANs.

- Aggregate policers are not supported in hierarchical policy maps.

- When VLAN-based QoS is enabled, the switch supports VLAN-based features, such as the VLAN map.

- You can configure a hierarchical policy map only on the primary VLAN of a private VLAN.

Beginning in privileged EXEC mode, follow these steps to create a hierarchical policy map:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
</tr>
<tr>
<td><code>configure terminal</code></td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Create a VLAN-level class map, and enter class-map configuration mode. For information about creating a class map, see the “Classifying Traffic by Using Class Maps” section on page 27-45. By default, no class maps are defined.</td>
</tr>
<tr>
<td>`class-map [match-all</td>
<td>match-any] class-map-name`</td>
</tr>
<tr>
<td></td>
<td>(Optional) Use the <strong>match-any</strong> keyword to perform a logical-OR of all matching statements under this class map. One or more match criteria must be matched.</td>
</tr>
<tr>
<td></td>
<td>For <strong>class-map-name</strong>, specify the name of the class map.</td>
</tr>
<tr>
<td></td>
<td>If neither the <strong>match-all</strong> or <strong>match-any</strong> keyword is specified, the default is <strong>match-all</strong>.</td>
</tr>
</tbody>
</table>

**Note** Because only one **match** command per class map is supported, the **match-all** and **match-any** keywords function the same.
### Chapter 27  Configuring QoS

#### Configuring Standard QoS

**Step 3**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>match {access-group acl-index-or-name</td>
<td>Define the match criterion to classify traffic. By default, no match criterion is defined. Only one match criterion per class map is supported, and only one ACL per class map is supported.</td>
</tr>
<tr>
<td>ip dscp dscp-list</td>
<td>For <strong>access-group acl-index-or-name</strong>, specify the number or name of the ACL.</td>
</tr>
<tr>
<td>ip precedence ip-precedence-list}</td>
<td>For <strong>ip dscp dscp-list</strong>, enter a list of up to eight IP DSCP values to match against incoming packets. Separate each value with a space. The range is 0 to 63.</td>
</tr>
</tbody>
</table>

**Step 4**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>exit</td>
<td>Return to class-map configuration mode.</td>
</tr>
</tbody>
</table>

**Step 5**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>exit</td>
<td>Return to global configuration mode.</td>
</tr>
</tbody>
</table>

**Step 6**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>class-map [match-all</td>
<td>Create an interface-level class map, and enter class-map configuration mode. By default, no class maps are defined.</td>
</tr>
<tr>
<td>match-any] class-map-name</td>
<td>(Optional) Use the <strong>match-all</strong> keyword to perform a logical-AND of all matching statements under this class map. All match criteria in the class map must be matched.</td>
</tr>
<tr>
<td></td>
<td>(Optional) Use the <strong>match-any</strong> keyword to perform a logical-OR of all matching statements under this class map. One or more match criteria must be matched.</td>
</tr>
<tr>
<td></td>
<td>For <strong>class-map-name</strong>, specify the name of the class map.</td>
</tr>
<tr>
<td></td>
<td>If neither the <strong>match-all</strong> or <strong>match-any</strong> keyword is specified, the default is <strong>match-all</strong>.</td>
</tr>
</tbody>
</table>

**Note** Because only one **match** command per class map is supported, the **match-all** and **match-any** keywords function the same.

**Step 7**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>match input-interface interface-id-list</td>
<td>Specify the physical ports on which the interface-level class map acts. You can specify up to six ports as follows:</td>
</tr>
<tr>
<td></td>
<td>• A single port (counts as one entry)</td>
</tr>
<tr>
<td></td>
<td>• A list of ports separated by a space (each port counts as an entry)</td>
</tr>
<tr>
<td></td>
<td>• A range of ports separated by a hyphen (counts as two entries)</td>
</tr>
<tr>
<td></td>
<td>This command can only be used in the child-level policy map and must be the only match condition in the child-level policy map.</td>
</tr>
</tbody>
</table>

**Step 8**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>exit</td>
<td>Return to class-map configuration mode.</td>
</tr>
</tbody>
</table>

**Step 9**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>exit</td>
<td>Return to global configuration mode.</td>
</tr>
</tbody>
</table>

**Step 10**

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>policy-map policy-map-name</td>
<td>Create an interface-level policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined, and no policing is performed.</td>
</tr>
</tbody>
</table>
### Command Purpose

**Step 11** class-map *class-map-name*  
Define an interface-level traffic classification, and enter policy-map configuration mode.  
By default, no policy-map class-maps are defined.  
If a traffic class has already been defined by using the class-map global configuration command, specify its name for *class-map-name* in this command.

**Step 12** police *rate-bps* burst-byte [exceed-action {drop | policed-dscp-transmit}]  
Define an individual policer for the classified traffic.  
By default, no policer is defined. For information on the number of policers supported, see the “Standard QoS Configuration Guidelines” section on page 27-32.  
- For *rate-bps*, specify average traffic rate in bits per second (bps). The range is 8000 to 1000000000.  
- For *burst-byte*, specify the normal burst size in bytes. The range is 8000 to 1000000.  
- (Optional) Specify the action to take when the rates are exceeded. Use the exceed-action drop keywords to drop the packet. Use the exceed-action policed-dscp-transmit keywords to mark down the DSCP value (by using the policed-DSCP map) and to send the packet. For more information, see the “Configuring the Policed-DSCP Map” section on page 27-60.

**Step 13** exit  
Return to policy-map configuration mode.

**Step 14** exit  
Return to global configuration mode.

**Step 15** policy-map *policy-map-name*  
Create a VLAN-level policy map by entering the policy-map name, and enter policy-map configuration mode.  
By default, no policy maps are defined.  
The default behavior of a policy map is to set the DSCP to 0 if the packet is an IP packet and to set the CoS to 0 if the packet is tagged. No policing is performed.

**Step 16** class *class-map-name*  
Define a VLAN-level traffic classification, and enter policy-map class configuration mode.  
By default, no policy-map class-maps are defined.  
If a traffic class has already been defined by using the class-map global configuration command, specify its name for *class-map-name* in this command.
### Command Purpose

| Step 17 | trust [cos | dscp | ip-precedence] | Configure the trust state, which QoS uses to generate a CoS-based or DSCP-based QoS label.  
**Note**  
This command is mutually exclusive with the `set` command within the same policy map. If you enter the `trust` command, omit Step 18.  
By default, the port is not trusted. If no keyword is specified when the command is entered, the default is `dscp`.  
The keywords have these meanings:  
- **cos**—QoS derives the DSCP value by using the received or default port CoS value and the CoS-to-DSCP map.  
- **dscp**—QoS derives the DSCP value by using the DSCP value from the ingress packet. For non-IP packets that are tagged, QoS derives the DSCP value by using the received CoS value; for non-IP packets that are untagged, QoS derives the DSCP value by using the default port CoS value. In either case, the DSCP value is derived from the CoS-to-DSCP map.  
- **ip-precedence**—QoS derives the DSCP value by using the IP precedence value from the ingress packet and the IP-precedence-to-DSCP map. For non-IP packets that are tagged, QoS derives the DSCP value by using the received CoS value; for non-IP packets that are untagged, QoS derives the DSCP value by using the default port CoS value. In either case, the DSCP value is derived from the CoS-to-DSCP map.  
For more information, see the “Configuring the CoS-to-DSCP Map” section on page 27-58. |
| Step 18 | set {dscp new-dscp | ip precedence new-precedence} | Classify IP traffic by setting a new value in the packet.  
- For **dscp new-dscp**, enter a new DSCP value to be assigned to the classified traffic. The range is 0 to 63.  
- For **ip precedence new-precedence**, enter a new IP-precedence value to be assigned to the classified traffic. The range is 0 to 7. |
| Step 19 | service-policy policy-map-name | Specify the interface-level policy-map name (from Step 10) and associate it with the VLAN-level policy map.  
If the VLAN-level policy map specifies more than one class, each class can have a different **service-policy policy-map-name** command. |
| Step 20 | exit | Return to policy-map configuration mode. |
| Step 21 | exit | Return to global configuration mode. |
| Step 22 | interface interface-id | Specify the SVI to which to attach the hierarchical policy map, and enter interface configuration mode. |
To delete an existing policy map, use the `no policy-map policy-map-name` global configuration command. To delete an existing class map, use the `no class class-map-name` policy-map configuration command.

To return to the untrusted state in a policy map, use the `no trust policy-map configuration` command.

To remove an assigned DSCP or IP precedence value, use the `no set {dscp new-dscp | ip precedence new-precedence}` policy-map configuration command.

To remove an existing policer in an interface-level policy map, use the `no police rate-bps burst-byte [exceed-action {drop | policed-dscp-transmit}]` policy-map configuration command. To remove the hierarchical policy map and port associations, use the `no service-policy input policy-map-name` interface configuration command.

This example shows how to create a hierarchical policy map:

```
Switch>enable
Switch#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#access-list 101 permit ip any any
Switch(config)#class-map cm-1
Switch(config-cmap)#match access 101
Switch(config-cmap)#exit
Switch(config)#exit
Switch#
```

### Classifying, Policing, and Marking Traffic by Using Aggregate Policers

By using an aggregate policer, you can create a policer that is shared by multiple traffic classes within the same policy map. However, you cannot use the aggregate policer across different policy maps or ports.

You can configure aggregate policers only in nonhierarchical policy maps on physical ports.
Beginning in privileged EXEC mode, follow these steps to create an aggregate policer:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>mls qos aggregate-policer</td>
</tr>
<tr>
<td></td>
<td>aggregate-policer-name rate-bps burst-byte exceed-action {drop</td>
</tr>
<tr>
<td></td>
<td>For aggregate-policer-name, specify the name of the aggregate policer.</td>
</tr>
<tr>
<td></td>
<td>For rate-bps, specify average traffic rate in bits per second (bps). The range is 8000 to 100000000.</td>
</tr>
<tr>
<td></td>
<td>For burst-byte, specify the normal burst size in bytes. The range is 8000 to 1000000.</td>
</tr>
<tr>
<td></td>
<td>Specify the action to take when the rates are exceeded. Use the exceed-action drop keywords to drop the packet. Use the exceed-action policed-dscp-transmit keywords to mark down the DSCP value (by using the policed-DSCP map) and to send the packet. For more information, see the “Configuring the Policed-DSCP Map” section on page 27-60.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>class-map [match-all</td>
</tr>
<tr>
<td></td>
<td>class-map-name</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>policy-map policy-map-name</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>class class-map-name</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>police aggregate aggregate-policer-name</td>
</tr>
<tr>
<td><strong>Step 7</strong></td>
<td>exit</td>
</tr>
<tr>
<td><strong>Step 8</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 9</strong></td>
<td>service-policy input policy-map-name</td>
</tr>
<tr>
<td><strong>Step 10</strong></td>
<td>end</td>
</tr>
</tbody>
</table>
Chapter 27  Configuring QoS

Configuring Standard QoS

To remove the specified aggregate policer from a policy map, use the `no police aggregate aggregate-policer-name` policy map configuration mode. To delete an aggregate policer and its parameters, use the `no mls qos aggregate-policer aggregate-policer-name` global configuration command.

This example shows how to create an aggregate policer and attach it to multiple classes within a policy map. In the configuration, the IP ACLs permit traffic from network 10.1.0.0 and from host 11.3.1.1. For traffic coming from network 10.1.0.0, the DSCP in the incoming packets is trusted. For traffic coming from host 11.3.1.1, the DSCP in the packet is changed to 56. The traffic rate from the 10.1.0.0 network and from host 11.3.1.1 is policed. If the traffic exceeds an average rate of 48000 b/s and a normal burst size of 8000 bytes, its DSCP is marked down (based on the policed-DSCP map) and sent. The policy map is attached to an ingress port.

```
Switch(config)# access-list 1 permit 10.1.0.0 0.0.255.255
Switch(config)# access-list 2 permit 11.3.1.1
Switch(config)# mls qos aggregate-policer transmit1 48000 8000 exceed-action policed-dscp-transmit
Switch(config)# class-map ipclass1
Switch(config-cmap)# match access-group 1
Switch(config-cmap)# exit
Switch(config)# class-map ipclass2
Switch(config-cmap)# match access-group 2
Switch(config-cmap)# exit
Switch(config)# policy-map aggflow1
Switch(config-pmap)# class ipclass1
Switch(config-pmap-c)# trust dscp
Switch(config-pmap-c)# policy aggregate transmit1
Switch(config-pmap-c)# exit
Switch(config-pmap)# class ipclass2
Switch(config-pmap-c)# set dscp 56
Switch(config-pmap-c)# policy aggregate transmit1
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# service-policy input aggflow1
Switch(config-if)# exit
```

Configuring DSCP Maps

These sections contain this configuration information:

- Configuring the CoS-to-DSCP Map, page 27-58 (optional)
- Configuring the IP-Precedence-to-DSCP Map, page 27-59 (optional)
- Configuring the Policed-DSCP Map, page 27-60 (optional, unless the null settings in the map are not appropriate)
- Configuring the DSCP-to-CoS Map, page 27-61 (optional)
- Configuring the DSCP-to-DSCP-Mutation Map, page 27-62 (optional, unless the null settings in the map are not appropriate)

All the maps, except the DSCP-to-DSCP-mutation map, are globally defined and are applied to all ports.
Configuring the CoS-to-DSCP Map

You use the CoS-to-DSCP map to map CoS values in incoming packets to a DSCP value that QoS uses internally to represent the priority of the traffic.

Table 27-12 shows the default CoS-to-DSCP map.

<table>
<thead>
<tr>
<th>CoS Value</th>
<th>DSCP Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>48</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 27-12 Default CoS-to-DSCP Map

If these values are not appropriate for your network, you need to modify them.

Beginning in privileged EXEC mode, follow these steps to modify the CoS-to-DSCP map. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 mls qos map cos-dscp $dscp1...$dscp8</td>
<td>Modify the CoS-to-DSCP map. For $dscp1...$dscp8, enter eight DSCP values that correspond to CoS values 0 to 7. Separate each DSCP value with a space. The DSCP range is 0 to 63.</td>
</tr>
<tr>
<td>Step 3 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4 show mls qos maps cos-dscp</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 5 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default map, use the no mls qos cos-dscp global configuration command.

This example shows how to modify and display the CoS-to-DSCP map:

```
Switch(config)# mls qos map cos-dscp 10 15 20 25 30 35 40 45
Switch(config)# end
Switch# show mls qos maps cos-dscp
Cos-dscp map:
  cos: 0 1 2 3 4 5 6 7
  dscp: 10 15 20 25 30 35 40 45
```
Configuring the IP-Precedence-to-DSCP Map

You use the IP-precedence-to-DSCP map to map IP precedence values in incoming packets to a DSCP value that QoS uses internally to represent the priority of the traffic.

Table 27-13 shows the default IP-precedence-to-DSCP map:

<table>
<thead>
<tr>
<th>IP Precedence Value</th>
<th>DSCP Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>48</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
</tr>
</tbody>
</table>

If these values are not appropriate for your network, you need to modify them.

Beginning in privileged EXEC mode, follow these steps to modify the IP-precedence-to-DSCP map. This procedure is optional.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>mls qos map ip-prec-dscp dscp1...dscp8</td>
<td>Modify the IP-precedence-to-DSCP map.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For dscp1...dscp8, enter eight DSCP values that correspond to the IP precedence values 0 to 7. Separate each DSCP value with a space. The DSCP range is 0 to 63.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>4</td>
<td>show mls qos maps ip-prec-dscp</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default map, use the no mls qos ip-prec-dscp global configuration command.

This example shows how to modify and display the IP-precedence-to-DSCP map:

```
Switch(config)# mls qos map ip-prec-dscp 10 15 20 25 30 35 40 45
Switch(config)# end
Switch# show mls qos maps ip-prec-dscp
IpPrecedence-dscp map:
  ipprec:   0 1 2 3 4 5 6 7
--------------------
  dscp: 10 15 20 25 30 35 40 45
```
Configuring the Policed-DSCP Map

You use the policed-DSCP map to mark down a DSCP value to a new value as the result of a policing and marking action.

The default policed-DSCP map is a null map, which maps an incoming DSCP value to the same DSCP value.

Beginning in privileged EXEC mode, follow these steps to modify the policed-DSCP map. This procedure is optional.

---

**Command**

**Step 1**

configure terminal

Enter global configuration mode.

**Step 2**

```bash
mls qos map policed-dscp dscp-list to mark-down-dscp
```

Modify the policed-DSCP map.

- For `dscp-list`, enter up to eight DSCP values separated by spaces. Then enter the `to` keyword.
- For `mark-down-dscp`, enter the corresponding policed (marked down) DSCP value.

**Step 3**

```bash
end
```

Return to privileged EXEC mode.

**Step 4**

```bash
show mls qos maps policed-dscp
```

Verify your entries.

**Step 5**

```bash
copy running-config startup-config
```

(Optional) Save your entries in the configuration file.

To return to the default map, use the `no mls qos policed-dscp` global configuration command.

This example shows how to map DSCP 50 to 57 to a marked-down DSCP value of 0:

```bash
Switch(config)# mls qos map policed-dscp 50 51 52 53 54 55 56 57 to 0
Switch(config)# end
Switch# show mls qos maps policed-dscp
Policed-dscp map:
  d1 :  d2 0 1 2 3 4 5 6 7 8 9
  --------------------------------------
    0 :    00 01 02 03 04 05 06 07 08 09
    1 :    10 11 12 13 14 15 16 17 18 19
    2 :    20 21 22 23 24 25 26 27 28 29
    3 :    30 31 32 33 34 35 36 37 38 39
    4 :    40 41 42 43 44 45 46 47 48 49
    5 :    00 00 00 00 00 00 00 50 51 52
    6 :    60 61 62 63
```

---

**Note**

In this policed-DSCP map, the marked-down DSCP values are shown in the body of the matrix. The d1 column specifies the most-significant digit of the original DSCP; the d2 row specifies the least-significant digit of the original DSCP. The intersection of the d1 and d2 values provides the marked-down value. For example, an original DSCP value of 53 corresponds to a marked-down DSCP value of 0.
Configuring the DSCP-to-CoS Map

You use the DSCP-to-CoS map to generate a CoS value, which is used to select one of the four egress queues.

Table 27-14 shows the default DSCP-to-CoS map.

Table 27-14  Default DSCP-to-CoS Map

<table>
<thead>
<tr>
<th>DSCP Value</th>
<th>CoS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7</td>
<td>0</td>
</tr>
<tr>
<td>8–15</td>
<td>1</td>
</tr>
<tr>
<td>16–23</td>
<td>2</td>
</tr>
<tr>
<td>24–31</td>
<td>3</td>
</tr>
<tr>
<td>32–39</td>
<td>4</td>
</tr>
<tr>
<td>40–47</td>
<td>5</td>
</tr>
<tr>
<td>48–55</td>
<td>6</td>
</tr>
<tr>
<td>56–63</td>
<td>7</td>
</tr>
</tbody>
</table>

If these values are not appropriate for your network, you need to modify them.

Beginning in privileged EXEC mode, follow these steps to modify the DSCP-to-CoS map. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>mls qos map dscp-cos dscp-list to cos</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>end</td>
</tr>
<tr>
<td>Step 4</td>
<td>show mls qos maps dscp-to-cos</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default map, use the no mls qos dscp-cos global configuration command.

This example shows how to map DSCP values 0, 8, 16, 24, 32, 40, 48, and 50 to CoS value 0 and to display the map:

```
Switch(config)# mls qos map dscp-cos 0 8 16 24 32 40 48 50 to 0
Switch(config)# end
Switch# show mls qos maps dscp-cos
Dscp-cos map:  
d1 : d2 0 1 2 3 4 5 6 7 8 9
---------------------------------------
0 : 00 00 00 00 00 00 00 00 00 00 01
1 : 01 01 01 01 01 01 00 00 02 02 02
2 : 02 02 02 02 00 03 03 03 03 03 03
```
Chapter 27  Configuring QoS

Configuring Standard QoS

3 : 03 03 00 04 04 04 04 04 04 04
4 : 00 05 05 05 05 05 05 00 06
5 : 00 06 06 06 06 06 07 07 07 07
6 : 07 07 07 07

Note

In the above DSCP-to-CoS map, the CoS values are shown in the body of the matrix. The d1 column specifies the most-significant digit of the DSCP; the d2 row specifies the least-significant digit of the DSCP. The intersection of the d1 and d2 values provides the CoS value. For example, in the DSCP-to-CoS map, a DSCP value of 08 corresponds to a CoS value of 0.

Configuring the DSCP-to-DSCP-Mutation Map

If two QoS domains have different DSCP definitions, use the DSCP-to-DSCP-mutation map to translate one set of DSCP values to match the definition of another domain. You apply the DSCP-to-DSCP-mutation map to the receiving port (ingress mutation) at the boundary of a QoS administrative domain.

With ingress mutation, the new DSCP value overwrites the one in the packet, and QoS treats the packet with this new value. The switch sends the packet out the port with the new DSCP value.

You can configure multiple DSCP-to-DSCP-mutation maps on an ingress port. The default DSCP-to-DSCP-mutation map is a null map, which maps an incoming DSCP value to the same DSCP value.

Beginning in privileged EXEC mode, follow these steps to modify the DSCP-to-DSCP-mutation map. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>mls qos map dscp-mutation</strong></td>
</tr>
</tbody>
</table>
| | *dscp-mutation-name in-dscp to out-dscp* | • For *dscp-mutation-name*, enter the mutation map name. You can create more than one map by specifying a new name.  
  • For *in-dscp*, enter up to eight DSCP values separated by spaces. Then enter the *to* keyword.  
  • For *out-dscp*, enter a single DSCP value.  
  The DSCP range is 0 to 63. |
| **Step 3** | **interface interface-id** | Specify the port to which to attach the map, and enter interface configuration mode.  
Valid interfaces include physical ports. |
| **Step 4** | **mls qos trust dscp** | Configure the ingress port as a DSCP-trusted port. By default, the port is not trusted. |
| **Step 5** | **mls qos dscp-mutation** | Apply the map to the specified ingress DSCP-trusted port.  
For *dscp-mutation-name*, enter the mutation map name specified in Step 2. |
| | *dscp-mutation-name* | |
| **Step 6** | **end** | Return to privileged EXEC mode. |
| **Step 7** | **show mls qos maps dscp-mutation** | Verify your entries. |
| **Step 8** | **copy running-config startup-config** | (Optional) Save your entries in the configuration file. |
To return to the default map, use the **no mls qos dscp-mutation dscp-mutation-name** global configuration command.

This example shows how to define the DSCP-to-DSCP-mutation map. All the entries that are not explicitly configured are not modified (remains as specified in the null map):

```
Switch(config)# mls qos map dscp-mutation mutation1 1 2 3 4 5 6 7 to 0
Switch(config)# mls qos map dscp-mutation mutation1 8 9 10 11 12 13 to 10
Switch(config)# mls qos map dscp-mutation mutation1 20 21 22 to 20
Switch(config)# mls qos map dscp-mutation mutation1 30 31 32 33 34 to 30
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# mls qos trust dscp
Switch(config-if)# mls qos dscp-mutation mutation1
Switch(config-if)# end
Switch# show mls qos maps dscp-mutation mutation1
Dscp-dscp mutation map:
mutation1:
  d1 :  d2  0  1  2  3  4  5  6  7  8  9
   --------------------------------------
    0 :    00 00 00 00 00 00 00 00 10 10
    1 :    10 10 10 10 14 15 16 17 18 19
    2 :    20 20 20 23 24 25 26 27 28 29
    3 :    30 30 30 30 35 36 37 38 39
    4 :    40 41 42 43 44 45 46 47 48 49
    5 :    50 51 52 53 54 55 56 57 58 59
    6 :    60 61 62 63
```

**Note**

In the above DSCP-to-DSCP-mutation map, the mutated values are shown in the body of the matrix. The d1 column specifies the most-significant digit of the original DSCP; the d2 row specifies the least-significant digit of the original DSCP. The intersection of the d1 and d2 values provides the mutated value. For example, a DSCP value of 12 corresponds to a mutated value of 10.

**Configuring Ingress Queue Characteristics**

Depending on the complexity of your network and your QoS solution, you might need to perform all of the tasks in the next sections. You will need to make decisions about these characteristics:

- Which packets are assigned (by DSCP or CoS value) to each queue?
- What drop percentage thresholds apply to each queue, and which CoS or DSCP values map to each threshold?
- How much of the available buffer space is allocated between the queues?
- How much of the available bandwidth is allocated between the queues?
- Is there traffic (such as voice) that should be given high priority?

These sections contain this configuration information:

- **Mapping DSCP or CoS Values to an Ingress Queue and Setting WTD Thresholds, page 27-64** (optional)
- **Allocating Buffer Space Between the Ingress Queues, page 27-65** (optional)
- **Allocating Bandwidth Between the Ingress Queues, page 27-65** (optional)
- **Configuring the Ingress Priority Queue, page 27-66** (optional)
Mapping DSCP or CoS Values to an Ingress Queue and Setting WTD Thresholds

You can prioritize traffic by placing packets with particular DSCPs or CoSs into certain queues and adjusting the queue thresholds so that packets with lower priorities are dropped.

Beginning in privileged EXEC mode, follow these steps to map DSCP or CoS values to an ingress queue and to set WTD thresholds. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>mls qos srr-queue input dscp-map queue queue-id threshold threshold-id dscp1...dscp8</td>
</tr>
<tr>
<td>Step 2</td>
<td>mls qos srr-queue input cos-map queue queue-id threshold threshold-id cos1...cos8</td>
</tr>
<tr>
<td>Step 3</td>
<td>mls qos srr-queue input threshold queue-id threshold-percentage1 threshold-percentage2</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show mls qos maps</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default CoS input queue threshold map or the default DSCP input queue threshold map, use the no mls qos srr-queue input cos-map or the no mls qos srr-queue input dscp-map global configuration command. To return to the default WTD threshold percentages, use the no mls qos srr-queue input threshold queue-id global configuration command.
This example shows how to map DSCP values 0 to 6 to ingress queue 1 and to threshold 1 with a drop threshold of 50 percent. It maps DSCP values 20 to 26 to ingress queue 1 and to threshold 2 with a drop threshold of 70 percent:

```
Switch(config)# mls qos srr-queue input dscp-map queue 1 threshold 1 0 1 2 3 4 5 6
Switch(config)# mls qos srr-queue input dscp-map queue 1 threshold 2 20 21 22 23 24 25 26
Switch(config)# mls qos srr-queue input threshold 1 50 70
```

In this example, the DSCP values (0 to 6) are assigned the WTD threshold of 50 percent and will be dropped sooner than the DSCP values (20 to 26) assigned to the WTD threshold of 70 percent.

### Allocating Buffer Space Between the Ingress Queues

You define the ratio (allocate the amount of space) with which to divide the ingress buffers between the two queues. The buffer and the bandwidth allocation control how much data can be buffered before packets are dropped.

Beginning in privileged EXEC mode, follow these steps to allocate the buffers between the ingress queues. This procedure is optional.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>2</td>
<td>mls qos srr-queue input buffers percentage1 percentage2</td>
<td>Allocate the buffers between the ingress queues. By default, 90 percent of the buffers are allocated to queue 1, and 10 percent of the buffers are allocated to queue 2. For percentage1 percentage2, the range is 0 to 100. Separate each value with a space. You should allocate the buffers so that the queues can handle any incoming bursty traffic.</td>
</tr>
<tr>
<td>3</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>4</td>
<td>show mls qos interface buffer</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td></td>
<td>or show mls qos input-queue</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the `no mls qos srr-queue input buffers` global configuration command.

This example shows how to allocate 60 percent of the buffer space to ingress queue 1 and 40 percent of the buffer space to ingress queue 2:

```
Switch(config)# mls qos srr-queue input buffers 60 40
```

### Allocating Bandwidth Between the Ingress Queues

You need to specify how much of the available bandwidth is allocated between the ingress queues. The ratio of the weights is the ratio of the frequency in which the SRR scheduler sends packets from each queue. The bandwidth and the buffer allocation control how much data can be buffered before packets are dropped. On ingress queues, SRR operates only in shared mode.
Beginning in privileged EXEC mode, follow these steps to allocate bandwidth between the ingress queues. This procedure is optional.

**Command | Purpose**
--- | ---
**Step 1** configure terminal | Enter global configuration mode.
**Step 2** mls qos srr-queue input bandwidth weight1 weight2 | Assign shared round robin weights to the ingress queues. The default setting for weight1 and weight2 is 4 (1/2 of the bandwidth is equally shared between the two queues). For weight1 and weight2, the range is 1 to 100. Separate each value with a space. SRR services the priority queue for its configured weight as specified by the bandwidth keyword in the mls qos srr-queue input priority-queue queue-id bandwidth weight global configuration command. Then, SRR shares the remaining bandwidth with both ingress queues and services them as specified by the weights configured with the mls qos srr-queue input bandwidth weight1 weight2 global configuration command. For more information, see the “Configuring the Ingress Priority Queue” section on page 27-66.
**Step 3** end | Return to privileged EXEC mode.
**Step 4** show mls qos interface queueing or show mls qos input-queue | Verify your entries.
**Step 5** copy running-config startup-config | (Optional) Save your entries in the configuration file.

To return to the default setting, use the no mls qos srr-queue input bandwidth global configuration command.

This example shows how to assign the ingress bandwidth to the queues. Priority queueing is disabled, and the shared bandwidth ratio allocated to queue 1 is 25/(25+75) and to queue 2 is 75/(25+75):

Switch(config)# mls qos srr-queue input priority-queue 2 bandwidth 0
Switch(config)# mls qos srr-queue input bandwidth 25 75

### Configuring the Ingress Priority Queue

You should use the priority queue only for traffic that needs to be expedited (for example, voice traffic, which needs minimum delay and jitter).

The priority queue is guaranteed part of the bandwidth to reduce the delay and jitter under heavy network traffic on an oversubscribed ring (when there is more traffic than the backplane can carry, and the queues are full and dropping frames). SRR services the priority queue for its configured weight as specified by the bandwidth keyword in the mls qos srr-queue input priority-queue queue-id bandwidth weight global configuration command. Then, SRR shares the remaining bandwidth with both ingress queues and services them as specified by the weights configured with the mls qos srr-queue input bandwidth weight1 weight2 global configuration command.
Beginning in privileged EXEC mode, follow these steps to configure the priority queue. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>mls qos srr-queue input priority-queue queue-id bandwidth weight Assign a queue as the priority queue and guarantee bandwidth on the internal ring if the ring is congested. By default, the priority queue is queue 2, and 10 percent of the bandwidth is allocated to it. • For queue-id, the range is 1 to 2. • For bandwidth weight, assign the bandwidth percentage of the internal ring. The range is 0 to 40. The amount of bandwidth that can be guaranteed is restricted because a large value affects the entire ring and can degrade performance.</td>
</tr>
<tr>
<td>Step 3</td>
<td>end Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 4</td>
<td>show mls qos interface queueing or show mls qos input-queue Verify your entries.</td>
</tr>
<tr>
<td>Step 5</td>
<td>copy running-config startup-config (Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the no mls qos srr-queue input priority-queue queue-id global configuration command. To disable priority queueing, set the bandwidth weight to 0, for example, mls qos srr-queue input priority-queue queue-id bandwidth 0.

This example shows how to assign the ingress bandwidths to the queues. Queue 1 is the priority queue with 10 percent of the bandwidth allocated to it. The bandwidth ratios allocated to queues 1 and 2 is 4/(4+4). SRR services queue 1 (the priority queue) first for its configured 10 percent bandwidth. Then SRR equally shares the remaining 90 percent of the bandwidth between queues 1 and 2 by allocating 45 percent to each queue:

```
Switch(config)# mls qos srr-queue input priority-queue 1 bandwidth 10
Switch(config)# mls qos srr-queue input bandwidth 4 4
```

**Configuring Egress Queue Characteristics**

Depending on the complexity of your network and your QoS solution, you might need to perform all of the tasks in the next sections. You will need to make decisions about these characteristics:

- Which packets are mapped by DSCP or CoS value to each queue and threshold ID?
- What drop percentage thresholds apply to the queue-set (four egress queues per port), and how much reserved and maximum memory is needed for the traffic type?
- How much of the fixed buffer space is allocated to the queue-set?
- Does the bandwidth of the port need to be rate limited?
- How often should the egress queues be serviced and which technique (shaped, shared, or both) should be used?
These sections contain this configuration information:

- Configuration Guidelines, page 27-68
- Allocating Buffer Space to and Setting WTD Thresholds for an Egress Queue-Set, page 27-68 (optional)
- Mapping DSCP or CoS Values to an Egress Queue and to a Threshold ID, page 27-70 (optional)
- Configuring SRR Shaped Weights on Egress Queues, page 27-72 (optional)
- Configuring SRR Shared Weights on Egress Queues, page 27-73 (optional)
- Configuring the Egress Expedite Queue, page 27-74 (optional)
- Limiting the Bandwidth on an Egress Interface, page 27-74 (optional)

Configuration Guidelines

Follow these guidelines when the expedite queue is enabled or the egress queues are serviced based on their SRR weights:

- If the egress expedite queue is enabled, it overrides the SRR shaped and shared weights for queue 1.
- If the egress expedite queue is disabled and the SRR shaped and shared weights are configured, the shaped mode overrides the shared mode for queue 1, and SRR services this queue in shaped mode.
- If the egress expedite queue is disabled and the SRR shaped weights are not configured, SRR services this queue in shared mode.

Allocating Buffer Space to and Setting WTD Thresholds for an Egress Queue-Set

You can guarantee the availability of buffers, set WTD thresholds, and configure the maximum memory allocation for a queue-set by using the `mls qos queue-set output qset-id threshold queue-id drop-threshold1 drop-threshold2 reserved-threshold maximum-threshold` global configuration command.

Each threshold value is a percentage of the queue’s allocated memory, which you specify by using the `mls qos queue-set output qset-id buffers allocation1 ... allocation4` global configuration command. The queues use WTD to support distinct drop percentages for different traffic classes.

**Note**

The egress queue default settings are suitable for most situations. You should change them only when you have a thorough understanding of the egress queues and if these settings do not meet your QoS solution.
Beginning in privileged EXEC mode, follow these steps to configure the memory allocation and to drop thresholds for a queue-set. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>mls qos queue-set output qset-id buffers allocation1 ... allocation4</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>mls qos queue-set output qset-id threshold queue-id drop-threshold1 drop-threshold2 reserved-threshold maximum-threshold</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>queue-set qset-id</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>end</td>
</tr>
</tbody>
</table>
Chapter 27  Configuring QoS

Configuring Standard QoS

To return to the default setting, use the `no mls qos queue-set output qset-id buffers` global configuration command. To return to the default WTD threshold percentages, use the `no mls qos queue-set output qset-id threshold [queue-id]` global configuration command.

This example shows how to map a port to queue-set 2. It allocates 40 percent of the buffer space to egress queue 1 and 20 percent to egress queues 2, 3, and 4. It configures the drop thresholds for queue 2 to 40 and 60 percent of the allocated memory, guarantees (reserves) 100 percent of the allocated memory, and configures 200 percent as the maximum memory that this queue can have before packets are dropped:

```
Switch(config)# mls qos queue-set output 2 buffers 40 20 20 20
Switch(config)# mls qos queue-set output 2 threshold 2 40 60 100 200
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# queue-set 2
```

Mapping DSCP or CoS Values to an Egress Queue and to a Threshold ID

You can prioritize traffic by placing packets with particular DSCPs or costs of service into certain queues and adjusting the queue thresholds so that packets with lower priorities are dropped.

Note

The egress queue default settings are suitable for most situations. You should change them only when you have a thorough understanding of the egress queues and if these settings do not meet your QoS solution.
Beginning in privileged EXEC mode, follow these steps to map DSCP or CoS values to an egress queue and to a threshold ID. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td><strong>configure terminal</strong> Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td><strong>mls qos srr-queue output dscp-map queue queue-id threshold threshold-id dscp1...dscp8</strong> or <strong>mls qos srr-queue output cos-map queue queue-id threshold threshold-id cos1...cos8</strong> Map DSCP or CoS values to an egress queue and to a threshold ID. By default, DSCP values 0–15 are mapped to queue 2 and threshold 1. DSCP values 16–31 are mapped to queue 3 and threshold 1. DSCP values 32–39 and 48–63 are mapped to queue 4 and threshold 1. DSCP values 40–47 are mapped to queue 1 and threshold 1. By default, CoS values 0 and 1 are mapped to queue 2 and threshold 1. CoS values 2 and 3 are mapped to queue 3 and threshold 1. CoS values 4, 6, and 7 are mapped to queue 4 and threshold 1. CoS value 5 is mapped to queue 1 and threshold 1.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><strong>end</strong> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><strong>show mls qos maps</strong> Verify your entries. The DSCP output queue threshold map appears as a matrix. The d1 column specifies the most-significant digit of the DSCP number; the d2 row specifies the least-significant digit in the DSCP number. The intersection of the d1 and the d2 values provides the queue ID and threshold ID; for example, queue 2 and threshold 1 (02-01). The CoS output queue threshold map shows the CoS value in the top row and the corresponding queue ID and threshold ID in the second row; for example, queue 2 and threshold 2 (2-2).</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><strong>copy running-config startup-config</strong> <em>(Optional)</em> Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default DSCP output queue threshold map or the default CoS output queue threshold map, use the **no mls qos srr-queue output dscp-map** or the **no mls qos srr-queue output cos-map** global configuration command.

This example shows how to map DSCP values 10 and 11 to egress queue 1 and to threshold 2:

```
Switch(config)# mls qos srr-queue output dscp-map queue 1 threshold 2 10 11
```
Configuring SRR Shaped Weights on Egress Queues

You can specify how much of the available bandwidth is allocated to each queue. The ratio of the weights is the ratio of frequency in which the SRR scheduler sends packets from each queue.

You can configure the egress queues for shaped or shared weights, or both. Use shaping to smooth bursty traffic or to provide a smoother output over time. For information about shaped weights, see the “SRR Shaping and Sharing” section on page 27-14. For information about shared weights, see the “Configuring SRR Shared Weights on Egress Queues” section on page 27-73.

Beginning in privileged EXEC mode, follow these steps to assign the shaped weights and to enable bandwidth shaping on the four egress queues mapped to a port. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>interface interface-id</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>srr-queue bandwidth shape weight1 weight2 weight3 weight4</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>show mls qos interface interface-id queueing</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return to the default setting, use the **no srr-queue bandwidth shape** interface configuration command.

This example shows how to configure bandwidth shaping on queue 1. Because the weight ratios for queues 2, 3, and 4 are set to 0, these queues operate in shared mode. The bandwidth weight for queue 1 is 1/8, which is 12.5 percent:

Switch(config)# interface gigabitethernet0/1
Switch(config-if)# srr-queue bandwidth shape 8 0 0 0

---

**Command Purpose**

**Step 1**
- **configure terminal**
  - Enter global configuration mode.

**Step 2**
- **interface interface-id**
  - Specify the port of the outbound traffic, and enter interface configuration mode.

**Step 3**
- **srr-queue bandwidth shape weight1 weight2 weight3 weight4**
  - Assign SRR weights to the egress queues.
    - By default, weight1 is set to 25; weight2, weight3, and weight4 are set to 0, and these queues are in shared mode.
    - For `weight1 weight2 weight3 weight4`, enter the weights to control the percentage of the port that is shaped. The inverse ratio \(1/\text{weight}\) controls the shaping bandwidth for this queue. Separate each value with a space. The range is 0 to 65535.
    - If you configure a weight of 0, the corresponding queue operates in shared mode. The weight specified with the `srr-queue bandwidth shape` command is ignored, and the weights specified with the `srr-queue bandwidth share` interface configuration command for a queue come into effect.
    - When configuring queues in the same queue-set for both shaping and sharing, make sure that you configure the lowest number queue for shaping. The shaped mode overrides the shared mode.

**Step 4**
- **end**
  - Return to privileged EXEC mode.

**Step 5**
- **show mls qos interface interface-id queueing**
  - Verify your entries.

**Step 6**
- **copy running-config startup-config**
  - (Optional) Save your entries in the configuration file.

---

To return to the default setting, use the **no srr-queue bandwidth shape** interface configuration command.

This example shows how to configure bandwidth shaping on queue 1. Because the weight ratios for queues 2, 3, and 4 are set to 0, these queues operate in shared mode. The bandwidth weight for queue 1 is 1/8, which is 12.5 percent:

Switch(config)# interface gigabitethernet0/1
Switch(config-if)# srr-queue bandwidth shape 8 0 0 0
Chapter 27 Configuring QoS

Configuring Standard QoS

Configuring SRR Shared Weights on Egress Queues

In shared mode, the queues share the bandwidth among them according to the configured weights. The bandwidth is guaranteed at this level but not limited to it. For example, if a queue empties and does not require a share of the link, the remaining queues can expand into the unused bandwidth and share it among them. With sharing, the ratio of the weights controls the frequency of dequeuing; the absolute values are meaningless.

Note

The egress queue default settings are suitable for most situations. You should change them only when you have a thorough understanding of the egress queues and if these settings do not meet your QoS solution.

Beginning in privileged EXEC mode, follow these steps to assign the shared weights and to enable bandwidth sharing on the four egress queues mapped to a port. This procedure is optional.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
<td>Specify the port of the outbound traffic, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 3</td>
<td>srr-queue bandwidth share weight1 weight2 weight3 weight4</td>
<td>Assign SRR weights to the egress queues. By default, all four weights are 25 (1/4 of the bandwidth is allocated to each queue). For weight1 weight2 weight3 weight4, enter the weights to control the ratio of the frequency in which the SRR scheduler sends packets. Separate each value with a space. The range is 1 to 255.</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 5</td>
<td>show mls qos interface interface-id queueing</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return to the default setting, use the no srr-queue bandwidth share interface configuration command.

This example shows how to configure the weight ratio of the SRR scheduler running on an egress port. Four queues are used, and the bandwidth ratio allocated for each queue in shared mode is 1/(1+2+3+4), 2/(1+2+3+4), 3/(1+2+3+4), and 4/(1+2+3+4), which is 10 percent, 20 percent, 30 percent, and 40 percent for queues 1, 2, 3, and 4. This means that queue 4 has four times the bandwidth of queue 1, twice the bandwidth of queue 2, and one-and-a-third times the bandwidth of queue 3.

Switch(config)# interface gigabitethernet0/1
Switch(config-if)# srr-queue bandwidth share 1 2 3 4
Configuring the Egress Expedite Queue

You can ensure that certain packets have priority over all others by queuing them in the egress expedite queue. SRR services this queue until it is empty before servicing the other queues.

Beginning in privileged EXEC mode, follow these steps to enable the egress expedite queue. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 mls qos</td>
<td>Enable QoS on a switch.</td>
</tr>
<tr>
<td>Step 3 interface interface-id</td>
<td>Specify the egress port, and enter interface configuration mode.</td>
</tr>
<tr>
<td>Step 4 priority-queue out</td>
<td>Enable the egress expedite queue, which is disabled by default.</td>
</tr>
<tr>
<td></td>
<td>When you configure this command, the SRR weight and queue size ratios</td>
</tr>
<tr>
<td></td>
<td>are affected because there is one fewer queue participating in SRR. This</td>
</tr>
<tr>
<td></td>
<td>means that weight1 in the srr-queue bandwidth shape or the srr-queue</td>
</tr>
<tr>
<td></td>
<td>bandwidth share command is ignored (not used in the ratio calculation).</td>
</tr>
<tr>
<td>Step 5 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 6 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 7 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To disable the egress expedite queue, use the no priority-queue out interface configuration command.

This example shows how to enable the egress expedite queue when the SRR weights are configured. The egress expedite queue overrides the configured SRR weights.

```
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# srr-queue bandwidth shape 25 0 0 0
Switch(config-if)# srr-queue bandwidth share 30 20 25 25
Switch(config-if)# priority-queue out
Switch(config-if)# end
```

Limiting the Bandwidth on an Egress Interface

You can limit the bandwidth on an egress port. For example, if a customer pays only for a small percentage of a high-speed link, you can limit the bandwidth to that amount.

**Note**

The egress queue default settings are suitable for most situations. You should change them only when you have a thorough understanding of the egress queues and if these settings do not meet your QoS solution.

Beginning in privileged EXEC mode, follow these steps to limit the bandwidth on an egress port. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 interface interface-id</td>
<td>Specify the port to be rate limited, and enter interface configuration mode.</td>
</tr>
</tbody>
</table>
To return to the default setting, use the `no srr-queue bandwidth limit` interface configuration command.

This example shows how to limit the bandwidth on a port to 80 percent:

```plaintext
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# srr-queue bandwidth limit 80
```

When you configure this command to 80 percent, the port is idle 20 percent of the time. The line rate drops to 80 percent of the connected speed, which is 800 Mb/s. These values are not exact because the hardware adjusts the line rate in increments of six.

### Displaying Standard QoS Information

To display standard QoS information, use one or more of the privileged EXEC commands in Table 27-15:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show class-map [class-map-name]</td>
<td>Display QoS class maps, which define the match criteria to classify traffic.</td>
</tr>
<tr>
<td>show mls qos [aggregate-policer-name]</td>
<td>Display the aggregate policer configuration.</td>
</tr>
<tr>
<td>show mls qos input-queue [interface-id] [buffers</td>
<td>policers</td>
</tr>
<tr>
<td>show mls qos interface [interface-id] [cos-dscp</td>
<td>cos-input-q</td>
</tr>
<tr>
<td>show mls qos queue-set [qset-id]</td>
<td>Display QoS settings for the egress queues.</td>
</tr>
<tr>
<td>show mls qos vlan vlan-id</td>
<td>Display the policy maps attached to the specified SVI.</td>
</tr>
</tbody>
</table>
### Displaying Standard QoS Information

#### Table 27-15 Commands for Displaying Standard QoS Information (continued)

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| `show policy-map [policy-map-name [class class-map-name]]` | Display QoS policy maps, which define classification criteria for incoming traffic.  
**Note** Do not use the `show policy-map interface` privileged EXEC command to display classification information for incoming traffic. The `control-plane` and `interface` keywords are not supported, and the statistics shown in the display should be ignored. |
| `show running-config | include rewrite` | Display the DSCP transparency setting. |
Configuring EtherChannels and Layer 2 Trunk Failover

This chapter describes how to configure EtherChannels on Layer 2 ports on the switch. EtherChannel provides fault-tolerant high-speed links between switches, routers, and servers. You can use it to increase the bandwidth between the wiring closets and the data center, and you can deploy it anywhere in the network where bottlenecks are likely to occur. EtherChannel provides automatic recovery for the loss of a link by redistributing the load across the remaining links. If a link fails, EtherChannel redirects traffic from the failed link to the remaining links in the channel without intervention.

Note
For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:
- Understanding EtherChannels, page 28-1
- Configuring EtherChannels, page 28-8
- Displaying EtherChannel, PAgP, and LACP Status, page 28-17
- Understanding Layer 2 Trunk Failover, page 28-17

Understanding EtherChannels

These sections describe how EtherChannels work:
- EtherChannel Overview, page 28-2
- Port-Channel Interfaces, page 28-3
- Port Aggregation Protocol, page 28-4
- Link Aggregation Control Protocol, page 28-5
- EtherChannel On Mode, page 28-6
- Load Balancing and Forwarding Methods, page 28-6
EtherChannel Overview

An EtherChannel consists of individual Gigabit Ethernet links bundled into a single logical link as shown in Figure 28-1.

In Figure 28-1, the EtherChannel provides full-duplex bandwidth up to 8 Gb/s (Gigabit EtherChannel) between your switch and another switch or host.

Each EtherChannel can consist of up to eight compatibly configured Ethernet ports. All ports in each EtherChannel must be configured as Layer 2 ports. The number of EtherChannels is limited to 48. For more information, see the “EtherChannel Configuration Guidelines” section on page 28-9.

You can configure an EtherChannel in one of these modes: Port Aggregation Protocol (PAgP), Link Aggregation Control Protocol (LACP), or On. Configure both ends of the EtherChannel in the same mode:

- When you configure one end of an EtherChannel in either PAgP or LACP mode, the system negotiates with the other end of the channel to determine which ports should become active. In previous releases, the incompatible ports were suspended. Beginning with Cisco IOS Release 12.2(35)SE, instead of a suspended state, the local port is put into an independent state and continues to carry data traffic as would any other single link. The port configuration does not change, but the port does not participate in the EtherChannel.

- When you configure an EtherChannel in the on mode, no negotiations take place. The switch forces all compatible ports to become active in the EtherChannel. The other end of the channel (on the other switch) must also be configured in the on mode; otherwise, packet loss can occur.

If a link within an EtherChannel fails, traffic previously carried over that failed link moves to the remaining links within the EtherChannel. If traps are enabled on the switch, a trap is sent for a failure that identifies the switch, the EtherChannel, and the failed link. Inbound broadcast and multicast packets on one link in an EtherChannel are blocked from returning on any other link of the EtherChannel.
Port-Channel Interfaces

When you create a Layer 2 EtherChannel, a port-channel logical interface is involved. You can create the EtherChannel in these ways:

- Use the `channel-group` interface configuration command. This command automatically creates the port-channel logical interface when the channel group gets its first physical port. The `channel-group` command binds the physical (10/100/1000 ports) and the logical ports together as shown in Figure 28-2.

- Use the `interface port-channel port-channel-number` global configuration command to manually create the port-channel logical interface. Then use the `channel-group channel-group-number` interface configuration command to bind the logical interface to a physical port. The `channel-group-number` can be the same as the `port-channel-number`, or you can use a new number. If you use a new number, the `channel-group` command dynamically creates a new port channel.

Each EtherChannel has a port-channel logical interface numbered from 1 to 48. This port-channel interface number corresponds to the one specified with the `channel-group` interface configuration command.

Figure 28-2 Relationship of Physical Ports, Logical Port Channels, and Channel Groups

![Figure 28-2 Relationship of Physical Ports, Logical Port Channels, and Channel Groups](image)

After you configure an EtherChannel, configuration changes applied to the port-channel interface apply to all the physical ports assigned to the port-channel interface. Configuration changes applied to the physical port affect only the port where you apply the configuration. To change the parameters of all ports in an EtherChannel, apply configuration commands to the port-channel interface, for example, spanning-tree commands or commands to configure a Layer 2 EtherChannel as a trunk.
Port Aggregation Protocol

The Port Aggregation Protocol (PAgP) is a Cisco-proprietary protocol that can be run only on Cisco switches and on those switches licensed by vendors to support PAgP. PAgP facilitates the automatic creation of EtherChannels by exchanging PAgP packets between Ethernet ports.

By using PAgP, the switch learns the identity of partners capable of supporting PAgP and the capabilities of each port. It then dynamically groups similarly configured ports into a single logical link (channel or aggregate port). Similarly configured groups are based on hardware, administrative, and port parameter constraints. For example, PAgP groups the ports with the same speed, duplex mode, native VLAN, VLAN range, and trunking status and type. After grouping the links into an EtherChannel, PAgP adds the group to the spanning tree as a single switch port.

PAgP Modes

Table 28-1 shows the user-configurable EtherChannel PAgP modes for the channel-group interface configuration command.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>auto</td>
<td>Places a port into a passive negotiating state, in which the port responds to PAgP packets it receives but does not start PAgP packet negotiation. This setting minimizes the transmission of PAgP packets.</td>
</tr>
<tr>
<td>desirable</td>
<td>Places a port into an active negotiating state, in which the port starts negotiations with other ports by sending PAgP packets.</td>
</tr>
</tbody>
</table>

Switch ports exchange PAgP packets only with partner ports configured in the auto or desirable modes. Ports configured in the on mode do not exchange PAgP packets.

Both the auto and desirable modes enable ports to negotiate with partner ports to form an EtherChannel based on criteria such as port speed and, for Layer 2 EtherChannels, trunking state and VLAN numbers.

Ports can form an EtherChannel when they are in different PAgP modes as long as the modes are compatible. For example:

- A port in the desirable mode can form an EtherChannel with another port that is in the desirable or auto mode.
- A port in the auto mode can form an EtherChannel with another port in the desirable mode.

A port in the auto mode cannot form an EtherChannel with another port that is also in the auto mode because neither port starts PAgP negotiation.

If your switch is connected to a partner that is PAgP-capable, you can configure the switch port for nonsilent operation by using the non-silent keyword. If you do not specify non-silent with the auto or desirable mode, silent mode is assumed.

Use the silent mode when the switch is connected to a device that is not PAgP-capable and seldom, if ever, sends packets. An example of a silent partner is a file server or a packet analyzer that is not generating traffic. In this case, running PAgP on a physical port connected to a silent partner prevents that switch port from ever becoming operational. However, the silent setting allows PAgP to operate, to attach the port to a channel group, and to use the port for transmission.
Chapter 28      Configuring EtherChannels and Layer 2 Trunk Failover

Understanding EtherChannels

**PAgP Interaction with Other Features**

The Dynamic Trunking Protocol (DTP) and the Cisco Discovery Protocol (CDP) send and receive packets over the physical ports in the EtherChannel. Trunk ports send and receive PAgP protocol data units (PDUs) on the lowest numbered VLAN.

In Layer 2 EtherChannels, the first port in the channel that comes up provides its MAC address to the EtherChannel. If this port is removed from the bundle, one of the remaining ports in the bundle provides its MAC address to the EtherChannel. PAgP sends and receives PAgP PDUs only from ports that are up and have PAgP enabled for the auto or desirable mode.

**Link Aggregation Control Protocol**

The LACP is defined in IEEE 802.3ad and enables Cisco switches to manage Ethernet channels between switches that conform to the IEEE 802.3ad protocol. LACP facilitates the automatic creation of EtherChannels by exchanging LACP packets between Ethernet ports.

By using LACP, the switch learns the identity of partners capable of supporting LACP and the capabilities of each port. It then dynamically groups similarly configured ports into a single logical link (channel or aggregate port). Similarly configured ports are grouped based on hardware, administrative, and port parameter constraints. For example, LACP groups the ports with the same speed, duplex mode, native VLAN, VLAN range, and trunking status and type. After grouping the links into an EtherChannel, LACP adds the group to the spanning tree as a single switch port.

**LACP Modes**

Table 28-2 shows the user-configurable EtherChannel LACP modes for the `channel-group` interface configuration command.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>active</td>
<td>Places a port into an active negotiating state in which the port starts negotiations with other ports by sending LACP packets.</td>
</tr>
<tr>
<td>passive</td>
<td>Places a port into a passive negotiating state in which the port responds to LACP packets that it receives, but does not start LACP packet negotiation. This setting minimizes the transmission of LACP packets.</td>
</tr>
</tbody>
</table>

Both the active and passive LACP modes enable ports to negotiate with partner ports to an EtherChannel based on criteria such as port speed and, for Layer 2 EtherChannels, trunking state and VLAN numbers.

Ports can form an EtherChannel when they are in different LACP modes as long as the modes are compatible. For example:

- A port in the active mode can form an EtherChannel with another port that is in the active or passive mode.
- A port in the passive mode cannot form an EtherChannel with another port that is also in the passive mode because neither port starts LACP negotiation.
Understanding EtherChannels

LACP Interaction with Other Features

The DTP and the CDP send and receive packets over the physical ports in the EtherChannel. Trunk ports send and receive LACP PDUs on the lowest numbered VLAN.

In Layer 2 EtherChannels, the first port in the channel that comes up provides its MAC address to the EtherChannel. If this port is removed from the bundle, one of the remaining ports in the bundle provides its MAC address to the EtherChannel.

LACP sends and receives LACP PDUs only from ports that are up and have LACP enabled for the active or passive mode.

EtherChannel On Mode

EtherChannel on mode can be used to manually configure an EtherChannel. The on mode forces a port to join an EtherChannel without negotiations. The on mode can be useful if the remote device does not support PAgP or LACP. In the on mode, a usable EtherChannel exists only when the switches at both ends of the link are configured in the on mode.

Ports that are configured in the on mode in the same channel group must have compatible port characteristics, such as speed and duplex. Ports that are not compatible are suspended, even though they are configured in the on mode.

Caution

You should use care when using the on mode. This is a manual configuration, and ports on both ends of the EtherChannel must have the same configuration. If the group is misconfigured, packet loss or spanning-tree loops can occur.

Load Balancing and Forwarding Methods

EtherChannel balances the traffic load across the links in a channel by reducing part of the binary pattern formed from the addresses in the frame to a numerical value that selects one of the links in the channel. EtherChannel load balancing can use MAC addresses or IP addresses, source or destination addresses, or both source and destination addresses. The selected mode applies to all EtherChannels configured on the switch. You configure the load balancing and forwarding method by using the port-channel load-balance global configuration command.

With source-MAC address forwarding, when packets are forwarded to an EtherChannel, they are distributed across the ports in the channel based on the source-MAC address of the incoming packet. Therefore, to provide load balancing, packets from different hosts use different ports in the channel, but packets from the same host use the same port in the channel.

With destination-MAC address forwarding, when packets are forwarded to an EtherChannel, they are distributed across the ports in the channel based on the destination host’s MAC address of the incoming packet. Therefore, packets to the same destination are forwarded over the same port, and packets to a different destination are sent on a different port in the channel.

With source-and-destination MAC address forwarding, when packets are forwarded to an EtherChannel, they are distributed across the ports in the channel based on both the source and destination MAC addresses. This forwarding method, a combination source-MAC and destination-MAC address forwarding methods of load distribution, can be used if it is not clear whether source-MAC or destination-MAC address forwarding is better suited on a particular switch. With source-and-destination MAC-address forwarding, packets sent from host A to host B, host A to host C, and host C to host B could all use different ports in the channel.
With source-IP address-based forwarding, when packets are forwarded to an EtherChannel, they are distributed across the ports in the EtherChannel based on the source-IP address of the incoming packet. Therefore, to provide load-balancing, packets from different IP addresses use different ports in the channel, but packets from the same IP address use the same port in the channel.

With destination-IP address-based forwarding, when packets are forwarded to an EtherChannel, they are distributed across the ports in the EtherChannel based on the destination-IP address of the incoming packet. Therefore, to provide load-balancing, packets from the same IP source address sent to different IP destination addresses could be sent on different ports in the channel. But packets sent from different source IP addresses to the same destination IP address are always sent on the same port in the channel.

With source-and-destination IP address-based forwarding, packets are sent to an EtherChannel and distributed across the EtherChannel ports, based on both the source and destination IP addresses of the incoming packet. This forwarding method, a combination of source-IP and destination-IP address-based forwarding, can be used if it is not clear whether source-IP or destination-IP address-based forwarding is better suited on a particular switch. In this method, packets sent from the IP address A to IP address B, from IP address A to IP address C, and from IP address C to IP address B could all use different ports in the channel.

Different load-balancing methods have different advantages, and the choice of a particular load-balancing method should be based on the position of the switch in the network and the kind of traffic that needs to be load-distributed. In Figure 28-3, an EtherChannel from a blade switch that is aggregating data from sixteen blade servers communicates with a router. Because the router is a single-MAC-address device, source-based forwarding on the switch EtherChannel ensures that the switch uses all available bandwidth to the router. The router is configured for destination-based forwarding because the large number of workstations ensures that the traffic is evenly distributed from the router EtherChannel.

Use the option that provides the greatest variety in your configuration. For example, if the traffic on a channel is only going to a single MAC address, using the destination-MAC address always chooses the same link in the channel. Using source addresses or IP addresses might result in better load balancing.
Figure 28-3  Load Distribution and Forwarding Methods

Configuring EtherChannels

These sections contain this configuration information:

- Default EtherChannel Configuration, page 28-9
- EtherChannel Configuration Guidelines, page 28-9
- Configuring Layer 2 EtherChannels, page 28-10 (required)
- Configuring EtherChannel Load Balancing, page 28-12 (optional)
- Configuring the PAgP Learn Method and Priority, page 28-13 (optional)
- Configuring LACP Hot-Standby Ports, page 28-14 (optional)

Note  Make sure that the ports are correctly configured. For more information, see the “EtherChannel Configuration Guidelines” section on page 28-9.

Note  After you configure an EtherChannel, configuration changes applied to the port-channel interface apply to all the physical ports assigned to the port-channel interface, and configuration changes applied to the physical port affect only the port where you apply the configuration.
Default EtherChannel Configuration

Table 28-3 shows the default EtherChannel configuration.

Table 28-3  Default EtherChannel Configuration

<table>
<thead>
<tr>
<th>Feature</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel groups</td>
<td>None assigned.</td>
</tr>
<tr>
<td>Port-channel logical interface</td>
<td>None defined.</td>
</tr>
<tr>
<td>PAgP mode</td>
<td>No default.</td>
</tr>
<tr>
<td>PAgP learn method</td>
<td>Aggregate-port learning on all ports.</td>
</tr>
<tr>
<td>PAgP priority</td>
<td>128 on all ports.</td>
</tr>
<tr>
<td>LACP mode</td>
<td>No default.</td>
</tr>
<tr>
<td>LACP learn method</td>
<td>Aggregate-port learning on all ports.</td>
</tr>
<tr>
<td>LACP port priority</td>
<td>32768 on all ports.</td>
</tr>
<tr>
<td>LACP system priority</td>
<td>32768.</td>
</tr>
<tr>
<td>LACP system ID</td>
<td>LACP system priority and the switch MAC address.</td>
</tr>
<tr>
<td>Load balancing</td>
<td>Load distribution on the switch is based on the source-MAC address of the incoming packet.</td>
</tr>
</tbody>
</table>

EtherChannel Configuration Guidelines

If improperly configured, some EtherChannel ports are automatically disabled to avoid network loops and other problems. Follow these guidelines to avoid configuration problems:

- Do not try to configure more than 48 EtherChannels on the switch.
- Configure a PAgP EtherChannel with up to eight Ethernet ports of the same type.
- Configure a LACP EtherChannel with up to 16 Ethernet ports of the same type. Up to eight ports can be active, and up to eight ports can be in standby mode.
- Configure all ports in an EtherChannel to operate at the same speeds and duplex modes.
- Enable all ports in an EtherChannel. A port in an EtherChannel that is disabled by using the shutdown interface configuration command is treated as a link failure, and its traffic is transferred to one of the remaining ports in the EtherChannel.
- When a group is first created, all ports follow the parameters set for the first port to be added to the group. If you change the configuration of one of these parameters, you must also make the changes to all ports in the group:
  - Allowed-VLAN list
  - Spanning-tree path cost for each VLAN
  - Spanning-tree port priority for each VLAN
  - Spanning-tree Port Fast setting
- Do not configure a port to be a member of more than one EtherChannel group.
- Do not configure an EtherChannel in both the PAgP and LACP modes. EtherChannel groups running PAgP and LACP can coexist on the same switch. Individual EtherChannel groups can run either PAgP or LACP, but they cannot interoperate.
- Do not configure a Switched Port Analyzer (SPAN) destination port as part of an EtherChannel.
- Do not configure a secure port as part of an EtherChannel or the reverse.
- Do not configure a port that is an active or a not-yet-active member of an EtherChannel as an IEEE 802.1x port. If you try to enable IEEE 802.1x on an EtherChannel port, an error message appears, and IEEE 802.1x is not enabled.
- If EtherChannels are configured on switch interfaces, remove the EtherChannel configuration from the interfaces before globally enabling IEEE 802.1x on a switch by using the `dot1x system-auth-control` global configuration command.
- For Layer 2 EtherChannels:
  - Assign all ports in the EtherChannel to the same VLAN, or configure them as trunks. Ports with different native VLANs cannot form an EtherChannel.
  - If you configure an EtherChannel from trunk ports, verify that the trunking mode (ISL or IEEE 802.1Q) is the same on all the trunks. Inconsistent trunk modes on EtherChannel ports can have unexpected results.
  - An EtherChannel supports the same allowed range of VLANs on all the ports in a trunking Layer 2 EtherChannel. If the allowed range of VLANs is not the same, the ports do not form an EtherChannel even when PAgP is set to the `auto` or `desirable` mode.
  - Ports with different spanning-tree path costs can form an EtherChannel if they are otherwise compatibly configured. Setting different spanning-tree path costs does not, by itself, make ports incompatible for the formation of an EtherChannel.

**Configuring Layer 2 EtherChannels**

You configure Layer 2 EtherChannels by assigning ports to a channel group with the `channel-group` interface configuration command. This command automatically creates the port-channel logical interface.

Beginning in privileged EXEC mode, follow these steps to assign a Layer 2 Ethernet port to a Layer 2 EtherChannel. This procedure is required.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
</tr>
<tr>
<td>interface interface-id</td>
<td>Specify a physical port, and enter interface configuration mode. Valid interfaces include physical ports. For a PAgP EtherChannel, you can configure up to eight ports of the same type and speed for the same group. For a LACP EtherChannel, you can configure up to 16 Ethernet ports of the same type. Up to eight ports can be active, and up to eight ports can be in standby mode.</td>
</tr>
</tbody>
</table>
### Step 3

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>switchport mode {access</td>
<td>Assign all ports as static-access ports in the same VLAN, or</td>
</tr>
<tr>
<td></td>
<td>trunk}</td>
</tr>
<tr>
<td>switchport access vlan</td>
<td>If you configure the port as a static-access port, assign it to only</td>
</tr>
<tr>
<td>vlan vlan-id</td>
<td>one VLAN. The range is 1 to 4094.</td>
</tr>
</tbody>
</table>

### Step 4

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>channel-group channel-group-number mode {auto [non-silent]</td>
<td>Assign the port to a channel group, and specify the PAgP or the</td>
</tr>
<tr>
<td></td>
<td>desirable [non-silent]</td>
</tr>
<tr>
<td></td>
<td>on}</td>
</tr>
<tr>
<td></td>
<td>{active</td>
</tr>
<tr>
<td></td>
<td>passive}</td>
</tr>
<tr>
<td></td>
<td>the port into a passive negotiating state, in which the port</td>
</tr>
<tr>
<td></td>
<td>responds to PAgP packets it receives but does not start PAgP packet</td>
</tr>
<tr>
<td></td>
<td>negotiation.</td>
</tr>
<tr>
<td>- desirable—Unconditionally enables PAgP. It places the port into a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>active negotiating state, in which the port starts negotiations with</td>
</tr>
<tr>
<td></td>
<td>other ports by sending PAgP packets.</td>
</tr>
<tr>
<td>- on—Forces the port to channel without PAgP or LACP. In the on mode,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>an EtherChannel exists only when a port group in the on mode is</td>
</tr>
<tr>
<td></td>
<td>connected to another port group in the on mode.</td>
</tr>
<tr>
<td>- non-silent—If your switch is connected to a partner that is PAgP-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>capable, configure the switch port for nonsilent operation when the</td>
</tr>
<tr>
<td></td>
<td>port is in the auto or desirable mode. If you do not specify non-silent</td>
</tr>
<tr>
<td></td>
<td>, silent is assumed. The silent setting is for connections to file</td>
</tr>
<tr>
<td></td>
<td>servers or packet analyzers. This setting allows PAgP to operate, to</td>
</tr>
<tr>
<td></td>
<td>attach the port to a channel group, and to use the port for</td>
</tr>
<tr>
<td></td>
<td>transmission.</td>
</tr>
<tr>
<td>- active—Enables LACP only if a LACP device is detected. It places</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the port into an active negotiating state in which the port starts</td>
</tr>
<tr>
<td></td>
<td>negotiations with other ports by sending LACP packets.</td>
</tr>
<tr>
<td>- passive—Enables LACP on the port and places it into a passive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>negotiating state in which the port responds to LACP packets that it</td>
</tr>
<tr>
<td></td>
<td>receives, but does not start LACP packet negotiation.</td>
</tr>
</tbody>
</table>

For information on compatible modes for the switch and its partner, see the “PAgP Modes” section on page 28-4 and the “LACP Modes” section on page 28-5.

### Step 5

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>

### Step 6

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>show running-config</td>
<td>Verify your entries.</td>
</tr>
</tbody>
</table>

### Step 7

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To remove a port from the EtherChannel group, use the **no channel-group** interface configuration command.
Configuring EtherChannels and Layer 2 Trunk Failover

Chapter 28

Configuring EtherChannels

This example shows how to configure an EtherChannel. It assigns two ports as static-access ports in VLAN 10 to channel 5 with the PAgP mode desirable:

```
Switch# configure terminal
Switch(config)# interface range gigabitethernet0/1-2
Switch(config-if-range)# switchport mode access
Switch(config-if-range)# switchport access vlan 10
Switch(config-if-range)# channel-group 5 mode desirable non-silent
Switch(config-if-range)# end
```

This example shows how to configure an EtherChannel. It assigns two ports as static-access ports in VLAN 10 to channel 5 with the LACP mode active:

```
Switch# configure terminal
Switch(config)# interface range gigabitethernet0/1-2
Switch(config-if-range)# switchport mode access
Switch(config-if-range)# switchport access vlan 10
Switch(config-if-range)# channel-group 5 mode active
Switch(config-if-range)# end
```

Configuring EtherChannel Load Balancing

This section describes how to configure EtherChannel load balancing by using source-based or destination-based forwarding methods. For more information, see the “Load Balancing and Forwarding Methods” section on page 28-6.

Beginning in privileged EXEC mode, follow these steps to configure EtherChannel load balancing. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>port-channel load-balance {dst-ip</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>end</td>
</tr>
</tbody>
</table>
Configuring EtherChannels

To return EtherChannel load balancing to the default configuration, use the `no port-channel load-balance` global configuration command.

### Configuring the PAgP Learn Method and Priority

Network devices are classified as PAgP physical learners or aggregate-port learners. A device is a physical learner if it learns addresses by physical ports and directs transmissions based on that knowledge. A device is an aggregate-port learner if it learns addresses by aggregate (logical) ports. The learn method must be configured the same at both ends of the link.

When a device and its partner are both aggregate-port learners, they learn the address on the logical port-channel. The device sends packets to the source by using any of the ports in the EtherChannel. With aggregate-port learning, it is not important on which physical port the packet arrives.

PAgP cannot automatically detect when the partner device is a physical learner and when the local device is an aggregate-port learner. Therefore, you must manually set the learning method on the local device to learn addresses by physical ports. You also must set the load-distribution method to source-based distribution, so that any given source MAC address is always sent on the same physical port.

You also can configure a single port within the group for all transmissions and use other ports for hot standby. The unused ports in the group can be swapped into operation in just a few seconds if the selected single port loses hardware-signal detection. You can configure which port is always selected for packet transmission by changing its priority with the `pagp port-priority` interface configuration command. The higher the priority, the more likely that the port will be selected.

To verify the EtherChannel load-balancing configuration, use the `show etherchannel load-balance` command.

### Command Table

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><code>show etherchannel load-balance</code></td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>5</td>
<td><code>copy running-config startup-config</code></td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

Note

The switch supports address learning only on aggregate ports even though the `physical-port` keyword is provided in the CLI. The `pagp learn-method` command and the `pagp port-priority` command have no effect on the switch hardware, but they are required for PAgP interoperability with devices that only support address learning by physical ports.

When the link partner of the blade switch is a physical learner (such as a Catalyst 1900 series switch), we recommend that you configure the blade switch as a physical-port learner by using the `pagp learn-method physical-port` interface configuration command. Set the load-distribution method based on the source MAC address by using the `port-channel load-balance src-mac` global configuration command. The switch then sends packets to the Catalyst 1900 switch using the same port in the EtherChannel from which it learned the source address. Only use the `pagp learn-method` command in this situation.
Beginning in privileged EXEC mode, follow these steps to configure your switch as a PAgP physical-port learner and to adjust the priority so that the same port in the bundle is selected for sending packets. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>pagp learn-method physical-port</td>
</tr>
<tr>
<td>Step 4</td>
<td>pagp port-priority priority</td>
</tr>
<tr>
<td>Step 5</td>
<td>end</td>
</tr>
<tr>
<td>Step 6</td>
<td>show running-config</td>
</tr>
<tr>
<td>or</td>
<td>show pagp channel-group-number internal</td>
</tr>
<tr>
<td>Step 7</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the priority to its default setting, use the no pagp port-priority interface configuration command. To return the learning method to its default setting, use the no pagp learn-method interface configuration command.

### Configuring LACP Hot-Standby Ports

When enabled, LACP tries to configure the maximum number of LACP-compatible ports in a channel, up to a maximum of 16 ports. Only eight LACP links can be active at one time. The software places any additional links in a hot-standby mode. If one of the active links becomes inactive, a link that is in the hot-standby mode becomes active in its place.
If you configure more than eight links for an EtherChannel group, the software automatically decides which of the hot-standby ports to make active based on the LACP priority. To every link between systems that operate LACP, the software assigns a unique priority made up of these elements (in priority order):

- LACP system priority
- System ID (the switch MAC address)
- LACP port priority
- Port number

In priority comparisons, numerically lower values have higher priority. The priority decides which ports should be put in standby mode when there is a hardware limitation that prevents all compatible ports from aggregating.

Determining which ports are active and which are hot standby is a two-step procedure. First the system with a numerically lower system priority and system-id is placed in charge of the decision. Next, that system decides which ports are active and which are hot standby, based on its values for port priority and port number. The port-priority and port-number values for the other system are not used.

You can change the default values of the LACP system priority and the LACP port priority to affect how the software selects active and standby links. For more information, see the “Configuring the LACP System Priority” section on page 28-15 and the “Configuring the LACP Port Priority” section on page 28-16.

**Configuring the LACP System Priority**

You can configure the system priority for all the EtherChannels that are enabled for LACP by using the *lacp system-priority* global configuration command. You cannot configure a system priority for each LACP-configured channel. By changing this value from the default, you can affect how the software selects active and standby links.

You can use the *show etherchannel summary* privileged EXEC command to see which ports are in the hot-standby mode (denoted with an H port-state flag).

Beginning in privileged EXEC mode, follow these steps to configure the LACP system priority. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td><strong>Step 2</strong> lacp system-priority <em>priority</em></td>
<td>Configure the LACP system priority. For <em>priority</em>, the range is 1 to 65535. The default is 32768. The lower the value, the higher the system priority.</td>
</tr>
<tr>
<td><strong>Step 3</strong> end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 4</strong> show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>show lacp sys-id</td>
<td></td>
</tr>
<tr>
<td><strong>Step 5</strong> copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

To return the LACP system priority to the default value, use the *no lacp system-priority* global configuration command.
Configuring the LACP Port Priority

By default, all ports use the same port priority. If the local system has a lower value for the system priority and the system ID than the remote system, you can affect which of the hot-standby links become active first by changing the port priority of LACP EtherChannel ports to a lower value than the default. The hot-standby ports that have lower port numbers become active in the channel first. You can use the `show etherchannel summary` privileged EXEC command to see which ports are in the hot-standby mode (denoted with an `H` port-state flag).

Note
If LACP is not able to aggregate all the ports that are compatible (for example, the remote system might have more restrictive hardware limitations), all the ports that cannot be actively included in the EtherChannel are put in the hot-standby state and are used only if one of the channeled ports fails.

Beginning in privileged EXEC mode, follow these steps to configure the LACP port priority. This procedure is optional.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>configure terminal</td>
</tr>
<tr>
<td>Step 2</td>
<td>interface interface-id</td>
</tr>
<tr>
<td>Step 3</td>
<td>lACP port-priority priority</td>
</tr>
<tr>
<td>Step 4</td>
<td>end</td>
</tr>
<tr>
<td>Step 5</td>
<td>show running-config</td>
</tr>
<tr>
<td>or</td>
<td>show lACP [channel-group-number] internal</td>
</tr>
<tr>
<td>Step 6</td>
<td>copy running-config startup-config</td>
</tr>
</tbody>
</table>

To return the LACP port priority to the default value, use the `no lACP port-priority` interface configuration command.
Displaying EtherChannel, PAgP, and LACP Status

To display EtherChannel, PAgP, and LACP status information, use the privileged EXEC commands described in Table 28-4:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>show etherchannel</td>
<td>Displays EtherChannel information in a brief, detailed, and one-line summary form. Also displays the load-balance or frame-distribution scheme, port, port-channel, and protocol information.</td>
</tr>
<tr>
<td>show pagp</td>
<td>Displays PAgP information such as traffic information, the internal PAgP configuration, and neighbor information.</td>
</tr>
<tr>
<td>show lacp</td>
<td>Displays LACP information such as traffic information, the internal LACP configuration, and neighbor information.</td>
</tr>
</tbody>
</table>

You can clear PAgP channel-group information and traffic counters by using the clear pagp privileged EXEC command.

You can clear LACP channel-group information and traffic counters by using the clear lacp privileged EXEC command.

For detailed information about the fields in the displays, see the command reference for this release.

Understanding Layer 2 Trunk Failover

Layer 2 trunk failover, also known as link-state tracking, is a feature that provides Layer 2 redundancy in the network when used with server NIC adapter teaming. When the server network adapters are configured in a primary or secondary relationship known as teaming, if the link is lost on the primary interface, connectivity is transparently switched to the secondary interface.

When you enable Layer 2 trunk failover on the switch, the link state of the internal downstream ports are bound to the link state of one or more of the external upstream ports. An internal downstream port is an interface that is connected to the server. An external upstream port is an interface that is connected to the external network. When you associate a set of downstream ports to a set of upstream ports, if all of the upstream ports become unavailable, trunk failover automatically puts all of the associated downstream ports in an error-disabled state. This causes the server primary interface to failover to the secondary interface.

When Layer 2 trunk failover is not enabled, if the upstream interfaces lose connectivity, (the external switch or router goes down, the cables are disconnected, or link is lost), the link state of the downstream interfaces remain unchanged. The server is not aware that external connectivity has been lost and does not failover to the secondary interface.

An interface can be an aggregation of ports (an EtherChannel), or a single physical port in access or trunk mode. Each downstream interface can be associated with one or more upstream interfaces. Upstream interfaces can be bundled together, and each downstream interface can be associated with a single group consisting of multiple upstream interfaces. These groups are referred to as link-state groups.
In a link-state group, the link states of the downstream interfaces are dependent on the link states of the upstream interfaces. If all of the upstream interfaces in a link-state group are in the link-down state, the associated downstream interfaces are forced into the link-down state. If any one of the upstream interfaces in the link-state group is in a link-up state, the associated downstream interfaces can change to or remain in the link-up state.

**Figure 28-4  Typical Layer 2 Trunk Failover Configuration**

In Figure 28-4, downstream interfaces 1, 3, and 5 are defined in link-state group 1 with upstream interfaces 19 and 20. Similarly, downstream interfaces 2, 4, and 6 are defined in link-state group 2 with upstream interfaces 21 and 22.

If link is lost on upstream interface 19, the link states of downstream interfaces 1, 3, and 5 do not change. If upstream interface 20 also loses link, downstream interfaces 1, 3 and 5 go into a link-down state. Downstream interfaces 2, 4, and 6 do not change states.

You can recover a downstream interface link-down condition by removing the failed downstream port from the link-state group. To recover multiple downstream interfaces, disable the link-state group.

**Configuring Layer 2 Trunk Failover**

These sections describe how to configure trunk failover ports:

- Default Layer 2 Trunk Failover Configuration, page 28-18
- Layer 2 Trunk Failover Configuration Guidelines, page 28-19
- Configuring Layer 2 Trunk Failover, page 28-19

**Default Layer 2 Trunk Failover Configuration**

There are no link-state groups defined, and trunk failover is not enabled for any group.
Layer 2 Trunk Failover Configuration Guidelines

Follow these guidelines to avoid configuration problems:

- Do not configure a cross-connect interface (gi0/17 or gi0/18) as a member of a link-state group.
- Do not configure an EtherChannel as a downstream interface.
- Only interfaces gi0/1 through gi0/16 can be configured as downstream ports in a specific link-state group.
- Only interfaces gi0/19 through gi0/24 can be configured as upstream ports in a specific link-state group.
- An interface that is defined as an upstream interface cannot also be defined as a downstream interface in the same or a different link-state group. The reverse is also true.
- An interface cannot be a member of more than one link-state group.
- You can configure only two link-state groups per switch.

Configuring Layer 2 Trunk Failover

Beginning in privileged EXEC mode, follow these steps to configure a link-state group and to assign an interface to a group:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 configure terminal</td>
<td>Enter global configuration mode.</td>
</tr>
<tr>
<td>Step 2 link state track number</td>
<td>Create a link-state group, and enable link-state tracking. The group number can be 1 or 2; the default is 1.</td>
</tr>
<tr>
<td>Step 3 interface interface-id</td>
<td>Specify a physical interface or range of interfaces to configure, and enter interface configuration mode. Valid interfaces include physical ports in access or trunk mode (IEEE 802.1q) or multiple physical ports bundled into an EtherChannel interface (static or LACP), also in trunk mode.</td>
</tr>
<tr>
<td>Step 4 link state group [number] {upstream</td>
<td>downstream}</td>
</tr>
<tr>
<td>Step 5 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 6 show running-config</td>
<td>Verify your entries.</td>
</tr>
<tr>
<td>Step 7 copy running-config startup-config</td>
<td>(Optional) Save your entries in the configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to create a link-state group and configure the interfaces:

```
Switch# configure terminal
Switch(config)# link state track 1
Switch(config)# interface range gigabitethernet0/21 - 22
Switch(config-if)# link state group 1 upstream
Switch(config-if)# interface gigabitethernet0/1
Switch(config-if)# link state group 1 downstream
Switch(config-if)# interface gigabitethernet0/3
Switch(config-if)# link state group 1 downstream
Switch(config-if)# interface gigabitethernet0/5
Switch(config-if)# link state group 1 downstream
Switch(config-if)# end
```
Chapter 28  Configuring EtherChannels and Layer 2 Trunk Failover

Understanding Layer 2 Trunk Failover

Note

If the interfaces are part of an EtherChannel, you must specify the port channel name as part of the link-state group, not the individual port members.

This example shows how to create a link-state group using ports in an EtherChannel:

```plaintext
Switch# configure terminal
Switch(config)# link state track 1
Switch(config)# interface Po1
Switch(config-if)# link state group 1 upstream
Switch(config-if-range)# interface range gigabitethernet0/1, gigabitethernet0/3, gigabitethernet0/5
Switch(config-if)# link state group 1 downstream
Switch(config-if)# end
```

To disable a link-state group, use the `no link state track number` global configuration command.

Displaying Layer 2 Trunk Failover Status

Use the `show link state group` command to display the link-state group information. Enter this command without keywords to display information about all link-state groups. Enter the group number to display information specific to the group. Enter the detail keyword to display detailed information about the group.

This is an example of output from the `show link state group 1` command:

```
Switch> show link state group 1
Link State Group: 1      Status: Enabled, Up
```

This is an example of output from the `show link state group detail` command:

```
Switch> show link state group detail
Link State Group: 1      Status: Enabled, Up
Upstream Interfaces   : Po1(Up)
Downstream Interfaces : Gi0/3(Up) Gi0/4(Up)
```

<table>
<thead>
<tr>
<th>Upstream Interfaces</th>
<th>Status: Disabled, Down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream Interfaces</td>
<td></td>
</tr>
</tbody>
</table>

(Up): Interface up    (Dwn): Interface Down    (Dis): Interface disabled

For detailed information about the fields in the display, see the command reference for this release.
Troubleshooting

This chapter describes how to identify and resolve software problems related to the Cisco IOS software on the switch. Depending on the nature of the problem, you can use the command-line interface (CLI) or the device manager to identify and solve problems.

Additional troubleshooting information, such as LED descriptions, is provided in the hardware installation guide.

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release and the *Cisco IOS Command Summary, Release 12.2*.

This chapter consists of these sections:

- Recovering from a Software Failure, page 29-2
- Recovering from a Lost or Forgotten Password, page 29-3
- Recovering from a Command Switch Failure, page 29-8
- Recovering from Lost Cluster Member Connectivity, page 29-11

**Note** Recovery procedures require that you have physical access to the switch.

- Preventing Autonegotiation Mismatches, page 29-11
- SFP Module Security and Identification, page 29-12
- Monitoring SFP Module Status, page 29-12
- Using Ping, page 29-13
- Using Layer 2 Traceroute, page 29-14
- Using IP Traceroute, page 29-16
- Using TDR, page 29-18
- Using Debug Commands, page 29-18
- Using the show platform forward Command, page 29-20
- Using the crashinfo Files, page 29-22
Recovering from a Software Failure

Switch software can be corrupted during an upgrade, by downloading the wrong file to the switch, and by deleting the image file. In all of these cases, the switch does not pass the power-on self-test (POST), and there is no connectivity.

This procedure uses the Xmodem Protocol to recover from a corrupt or wrong image file. There are many software packages that support the Xmodem Protocol, and this procedure is largely dependent on the emulation software that you are using.

This recovery procedure requires that you have physical access to the switch.

Follow these steps to recover from a corrupt or wrong image file:

---

**Step 1**
From your PC, download the software image tar file (image_filename.tar) from Cisco.com.
The Cisco IOS image is stored as a bin file in a directory in the tar file. For information about locating the software image files on Cisco.com, see the release notes.

**Step 2**
Extract the bin file from the tar file.
- If you are using Windows, use a zip program that can read a tar file. Use the zip program to navigate to and extract the bin file.
- If you are using UNIX, follow these steps:
  1. Display the contents of the tar file by using the `tar -tvf image_filename.tar` UNIX command.
     ```
     unix% tar -tvf image_filename.tar
     ```
  2. Locate the bin file, and extract it by using the `tar -xvf image_filename.tar` UNIX command.
     ```
     hostname% tar -xvf image_filename.tar
     ```
  3. Verify that the bin file was extracted by using the `ls -l image_filename.bin` UNIX command.
     ```
     switch% ls -l image_filename.bin
     ```

**Step 3**
Connect your PC with terminal-emulation software supporting the Xmodem Protocol to the switch console port.

**Step 4**
Set the line speed on the emulation software to 9600 baud.

**Step 5**
Use a pointed device, such as a ballpoint pen, to press the Pwr/Rst button on the front panel of the switch.

**Step 6**
Press the Mode button and at the same time, reconnect the power cord to the switch.

You can release the Mode button a second or two after the LED above port 1 goes off. Several lines of information about the software appear along with instructions:

```
The system has been interrupted prior to initializing the flash file system. The following commands will initialize the flash file system, and finish loading the operating system software#
```

```
flash_init
load_helper
boot
```
Recovering from a Lost or Forgotten Password

The default configuration for the switch allows an end user with physical access to the switch to recover from a lost password by interrupting the bootup process during power-on and by entering a new password. These recovery procedures require that you have physical access to the switch.

Note

On these switches, a system administrator can disable some of the functionality of this feature by allowing an end user to reset a password only by agreeing to return to the default configuration. If you are an end user trying to reset a password when password recovery has been disabled, a status message shows this during the recovery process.

These sections describe how to recover a forgotten or lost switch password:

- Procedure with Password Recovery Enabled, page 29-4
- Procedure with Password Recovery Disabled, page 29-6

You enable or disable password recovery by using the service password-recovery global configuration command. Follow the steps in this procedure if you have forgotten or lost the switch password.

Step 1 Connect a terminal or PC with terminal-emulation software to the switch console port.

Step 2 Set the line speed on the emulation software to 9600 baud.
Step 3  Use a pointed device, such as a ballpoint pen, to press the Pwr/Rst button on the front panel of the switch.

Step 4  within 15 seconds, press the Mode button while the System LED is still flashing green. Continue pressing the Mode button until the System LED turns briefly amber and then solid green; then release the Mode button.

Several lines of information about the software appear with instructions, informing you if the password recovery procedure has been disabled or not.

- If you see a message that begins with this:
  The system has been interrupted prior to initializing the flash file system. The following commands will initialize the flash file system

  go to the “Procedure with Password Recovery Enabled” section on page 29-4, and follow the steps.

- If you see a message that begins with this:
  The password-recovery mechanism has been triggered, but is currently disabled.

  go to the “Procedure with Password Recovery Disabled” section on page 29-6, and follow the steps.

---

**Procedure with Password Recovery Enabled**

If the password-recovery mechanism is enabled, this message appears:

The system has been interrupted prior to initializing the flash file system. The following commands will initialize the flash file system, and finish loading the operating system software:

```
flash_init
load_helper
boot
```

Follow these steps to enable password recovery:

---

**Step 1**  Initialize the flash file system:

```
switch: flash_init
```

**Step 2**  If you had set the console port speed to anything other than 9600, it has been reset to that particular speed. Change the emulation software line speed to match that of the switch console port.

**Step 3**  Load any helper files:

```
switch: load_helper
```

**Step 4**  Display the contents of flash memory:

```
switch: dir flash:
```

The switch file system appears:

```
Directory of flash:
13 drwx  192  Mar 01 1993 22:30:48
11 -rwx  5825 Mar 01 1993 22:31:59  config.text
18 -rwx  720  Mar 01 1993 02:21:30  vlan.dat
```

16128000 bytes total (10003456 bytes free)
Step 5 Rename the configuration file to config.text.old.
This file contains the password definition.

```
switch: rename flash:config.text flash:config.text.old
```

Step 6 Boot up the system:

```
switch: boot
```

You are prompted to start the setup program. Enter N at the prompt:

```
Continue with the configuration dialog? [yes/no]: N
```

Step 7 At the switch prompt, enter privileged EXEC mode:

```
Switch> enable
```

Step 8 Rename the configuration file to its original name:

```
Switch# rename flash:config.text.old flash:config.text
```

**Note** Before continuing to Step 9, power on any connected stack members and wait until they have completely initialized. Failure to follow this step can result in a lost configuration depending on how your switch is set up.

Step 9 Copy the configuration file into memory:

```
Switch# copy flash:config.text system:running-config
Source filename [config.text]? Destination filename [running-config]?
```

Press **Return** in response to the confirmation prompts.

The configuration file is now reloaded, and you can change the password.

Step 10 Enter global configuration mode:

```
Switch# configure terminal
```

Step 11 Change the password:

```
Switch (config)# enable secret password
```

The secret password can be from 1 to 25 alphanumeric characters, can start with a number, is case sensitive, and allows spaces but ignores leading spaces.

Step 12 Return to privileged EXEC mode:

```
Switch (config)# exit
Switch#
```

```
Step 13  Write the running configuration to the startup configuration file:

Switch# copy running-config startup-config

The new password is now in the startup configuration.

Note  This procedure is likely to leave your switch virtual interface in a shutdown state. You can see which interface is in this state by entering the `show running-config` privileged EXEC command. To re-enable the interface, enter the `interface vlan vlan-id` global configuration command, and specify the VLAN ID of the shutdown interface. With the switch in interface configuration mode, enter the `no shutdown` command.

Step 14  Reload the switch:

Switch# reload

Procedure with Password Recovery Disabled

If the password-recovery mechanism is disabled, this message appears:

The password-recovery mechanism has been triggered, but is currently disabled. Access to the boot loader prompt through the password-recovery mechanism is disallowed at this point. However, if you agree to let the system be reset back to the default system configuration, access to the boot loader prompt can still be allowed.

Would you like to reset the system back to the default configuration (y/n)?

Caution  Returning the switch to the default configuration results in the loss of all existing configurations. We recommend that you contact your system administrator to verify if there are backup switch and VLAN configuration files.

- If you enter n (no), the normal bootup process continues as if the Mode button had not been pressed; you cannot access the bootloader prompt, and you cannot enter a new password. You see the message:

  Press Enter to continue........

- If you enter y (yes), the configuration file in flash memory and the VLAN database file are deleted. When the default configuration loads, you can reset the password.

Step 1  Elect to continue with password recovery and lose the existing configuration:

Would you like to reset the system back to the default configuration (y/n)? Y

Step 2  Load any helper files:

Switch: load_helper

Step 3  Display the contents of flash memory:

switch: dir flash:
The switch file system appears:

```
Directory of flash:
13  drwx         192   Mar 01 1993 22:30:48
16128000 bytes total (10003456 bytes free)
```

**Step 4**  Boot up the system:

```
Switch: boot
```

You are prompted to start the setup program. To continue with password recovery, enter N at the prompt:

```
Continue with the configuration dialog? [yes/no]: N
```

**Step 5**  At the switch prompt, enter privileged EXEC mode:

```
Switch> enable
```

**Step 6**  Enter global configuration mode:

```
Switch# configure terminal
```

**Step 7**  Change the password:

```
Switch (config)# enable secret password
```

The secret password can be from 1 to 25 alphanumeric characters, can start with a number, is case sensitive, and allows spaces but ignores leading spaces.

**Step 8**  Return to privileged EXEC mode:

```
Switch (config)# exit
Switch#
```

**Step 9**  Write the running configuration to the startup configuration file:

```
Switch# copy running-config startup-config
```

The new password is now in the startup configuration.

---

**Note**  This procedure is likely to leave your switch virtual interface in a shutdown state. You can see which interface is in this state by entering the `show running-config` privileged EXEC command. To re-enable the interface, enter the `interface vlan vlan-id` global configuration command, and specify the VLAN ID of the shutdown interface. With the switch in interface configuration mode, enter the `no shutdown` command.

**Step 10**  You must now reconfigure the switch. If the system administrator has the backup switch and VLAN configuration files available, you should use those.

**Step 11**  Reload the switch:

```
Switch# reload
```
Recovering from a Command Switch Failure

This section describes how to recover from a failed command switch. You can configure a redundant command switch group by using the Hot Standby Router Protocol (HSRP). For more information, see Chapter 6, “Clustering Switches.” For more information, see Chapter 6, “Clustering Switches.” Also see the Getting Started with Cisco Network Assistant, available on Cisco.com.

Note

HSRP is the preferred method for supplying redundancy to a cluster.

If you have not configured a standby command switch, and your command switch loses power or fails in some other way, management contact with the member switches is lost, and you must install a new command switch. However, connectivity between switches that are still connected is not affected, and the member switches forward packets as usual. You can manage the members as standalone switches through the console port, or, if they have IP addresses, through the other management interfaces.

You can prepare for a command switch failure by assigning an IP address to a member switch or another switch that is command-capable, making a note of the command-switch password, and cabling your cluster to provide redundant connectivity between the member switches and the replacement command switch. These sections describe two solutions for replacing a failed command switch:

- Replacing a Failed Command Switch with a Cluster Member, page 29-8
- Replacing a Failed Command Switch with Another Switch, page 29-10

These recovery procedures require that you have physical access to the switch.

For information on command-capable switches, see the release notes.

Replacing a Failed Command Switch with a Cluster Member

To replace a failed command switch with a command-capable member in the same cluster, follow these steps:

Step 1 Disconnect the command switch from the member switches, and physically remove it from the cluster.

Step 2 Insert the member switch in place of the failed command switch, and duplicate its connections to the cluster members.

Step 3 Start a CLI session on the new command switch.

You can access the CLI by using the console port or, if an IP address has been assigned to the switch, by using Telnet. For details about using the console port, see the switch hardware installation guide.

Step 4 At the switch prompt, enter privileged EXEC mode:

```
Switch> enable
Switch#
```

Step 5 Enter the password of the failed command switch.

Step 6 Enter global configuration mode.

```
Switch# configure terminal
```

Enter configuration commands, one per line. End with CNTL/Z.

Step 7 Remove the member switch from the cluster.

```
Switch(config)# no cluster commander-address
```
Step 8  Return to privileged EXEC mode.

Switch(config)# end
Switch#

Step 9  Use the setup program to configure the switch IP information. This program prompts you for IP address information and passwords. From privileged EXEC mode, enter setup, and press Return.

Switch# setup
--- System Configuration Dialog ---
Continue with configuration dialog? [yes/no]: y
At any point you may enter a question mark '?' for help. Use ctrl-c to abort configuration dialog at any prompt. Default settings are in square brackets '[]'.

Basic management setup configures only enough connectivity for management of the system, extended setup will ask you to configure each interface on the system

Would you like to enter basic management setup? [yes/no]:

Step 10 Enter Y at the first prompt.

The prompts in the setup program vary depending on the member switch that you selected to be the command switch:

Continue with configuration dialog? [yes/no]: y or

Configuring global parameters:

If this prompt does not appear, enter enable, and press Return. Enter setup, and press Return to start the setup program.

Step 11 Respond to the questions in the setup program.

When prompted for the hostname, recall that on a command switch, the hostname is limited to 28 characters; on a member switch to 31 characters. Do not use -n, where n is a number, as the last characters in a hostname for any switch.

When prompted for the Telnet (virtual terminal) password, recall that it can be from 1 to 25 alphanumeric characters, is case sensitive, allows spaces, but ignores leading spaces.

Step 12 When prompted for the enable secret and enable passwords, enter the passwords of the failed command switch again.

Step 13 When prompted, make sure to enable the switch as the cluster command switch, and press Return.

Step 14 When prompted, assign a name to the cluster, and press Return.

The cluster name can be 1 to 31 alphanumeric characters, dashes, or underscores.

Step 15 After the initial configuration displays, verify that the addresses are correct.

Step 16 If the displayed information is correct, enter Y, and press Return.

If this information is not correct, enter N, press Return, and begin again at Step 9.

Step 17 Start your browser, and enter the IP address of the new command switch.

Step 18 From the Cluster menu, select Add to Cluster to display a list of candidate switches to add to the cluster.
Recovering from a Command Switch Failure

Replacing a Failed Command Switch with Another Switch

To replace a failed command switch with a switch that is command-capable but not part of the cluster, follow these steps:

---

**Step 1** Insert the new switch in place of the failed command switch, and duplicate its connections to the cluster members.

**Step 2** Start a CLI session on the new command switch.

You can access the CLI by using the console port or, if an IP address has been assigned to the switch, by using Telnet. For details about using the console port, see the switch hardware installation guide.

**Step 3** At the switch prompt, enter privileged EXEC mode:

```
Switch> enable
Switch#
```

**Step 4** Enter the password of the failed command switch.

**Step 5** Use the setup program to configure the switch IP information.

This program prompts you for IP address information and passwords. From privileged EXEC mode, enter `setup`, and press `Return`.

```
Switch# setup
--- System Configuration Dialog ---
Continue with configuration dialog? [yes/no]: y
```

At any point you may enter a question mark '?' for help.
Use `ctrl-c` to abort configuration dialog at any prompt.
Default settings are in square brackets '[]'.

Basic management setup configures only enough connectivity for management of the system, extended setup will ask you to configure each interface on the system.

```
Would you like to enter basic management setup? [yes/no]:
```

**Step 6** Enter **Y** at the first prompt.

The prompts in the setup program vary depending on the switch you selected to be the command switch:

```
Continue with configuration dialog? [yes/no]: y
```

or

Configuring global parameters:

If this prompt does not appear, enter **enable**, and press **Return**. Enter **setup**, and press **Return** to start the setup program.

**Step 7** Respond to the questions in the setup program.

When prompted for the hostname, recall that on a command switch, the hostname is limited to 28 characters. Do not use `-n`, where `n` is a number, as the last character in a hostname for any switch.

When prompted for the Telnet (virtual terminal) password, recall that it can be from 1 to 25 alphanumeric characters, is case sensitive, allows spaces, but ignores leading spaces.

**Step 8** When prompted for the **enable secret** and **enable** passwords, enter the passwords of the **failed command switch** again.

**Step 9** When prompted, make sure to enable the switch as the cluster command switch, and press **Return**.
Step 10  When prompted, assign a name to the cluster, and press Return.
         The cluster name can be 1 to 31 alphanumeric characters, dashes, or underscores.
Step 11  When the initial configuration displays, verify that the addresses are correct.
Step 12  If the displayed information is correct, enter Y, and press Return.
         If this information is not correct, enter N, press Return, and begin again at Step 9.
Step 13  Start your browser, and enter the IP address of the new command switch.
Step 14  From the Cluster menu, select Add to Cluster to display a list of candidate switches to add to the cluster.

Recovering from Lost Cluster Member Connectivity

Some configurations can prevent the command switch from maintaining contact with member switches. If you are unable to maintain management contact with a member, and the member switch is forwarding packets normally, check for these conflicts:

- A member switch (Catalyst 3750, Catalyst 3560, Catalyst 3550, Catalyst 3500 XL, Catalyst 2970, Catalyst 2960, CGESM, Catalyst 2950, Catalyst 2900 XL, Catalyst 2820, and Catalyst 1900 switch) cannot connect to the command switch through a port that is defined as a network port.
- Catalyst 3500 XL, Catalyst 2900 XL, Catalyst 2820, and Catalyst 1900 member switches must connect to the command switch through a port that belongs to the same management VLAN.
- A member switch (Catalyst 3750, Catalyst 3560, Catalyst 3550, Catalyst 2970, Catalyst 2960, CGESM, Catalyst 2950, Catalyst 3500 XL, Catalyst 2900 XL, Catalyst 2820, and Catalyst 1900 switch) connected to the command switch through a secured port can lose connectivity if the port is disabled because of a security violation.

Preventing Autonegotiation Mismatches

The IEEE 802.3ab autonegotiation protocol manages the switch settings for speed (10 Mb/s, 100 Mb/s, and 1000 Mb/s, excluding SFP module ports) and duplex (half or full). There are situations when this protocol can incorrectly align these settings, reducing performance. A mismatch occurs under these circumstances:

- A manually set speed or duplex parameter is different from the manually set speed or duplex parameter on the connected port.
- A port is set to autonegotiate, and the connected port is set to full duplex with no autonegotiation.
To maximize switch performance and ensure a link, follow one of these guidelines when changing the settings for duplex and speed:

- Let both ports autonegotiate both speed and duplex.
- Manually set the speed and duplex parameters for the ports on both ends of the connection.

**Note**

If a remote device does not autonegotiate, configure the duplex settings on the two ports to match. The speed parameter can adjust itself even if the connected port does not autonegotiate.

### SFP Module Security and Identification

Cisco small form-factor pluggable (SFP) modules have a serial EEPROM that contains the module serial number, the vendor name and ID, a unique security code, and cyclic redundancy check (CRC). When an SFP module is inserted in the switch, the switch software reads the EEPROM to verify the serial number, vendor name and vendor ID, and recompute the security code and CRC. If the serial number, the vendor name or vendor ID, the security code, or CRC is invalid, the software generates a security error message and places the interface in an error-disabled state.

**Note**

The security error message references the GBIC_SECURITY facility. The switch supports SFP modules and does not support GBIC modules. Although the error message text refers to GBIC interfaces and modules, the security messages actually refer to the SFP modules and module interfaces. For more information about error messages, see the system message guide for this release.

If you are using a non-Cisco SFP module, remove the SFP module from the switch, and replace it with a Cisco module. After inserting a Cisco SFP module, use the `errdisable recovery cause gbic-invalid` global configuration command to verify the port status, and enter a time interval for recovering from the error-disabled state. After the elapsed interval, the switch brings the interface out of the error-disabled state and retries the operation. For more information about the `errdisable recovery` command, see the command reference for this release.

If the module is identified as a Cisco SFP module, but the system is unable to read vendor-data information to verify its accuracy, an SFP module error message is generated. In this case, you should remove and re-insert the SFP module. If it continues to fail, the SFP module might be defective.

### Monitoring SFP Module Status

You can check the physical or operational status of an SFP module by using the `show interfaces transceiver` privileged EXEC command. This command shows the operational status, such as the temperature and the current for an SFP module on a specific interface and the alarm status. You can also use the command to check the speed and the duplex settings on an SFP module. For more information, see the `show interfaces transceiver` command in the command reference for this release.
Using Ping

These sections contain this information:
- Understanding Ping, page 29-13
- Executing Ping, page 29-13

Understanding Ping

The switch supports IP ping, which you can use to test connectivity to remote hosts. Ping sends an echo request packet to an address and waits for a reply. Ping returns one of these responses:
- Normal response—The normal response (hostname is alive) occurs in 1 to 10 seconds, depending on network traffic.
- Destination does not respond—If the host does not respond, a no-answer message is returned.
- Unknown host—If the host does not exist, an unknown host message is returned.
- Destination unreachable—If the default gateway cannot reach the specified network, a destination-unreachable message is returned.
- Network or host unreachable—If there is no entry in the route table for the host or network, a network or host unreachable message is returned.

Executing Ping

Beginning in privileged EXEC mode, use this command to ping another device on the network from the switch:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ping ip host</td>
<td>Ping a remote host through IP or by supplying the hostname or network address.</td>
</tr>
</tbody>
</table>

Though other protocol keywords are available with the ping command, they are not supported in this release.

This example shows how to ping an IP host:

Switch# ping 172.20.52.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.20.52.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Switch#
Table 29-1 describes the possible ping character output.

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>!</td>
<td>Each exclamation point means receipt of a reply.</td>
</tr>
<tr>
<td>.</td>
<td>Each period means the network server timed out while waiting for a reply.</td>
</tr>
<tr>
<td>U</td>
<td>A destination unreachable error PDU was received.</td>
</tr>
<tr>
<td>C</td>
<td>A congestion experienced packet was received.</td>
</tr>
<tr>
<td>I</td>
<td>User interrupted test.</td>
</tr>
<tr>
<td>?</td>
<td>Unknown packet type.</td>
</tr>
<tr>
<td>&amp;</td>
<td>Packet lifetime exceeded.</td>
</tr>
</tbody>
</table>

To end a ping session, enter the escape sequence (Ctrl-^ X by default). Simultaneously press and release the Ctrl, Shift, and 6 keys and then press the X key.

**Using Layer 2 Traceroute**

These sections contain this information:
- Understanding Layer 2 Traceroute, page 29-14
- Usage Guidelines, page 29-15
- Displaying the Physical Path, page 29-16

**Understanding Layer 2 Traceroute**

The Layer 2 traceroute feature allows the switch to identify the physical path that a packet takes from a source device to a destination device. Layer 2 traceroute supports only unicast source and destination MAC addresses. It finds the path by using the MAC address tables of the switches in the path. When the switch detects a device in the path that does not support Layer 2 traceroute, the switch continues to send Layer 2 trace queries and lets them time out.

The switch can only identify the path from the source device to the destination device. It cannot identify the path that a packet takes from source host to the source device or from the destination device to the destination host.
Usage Guidelines

These are the Layer 2 traceroute usage guidelines:

- Cisco Discovery Protocol (CDP) must be enabled on all the devices in the network. For Layer 2 traceroute to function properly, do not disable CDP.

  For a list of switches that support Layer 2 traceroute, see the “Usage Guidelines” section on page 29-15. If any devices in the physical path are transparent to CDP, the switch cannot identify the path through these devices. For more information about enabling CDP, see Chapter 19, “Configuring CDP.”

- A switch is reachable from another switch when you can test connectivity by using the ping privileged EXEC command. All switches in the physical path must be reachable from each other.

- The maximum number of hops identified in the path is ten.

- You can enter the `traceroute mac` or the `traceroute mac ip` privileged EXEC command on a switch that is not in the physical path from the source device to the destination device. All switches in the path must be reachable from this switch.

- The `traceroute mac` command output shows the Layer 2 path only when the specified source and destination MAC addresses belong to the same VLAN. If you specify source and destination MAC addresses that belong to different VLANs, the Layer 2 path is not identified, and an error message appears.

- If you specify a multicast source or destination MAC address, the path is not identified, and an error message appears.

- If the source or destination MAC address belongs to multiple VLANs, you must specify the VLAN to which both the source and destination MAC addresses belong. If the VLAN is not specified, the path is not identified, and an error message appears.

- The `traceroute mac ip` command output shows the Layer 2 path when the specified source and destination IP addresses belong to the same subnet. When you specify the IP addresses, the switch uses the Address Resolution Protocol (ARP) to associate the IP addresses with the corresponding MAC addresses and the VLAN IDs.

  - If an ARP entry exists for the specified IP address, the switch uses the associated MAC address and identifies the physical path.

  - If an ARP entry does not exist, the switch sends an ARP query and tries to resolve the IP address. If the IP address is not resolved, the path is not identified, and an error message appears.

- When multiple devices are attached to one port through hubs (for example, multiple CDP neighbors are detected on a port), the Layer 2 traceroute feature is not supported. When more than one CDP neighbor is detected on a port, the Layer 2 path is not identified, and an error message appears.

- This feature is not supported in Token Ring VLANs.
Displaying the Physical Path

You can display the physical path that a packet takes from a source device to a destination device by using one of these privileged EXEC commands:

- `tracetroute mac [interface interface-id] {source-mac-address} [interface interface-id] {destination-mac-address} [vlan vlan-id] [detail]`
- `tracetroute mac ip {source-ip-address | source-hostname} {destination-ip-address | destination-hostname} [detail]`

For more information, see the command reference for this release.

Using IP Traceroute

These sections contain this information:
- Understanding IP Traceroute, page 29-16
- Executing IP Traceroute, page 29-17

Understanding IP Traceroute

You can use IP traceroute to identify the path that packets take through the network on a hop-by-hop basis. The command output displays all network layer (Layer 3) devices, such as routers, that the traffic passes through on the way to the destination.

Your switches can participate as the source or destination of the `traceroute` privileged EXEC command and might or might not appear as a hop in the `traceroute` command output. If the switch is the destination of the traceroute, it is displayed as the final destination in the traceroute output. Intermediate switches do not show up in the traceroute output if they are only bridging the packet from one port to another within the same VLAN. However, if the intermediate switch is a multilayer switch that is routing a particular packet, this switch shows up as a hop in the traceroute output.

The `traceroute` privileged EXEC command uses the Time To Live (TTL) field in the IP header to cause routers and servers to generate specific return messages. Traceroute starts by sending a User Datagram Protocol (UDP) datagram to the destination host with the TTL field set to 1. If a router finds a TTL value of 1 or 0, it drops the datagram and sends an Internet Control Message Protocol (ICMP) time-to-live-exceeded message to the sender. Traceroute finds the address of the first hop by examining the source address field of the ICMP time-to-live-exceeded message.

To identify the next hop, traceroute sends a UDP packet with a TTL value of 2. The first router decrements the TTL field by 1 and sends the datagram to the next router. The second router sees a TTL value of 1, discards the datagram, and returns the time-to-live-exceeded message to the source. This process continues until the TTL is incremented to a value large enough for the datagram to reach the destination host (or until the maximum TTL is reached).

To learn when a datagram reaches its destination, traceroute sets the UDP destination port number in the datagram to a very large value that the destination host is unlikely to be using. When a host receives a datagram destined to itself containing a destination port number that is unused locally, it sends an ICMP port-unreachable error to the source. Because all errors except port-unreachable errors come from intermediate hops, the receipt of a port-unreachable error means that this message was sent by the destination port.
Executing IP Traceroute

Beginning in privileged EXEC mode, follow this step to trace the path that packets take through the network:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>traceroute ip host</td>
<td>Trace the path that packets take through the network.</td>
</tr>
</tbody>
</table>

**Note**

Though other protocol keywords are available with the `traceroute` privileged EXEC command, they are not supported in this release.

This example shows how to perform a `traceroute` to an IP host:

```
Switch# traceroute ip 171.9.15.10
```

Type escape sequence to abort.
Tracing the route to 171.69.115.10

```
1 172.2.52.1 0 msec 0 msec 4 msec
2 172.2.1.203 12 msec 8 msec 0 msec
3 171.9.16.6 4 msec 0 msec 0 msec
4 171.9.4.5 0 msec 4 msec 0 msec
5 171.9.121.34 0 msec 4 msec 4 msec
6 171.9.15.9 120 msec 132 msec 128 msec
7 171.9.15.10 132 msec 128 msec 128 msec
```

```
Switch#
```

The display shows the hop count, the IP address of the router, and the round-trip time in milliseconds for each of the three probes that are sent.

**Table 29-2 Traceroute Output Display Characters**

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>The probe timed out.</td>
</tr>
<tr>
<td>?</td>
<td>Unknown packet type.</td>
</tr>
<tr>
<td>A</td>
<td>Administratively unreachable. Usually, this output means that an access list is blocking traffic.</td>
</tr>
<tr>
<td>H</td>
<td>Host unreachable.</td>
</tr>
<tr>
<td>N</td>
<td>Network unreachable.</td>
</tr>
<tr>
<td>P</td>
<td>Protocol unreachable.</td>
</tr>
<tr>
<td>Q</td>
<td>Source quench.</td>
</tr>
<tr>
<td>U</td>
<td>Port unreachable.</td>
</tr>
</tbody>
</table>

To end a trace in progress, enter the escape sequence (Ctrl-^ X by default). Simultaneously press and release the Ctrl, Shift, and 6 keys and then press the X key.
Using TDR

These sections contain this information:

- Understanding TDR, page 29-18
- Running TDR and Displaying the Results, page 29-18

Understanding TDR

You can use the Time Domain Reflector (TDR) feature to diagnose and resolve cabling problems. When running TDR, a local device sends a signal through a cable and compares the reflected signal to the initial signal.

TDR is supported only on 10/100 and 10/100/1000 copper Ethernet ports. It is not supported on SFP module ports.

TDR can detect these cabling problems:

- Open, broken, or cut twisted-pair wires—The wires are not connected to the wires from the remote device.
- Shorted twisted-pair wires—The wires are touching each other or the wires from the remote device. For example, a shorted twisted pair can occur if one wire of the twisted pair is soldered to the other wire.

If one of the twisted-pair wires is open, TDR can find the length at which the wire is open.

Use TDR to diagnose and resolve cabling problems in these situations:

- Replacing a switch
- Setting up a wiring closet
- Troubleshooting a connection between two devices when a link cannot be established or when it is not operating properly

Running TDR and Displaying the Results

To run TDR, enter the `test cable-diagnostics tdr interface interface-id` privileged EXEC command:

To display the results, enter the `show cable-diagnostics tdr interface interface-id` privileged EXEC command. For a description of the fields in the display, see the command reference for this release.

Using Debug Commands

These sections explains how you use `debug` commands to diagnose and resolve internetworking problems:

- Enabling Debugging on a Specific Feature, page 29-19
- Enabling All-System Diagnostics, page 29-19
- Redirecting Debug and Error Message Output, page 29-20
Because debugging output is assigned high priority in the CPU process, it can render the system unusable. For this reason, use `debug` commands only to troubleshoot specific problems or during troubleshooting sessions with Cisco technical support staff. It is best to use `debug` commands during periods of lower network traffic and fewer users. Debugging during these periods decreases the likelihood that increased `debug` command processing overhead will affect system use.

---

**Caution**

For complete syntax and usage information for specific `debug` commands, see the command reference for this release.

---

### Enabling Debugging on a Specific Feature

All `debug` commands are entered in privileged EXEC mode, and most `debug` commands take no arguments. For example, beginning in privileged EXEC mode, enter this command to enable the debugging for Switched Port Analyzer (SPAN):

```
Switch# debug span-session
```

The switch continues to generate output until you enter the `no` form of the command.

If you enable a `debug` command and no output appears, consider these possibilities:

- The switch might not be properly configured to generate the type of traffic you want to monitor. Use the `show running-config` command to check its configuration.
- Even if the switch is properly configured, it might not generate the type of traffic you want to monitor during the particular period that debugging is enabled. Depending on the feature you are debugging, you can use commands such as the TCP/IP `ping` command to generate network traffic.

To disable debugging of SPAN, enter this command in privileged EXEC mode:

```
Switch# no debug span-session
```

Alternately, in privileged EXEC mode, you can enter the `undebug` form of the command:

```
Switch# undebug span-session
```

To display the state of each debugging option, enter this command in privileged EXEC mode:

```
Switch# show debugging
```

### Enabling All-System Diagnostics

Beginning in privileged EXEC mode, enter this command to enable all-system diagnostics:

```
Switch# debug all
```

**Caution**

Because debugging output takes priority over other network traffic, and because the `debug all` privileged EXEC command generates more output than any other `debug` command, it can severely diminish switch performance or even render it unusable. In virtually all cases, it is best to use more specific `debug` commands.
The **no debug all** privileged EXEC command disables all diagnostic output. Using the **no debug all** command is a convenient way to ensure that you have not accidentally left any **debug** commands enabled.

### Redirecting Debug and Error Message Output

By default, the network server sends the output from **debug** commands and system error messages to the console. If you use this default, you can use a virtual terminal connection to monitor debug output instead of connecting to the console port.

Possible destinations include the console, virtual terminals, internal buffer, and UNIX hosts running a syslog server. The syslog format is compatible with 4.3 Berkeley Standard Distribution (BSD) UNIX and its derivatives.

**Note**

Be aware that the debugging destination you use affects system overhead. Logging messages to the console produces very high overhead, whereas logging messages to a virtual terminal produces less overhead. Logging messages to a syslog server produces even less, and logging to an internal buffer produces the least overhead of any method.

For more information about system message logging, see Chapter 24, “Configuring System Message Logging.”

### Using the show platform forward Command

The output from the **show platform forward** privileged EXEC command provides some useful information about the forwarding results if a packet entering an interface is sent through the system. Depending upon the parameters entered about the packet, the output provides lookup table results and port maps used to calculate forwarding destinations, bitmaps, and egress information.

**Note**

For more syntax and usage information for the **show platform forward** command, see the switch command reference for this release.

Most of the information in the output from the command is useful mainly for technical support personnel, who have access to detailed information about the switch application-specific integrated circuits (ASICs). However, packet forwarding information can also be helpful in troubleshooting.

This is an example of the output from the **show platform forward** command on port 1 in VLAN 5 when the packet entering that port is addressed to unknown MAC addresses. The packet should be flooded to all other ports in VLAN 5.

```
Switch# show platform forward gigabitethernet0/1 vlan 5 1.1.1 2.2.2 ip 13.1.1.1 13.2.2.2 udp 10 20
Global Port Number:24, Asic Number:5
Src Real Vlan Id:5, Mapped Vlan Id:5
Ingress:
  Lookup Key-Used Index-Hit A-Data
  ImptACL 40_0D020202_0D010101-00_40000014_000A0000 01FFA 03000000
  L2Local 80_00050002_00020002-00_00000000_00000000 00C71 00000002B
Station Descriptor:02340000, DestIndex:0239, RewriteIndex:F005
```

==========================================
### Using the show platform forward Command

**Egress: Asic 2, switch 1**

Output Packets:

<table>
<thead>
<tr>
<th>Packet</th>
<th>Lookup</th>
<th>Key-Used</th>
<th>Index-Hit</th>
<th>A-Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet 1</td>
<td>OutptACL 50_0D020202_0D010101-00_40000014_000A0000</td>
<td>01FFE</td>
<td>03000000</td>
<td></td>
</tr>
<tr>
<td>Port</td>
<td>Vlan</td>
<td>SrcMac</td>
<td>DstMac</td>
<td>Cos</td>
</tr>
<tr>
<td>Gi0/1</td>
<td>0005</td>
<td>0001.0001.0001</td>
<td>0002.0002.0002</td>
<td></td>
</tr>
</tbody>
</table>

| Packet 2 | OutptACL 50_0D020202_0D010101-00_40000014_000A0000 | 01FFE | 03000000 |
| Port | Vlan | SrcMac | DstMac | Cos | DscpV |
| Gi0/2 | 0005 | 0001.0001.0001 | 0002.0002.0002 |

<output truncated>

| Packet 10 | OutptACL 50_0D020202_0D010101-00_40000014_000A0000 | 01FFE | 03000000 |
| Packet dropped due to failed DEJA_VU Check on Gi0/2 |

This is an example of the output when the packet coming in on port 1 in VLAN 5 is sent to an address already learned on the VLAN on another port. It should be forwarded from the port on which the address was learned.

```bash
Switch# show platform forward gigabitethernet0/1 vlan 5 1.1.1 0009.43A8.0145 ip 13.1.1.1 13.2.2.2 udp 10 20
Global Port Number:24, Asic Number:5
Src Real Vlan Id:5, Mapped Vlan Id:5

Ingress:
<table>
<thead>
<tr>
<th>Lookup</th>
<th>Key-Used</th>
<th>Index-Hit</th>
<th>A-Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>InptACL 40_0D020202_0D010101-00_40000014_000A0000</td>
<td>01FFA</td>
<td>03000000</td>
<td></td>
</tr>
<tr>
<td>L2Local 80_00050009_43A80145-00_00000000_00000000</td>
<td>00086</td>
<td>02010197</td>
<td></td>
</tr>
<tr>
<td>Station Descriptor:F0050003, DestIndex:F005, RewriteIndex:0003</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Egress: Asic 3, switch 1

Output Packets:

<table>
<thead>
<tr>
<th>Packet</th>
<th>Lookup</th>
<th>Key-Used</th>
<th>Index-Hit</th>
<th>A-Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet 1</td>
<td>OutptACL 50_0D020202_0D010101-00_40000014_000A0000</td>
<td>01FFE</td>
<td>03000000</td>
<td></td>
</tr>
<tr>
<td>Port</td>
<td>Vlan</td>
<td>SrcMac</td>
<td>DstMac</td>
<td>Cos</td>
</tr>
<tr>
<td>Gi0/2</td>
<td>0005</td>
<td>0001.0001.0001</td>
<td>0009.43A8.0145</td>
<td></td>
</tr>
</tbody>
</table>
```
Using the crashinfo Files

The crashinfo files save information that helps Cisco technical support representatives to debug problems that caused the Cisco IOS image to fail (crash). The switch writes the crash information to the console at the time of the failure. The switch creates two types of crashinfo files:

- Basic crashinfo file—The switch automatically creates this file the next time you boot up the Cisco IOS image after the failure.
- Extended crashinfo file—The switch automatically creates this file when the system is failing.

Basic crashinfo Files

The information in the basic file includes the Cisco IOS image name and version that failed, a list of the processor registers, and a stack trace. You can provide this information to the Cisco technical support representative by using the `show tech-support` privileged EXEC command.

Basic crashinfo files are kept in this directory on the flash file system:

flash:/crashinfo/.

The filenames are crashinfo_<n> where n is a sequence number.

Each new crashinfo file that is created uses a sequence number that is larger than any previously existing sequence number, so the file with the largest sequence number describes the most recent failure. Version numbers are used instead of a timestamp because the switches do not include a real-time clock. You cannot change the name of the file that the system will use when it creates the file. However, after the file is created, you can use the `rename` privileged EXEC command to rename it, but the contents of the renamed file will not be displayed by the `show tech-support` privileged EXEC command. You can delete crashinfo files by using the `delete` privileged EXEC command.

You can display the most recent basic crashinfo file (that is, the file with the highest sequence number at the end of its filename) by entering the `show tech-support` privileged EXEC command. You also can access the file by using any command that can copy or display files, such as the `more` or the `copy` privileged EXEC command.

Extended crashinfo Files

In Cisco IOS Release 12.2(25)SEC or later, the switch creates the extended crashinfo file when the system is failing. The information in the extended file includes additional information that can help determine the cause of the switch failure. You provide this information to the Cisco technical support representative by manually accessing the file and using the `more` or the `copy` privileged EXEC command.

Extended crashinfo files are kept in this directory on the flash file system:

flash:/crashinfo_ext/.

The filenames are crashinfo_ext_<n> where n is a sequence number.

You can configure the switch to not create the extended crashinfo file by using the `no exception crashinfo` global configuration command.
Supported MIBs

This appendix lists the supported management information base (MIBs) for this release on the switch. It contains these sections:

- MIB List, page A-1
- Using FTP to Access the MIB Files, page A-3

MIB List

- BRIDGE-MIB

  Note  The BRIDGE-MIB supports the context of a single VLAN. By default, SNMP messages using the configured community string always provide information for VLAN 1. To obtain the BRIDGE-MIB information for other VLANs, for example VLAN x, use this community string in the SNMP message: configured community string @x.

- CISCO-CABLE-DIAG-MIB
- CISCO-CDP-MIB
- CISCO-CLUSTER-MIB
- CISCO-CONFIG-COPY-MIB
- CISCO-CONFIG-MAN-MIB
- CISCO-ENTITY-VENDORTYPE-OID-MIB
- CISCO-ENVMON-MIB
- CISCO-ERR-DISABLE-MIB
- CISCO-FLASH-MIB (Flash memory on all switches is modeled as removable flash memory.)
- CISCO-FTP-CLIENT-MIB
- CISCO-IGMP-FILTER-MIB
- CISCO-IMAGE-MIB
- CISCO-IP-STAT-MIB
- CISCO-LAG-MIB
- CISCO-MAC-NOTIFICATION-MIB
- CISCO-MEMORY-POOL-MIB
- CISCO-PAE-MIB
- CISCO-PAGP-MIB
- CISCO-PING-MIB
- CISCO-PRODUCTS-MIB
- CISCO-PROCESS-MIB
- CISCO-RTTMON-MIB
- CISCO-SMI-MIB
- CISCO-STP-EXTENSIONS-MIB
- CISCO-SYSLOG-MIB
- CISCO-TC-MIB
- CISCO-TCP-MIB
- CISCO-UDLDP-MIB
- CISCO-VLAN-IFTABLE-RELATIONSHIP-MIB
- CISCO-VLAN-MEMBERSHIP-MIB
- CISCO-VTP-MIB
- ENTITY-MIB
- ETHERLIKE-MIB
- IEEE8021-PAE-MIB
- IEEE8023-LAG-MIB
- IF-MIB (In and out counters for VLANs are not supported.)
- INET-ADDRESS-MIB
- OLD-CISCO-CHASSIS-MIB
- OLD-CISCO-FLASH-MIB
- OLD-CISCO-INTERFACES-MIB
- OLD-CISCO-IP-MIB
- OLD-CISCO-SYS-MIB
- OLD-CISCO-TCP-MIB
- OLD-CISCO-TS-MIB
- RFC1213-MIB (Functionality is as per the agent capabilities specified in the CISCO-RFC1213-CAPABILITY.my.)
- RMON-MIB
- RMON2-MIB
- SNMP-FRAMEWORK-MIB
- SNMP-MPD-MIB
- SNMP-NOTIFICATION-MIB
- SNMP-TARGET-MIB
- SNMPv2-MIB
Using FTP to Access the MIB Files

You can get each MIB file by using this procedure:

**Step 1**  Make sure that your FTP client is in passive mode.

**Note**  Some FTP clients do not support passive mode.

**Step 2**  Use FTP to access the server ftp.cisco.com.

**Step 3**  Log in with the username anonymous.

**Step 4**  Enter your e-mail username when prompted for the password.

**Step 5**  At the ftp> prompt, change directories to /pub/mibs/v1 and /pub/mibs/v2.

**Step 6**  Use the get MIB_filename command to obtain a copy of the MIB file.
Working with the Cisco IOS File System, Configuration Files, and Software Images

This appendix describes how to manipulate the switch flash file system, how to copy configuration files, and how to archive (upload and download) software images to a switch.

Note
For complete syntax and usage information for the commands used in this chapter, see the switch command reference for this release and the Cisco IOS Configuration Fundamentals Command Reference, Release 12.2.

This appendix consists of these sections:
- Working with the Flash File System, page B-1
- Working with Configuration Files, page B-8
- Working with Software Images, page B-20

Working with the Flash File System

The flash file system is a single flash device on which you can store files. It also provides several commands to help you manage software image and configuration files. The default flash file system on the switch is named flash:

These sections contain this configuration information:
- Displaying Available File Systems, page B-2
- Setting the Default File System, page B-3
- Displaying Information about Files on a File System, page B-3
- Creating and Removing Directories, page B-4
- Copying Files, page B-4
- Deleting Files, page B-5
- Creating, Displaying, and Extracting tar Files, page B-5
- Displaying the Contents of a File, page B-8
Displaying Available File Systems

To display the available file systems on your switch, use the `show file systems` privileged EXEC command as shown in this example.

```
Switch# show file systems
File Systems:
  Size(b) Free(b) Type Flags Prefixes
  15998976 5135872 flash rw flash:
  - - opaque rw bs:
  - - opaque rw vb:
  524288 520138 nvram rw nvram:
  - - network rw tftp:
  - - opaque rw null:
  - - opaque rw system:
  - - opaque ro xmodem:
  - - opaque ro ymodem:
```

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size(b)</td>
<td>Amount of memory in the file system in bytes.</td>
</tr>
<tr>
<td>Free(b)</td>
<td>Amount of free memory in the file system in bytes.</td>
</tr>
<tr>
<td>Type</td>
<td>Type of file system.</td>
</tr>
<tr>
<td>flash</td>
<td>The file system is for a flash memory device.</td>
</tr>
<tr>
<td>nvram</td>
<td>The file system is for a NVRAM device.</td>
</tr>
<tr>
<td>opaque</td>
<td>The file system is a locally generated pseudo file system (for example, the system) or a download interface, such as brimux.</td>
</tr>
<tr>
<td>unknown</td>
<td>The file system is an unknown type.</td>
</tr>
<tr>
<td>Flags</td>
<td>Permission for file system.</td>
</tr>
<tr>
<td>ro</td>
<td>read-only.</td>
</tr>
<tr>
<td>rw</td>
<td>read/write.</td>
</tr>
<tr>
<td>wo</td>
<td>write-only.</td>
</tr>
<tr>
<td>Prefixes</td>
<td>Alias for file system.</td>
</tr>
<tr>
<td>flash:</td>
<td>Flash file system.</td>
</tr>
<tr>
<td>nvram:</td>
<td>NVRAM.</td>
</tr>
<tr>
<td>null:</td>
<td>Null destination for copies. You can copy a remote file to null to find its size.</td>
</tr>
<tr>
<td>rcp:</td>
<td>Remote Copy Protocol (RCP) network server.</td>
</tr>
<tr>
<td>system:</td>
<td>Contains the system memory, including the running configuration.</td>
</tr>
<tr>
<td>tftp:</td>
<td>TFTP network server.</td>
</tr>
<tr>
<td>xmodem:</td>
<td>Obtain the file from a network machine by using the Xmodem protocol.</td>
</tr>
<tr>
<td>ymodem:</td>
<td>Obtain the file from a network machine by using the Ymodem protocol.</td>
</tr>
</tbody>
</table>
Setting the Default File System

You can specify the file system or directory that the system uses as the default file system by using the `cd filesystem:` privileged EXEC command. You can set the default file system to omit the `filesystem:` argument from related commands. For example, for all privileged EXEC commands that have the optional `filesystem:` argument, the system uses the file system specified by the `cd` command.

By default, the default file system is `flash:`.

You can display the current default file system as specified by the `cd` command by using the `pwd` privileged EXEC command.

Displaying Information about Files on a File System

You can view a list of the contents of a file system before manipulating its contents. For example, before copying a new configuration file to flash memory, you might want to verify that the file system does not already contain a configuration file with the same name. Similarly, before copying a flash configuration file to another location, you might want to verify its filename for use in another command.

To display information about files on a file system, use one of the privileged EXEC commands in Table B-2:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>dir [full] [filesystem:]filename</code></td>
<td>Display a list of files on a file system.</td>
</tr>
<tr>
<td><code>show file systems</code></td>
<td>Display more information about each of the files on a file system.</td>
</tr>
<tr>
<td><code>show file information file-url</code></td>
<td>Display information about a specific file.</td>
</tr>
<tr>
<td><code>show file descriptors</code></td>
<td>Display a list of open file descriptors. File descriptors are the internal representations of open files. You can use this command to see if another user has a file open.</td>
</tr>
</tbody>
</table>

Changing Directories and Displaying the Working Directory

Beginning in privileged EXEC mode, follow these steps to change directories and display the working directory.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td><code>dir filesystem:</code></td>
<td>Display the directories on the specified file system. For <code>filesystem:</code> , use <code>flash:</code> for the system board flash device.</td>
</tr>
<tr>
<td>Step 2</td>
<td><code>cd new_configs</code></td>
<td>Change to the directory of interest. The command example shows how to change to the directory named <code>new_configs</code>.</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>pwd</code></td>
<td>Display the working directory.</td>
</tr>
</tbody>
</table>
Creating and Removing Directories

Beginning in privileged EXEC mode, follow these steps to create and remove a directory:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>dir filesystem:</td>
</tr>
<tr>
<td></td>
<td>Display the directories on the specified file system.</td>
</tr>
<tr>
<td></td>
<td>For filesystem:, use flash: for the system board flash device.</td>
</tr>
<tr>
<td>Step 2</td>
<td>mkdir old_configs</td>
</tr>
<tr>
<td></td>
<td>Create a new directory.</td>
</tr>
<tr>
<td></td>
<td>The command example shows how to create the directory named old_configs.</td>
</tr>
<tr>
<td></td>
<td>Directory names are case sensitive.</td>
</tr>
<tr>
<td></td>
<td>Directory names are limited to 45 characters between the slashes (/);</td>
</tr>
<tr>
<td></td>
<td>the name cannot contain control characters, spaces, deletes, slashes,</td>
</tr>
<tr>
<td></td>
<td>quotes, semicolons, or colons.</td>
</tr>
<tr>
<td>Step 3</td>
<td>dir filesystem:</td>
</tr>
<tr>
<td></td>
<td>Verify your entry.</td>
</tr>
</tbody>
</table>

To delete a directory with all its files and subdirectories, use the **delete /force /recursive filesystem:file-url** privileged EXEC command.

Use the /recursive keyword to delete the named directory and all subdirectories and the files contained in it. Use the /force keyword to suppress the prompting that confirms a deletion of each file in the directory. You are prompted only once at the beginning of this deletion process. Use the /force and /recursive keywords for deleting old software images that were installed by using the **archive download-sw** command but are no longer needed.

For filesystem, use flash: for the system board flash device. For file-url, enter the name of the directory to be deleted. All the files in the directory and the directory are removed.

⚠️ Caution

When files and directories are deleted, their contents cannot be recovered.

Copying Files

To copy a file from a source to a destination, use the **copy source-url destination-url** privileged EXEC command. For the source and destination URLs, you can use **running-config** and **startup-config** keyword shortcuts. For example, the **copy running-config startup-config** command saves the currently running configuration file to the NVRAM section of flash memory to be used as the configuration during system initialization.

You can also copy from special file systems (**xmodem:**, **ymodem:**) as the source for the file from a network machine that uses the Xmodem or Ymodem protocol.

Network file system URLs include **ftp:**, **rcp:**, and **tftp:** and have these syntaxes:
- **FTP**—**ftp:**[[@Username [[:password:]]@location]/directory]/filename
- **RCP**—**rcp:**[[@Username@location]/directory]/filename
- **TFTP**—**tftp:**[@location]/directory]/filename
Local writable file systems include flash:.

Some invalid combinations of source and destination exist. Specifically, you cannot copy these combinations:

- From a running configuration to a running configuration
- From a startup configuration to a startup configuration
- From a device to the same device (for example, the copy flash: flash: command is invalid)

For specific examples of using the copy command with configuration files, see the “Working with Configuration Files” section on page B-8.

To copy software images either by downloading a new version or by uploading the existing one, use the archive download-sw or the archive upload-sw privileged EXEC command. For more information, see the “Working with Software Images” section on page B-20.

Deleting Files

When you no longer need a file on a flash memory device, you can permanently delete it. To delete a file or directory from a specified flash device, use the delete [/force] [/recursive] [filesystem:]file-url privileged EXEC command.

Use the /recursive keyword for deleting a directory and all subdirectories and the files contained in it. Use the /force keyword to suppress the prompting that confirms a deletion of each file in the directory. You are prompted only once at the beginning of this deletion process. Use the /force and /recursive keywords for deleting old software images that were installed by using the archive download-sw command but are no longer needed.

If you omit the filesystem option, the switch uses the default device specified by the cd command. For file-url, you specify the path (directory) and the name of the file to be deleted.

When you attempt to delete any files, the system prompts you to confirm the deletion.

Caution

When files are deleted, their contents cannot be recovered.

This example shows how to delete the file myconfig from the default flash memory device:

Switch# delete myconfig

Creating, Displaying, and Extracting tar Files

You can create a tar file and write files into it, list the files in a tar file, and extract the files from a tar file as described in the next sections.

Note

Instead of using the copy privileged EXEC command or the archive tar privileged EXEC command, we recommend using the archive download-sw and archive upload-sw privileged EXEC commands to download and upload software image files.
Creating a tar File

To create a tar file and write files into it, use this privileged EXEC command:

```
archive tar /create destination-url flash:/file-url
```

For `destination-url`, specify the destination URL alias for the local or network file system and the name of the tar file to create. These options are supported:

- For the local flash file system, the syntax is `flash:`
- For the FTP, the syntax is `ftp://[username:[password]@location]/directory]/tar-filename.tar`
- For the RCP, the syntax is `rcp://[username@location]/directory]/tar-filename.tar`
- For the TFTP, the syntax is `tftp://[location]/directory]/tar-filename.tar`

The `tar-filename.tar` is the tar file to be created.

For `flash:/file-url`, specify the location on the local flash file system from which the new tar file is created. You can also specify an optional list of files or directories within the source directory to write to the new tar file. If none are specified, all files and directories at this level are written to the newly created tar file.

This example shows how to create a tar file. This command writes the contents of the `new-configs` directory on the local flash device to a file named `saved.tar` on the TFTP server at 172.20.10.30:

```
Switch# archive tar /create tftp:172.20.10.30/saved.tar flash:/new-configs
```

Displaying the Contents of a tar File

To display the contents of a tar file on the screen, use this privileged EXEC command:

```
archive tar /table source-url
```

For `source-url`, specify the source URL alias for the local or network file system. These options are supported:

- For the local flash file system, the syntax is `flash:`
- For the FTP, the syntax is `ftp://[username:[password]@location]/directory]/tar-filename.tar`
- For the RCP, the syntax is `rcp://[username@location]/directory]/tar-filename.tar`
- For the TFTP, the syntax is `tftp://[location]/directory]/tar-filename.tar`

The `tar-filename.tar` is the tar file to display.

You can also limit the display of the files by specifying an optional list of files or directories after the tar file; then only those files appear. If none are specified, all files and directories appear.
This example shows how to display the contents of a switch tar file that is in flash memory:

```
Switch# archive tar /table flash:cgesm-i6l2-mz.122-25.SE1.tar info (219 bytes)
cgesm-1612-mz.122-25.SE1/ (directory)
cgesm-1612-mz.122-25.SE1/html/ (directory)
cgesm-1612-mz.122-25.SE1/html/troubleshooting_OS.htm (2508 bytes)
cgesm-1612-mz.122-25.SE1/html/helpframework.js (858 bytes)
cgesm-1612-mz.122-25.SE1/html/const.htm (556 bytes)
cgesm-1612-mz.122-25.SE1/html/forms.js (12940 bytes)
cgesm-1612-mz.122-25.SE1/html/xhome.htm (9249 bytes)
cgesm-1612-mz.122-25.SE1/html/stylesheets.css (8273 bytes)
cgesm-1612-mz.122-25.SE1/html/menu.js (7750 bytes)
cgesm-1612-mz.122-25.SE1/html/nsback.htm (425 bytes)
cgesm-1612-mz.122-25.SE1/html/border.htm (251 bytes)
cgesm-1612-mz.122-25.SE1/html/status.htm (8107 bytes)
cgesm-1612-mz.122-25.SE1/html/troubleshooting_Browser.htm (3107 bytes)
cgesm-1612-mz.122-25.SE1/html/more.txt (62 bytes)
cgesm-1612-mz.122-25.SE1/html/homepage.htm (471 bytes)
cgesm-1612-mz.122-25.SE1/html/appsui.js (1389 bytes)
cgesm-1612-mz.122-25.SE1/html/redirect.htm (1018 bytes)
cgesm-1612-mz.122-25.SE1/html/sorttable.js (39742 bytes)
cgesm-1612-mz.122-25.SE1/html/empty.htm (313 bytes)
```

This example shows how to display only the /html directory and its contents:

```
cgesm-1612-mz.122-25.SE1/html/ (directory)
cgesm-1612-mz.122-25.SE1/html/troubleshooting_OS.htm (2508 bytes)
cgesm-1612-mz.122-25.SE1/html/helpframework.js (858 bytes)
cgesm-1612-mz.122-25.SE1/html/const.htm (556 bytes)
cgesm-1612-mz.122-25.SE1/html/forms.js (12940 bytes)
cgesm-1612-mz.122-25.SE1/html/xhome.htm (9249 bytes)
cgesm-1612-mz.122-25.SE1/html/stylesheets.css (8273 bytes)
cgesm-1612-mz.122-25.SE1/html/menu.js (7750 bytes)
cgesm-1612-mz.122-25.SE1/html/nsback.htm (425 bytes)
cgesm-1612-mz.122-25.SE1/html/border.htm (251 bytes)
cgesm-1612-mz.122-25.SE1/html/status.htm (8107 bytes)
cgesm-1612-mz.122-25.SE1/html/troubleshooting_Browser.htm (3107 bytes)
cgesm-1612-mz.122-25.SE1/html/more.txt (62 bytes)
cgesm-1612-mz.122-25.SE1/html/homepage.htm (471 bytes)
cgesm-1612-mz.122-25.SE1/html/appsui.js (1389 bytes)
cgesm-1612-mz.122-25.SE1/html/redirect.htm (1018 bytes)
cgesm-1612-mz.122-25.SE1/html/sorttable.js (39742 bytes)
cgesm-1612-mz.122-25.SE1/html/empty.htm (313 bytes)
```
Extracting a tar File

To extract a tar file into a directory on the flash file system, use this privileged EXEC command:

```
archive tar /xtract source-url flash:/file-url [dir/file...]
```

For `source-url`, specify the source URL alias for the local file system. These options are supported:

- For the local flash file system, the syntax is `flash:`.
- For the FTP, the syntax is `ftp://[username[:password]@location]/directory]/tar-filename.tar`
- For the RCP, the syntax is `rcp://[username@location]/directory]/tar-filename.tar`
- For the TFTP, the syntax is `tftp://[location]/directory]/tar-filename.tar`

The `tar-filename.tar` is the tar file from which to extract files.

For `flash:/file-url [dir/file...]`, specify the location on the local flash file system into which the tar file is extracted. Use the `dir/file...` option to specify an optional list of files or directories within the tar file to be extracted. If none are specified, all files and directories are extracted.

This example shows how to extract the contents of a tar file located on the TFTP server at 172.20.10.30. This command extracts just the `new-configs` directory into the root directory on the local flash file system. The remaining files in the `saved.tar` file are ignored.

```
Switch# archive tar /xtract tftp://172.20.10.30/saved.tar flash:/new-configs
```

Displaying the Contents of a File

To display the contents of any readable file, including a file on a remote file system, use the `more [/ascii /binary /ebcdic] file-url` privileged EXEC command:

```
Switch# more tftp://serverA/hampton/savedconfig
```

This example shows how to display the contents of a configuration file on a TFTP server:

```
! Saved configuration on server
!
version 11.3
service timestamps log datetime localtime
service linenumber
service udp-small-servers
service pt-vty-logging
!
<output truncated>
```

Working with Configuration Files

This section describes how to create, load, and maintain configuration files.

Configuration files contain commands entered to customize the function of the Cisco IOS software. A way to create a basic configuration file is to use the `setup` program or to enter the `setup` privileged EXEC command. For more information, see Chapter 3, “Assigning the Switch IP Address and Default Gateway.”
You can copy (download) configuration files from a TFTP, FTP, or RCP server to the running configuration or startup configuration of the switch. You might want to perform this for one of these reasons:

- To restore a backed-up configuration file.
- To use the configuration file for another switch. For example, you might add another switch to your network and want it to have a configuration similar to the original switch. By copying the file to the new switch, you can change the relevant parts rather than recreating the whole file.
- To load the same configuration commands on all the switches in your network so that all the switches have similar configurations.

You can copy (upload) configuration files from the switch to a file server by using TFTP, FTP, or RCP. You might perform this task to back up a current configuration file to a server before changing its contents so that you can later restore the original configuration file from the server.

The protocol you use depends on which type of server you are using. The FTP and RCP transport mechanisms provide faster performance and more reliable delivery of data than TFTP. These improvements are possible because FTP and RCP are built on and use the TCP/IP stack, which is connection-oriented.

On a CGESM switch, which does not initially obtain its running configuration from the file flash:config.text, ports 17 and 18 initialize to the shutdown state and remain that way until you enter the `no shutdown` interface configuration command on these interfaces. To automatically enable ports 17 and 18, the file from which the running configuration is obtained must explicitly provide the `no shutdown` configuration command for ports 17 and 18. To do this, you need to use your PC or workstation text editor to manually add the `no shutdown` configuration command in the configuration sections for ports 17 and 18, and then save these changes.

Note: You cannot edit files that are stored on the CGESM flash by using a PC or workstation text editor. To manually edit files on the CGESM flash, copy the file from the CGESM flash to a server by using TFTP, FTP or RCP. Use your workstation or PC text editor to edit and save the file, then copy the modified file from the server to the CGESM flash.

Note: When you display the contents of this new running configuration file, it will show `!` following port 17 and port 18. The ports are now set to `no shutdown`, but the parameter `no shutdown` does not display because no shutdown is the Cisco IOS default.

This example shows the configuration file that by default enables shutdown on ports 17 and 18 before you have copied the new configuration text file to the running configuration file:

```
Loading config from tftp server:
Default config file:
!
interface GigabitEthernet0/17
```

These sections contain this configuration information:

- Guidelines for Creating and Using Configuration Files, page B-10
- Configuration File Types and Location, page B-10
- Creating a Configuration File By Using a Text Editor, page B-11
- Copying Configuration Files By Using TFTP, page B-11
- Copying Configuration Files By Using FTP, page B-13
Guidelines for Creating and Using Configuration Files

Creating configuration files can aid in your switch configuration. Configuration files can contain some or all of the commands needed to configure one or more switches. For example, you might want to download the same configuration file to several switches that have the same hardware configuration.

Use these guidelines when creating a configuration file:

- We recommend that you connect through the console port for the initial configuration of the switch.
  - If you are accessing the switch through a network connection instead of through a direct connection to the console port, keep in mind that some configuration changes (such as changing the switch IP address or disabling ports) can cause a loss of connectivity to the switch.

- If no password has been set on the switch, we recommend that you set one by using the `enable secret secret-password` global configuration command.

The `copy {ftp: | rcp: | tftp:} system:running-config` privileged EXEC command loads the configuration files on the switch as if you were entering the commands at the command line. The switch does not erase the existing running configuration before adding the commands. If a command in the copied configuration file replaces a command in the existing configuration file, the existing command is erased. For example, if the copied configuration file contains a different IP address in a particular command than the existing configuration, the IP address in the copied configuration is used. However, some commands in the existing configuration might not be replaced or negated. In this case, the resulting configuration file is a mixture of the existing configuration file and the copied configuration file, with the copied configuration file having precedence.

To restore a configuration file to an exact copy of a file stored on a server, copy the configuration file directly to the startup configuration (by using the `copy {ftp: | rcp: | tftp:} nvram:startup-config` privileged EXEC command), and reload the switch.

Configuration File Types and Location

Startup configuration files are used during system startup to configure the software. Running configuration files contain the current configuration of the software. The two configuration files can be different. For example, you might want to change the configuration for a short time period rather than permanently. In this case, you would change the running configuration but not save the configuration by using the `copy running-config startup-config` privileged EXEC command.

The running configuration is saved in DRAM; the startup configuration is stored in the NVRAM section of flash memory.
Creating a Configuration File By Using a Text Editor

When creating a configuration file, you must list commands logically so that the system can respond appropriately. This is one method of creating a configuration file:

Step 1  Copy an existing configuration from a switch to a server.
For more information, see the “Downloading the Configuration File By Using TFTP” section on page B-12, the “Downloading a Configuration File By Using FTP” section on page B-14, or the “Downloading a Configuration File By Using RCP” section on page B-18.

Step 2  Open the configuration file in a text editor, such as vi or emacs on UNIX or Notepad on a PC.

Step 3  Extract the portion of the configuration file with the desired commands, and save it in a new file.

Step 4  Copy the configuration file to the appropriate server location. For example, copy the file to the TFTP directory on the workstation (usually /tftpboot on a UNIX workstation).

Step 5  Make sure the permissions on the file are set to world-read.

Copying Configuration Files By Using TFTP

You can configure the switch by using configuration files you create, download from another switch, or download from a TFTP server. You can copy (upload) configuration files to a TFTP server for storage.

These sections contain this configuration information:

- Preparing to Download or Upload a Configuration File By Using TFTP, page B-11
- Downloading the Configuration File By Using TFTP, page B-12
- Uploading the Configuration File By Using TFTP, page B-12

Preparing to Download or Upload a Configuration File By Using TFTP

Before you begin downloading or uploading a configuration file by using TFTP, do these tasks:

- Ensure that the workstation acting as the TFTP server is properly configured. On a Sun workstation, make sure that the /etc/inetd.conf file contains this line:

  tftp dgram udp wait root /usr/etc/in.tftpd in.tftpd -p -s /tftpboot

  Make sure that the /etc/services file contains this line:

  tftp 69/udp

  Note  You must restart the inetd daemon after modifying the /etc/inetd.conf and /etc/services files. To restart the daemon, either stop the inetd process and restart it, or enter a fastboot command (on the SunOS 4.x) or a reboot command (on Solaris 2.x or SunOS 5.x). For more information on the TFTP daemon, see the documentation for your workstation.

- Ensure that the switch has a route to the TFTP server. The switch and the TFTP server must be in the same subnetwork if you do not have a router to route traffic between subnets. Check connectivity to the TFTP server by using the ping command.
• Ensure that the configuration file to be downloaded is in the correct directory on the TFTP server (usually /tftpboot on a UNIX workstation).

• For download operations, ensure that the permissions on the file are set correctly. The permission on the file should be world-readable.

• Before uploading the configuration file, you might need to create an empty file on the TFTP server. To create an empty file, enter the `touch filename` command, where `filename` is the name of the file you will use when uploading it to the server.

• During upload operations, if you are overwriting an existing file (including an empty file, if you had to create one) on the server, ensure that the permissions on the file are set correctly. Permissions on the file should be world-write.

### Downloading the Configuration File By Using TFTP

To configure the switch by using a configuration file downloaded from a TFTP server, follow these steps:

1. **Step 1** Copy the configuration file to the appropriate TFTP directory on the workstation.

2. **Step 2** Verify that the TFTP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using TFTP” section on page B-11.

3. **Step 3** Log into the switch through the console port or a Telnet session.

4. **Step 4** Download the configuration file from the TFTP server to configure the switch.

   Specify the IP address or hostname of the TFTP server and the name of the file to download. Use one of these privileged EXEC commands:

   • `copy tftp://[hostname|IP]/[directory]/[filename] system:running-config`
   • `copy tftp://[hostname|IP]/[directory]/[filename] nvram:startup-config`

   The configuration file downloads, and the commands are executed as the file is parsed line-by-line.

   This example shows how to configure the software from the file `tokyo-confg` at IP address 172.16.2.155:

   ```
   Switch# copy tftp://172.16.2.155/tokyo-confg system:running-config
   Configure using tokyo-confg from 172.16.2.155? [confirm] y
   Booting tokyo-confg from 172.16.2.155:!!! [OK - 874/16000 bytes]
   ```

### Uploading the Configuration File By Using TFTP

To upload a configuration file from a switch to a TFTP server for storage, follow these steps:

1. **Step 1** Verify that the TFTP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using TFTP” section on page B-11.

2. **Step 2** Log into the switch through the console port or a Telnet session.

   This example shows how to upload the configuration file `tokyo-confg` to the TFTP server:

   ```
   Switch copy system:running-config tftp://172.16.2.155/tokyo-confg
   ```
Step 3
Upload the switch configuration to the TFTP server. Specify the IP address or hostname of the TFTP server and the destination filename.

Use one of these privileged EXEC commands:

- `copy system:running-config tftp:[[[//location][directory][filename]]`
- `copy nvram:startup-config tftp:[[[//location][directory][filename]]`

The file is uploaded to the TFTP server.

This example shows how to upload a configuration file from a switch to a TFTP server:

```
Switch# copy system:running-config tftp://172.16.2.155/tokyo-config
Write file tokyo-config on host 172.16.2.155? [confirm] y
#
Writing tokyo-config!!! [OK]
```

Copying Configuration Files By Using FTP

You can copy configuration files to or from an FTP server.

The FTP protocol requires a client to send a remote username and password on each FTP request to a server. When you copy a configuration file from the switch to a server by using FTP, the Cisco IOS software sends the first valid username in this list:

- The username specified in the `copy` command if a username is specified.
- The username set by the `ip ftp username username` global configuration command if the command is configured.
- Anonymous.

The switch sends the first valid password in this list:

- The password specified in the `copy` command if a password is specified.
- The password set by the `ip ftp password password` global configuration command if the command is configured.
- The switch forms a password named `username@switchname.domain`. The variable `username` is the username associated with the current session, `switchname` is the configured hostname, and `domain` is the domain of the switch.

The username and password must be associated with an account on the FTP server. If you are writing to the server, the FTP server must be properly configured to accept your FTP write request.

Use the `ip ftp username` and `ip ftp password` commands to specify a username and password for all copies. Include the username in the `copy` command if you want to specify only a username for that copy operation.

If the server has a directory structure, the configuration file is written to or copied from the directory associated with the username on the server. For example, if the configuration file resides in the home directory of a user on the server, specify that user's name as the remote username.

For more information, see the documentation for your FTP server.
These sections contain this configuration information:

- Preparing to Download or Upload a Configuration File By Using FTP, page B-14
- Downloading a Configuration File By Using FTP, page B-14
- Uploading a Configuration File By Using FTP, page B-15

Preparing to Download or Upload a Configuration File By Using FTP

Before you begin downloading or uploading a configuration file by using FTP, do these tasks:

- Ensure that the switch has a route to the FTP server. The switch and the FTP server must be in the same subnetwork if you do not have a router to route traffic between subnets. Check connectivity to the FTP server by using the `ping` command.

- If you are accessing the switch through the console or a Telnet session and you do not have a valid username, make sure that the current FTP username is the one that you want to use for the FTP download. You can enter the `show users` privileged EXEC command to view the valid username. If you do not want to use this username, create a new FTP username by using the `ip ftp username username` global configuration command during all copy operations. The new username is stored in NVRAM. If you are accessing the switch through a Telnet session and you have a valid username, this username is used, and you do not need to set the FTP username. Include the username in the `copy` command if you want to specify a username for only that copy operation.

- When you upload a configuration file to the FTP server, it must be properly configured to accept the write request from the user on the switch.

For more information, see the documentation for your FTP server.

Downloading a Configuration File By Using FTP

Beginning in privileged EXEC mode, follow these steps to download a configuration file by using FTP:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Verify that the FTP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using FTP” section on page B-14.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>Enter global configuration mode on the switch.</td>
</tr>
<tr>
<td><code>configure terminal</code></td>
<td>This step is required only if you override the default remote username or password (see Steps 4, 5, and 6).</td>
</tr>
<tr>
<td><strong>Step 4</strong> <code>ip ftp username username</code></td>
<td>(Optional) Change the default remote username.</td>
</tr>
<tr>
<td><strong>Step 5</strong> <code>ip ftp password password</code></td>
<td>(Optional) Change the default password.</td>
</tr>
</tbody>
</table>
Appendix B   Working with the Cisco IOS File System, Configuration Files, and Software Images

### Working with Configuration Files

This example shows how to copy a configuration file named *host1-confg* from the *netadmin1* directory on the remote server with an IP address of 172.16.101.101 and to load and run those commands on the switch:

```
Switch# copy ftp://netadmin1:mypass@172.16.101.101/host1-confg system:running-config
Configure using host1-confg from 172.16.101.101? [confirm]
Connected to 172.16.101.101
Loading 1112 byte file host1-confg: ![OK]
Switch#
%SYS-5-CONFIG: Configured from host1-config by ftp from 172.16.101.101
```

This example shows how to specify a remote username of *netadmin1*. The software copies the configuration file *host2-confg* from the *netadmin1* directory on the remote server with an IP address of 172.16.101.101 to the switch startup configuration.

```
Switch# configure terminal
Switch(config)# ip ftp username netadmin1
Switch(config)# ip ftp password mypass
Switch(config)# end
Switch# copy ftp: nvram:startup-config
Address of remote host [255.255.255.255]? 172.16.101.101
Name of configuration file[rtr2-confg]? host2-confg
Configure using host2-confg from 172.16.101.101?[confirm]
Connected to 172.16.101.101
Loading 1112 byte file host2-confg: ![OK]
[OK]
Switch#
%SYS-5-CONFIG_NV: Non-volatile store configured from host2-config by ftp from 172.16.101.101
```

### Uploading a Configuration File By Using FTP

Beginning in privileged EXEC mode, follow these steps to upload a configuration file by using FTP:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 6 end</td>
<td>Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7 copy ftp://[[username]:password@]location[/directory]/filename system:running-config or copy ftp://[[username]:password@]location[/directory]/filename nvram:startup-config</td>
<td>Using FTP, copy the configuration file from a network server to the running configuration or to the startup configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to copy a configuration file named *host1-confg* from the *netadmin1* directory on the remote server with an IP address of 172.16.101.101 and to load and run those commands on the switch:

```
Switch# copy ftp://netadmin1:mypass@172.16.101.101/host1-confg system:running-config
Configure using host1-confg from 172.16.101.101? [confirm]
Connected to 172.16.101.101
Loading 1112 byte file host1-confg: ![OK]
Switch#
%SYS-5-CONFIG: Configured from host1-config by ftp from 172.16.101.101
```

This example shows how to specify a remote username of *netadmin1*. The software copies the configuration file *host2-confg* from the *netadmin1* directory on the remote server with an IP address of 172.16.101.101 to the switch startup configuration.

```
Switch# configure terminal
Switch(config)# ip ftp username netadmin1
Switch(config)# ip ftp password mypass
Switch(config)# end
Switch# copy ftp: nvram:startup-config
Address of remote host [255.255.255.255]? 172.16.101.101
Name of configuration file[rtr2-confg]? host2-confg
Configure using host2-confg from 172.16.101.101?[confirm]
Connected to 172.16.101.101
Loading 1112 byte file host2-confg: ![OK]
[OK]
Switch#
%SYS-5-CONFIG_NV: Non-volatile store configured from host2-config by ftp from 172.16.101.101
```

### Uploading a Configuration File By Using FTP

Beginning in privileged EXEC mode, follow these steps to upload a configuration file by using FTP:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 Verify that the FTP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using FTP” section on page B-14.</td>
<td>Purpose</td>
</tr>
<tr>
<td>Step 2 Log into the switch through the console port or a Telnet session.</td>
<td>Purpose</td>
</tr>
</tbody>
</table>
Working with Configuration Files

Command | Purpose
--- | ---
**Step 3** configure terminal | Enter global configuration mode. This step is required only if you override the default remote username or password (see Steps 4, 5, and 6).

**Step 4** ip ftp username username | (Optional) Change the default remote username.
**Step 5** ip ftp password password | (Optional) Change the default password.

**Step 6** end | Return to privileged EXEC mode.

**Step 7**
- **copy system:running-config**
  - ftp://[username]:password@location/directory/filename
  - or
  - **copy nvram:startup-config**
    - ftp://[username]:password@location/directory/filename

  Using FTP, store the switch running or startup configuration file to the specified location.

This example shows how to copy the running configuration file named switch2-config to the netadmin1 directory on the remote host with an IP address of 172.16.101.101:

```
Switch# copy system:running-config ftp://netadmin1:mypass@172.16.101.101/switch2-config
Write file switch2-config on host 172.16.101.101?[confirm]
Building configuration...[OK]
Connected to 172.16.101.101
Switch#
```

This example shows how to store a startup configuration file on a server by using FTP to copy the file:

```
Switch# configure terminal
Switch(config)# ip ftp username netadmin2
Switch(config)# ip ftp password mypass
Switch(config)# end
Switch# copy nvram:startup-config ftp:
Remote host[]? 172.16.101.101
Name of configuration file to write [switch2-config]? switch2-config
Write file switch2-config on host 172.16.101.101?[confirm]
! [OK]
```
Copy Configuration Files By Using RCP

The RCP provides another method of downloading, uploading, and copying configuration files between remote hosts and the switch. Unlike TFTP, which uses User Datagram Protocol (UDP), a connectionless protocol, RCP uses TCP, which is connection-oriented.

To use RCP to copy files, the server from or to which you will be copying files must support RCP. The RCP copy commands rely on the rsh server (or daemon) on the remote system. To copy files by using RCP, you do not need to create a server for file distribution as you do with TFTP. You only need to have access to a server that supports the remote shell (rsh). (Most UNIX systems support rsh.) Because you are copying a file from one place to another, you must have read permission on the source file and write permission on the destination file. If the destination file does not exist, RCP creates it for you.

The RCP requires a client to send a remote username with each RCP request to a server. When you copy a configuration file from the switch to a server, the Cisco IOS software sends the first valid username in this list:

- The username specified in the copy command if a username is specified.
- The username set by the ip rcmd remote-username username global configuration command if the command is configured.
- The remote username associated with the current TTY (terminal) process. For example, if the user is connected to the router through Telnet and was authenticated through the username command, the switch software sends the Telnet username as the remote username.
- The switch hostname.

For a successful RCP copy request, you must define an account on the network server for the remote username. If the server has a directory structure, the configuration file is written to or copied from the directory associated with the remote username on the server. For example, if the configuration file is in the home directory of a user on the server, specify that user's name as the remote username.

These sections contain this configuration information:

- Preparing to Download or Upload a Configuration File By Using RCP, page B-17
- Downloading a Configuration File By Using RCP, page B-18
- Uploading a Configuration File By Using RCP, page B-19

Preparing to Download or Upload a Configuration File By Using RCP

Before you begin downloading or uploading a configuration file by using RCP, do these tasks:

- Ensure that the workstation acting as the RCP server supports the remote shell (rsh).
- Ensure that the switch has a route to the RCP server. The switch and the server must be in the same subnet if you do not have a router to route traffic between subnets. Check connectivity to the RCP server by using the ping command.
- If you are accessing the switch through the console or a Telnet session and you do not have a valid username, make sure that the current RCP username is the one that you want to use for the RCP download. You can enter the show users privileged EXEC command to view the valid username. If you do not want to use this username, create a new RCP username by using the ip rcmd remote-username username global configuration command to be used during all copy operations. The new username is stored in NVRAM. If you are accessing the switch through a Telnet session and you have a valid username, this username is used, and you do not need to set the RCP username. Include the username in the copy command if you want to specify a username for only that copy operation.
When you upload a file to the RCP server, it must be properly configured to accept the RCP write request from the user on the switch. For UNIX systems, you must add an entry to the .rhosts file for the remote user on the RCP server. For example, suppose that the switch contains these configuration lines:

```
hostname Switch1
ip rcmd remote-username User0
```

If the switch IP address translates to `Switch1.company.com`, the .rhosts file for User0 on the RCP server should contain this line:

```
Switch1.company.com Switch1
```

For more information, see the documentation for your RCP server.

### Downloading a Configuration File By Using RCP

Beginning in privileged EXEC mode, follow these steps to download a configuration file by using RCP:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Verify that the RCP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using RCP” section on page B-17.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>configure terminal</code> Enter global configuration mode. This step is required only if you override the default remote username (see Steps 4 and 5).</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>ip rcmd remote-username username</code> (Optional) Specify the remote username.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td><code>copy rcp://username@location/directory/filename</code> system:running-config or <code>copy rcp://username@location/directory/filename</code> nvram:startup-config Using RCP, copy the configuration file from a network server to the running configuration or to the startup configuration file.</td>
</tr>
</tbody>
</table>

This example shows how to copy a configuration file named `host1-config` from the `netadmin1` directory on the remote server with an IP address of 172.16.101.101 and load and run those commands on the switch:

```
Switch# copy rcp://netadmin1@172.16.101.101/host1-config system:running-config
Configure using host1-config from 172.16.101.101? [confirm]
Connected to 172.16.101.101
Loading 1112 byte file host1-config: ![OK]
Switch#
%SYS-5-CONFIG: Configured from host1-config by rcp from 172.16.101.101
```
This example shows how to specify a remote username of netadmin1. Then it copies the configuration file host2-confg from the netadmin1 directory on the remote server with an IP address of 172.16.101.101 to the startup configuration:

Switch# configure terminal
Switch(config)# ip rcmd remote-username netadmin1
Switch(config)# end
Switch# copy rcp: nvram:startup-config
Address of remote host [255.255.255.255]? 172.16.101.101
Name of configuration file[rttr2-confg]? host2-confg
Configure using host2-confg from 172.16.101.101?[confirm]
Connected to 172.16.101.101
Loading 1112 byte file host2-confg:!
[OK]
[OK]
Switch#
%SYS-5-CONFIG_NV:Non-volatile store configured from host2-confg by rcp from 172.16.101.101

### Uploading a Configuration File By Using RCP

Beginning in privileged EXEC mode, follow these steps to upload a configuration file by using RCP:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Verify that the RCP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using RCP” section on page B-17.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>configure terminal</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>ip rcmd remote-username username</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>end</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>copy system:running-config rcp://username@location/directory/filename or copy nvram:startup-config rcp://username@location/directory/filename</td>
</tr>
</tbody>
</table>

This example shows how to copy the running configuration file named switch2-confg to the netadmin1 directory on the remote host with an IP address of 172.16.101.101:

Switch# copy system:running-config rcp://netadmin1@172.16.101.101/switch2-confg
Write file switch-conf on host 172.16.101.101?[confirm]
Building configuration...[OK]
Connected to 172.16.101.101
Switch#

This example shows how to store a startup configuration file on a server:

Switch# configure terminal
Switch(config)# ip rcmd remote-username netadmin2
Switch(config)# end
Switch# copy nvram:startup-config rcp:
Remote host[]? 172.16.101.101
Name of configuration file to write [switch2-config]?
Write file switch2-config on host 172.16.101.101?[confirm]
! [OK]

Clearing Configuration Information

You can clear the configuration information from the startup configuration. If you reboot the switch with no startup configuration, the switch enters the setup program so that you can reconfigure the switch with all new settings.

Clearing the Startup Configuration File

To clear the contents of your startup configuration, use the erase nvram: or the erase startup-config privileged EXEC command.

⚠️ Caution
You cannot restore the startup configuration file after it has been deleted.

Deleting a Stored Configuration File

To delete a saved configuration from flash memory, use the delete flash:filename privileged EXEC command. Depending on the setting of the file prompt global configuration command, you might be prompted for confirmation before you delete a file. By default, the switch prompts for confirmation on destructive file operations. For more information about the file prompt command, see the Cisco IOS Command Reference for Release 12.2.

⚠️ Caution
You cannot restore a file after it has been deleted.

Working with Software Images

This section describes how to archive (download and upload) software image files, which contain the system software, the Cisco IOS code, and the embedded device manager software.

⚠️ Note
Instead of using the copy privileged EXEC command or the archive tar privileged EXEC command, we recommend using the archive download-sw and archive upload-sw privileged EXEC commands to download and upload software image files.

You can download a switch image file from a TFTP, FTP, or RCP server to upgrade the switch software. If you do not have access to a TFTP server, you can download a software image file directly to your PC or workstation by using a web browser (HTTP) and then by using the device manager to upgrade your switch. For information about upgrading your switch by using a TFTP server or a web browser (HTTP), see the release notes.

You can replace the current image with the new one or keep the current image in flash memory after a download.
You upload a switch image file to a TFTP, FTP, or RCP server for backup purposes. You can use this uploaded image for future downloads to the same switch or to another of the same type.

The protocol that you use depends on which type of server you are using. The FTP and RCP transport mechanisms provide faster performance and more reliable delivery of data than TFTP. These improvements are possible because FTP and RCP are built on and use the TCP/IP stack, which is connection-oriented.

These sections contain this configuration information:

- Image Location on the Switch, page B-21
- tar File Format of Images on a Server or Cisco.com, page B-21
- Copying Image Files By Using TFTP, page B-22
- Copying Image Files By Using FTP, page B-25
- Copying Image Files By Using RCP, page B-29

Note

For a list of software images and the supported upgrade paths, see the release notes.

### Image Location on the Switch

The Cisco IOS image is stored as a .bin file in a directory that shows the version number. A subdirectory contains the files needed for web management. The image is stored on the system board flash memory (flash:).

You can use the `show version` privileged EXEC command to see the software version that is currently running on your switch. In the display, check the line that begins with `System image file is...`. It shows the directory name in flash memory where the image is stored.

You can also use the `dir filesystem` privileged EXEC command to see the directory names of other software images that you might have stored in flash memory.

### tar File Format of Images on a Server or Cisco.com

Software images located on a server or downloaded from Cisco.com are provided in a tar file format, which contains these files:

- An info file, which serves as a table of contents for the tar file
- One or more subdirectories containing other images and files, such as Cisco IOS images and web management files

This example shows some of the information contained in the info file. Table B-3 provides additional details about this information:

```plaintext
system_type:0x00000000:cgesm-i6l2-mz.122.25-SE
    image_family:cgesm
    stacking_number:1.0
    info_end:

version_suffix:i6l2-122.25-SE
    version_directory:cgesm-i6l2-mz.122.25-SE
    image_system_type_id:0x00000000
    image_name:cgesm-i6l2-mz.122.25-SE.bin
    ios_image_file_size:2939392
    total_image_file_size:4884992
```
image_feature: LAYER_2 | MIN_DRAM_MEG=32
image_family: cgesm
stacking_number: 1.0
board_ids: 0x00000008
info_end:

**Note**
Disregard the stacking_number field. It does not apply to the switch.

### Table B-3 info File Description

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>version_suffix</td>
<td>Specifies the Cisco IOS image version string suffix</td>
</tr>
<tr>
<td>version_directory</td>
<td>Specifies the directory where the Cisco IOS image and the HTML subdirectory are installed</td>
</tr>
<tr>
<td>image_name</td>
<td>Specifies the name of the Cisco IOS image within the tar file</td>
</tr>
<tr>
<td>ios_image_file_size</td>
<td>Specifies the Cisco IOS image size in the tar file, which is an approximate measure of how much flash memory is required to hold just the Cisco IOS image</td>
</tr>
<tr>
<td>total_image_file_size</td>
<td>Specifies the size of all the images (the Cisco IOS image and the web management files) in the tar file, which is an approximate measure of how much flash memory is required to hold them</td>
</tr>
<tr>
<td>image_feature</td>
<td>Describes the core functionality of the image</td>
</tr>
<tr>
<td>image_min_dram</td>
<td>Specifies the minimum amount of DRAM needed to run this image</td>
</tr>
<tr>
<td>image_family</td>
<td>Describes the family of products on which the software can be installed</td>
</tr>
</tbody>
</table>

### Copying Image Files By Using TFTP

You can download a switch image from a TFTP server or upload the image from the switch to a TFTP server.

You download a switch image file from a server to upgrade the switch software. You can overwrite the current image with the new one or keep the current image after a download.

You upload a switch image file to a server for backup purposes; this uploaded image can be used for future downloads to the same or another switch of the same type.

**Note**
Instead of using the `copy` privileged EXEC command or the `archive tar` privileged EXEC command, we recommend using the `archive download-sw` and `archive upload-sw` privileged EXEC commands to download and upload software image files.

These sections contain this configuration information:

- Preparing to Download or Upload an Image File By Using TFTP, page B-23
- Downloading an Image File By Using TFTP, page B-23
- Uploading an Image File By Using TFTP, page B-25
Preparing to Download or Upload an Image File By Using TFTP

Before you begin downloading or uploading an image file by using TFTP, do these tasks:

- Ensure that the workstation acting as the TFTP server is properly configured. On a Sun workstation, make sure that the /etc/inetd.conf file contains this line:
  
  tftp dgram udp wait root /usr/etc/in.tftpd in.tftpd -p -s /tftpboot

  Make sure that the /etc/services file contains this line:

  tftp 69/udp

  **Note** You must restart the inetd daemon after modifying the /etc/inetd.conf and /etc/services files. To restart the daemon, either stop the inetd process and restart it, or enter a `fastboot` command (on the SunOS 4.x) or a `reboot` command (on Solaris 2.x or SunOS 5.x). For more information on the TFTP daemon, see the documentation for your workstation.

- Ensure that the switch has a route to the TFTP server. The switch and the TFTP server must be in the same subnetwork if you do not have a router to route traffic between subnets. Check connectivity to the TFTP server by using the `ping` command.

- Ensure that the image to be downloaded is in the correct directory on the TFTP server (usually /tftpboot on a UNIX workstation).

- For download operations, ensure that the permissions on the file are set correctly. The permission on the file should be world-readable.

- Before uploading the image file, you might need to create an empty file on the TFTP server. To create an empty file, enter the `touch filename` command, where `filename` is the name of the file you will use when uploading the image to the server.

- During upload operations, if you are overwriting an existing file (including an empty file, if you had to create one) on the server, ensure that the permissions on the file are set correctly. Permissions on the file should be world-write.

Downloading an Image File By Using TFTP

You can download a new image file and replace the current image or keep the current image.

Beginning in privileged EXEC mode, follow Steps 1 through 3 to download a new image from a TFTP server and overwrite the existing image. To keep the current image, go to Step 3.

<table>
<thead>
<tr>
<th>Step</th>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Copy the image to the appropriate TFTP directory on the workstation. Make sure the TFTP server is properly configured; see the “Preparing to Download or Upload an Image File By Using TFTP” section on page B-23.</td>
<td>Copy the image to the appropriate TFTP directory on the workstation. Make sure the TFTP server is properly configured; see the “Preparing to Download or Upload an Image File By Using TFTP” section on page B-23.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Log into the switch through the console port or a Telnet session.</td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
</tbody>
</table>
### Working with Software Images

The download algorithm verifies that the image is appropriate for the switch model and that enough DRAM is present, or it aborts the process and reports an error. If you specify the `/overwrite` option, the download algorithm removes the existing image on the flash device whether or not it is the same as the new one, downloads the new image, and then reloads the software.

#### Step 3

**Command**

```plaintext
archive download-sw /overwrite /reload
tftp://[//location]/[directory]/image-name.tar
```

**Purpose**

Download the image file from the TFTP server to the switch, and overwrite the current image.

- **/overwrite** option overwrites the software image in flash memory with the downloaded image.
- **/reload** option reloads the system after downloading the image unless the configuration has been changed and not been saved.
- For `/location`, specify the IP address of the TFTP server.
- For `/directory/image-name.tar`, specify the directory (optional) and the image to download. Directory and image names are case sensitive.

#### Step 4

**Command**

```plaintext
archive download-sw /leave-old-sw /reload
tftp://[//location]/[directory]/image-name.tar
```

**Purpose**

Download the image file from the TFTP server to the switch, and keep the current image.

- **/leave-old-sw** option keeps the old software version after a download.
- **/reload** option reloads the system after downloading the image unless the configuration has been changed and not been saved.
- For `/location`, specify the IP address of the TFTP server.
- For `/directory/image-name.tar`, specify the directory (optional) and the image to download. Directory and image names are case sensitive.

The download algorithm verifies that the image is appropriate for the switch model and that enough DRAM is present, or it aborts the process and reports an error. If you specify the `/overwrite` option, the download algorithm removes the existing image on the flash device whether or not it is the same as the new one, downloads the new image, and then reloads the software.

**Note**

If the flash device has sufficient space to hold two images and you want to overwrite one of these images with the same version, you must specify the `/overwrite` option.

If you specify the `/leave-old-sw`, the existing files are not removed. If there is not enough space to install the new image and keep the current running image, the download process stops, and an error message is displayed.

The algorithm installs the downloaded image on the system board flash device (`flash:`). The image is placed into a new directory named with the software version string, and the `BOOT` environment variable is updated to point to the newly installed image.

If you kept the old image during the download process (you specified the `/leave-old-sw` keyword), you can remove it by entering the `delete /force /recursive filesystem/file-url` privileged EXEC command. For `filesystem`, use `flash:` for the system board flash device. For `file-url`, enter the directory name of the old image. All the files in the directory and the directory are removed.

**Caution**

For the download and upload algorithms to operate properly, do not rename image names.
Uploading an Image File By Using TFTP

You can upload an image from the switch to a TFTP server. You can later download this image to the switch or to another switch of the same type.

Use the upload feature only if the web management pages associated with the embedded device manager have been installed with the existing image.

Beginning in privileged EXEC mode, follow these steps to upload an image to a TFTP server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Make sure the TFTP server is properly configured; see the “Preparing to Download or Upload an Image File By Using TFTP” section on page B-23.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td>Step 3</td>
<td>archive upload-sw tftp:////[//location][//directory][//image-name.tar</td>
</tr>
<tr>
<td></td>
<td>Upload the currently running switch image to the TFTP server.</td>
</tr>
<tr>
<td></td>
<td>• For //location, specify the IP address of the TFTP server.</td>
</tr>
<tr>
<td></td>
<td>• For //directory//image-name.tar, specify the directory (optional) and the name of the software image to be uploaded. Directory and image names are case sensitive. The image-name.tar is the name of the software image to be stored on the server.</td>
</tr>
</tbody>
</table>

The archive upload-sw privileged EXEC command builds an image file on the server by uploading these files in order: info, the Cisco IOS image, and the web management files. After these files are uploaded, the upload algorithm creates the tar file format.

Caution

For the download and upload algorithms to operate properly, do not rename image names.

Copying Image Files By Using FTP

You can download a switch image from an FTP server or upload the image from the switch to an FTP server.

You download a switch image file from a server to upgrade the switch software. You can overwrite the current image with the new one or keep the current image after a download.

You upload a switch image file to a server for backup purposes. You can use this uploaded image for future downloads to the switch or another switch of the same type.

Note

Instead of using the copy privileged EXEC command or the archive tar privileged EXEC command, we recommend using the archive download-sw and archive upload-sw privileged EXEC commands to download and upload software image files.
These sections contain this configuration information:

- Preparing to Download or Upload an Image File By Using FTP, page B-26
- Downloading an Image File By Using FTP, page B-27
- Uploading an Image File By Using FTP, page B-28

Preparing to Download or Upload an Image File By Using FTP

You can copy images files to or from an FTP server.

The FTP protocol requires a client to send a remote username and password on each FTP request to a server. When you copy an image file from the switch to a server by using FTP, the Cisco IOS software sends the first valid username in this list:

- The username specified in the `archive download-sw` or `archive upload-sw` privileged EXEC command if a username is specified.
- The username set by the `ip ftp username username` global configuration command if the command is configured.
- Anonymous.

The switch sends the first valid password in this list:

- The password specified in the `archive download-sw` or `archive upload-sw` privileged EXEC command if a password is specified.
- The password set by the `ip ftp password password` global configuration command if the command is configured.
- The switch forms a password named `username@switchname.domain`. The variable `username` is the username associated with the current session, `switchname` is the configured hostname, and `domain` is the domain of the switch.

The username and password must be associated with an account on the FTP server. If you are writing to the server, the FTP server must be properly configured to accept the FTP write request from you.

Use the `ip ftp username` and `ip ftp password` commands to specify a username and password for all copies. Include the username in the `archive download-sw` or `archive upload-sw` privileged EXEC command if you want to specify a username only for that operation.

If the server has a directory structure, the image file is written to or copied from the directory associated with the username on the server. For example, if the image file resides in the home directory of a user on the server, specify that user’s name as the remote username.

Before you begin downloading or uploading an image file by using FTP, do these tasks:

- Ensure that the switch has a route to the FTP server. The switch and the FTP server must be in the same subnet if you do not have a router to route traffic between subnets. Check connectivity to the FTP server by using the `ping` command.
- If you are accessing the switch through the console or a Telnet session and you do not have a valid username, make sure that the current FTP username is the one that you want to use for the FTP download. You can enter the `show users` privileged EXEC command to view the valid username. If you do not want to use this username, create a new FTP username by using the `ip ftp username username` global configuration command. This new name will be used during all archive operations. The new username is stored in NVRAM. If you are accessing the switch through a Telnet session and you have a valid username, this username is used, and you do not need to set the FTP username. Include the username in the `archive download-sw` or `archive upload-sw` privileged EXEC command if you want to specify a username for that operation only.
When you upload an image file to the FTP server, it must be properly configured to accept the write request from the user on the switch.

For more information, see the documentation for your FTP server.

**Downloading an Image File By Using FTP**

You can download a new image file and overwrite the current image or keep the current image.

Beginning in privileged EXEC mode, follow Steps 1 through 7 to download a new image from an FTP server and overwrite the existing image. To keep the current image, go to Step 7.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Verify that the FTP server is properly configured by referring to the “Preparing to Download or Upload an Image File By Using FTP” section on page B-26.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td>Step 3</td>
<td><code>configure terminal</code> Enter global configuration mode. This step is required only if you override the default remote username or password (see Steps 4, 5, and 6).</td>
</tr>
<tr>
<td>Step 4</td>
<td><code>ip ftp username username</code> (Optional) Change the default remote username.</td>
</tr>
<tr>
<td>Step 5</td>
<td><code>ip ftp password password</code> (Optional) Change the default password.</td>
</tr>
<tr>
<td>Step 6</td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
<tr>
<td>Step 7</td>
<td><code>archive download-sw /overwrite /reload ftp://[//Username[:password]@location]/directory]/image-name.tar</code> Download the image file from the FTP server to the switch, and overwrite the current image.</td>
</tr>
</tbody>
</table>

- The `/overwrite` option overwrites the software image in flash memory with the downloaded image.
- The `/reload` option reloads the system after downloading the image unless the configuration has been changed and not been saved.
- For `/Username[:password]`, specify the username and password; these must be associated with an account on the FTP server. For more information, see the “Preparing to Download or Upload an Image File By Using FTP” section on page B-26.
- For `/location`, specify the IP address of the FTP server.
- For `/directory/image-name.tar`, specify the directory (optional) and the image to download. Directory and image names are case sensitive.
Appendix B  Working with the Cisco IOS File System, Configuration Files, and Software Images

Appendix B  Working with Software Images

Working with Software Images

Working with Software Images

The download algorithm verifies that the image is appropriate for the switch model and that enough
DRAM is present, or it aborts the process and reports an error. If you specify the /overwrite option, the
download algorithm removes the existing image on the flash device, whether or not it is the same as the
new one, downloads the new image, and then reloads the software.

Note
If the flash device has sufficient space to hold two images and you want to overwrite one of these images
with the same version, you must specify the /overwrite option.

If you specify the /leave-old-sw, the existing files are not removed. If there is not enough space to install
the new image and keep the running image, the download process stops, and an error message is
displayed.

The algorithm installs the downloaded image onto the system board flash device (flash:). The image is
placed into a new directory named with the software version string, and the BOOT environment variable
is updated to point to the newly installed image.

If you kept the old image during the download process (you specified the /leave-old-sw keyword), you
can remove it by entering the delete /force /recursive filesystem:/file-url privileged EXEC command.
For filesystem, use flash: for the system board flash device. For file-url, enter the directory name of the
old software image. All the files in the directory and the directory are removed.

Caution
For the download and upload algorithms to operate properly, do not rename image names.

Uploading an Image File By Using FTP

You can upload an image from the switch to an FTP server. You can later download this image to the
same switch or to another switch of the same type.

Use the upload feature only if the web management pages associated with the embedded device manager
have been installed with the existing image.
Beginning in privileged EXEC mode, follow these steps to upload an image to an FTP server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Verify that the FTP server is properly configured by referring to the “Preparing to Download or Upload a Configuration File By Using FTP” section on page B-14.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>configure terminal Enter global configuration mode. This step is required only if you override the default remote username or password (see Steps 4, 5, and 6).</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>ip ftp username <em>username</em> (Optional) Change the default remote username.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>ip ftp password <em>password</em> (Optional) Change the default password.</td>
</tr>
<tr>
<td><strong>Step 6</strong></td>
<td>end Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
| **Step 7** | **archive upload-sw** ftp://[[//username[:password]@]location]/directory/image-name.tar Upload the currently running switch image to the FTP server.  
  - For *username*:password, specify the username and password. These must be associated with an account on the FTP server. For more information, see the “Preparing to Download or Upload an Image File By Using FTP” section on page B-26.  
  - For @*location*, specify the IP address of the FTP server.  
  - For *directory*/*image-name.tar*, specify the directory (optional) and the name of the software image to be uploaded. Directory and image names are case sensitive. The *image-name.tar* is the name of the software image to be stored on the server. |

The **archive upload-sw** command builds an image file on the server by uploading these files in order: info, the Cisco IOS image, and the web management files. After these files are uploaded, the upload algorithm creates the tar file format.

**Caution**  
For the download and upload algorithms to operate properly, do not rename image names.

**Copying Image Files By Using RCP**

You can download a switch image from an RCP server or upload the image from the switch to an RCP server.

You download a switch image file from a server to upgrade the switch software. You can overwrite the current image with the new one or keep the current image after a download.

You upload a switch image file to a server for backup purposes. You can use this uploaded image for future downloads to the same switch or another of the same type.
Instead of using the copy privileged EXEC command or the archive tar privileged EXEC command, we recommend using the archive download-sw and archive upload-sw privileged EXEC commands to download and upload software image files.

These sections contain this configuration information:

- Preparing to Download or Upload an Image File By Using RCP, page B-30
- Downloading an Image File By Using RCP, page B-31
- Uploading an Image File By Using RCP, page B-33

Preparing to Download or Upload an Image File By Using RCP

RCP provides another method of downloading and uploading image files between remote hosts and the switch. Unlike TFTP, which uses User Datagram Protocol (UDP), a connectionless protocol, RCP uses TCP, which is connection-oriented.

To use RCP to copy files, the server from or to which you will be copying files must support RCP. The RCP copy commands rely on the rsh server (or daemon) on the remote system. To copy files by using RCP, you do not need to create a server for file distribution as you do with TFTP. You only need to have access to a server that supports the remote shell (rsh). (Most UNIX systems support rsh.) Because you are copying a file from one place to another, you must have read permission on the source file and write permission on the destination file. If the destination file does not exist, RCP creates it for you.

RCP requires a client to send a remote username on each RCP request to a server. When you copy an image from the switch to a server by using RCP, the Cisco IOS software sends the first valid username in this list:

- The username specified in the archive download-sw or archive upload-sw privileged EXEC command if a username is specified.
- The username set by the ip rcmd remote-username username global configuration command if the command is entered.
- The remote username associated with the current TTY (terminal) process. For example, if the user is connected to the router through Telnet and was authenticated through the username command, the switch software sends the Telnet username as the remote username.
- The switch hostname.

For the RCP copy request to execute successfully, an account must be defined on the network server for the remote username. If the server has a directory structure, the image file is written to or copied from the directory associated with the remote username on the server. For example, if the image file resides in the home directory of a user on the server, specify that user’s name as the remote username.

Before you begin downloading or uploading an image file by using RCP, do these tasks:

- Ensure that the workstation acting as the RCP server supports the remote shell (rsh).
- Ensure that the switch has a route to the RCP server. The switch and the server must be in the same subnetwork if you do not have a router to route traffic between subnets. Check connectivity to the RCP server by using the ping command.
- If you are accessing the switch through the console or a Telnet session and you do not have a valid username, make sure that the current RCP username is the one that you want to use for the RCP download. You can enter the show users privileged EXEC command to view the valid username. If you do not want to use this username, create a new RCP username by using the ip rcmd remote-username username global configuration command to be used during all archive
operations. The new username is stored in NVRAM. If you are accessing the switch through a Telnet session and you have a valid username, this username is used, and there is no need to set the RCP username. Include the username in the `archive download-sw` or `archive upload-sw` privileged EXEC command if you want to specify a username only for that operation.

- When you upload an image to the RCP to the server, it must be properly configured to accept the RCP write request from the user on the switch. For UNIX systems, you must add an entry to the `.rhosts` file for the remote user on the RCP server. For example, suppose the switch contains these configuration lines:

```
hostname Switch1
ip rcmd remote-username User0
```

If the switch IP address translates to `Switch1.company.com`, the `.rhosts` file for User0 on the RCP server should contain this line:

```
Switch1.company.com Switch1
```

For more information, see the documentation for your RCP server.

### Downloading an Image File By Using RCP

You can download a new image file and replace or keep the current image.

Beginning in privileged EXEC mode, follow Steps 1 through 6 to download a new image from an RCP server and overwrite the existing image. To keep the current image, go to Step 6.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Verify that the RCP server is properly configured by referring to the “Preparing to Download or Upload an Image File By Using RCP” section on page B-30.</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Log into the switch through the console port or a Telnet session.</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td><code>configure terminal</code> Enter global configuration mode. This step is required only if you override the default remote username (see Steps 4 and 5).</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td><code>ip rcmd remote-username username</code> (Optional) Specify the remote username.</td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td><code>end</code> Return to privileged EXEC mode.</td>
</tr>
</tbody>
</table>
### Working with Software Images

#### Working with Software Images

The download algorithm verifies that the image is appropriate for the switch model and that enough DRAM is present, or it aborts the process and reports an error. If you specify the `/overwrite` option, the download algorithm removes the existing image on the flash device whether or not it is the same as the new one, downloads the new image, and then reloads the software.

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 6**
archive download-sw /overwrite /reload rcp:\[[[username@]location]/directory]/image-name.tar | Download the image file from the RCP server to the switch, and overwrite the current image. |
| | • The `/overwrite` option overwrites the software image in flash memory with the downloaded image. |
| | • The `/reload` option reloads the system after downloading the image unless the configuration has been changed and not been saved. |
| | • For `/username`, specify the username. For the RCP copy request to execute successfully, an account must be defined on the network server for the remote username. For more information, see the “Preparing to Download or Upload an Image File By Using RCP” section on page B-30. |
| | • For `@location`, specify the IP address of the RCP server. |
| | • For `/directory`/image-name.tar, specify the directory (optional) and the image to download. Directory and image names are case sensitive. |
| **Step 7**
archive download-sw /leave-old-sw /reload rcp:\[[[username@]location]/directory]/image-name.tar | Download the image file from the RCP server to the switch, and keep the current image. |
| | • The `/leave-old-sw` option keeps the old software version after a download. |
| | • The `/reload` option reloads the system after downloading the image unless the configuration has been changed and not been saved. |
| | • For `/username`, specify the username. For the RCP copy request to execute, an account must be defined on the network server for the remote username. For more information, see the “Preparing to Download or Upload an Image File By Using RCP” section on page B-30. |
| | • For `@location`, specify the IP address of the RCP server. |
| | • For `/directory`/image-name.tar, specify the directory (optional) and the image to download. Directory and image names are case sensitive. |

The download algorithm verifies that the image is appropriate for the switch model and that enough DRAM is present, or it aborts the process and reports an error. If you specify the `/overwrite` option, the download algorithm removes the existing image on the flash device whether or not it is the same as the new one, downloads the new image, and then reloads the software.

**Note**

If the flash device has sufficient space to hold two images and you want to overwrite one of these images with the same version, you must specify the `/overwrite` option.

If you specify the `/leave-old-sw`, the existing files are not removed. If there is not enough room to install the new image an keep the running image, the download process stops, and an error message is displayed.
The algorithm installs the downloaded image onto the system board flash device (flash:). The image is placed into a new directory named with the software version string, and the BOOT environment variable is updated to point to the newly installed image.

If you kept the old software during the download process (you specified the leave-old-sw keyword), you can remove it by entering the delete /force /recursive filesystem:file-url privileged EXEC command. For filesystem, use flash: for the system board flash device. For file-url, enter the directory name of the old software image. All the files in the directory and the directory are removed.

⚠️ Caution

For the download and upload algorithms to operate properly, do not rename image names.

### Uploading an Image File By Using RCP

You can upload an image from the switch to an RCP server. You can later download this image to the same switch or to another switch of the same type.

The upload feature should be used only if the web management pages associated with the embedded device manager have been installed with the existing image.

Beginning in privileged EXEC mode, follow these steps to upload an image to an RCP server:

<table>
<thead>
<tr>
<th>Command</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Step 1
| Verify that the RCP server is properly configured by referring to the “Preparing to Download or Upload an Image File By Using RCP” section on page B-30. |
| Step 2
| Log into the switch through the console port or a Telnet session.      |
| Step 3
| configure terminal                                                     |
| Enter global configuration mode.                                       |
| This step is required only if you override the default remote username (see Steps 4 and 5). |
| Step 4
| ip rcmd remote-username username                                        |
| (Optional) Specify the remote username.                                |
| Step 5
| end                                                                     |
| Return to privileged EXEC mode.                                         |
| Step 6
| archive upload-sw rcp:[[//username@]location]/directory/image-name.tar |
| Upload the currently running switch image to the RCP server.            |
| • For //username, specify the username; for the RCP copy request to execute, an account must be defined on the network server for the remote username. For more information, see the “Preparing to Download or Upload an Image File By Using RCP” section on page B-30. |
| • For @location, specify the IP address of the RCP server.             |
| • For /directory/image-name.tar, specify the directory (optional) and the name of the software image to be uploaded. Directory and image names are case sensitive. |
| • The image-name.tar is the name of software image to be stored on the server. |
The **archive upload-sw** privileged EXEC command builds an image file on the server by uploading these files in order: info, the Cisco IOS image, and the web management files. After these files are uploaded, the upload algorithm creates the tar file format.

**Caution**

For the download and upload algorithms to operate properly, do *not* rename image names.
Unsupported Commands in Cisco IOS Release 12.2(37)SE

This appendix lists some of the command-line interface (CLI) commands that appear when you enter the question mark (?) at the switch prompt but are not supported in this release, either because they are not tested or because of switch hardware limitations. This is not a complete list. The unsupported commands are listed by software feature and command mode.

Access Control Lists

Unsupported Privileged EXEC Commands

access-enable [host] [timeout minutes]
access-template [access-list-number | name] [dynamic-name] [source] [destination] [timeout minutes]
clear access-template [access-list-number | name] [dynamic-name] [source] [destination].
show access-lists rate-limit [destination]
show accounting
show ip accounting [checkpoint] [output-packets | access violations]
show ip cache [prefix-mask] [type number]

Unsupported Global Configuration Commands

access-list rate-limit acl-index {precedence | mask prec-mask}
access-list dynamic extended

Unsupported Route-Map Configuration Command

match ip address prefix-list prefix-list-name [prefix-list-name...]
Bootloader Commands

Unsupported Global Configuration Command

boot buffersize

Debug Commands

Unsupported Privileged EXEC Commands

debug platform cli-redirection main
debug platform configuration

IGMP Snooping Commands

Unsupported Global Configuration Command

ip igmp snooping tcn

Interface Commands

Unsupported Privileged EXEC Command

show interfaces [interface-id | vlan vlan-id | crb | fair-queue | irb | mac-accounting | precedence | irb | random-detect | rate-limit | shape]

Unsupported Global Configuration Command

interface tunnel

Unsupported Interface Configuration Command

transmit-interface type number
MAC Address Commands

Unsupported Privileged EXEC Commands

- show mac-address-table
- show mac-address-table address
- show mac-address-table aging-time
- show mac-address-table count
- show mac-address-table dynamic
- show mac-address-table interface
- show mac-address-table multicast
- show mac-address-table notification
- show mac-address-table static
- show mac-address-table vlan
- show mac-address-table multicast

Note: Use the `show ip igmp snooping groups` privileged EXEC command to display Layer 2 multicast address-table entries for a VLAN.

Unsupported Global Configuration Commands

- mac-address-table aging-time
- mac-address-table notification
- mac-address-table static

Miscellaneous

Unsupported Privileged EXEC Commands

- file verify auto
- remote command
- show cable-diagnostics prbs
- test cable-diagnostics prbs

Unsupported Global Configuration Commands

- errdisable recovery cause unicast flood
Network Address Translation (NAT) Commands

Unsupported Privileged EXEC Commands

- show ip nat statistics
- show ip nat translations

QoS

Unsupported Global Configuration Command

- priority-list

Unsupported Interface Configuration Commands

- priority-group
- rate-limit

Unsupported Policy-Map Configuration Command

- class class-default where class-default is the class-map-name.

RADIUS

Unsupported Global Configuration Commands

- aaa nas port extended
- aaa authentication feature default enable
- aaa authentication feature default line
- radius-server attribute nas-port
- radius-server configure
- radius-server extended-portnames
SNMP

Unsupported Global Configuration Commands

snmp-server enable informs
snmp-server ifindex persist

Spanning Tree

Unsupported Global Configuration Command

spanning-tree pathcost method {long | short}

Unsupported Interface Configuration Command

spanning-tree stack-port

VLAN

Unsupported Global Configuration Command

vlan internal allocation policy {ascending | descending}

Unsupported vlan-config Command

private-vlan

Unsupported User EXEC Commands

show running-config vlan
show vlan ifindex
show vlan private-vlan
Unlocked

Unsupported Privileged EXEC Command

```
vtp {password password \ pruning \ version number}
```

Note

This command has been replaced by the `vtp` global configuration command.
INDEX

A

abbreviating commands 2-4
access-class command 26-16
access control entries
  See ACEs
access-denied response, VMPS 9-25
access groups, applying IPv4 ACLs to interfaces 26-17
access lists
  See ACLs
access ports, defined 7-2
accounting
  with 802.1x 6-30
  with IEEE 802.1x 6-9
  with RADIUS 5-28
  with TACACS+ 5-11, 5-17
ACEs
  and QoS 27-7
  defined 26-2
  Ethernet 26-2
  IP 26-2
ACLs
  ACEs 26-2
  any keyword 26-10
  applying
    time ranges to 26-14
    to an interface 26-17
    to QoS 27-7
  classifying traffic for QoS 27-42
  comments in 26-16
  compiling 26-18
  defined 26-1, 26-6
  examples of 26-18, 27-42
ACLs (continued)
  extended IP, configuring for QoS classification 27-43
  extended IPv4
    creating 26-8
    matching criteria 26-6
  hardware and software handling 26-18
  host keyword 26-10
  IP
    creating 26-6
    fragments and QoS guidelines 27-32
    implicit deny 26-8, 26-11, 26-13
    implicit masks 26-8
    matching criteria 26-6
    undefined 26-17
  IPv4
    applying to interfaces 26-17
    creating 26-6
    matching criteria 26-6
    named 26-12
    numbers 26-6
    terminal lines, setting on 26-16
    unsupported features 26-5
  MAC extended 26-20, 27-44
  matching 26-6, 26-17
  monitoring 26-29
  named, IPv4 26-12
  number per QoS class map 27-32
  port 26-2
  precedence of 26-2
  QoS 27-7, 27-42
  resequencing entries 26-12
  standard IP, configuring for QoS classification 27-42
ACLs (continued)
Index

IN-2

Cisco Gigabit Ethernet Switch Module for HP p-Class BladeSystem Software Configuration Guide

380261-003

standard IPv4
creating 26-7
matching criteria 26-6
support for 1-7
support in hardware 26-18
time ranges 26-14
types supported 26-2
unsupported features, IPv4 26-5
VLAN maps
configuration guidelines 26-23
configuring 26-22
active links 15-2
address aliasing 17-2
addresses
displaying the MAC address table 4-26
dynamic
accelerated aging 12-8
changing the aging time 4-21
default aging 12-8
defined 4-19
learning 3-10, 4-20
removing 4-22
MAC, discovering 4-26
multicast, STP address management 12-8
static
adding and removing 4-24
defined 4-19
address resolution 4-26
Address Resolution Protocol
See ARP
advertisements
CDP 19-1
LLDP 20-1, 20-2
VTP 9-17, 10-3
aggregated ports
See EtherChannel
aggregate policers 27-55
aggregate policing 1-8
aging, accelerating 12-8
aging time
accelerated
for MSTP 13-23
for STP 12-8, 12-21
MAC address table 4-21
maximum
for MSTP 13-23, 13-24
for STP 12-21, 12-22
alarms, RMON 23-3
allowed-VLAN list 9-19
ARP
defined 1-4, 4-26
table
address resolution 4-26
managing 4-26
attributes, RADIUS
vendor-proprietary 5-31
vendor-specific 5-29
audience xxix
authentication
local mode with AAA 5-36
NTP associations 4-4
RADIUS
defined 5-21
key 5-23
TACACS+
defined 5-11
key 5-13
login 5-14
See also port-based authentication
authentication failed VLAN
See restricted VLAN
authoritative time source, described 4-2
authorization
with RADIUS 5-27
with TACACS+ 5-11, 5-16
authorized ports with IEEE 802.1x 6-7
autoconfiguration 3-3
automatic QoS
  See QoS
auto-MDI
  configuring 7-13
  described 7-13
autonegotiation
  duplex mode 1-3
  interface configuration guidelines 7-11
  mismatches 29-11
autosensing, port speed 1-3
auxiliary VLAN
  See voice VLAN
availability, features 1-5

B
BackboneFast
  described 14-5
  disabling 14-14
  enabling 14-13
  support for 1-5
backup interfaces
  See Flex Links
backup links 15-2
banners
  configuring
    login 4-19
    message-of-the-day login 4-18
  default configuration 4-17
  when displayed 4-17
binding table, DHCP snooping
  See DHCP snooping binding database
blocking packets 18-6
booting
  boot loader, function of 3-2
  boot process 3-1
  manually 3-13
  specific image 3-14
boot loader
  accessing 3-15
  described 3-2
  environment variables 3-15
  prompt 3-15
  trap-door mechanism 3-2
BPDU
  error-disabled state 14-2
  filtering 14-3
  RSTP format 13-12
BPDU filtering
  described 14-3
  disabling 14-12
  enabling 14-12
  support for 1-6
BPDU guard
  described 14-2
  disabling 14-12
  enabling 14-11
  support for 1-6
bridge protocol data unit
  See BPDU
broadcast storm-control command 18-4
broadcast storms 18-1

C
cables, monitoring for unidirectional links 21-1
CA trustpoint
  configuring 5-45
  defined 5-42
caution, described xxx
CDP
  and trusted boundary 27-38
  configuring 19-2
  default configuration 19-2
  defined with LLDP 20-1
  described 19-1
  disabling for routing device 19-3 to 19-4
CDP (continued)

enabling and disabling
- on an interface 19-4
- on a switch 19-3
monitoring 19-5
overview 19-1
support for 1-4
transmission timer and holdtime, setting 19-2
updates 19-2

CGMP
- as IGMP snooping learning method 17-8
- joining multicast group 17-3

CipherSuites 5-44
Cisco 7960 IP Phone 11-1
Cisco Discovery Protocol
- See CDP
Cisco Intelligence Engine 2100 Series Configuration Registrar
- See IE2100
Cisco IOS File System
- See IFS
Cisco Network Assistant
- See Network Assistant
CiscoWorks 2000 1-4, 25-4
CIST regional root
- See MSTP
CIST root
- See MSTP
class maps for QoS
- configuring 27-45
- described 27-7
- displaying 27-75
class of service
- See CoS
clearing interfaces 7-17

CLI
- abbreviating commands 2-4
- command modes 2-1
- configuration logging 2-5

CLI (continued)
- described 1-4
- editing features
- enabling and disabling 2-7
- keystroke editing 2-7
- wrapped lines 2-9
- error messages 2-5
- filtering command output 2-10
- getting help 2-3
- history
- changing the buffer size 2-6
- described 2-6
- disabling 2-7
- recalling commands 2-6
- no and default forms of commands 2-4
- client mode, VTP 10-3
- clock
- See system clock
- cluster requirements xxx
- clusters, switch
- benefits 1-2
- command-line interface
- See CLI
- command modes 2-1
- commands
- abbreviating 2-4
- no and default 2-4
- commands, setting privilege levels 5-8
- command switch
- configuration conflicts 29-11
- recovery
- from command-switch failure 29-8
- from lost member connectivity 29-11
- replacing
- with another switch 29-10
- with cluster member 29-8
community strings
  configuring  25-8
  for cluster switches  25-4
  overview  25-4
compatibility, feature  18-11
config.text  3-12
configurable leave timer, IGMP  17-5
configuration, initial
  defaults  1-9
  Express Setup  1-2
  See also getting started guide and hardware installation guide
configuration conflicts, recovering from lost member connectivity  29-11
configuration files
  clearing the startup configuration  B-20
  creating using a text editor  B-11
  default name  3-12
  deleting a stored configuration  B-20
  described  B-8
downloading
  automatically  3-13
  preparing  B-11, B-14, B-17
  reasons for  B-9
  using FTP  B-14
  using RCP  B-18
  using TFTP  B-12
guidelines for creating and using  B-10
invalid combinations when copying  B-5
limiting TFTP server access  25-16
obtaining with DHCP  3-7
password recovery disable considerations  5-5
specifying the filename  3-13
system contact and location information  25-15
types and location  B-10
configuration files (continued)
  uploading
    preparing  B-11, B-14, B-17
    reasons for  B-9
    using FTP  B-15
    using RCP  B-19
    using TFTP  B-12
configuration logging  2-5
configuration settings, saving  3-11
configure terminal command  7-5
config-vlan mode  2-2, 9-6
conflicts, configuration  29-11
connections, secure remote  5-38
connectivity problems  29-13, 29-14, 29-16
consistency checks in VTP Version 2  10-4
custom console port, connecting to  2-10
conventions
  command  xxx
  for examples  xxx
  publication  xxx
  text  xxx
corrupted software, recovery steps with Xmodem  29-2
CoS
  in Layer 2 frames  27-2
  override priority  11-6
  trust priority  11-6
CoS input queue threshold map for QoS  27-16
CoS output queue threshold map for QoS  27-19
CoS-to-DSCP map for QoS  27-58
counters, clearing interface  7-17
trashinfo file  29-22
critical authentication, IEEE 802.1x  6-33
cryptographic software image
  Kerberos  5-32
  SSH  5-37
daylight saving time 4-13
default configuration
   802.1x 6-19
   auto-QoS 27-21
   banners 4-17
   booting 3-12
   CDP 19-2
   DHCP 16-5
   DHCP option 82 16-6
   DHCP snooping 16-6
   DNS 4-16
   EtherChannel 28-9
   Ethernet interfaces 7-9
   Flex Links 15-5
   IGMP filtering 17-24
   IGMP snooping 17-6
   IGMP throttling 17-24
   initial switch information 3-3
   Layer 2 interfaces 7-9
   LLDP 20-3
   MAC address table 4-21
   MAC address-table move update 15-5
   MSTP 13-14
   MVR 17-19
   NTP 4-4
   optional spanning-tree configuration 14-9
   password and privilege level 5-2
   RADIUS 5-20
   RMON 23-3
   RSPAN 22-9
   SNMP 25-7
   SPAN 22-9
   SSL 5-44
   standard QoS 27-30
   STP 12-11
   system message logging 24-3
   system name and prompt 4-15
   TACACS+ 5-13
   UDLD 21-4
   VLAN, Layer 2 Ethernet interfaces 9-17
   VLANs 9-7
   VMPS 9-26
   voice VLAN 11-3
   VTP 10-6
default gateway 3-10
deleting VLANs 9-10
denial-of-service attack 18-1
description command 7-14
destination addresses, in IPv4 ACLs 26-9
destination-IP address-based forwarding, EtherChannel 28-7
destination-MAC address forwarding, EtherChannel 28-6
detecting indirect link failures, STP 14-5
device B-20
device discovery protocol 19-1, 20-1
device manager
   benefits 1-2
   described 1-4
   in-band management 1-5
   requirements xxx
   upgrading a switch B-20
DHCP
   Cisco IOS server database
   configuring 16-9
   enabling
      relay agent 16-7
DHCP-based autoconfiguration
- client request message exchange 3-4
  - configuring
    - client side 3-3
    - DNS 3-6
    - relay device 3-6
    - server side 3-5
    - TFTP server 3-6
  - example 3-8
  - lease options
    - for IP address information 3-5
    - for receiving the configuration file 3-5
  - overview 3-3
  - relationship to BOOTP 3-3
  - relay support 1-4
  - support for 1-4

DHCP binding table
- See DHCP snooping binding database

DHCP option 82
- circuit ID suboption 16-5
- configuration guidelines 16-6
- default configuration 16-5
  - displaying 16-9
  - overview 16-3
- packet format, suboption
  - circuit ID 16-5
  - remote ID 16-5
- remote ID suboption 16-5

DHCP snooping
- accepting untrusted packets form edge switch 16-3, 16-8
  - configuration guidelines 16-6
  - default configuration 16-5
  - displaying 16-9
  - message exchange process 16-4
  - option 82 data insertion 16-3
  - trusted interface 16-2
  - untrusted interface 16-2
  - untrusted messages 16-2

DHCP snooping binding database
- binding entries, displaying 16-9
  - default configuration 16-5
  - displaying 16-9

DHCP snooping binding table
- See DHCP snooping binding database

Differentiated Services architecture, QoS 27-2
Differentiated Services Code Point 27-2
directed unicast requests 1-4
directories
- changing B-3
- creating and removing B-4
- displaying the working B-3

DNS
- and DHCP-based autoconfiguration 3-6
  - default configuration 4-16
  - displaying the configuration 4-17
  - overview 4-15
  - setting up 4-16
  - support for 1-4
- documentation, related xxx
- document conventions xxx
domain names
  - DNS 4-15
  - VTP 10-8

Domain Name System
- See DNS
downloading
- configuration files
  - preparing B-11, B-14, B-17
  - reasons for B-9
  - using FTP B-14
  - using RCP B-18
  - using TFTP B-12
downloading (continued)

image files
  deleting old image  B-24
  preparing  B-23, B-26, B-30
  reasons for  B-20
  using CMS  B-27
  using FTP  B-27
  using HTTP  B-23, B-20
  using RCP  B-31
  using TFTP  B-23
  using the device manager or Network Assistant  B-20
DSCP  1-8, 27-2
DSCP input queue threshold map for QoS  27-16
DSCP output queue threshold map for QoS  27-19
DSCP-to-CoS map for QoS  27-61
DSCP-to-DSCP-mutation map for QoS  27-62
DSCP transparency  27-39
DTP  1-6, 9-15
  dynamic access ports
    characteristics  9-3
    configuring  9-28
    defined  7-2
  dynamic addresses
    See addresses
  dynamic auto trunking mode  9-16
  dynamic desirable trunking mode  9-16
Dynamic Host Configuration Protocol
  See DHCP-based autoconfiguration
dynamic port VLAN membership
  described  9-26
  reconfirming  9-29
  troubleshooting  9-30
  types of connections  9-28
Dynamic Trunking Protocol
  See DTP

E
  editing features
    enabling and disabling  2-7
    keystrokes used  2-7
    wrapped lines  2-9
    enable password  5-3
    enable secret password  5-3
    encryption, CipherSuite  5-44
    encryption for passwords  5-3
    environment variables, function of  3-16
    error-disabled state
      BPDU  14-2
  error messages during command entry  2-5
EtherChannel
  automatic creation of  28-4, 28-5
  channel groups
    binding physical and logical interfaces  28-3
    numbering of  28-3
    configuration guidelines  28-9
    configuring Layer 2 interfaces  28-10
    default configuration  28-9
    described  28-2
    displaying status  28-17
    forwarding methods  28-6, 28-12
    IEEE 802.3ad, described  28-5
    interaction
      with STP  28-9
      with VLANs  28-10
LACP
  described  28-5
  displaying status  28-17
  hot-standby ports  28-14
  interaction with other features  28-6
  modes  28-5
  port priority  28-16
  system priority  28-15
  load balancing  28-6, 28-12
PAgP
aggregate-port learners 28-13
compatibility with Catalyst 1900 28-13
described 28-4
displaying status 28-17
interaction with other features 28-5
learn method and priority configuration 28-13
modes 28-4
support for 1-3
port-channel interfaces
described 28-3
numbering of 28-3
port groups 7-3
support for 1-3
EtherChannel guard
described 14-7
disabling 14-14
enabling 14-14
Ethernet VLANs
adding 9-8
defaults and ranges 9-7
modifying 9-8
events, RMON 23-3
examples
conventions for xxx
expedite queue for QoS 27-74
Express Setup 1-2
See also getting started guide
extended crashinfo file 29-22
extended-range VLANs
collection guidelines 9-12
configuring 9-11
creating 9-12
defined 9-1
extended system ID
MSTP 13-17
STP 12-4, 12-14
Extensible Authentication Protocol over LAN 6-1

F
fa0 interface 1-5
features, incompatible 18-11
fiber-optic, detecting unidirectional links 21-1
files
basic crashinfo
description 29-22
location 29-22
crashinfo
description 29-22
deleting B-5
displaying the contents of B-8
extended crashinfo
description 29-22
location 29-22
tar
creating B-6
displaying the contents of B-6
extracting B-8
image file format B-21
file system
displaying available file systems B-2
displaying file information B-3
local file system names B-1
network file system names B-4
setting the default B-3
filtering
in a VLAN 26-22
non-IP traffic 26-20
show and more command output 2-10
filtering show and more command output 2-10
filters, IP
See ACLs, IP
flash device, number of B-1
Flex Links
  configuration guidelines 15-5
  configuring 15-6, 15-7
  configuring preferred VLAN 15-9
  configuring VLAN load balancing 15-8
  default configuration 15-5
  description 15-1
  link load balancing 15-2
  monitoring 15-11
  VLANs 15-2
floated traffic, blocking 18-7
flow-based packet classification 1-8
flowcharts
  QoS classification 27-6
  QoS egress queuing and scheduling 27-17
  QoS ingress queuing and scheduling 27-15
  QoS policing and marking 27-10
flowcontrol
  configuring 7-12
  described 7-12
forward-delay time
  MSTP 13-23
  STP 12-21
FTP
  accessing MIB files A-3
  configuration files
    downloading B-14
    overview B-13
    preparing the server B-14
    uploading B-15
  image files
    deleting old image B-28
    downloading B-27
    preparing the server B-26
    uploading B-28
get-bulk-request operation 25-3
get-next-request operation 25-3, 25-5
get-request operation 25-3, 25-5
get-response operation 25-3
global configuration mode 2-2
global leave, IGMP 17-12
guest VLAN and 802.1x 6-12
guide
  audience xxix
  purpose of xxix
guide mode 1-2
GUIs
  See device manager and Network Assistant

H
hello time
  MSTP 13-22
  STP 12-20
help, for the command line 2-3
hierarchical policy maps 27-8
  configuration guidelines 27-32
  configuring 27-50
  described 27-11
history
  changing the buffer size 2-6
  described 2-6
  disabling 2-7
  recalling commands 2-6
history table, level and number of syslog messages 24-9
hosts, limit on dynamic ports 9-30
HP OpenView 1-4
HTTP over SSL
  see HTTPS
HTTPS 5-42
  configuring 5-46
  self-signed certificate 5-43
HTTP secure server 5-42
ICMP

- time-exceeded messages  
  traceroute and  

ICMP ping

- executing  
- overview  

IDS appliances

- and ingress RSPAN  
- and ingress SPAN  

IEEE 802.1D

- See STP  

IEEE 802.1p  

IEEE 802.1Q

- and trunk ports  
- configuration limitations  
- encapsulation  
- native VLAN for untagged traffic  

IEEE 802.1s

- See MSTP  

IEEE 802.1w

- See RSTP  

IEEE 802.1x

- See port-based authentication  

IEEE 802.3ad

- See EtherChannel  

IEEE 802.3x flow control  

ifIndex values, SNMP  

IFS  

IGMP

- configurable leave timer  
  described  
  enabling  

IGMP (continued)

- flooded multicast traffic  
  controlling the length of time  
  disabling on an interface  
  global leave  
  query solicitation  
  recovering from flood mode  
  joining multicast group  
  join messages  
  leave processing, enabling  
  leaving multicast group  
  queries  
  report suppression  
  described  
  disabling  
  supported versions  
  support for  

IGMP filtering

- configuring  
- default configuration  
- described  
- monitoring  
- support for  

IGMP groups

- configuring filtering  
- setting the maximum number  

IGMP Immediate Leave

- configuration guidelines  
- described  
- enabling  

IGMP profile

- applying  
- configuration mode  
- configuring
IGMP snooping
   and address aliasing  17-2
   configuring  17-6
   default configuration  17-6
   definition  17-1
   enabling and disabling  17-7
   global configuration  17-7
   Immediate Leave  17-5
   method  17-8
   monitoring  17-15
   querier
      configuration guidelines  17-13
      configuring  17-13
      supported versions  17-2
   support for  1-3
   VLAN configuration  17-7
IGMP throttling
   configuring  17-27
   default configuration  17-24
   described  17-24
   displaying action  17-28
Immediate Leave, IGMP  17-5
inaccessible authentication bypass  6-14
initial configuration
   defaults  1-9
   Express Setup  1-2
   See also getting started guide and hardware installation guide
interface
   range macros  7-7
   interface command  7-4 to 7-5
   interface configuration mode  2-3
interfaces
   auto-MDIX, configuring  7-13
   configuration guidelines
      duplex and speed  7-10
   configuring
      procedure  7-5
   interfaces (continued)
      counters, clearing  7-17
      default configuration  7-9
      described  7-14
      descriptive name, adding  7-14
      displaying information about  7-16
      flow control  7-12
      management  1-4
      monitoring  7-16
      naming  7-14
      physical, identifying  7-4
      range of  7-6
      restarting  7-17
      shutting down  7-17
      speed and duplex, configuring  7-11
      status  7-16
      supported  7-4
      types of  7-1
      interfaces range macro command  7-7
      interface types  7-4
      Inter-Switch Link
         See ISL
   Intrusion Detection System
      See IDS appliances
   IP ACLs
      for QoS classification  27-7
      implicit deny  26-8, 26-11
      implicit masks  26-8
      named  26-12
      undefined  26-17
   IP addresses
      discovering  4-26
      ip igmp profile command  17-24
   IP information
      assigned
         manually  3-10
         through DHCP-based autoconfiguration  3-3
      default configuration  3-3
IP multicast routing
and IGMP snooping 17-1
IP phones
and QoS 11-1
automatic classification and queueing 27-20
configuring 11-4
ensuring port security with QoS 27-37
trusted boundary for QoS 27-37
IP precedence 27-2
IP-precedence-to-DSCP map for QoS 27-59
IP protocols in ACLs 26-9
IP traceroute
executing 29-17
overview 29-16
IPv4 ACLs
applying to interfaces 26-17
extended, creating 26-8
named 26-12
standard, creating 26-7
ISL
and trunk ports 7-3
encapsulation 9-14

K
KDC
described 5-32
See also Kerberos
Kerberos
authenticating to
boundary switch 5-34
KDC 5-34
network services 5-35
configuration examples 5-32
configuring 5-35
Kerberos (continued)
credentials 5-32
cryptographic software image 5-32
described 5-32
KDC 5-32
operation 5-34
realm 5-33
server 5-34
support for 1-8
switch as trusted third party 5-32
terms 5-33
TGT 5-34
tickets 5-32
key distribution center
See KDC

L
LACP
See EtherChannel
Layer 2 frames, classification with CoS 27-2
Layer 2 interfaces, default configuration 7-9
Layer 2 traceroute
and ARP 29-15
and CDP 29-15
broadcast traffic 29-14
described 29-14
IP addresses and subnets 29-15
MAC addresses and VLANs 29-15
multicast traffic 29-15
multiple devices on a port 29-15
unicast traffic 29-14
usage guidelines 29-15
Layer 2 trunk failover
described 28-17
Layer 3 packets, classification methods 27-2
LEDs, switch
See hardware installation guide
line configuration mode 2-3
Link Aggregation Control Protocol
   See EtherChannel
Link Failure
   detecting unidirectional 13-8
Link Layer Discovery Protocol
   See CDP
link redundancy
   See Flex Links
links, unidirectional 21-1
LLDP
   configuring 20-3
       characteristics 20-3
       default configuration 20-3
   disabling and enabling
       globally 20-4
       on an interface 20-5
   monitoring and maintaining 20-7
   overview 20-1
   supported tlvs 20-1
   switch stack considerations 20-2
   transmission timer and holdtime, setting 20-3
LLDP-MED
   configuring 20-3
       tlvs 20-6
   monitoring and maintaining 20-7
   overview 20-1, 20-2
   supported tlvs 20-2
LLDP Media Endpoint Discovery
   See LLDP-MED
local SPAN 22-2
login authentication
   with RADIUS 5-23
   with TACACS+ 5-14
login banners 4-17
log messages
   See system message logging
Long-Reach Ethernet (LRE) technology 1-13
loop guard
   described 14-9
   enabling 14-15
   support for 1-6

M
MAC 3-10
MAC addresses
   aging time 4-21
   and VLAN association 4-20
   building the address table 4-20
   default configuration 4-21
   discovering 4-26
   displaying 4-26
   dynamic
       learning 4-20
       removing 4-22
   in ACLs 26-20
   manually assigning IP address 3-10
   static
       adding 4-24
       allowing 4-25
       characteristics of 4-24
       dropping 4-25
       removing 4-24
MAC address notification, support for 1-9
MAC address-table move update
   configuration guidelines 15-5
   configuring 15-9
   default configuration 15-5
   description 15-3
   monitoring 15-11
MAC address-to-VLAN mapping 9-25
MAC extended access lists
applying to Layer 2 interfaces 26-21
configuring for QoS 27-44
creating 26-20
defined 26-20
for QoS classification 27-5
macros
See Smartports macros
magic packet 6-16
manageability features 1-4
management access
in-band
browser session 1-5
CLI session 1-5
device manager 1-5
SNMP 1-5
out-of-band console port connection 1-5
management options
CLI 2-1
clustering 1-2
Network Assistant 1-2
overview 1-4
mapping tables for QoS
configuring
CoS-to-DSCP 27-58
DSCP 27-57
DSCP-to-CoS 27-61
DSCP-to-DSCP-mutation 27-62
IP-precedence-to-DSCP 27-59
policed-DSCP 27-60
described 27-12
marking
action in policy map 27-47
action with aggregate policers 27-55
described 27-4, 27-8
meshing, IPv4 ACLs 26-6
maximum aging time
MSTP 13-23
STP 12-21
maximum hop count, MSTP 13-24
membership mode, VLAN port 9-3
member switch
recovering from lost connectivity 29-11
messages
to users through banners 4-17
messages, to users through banners 4-17
MIBs
accessing files with FTP A-3
location of files A-3
overview 25-1
SNMP interaction with 25-4
supported A-1
mirroring traffic for analysis 22-1
mismatches, autonegotiation 29-11
module number 7-4
monitoring
access groups 26-29
cables for unidirectional links 21-1
CDP 19-5
features 1-9
Flex Links 15-11
IGMP
filters 17-28
snooping 17-15
interfaces 7-16
IPv4 ACL configuration 26-29
MAC address-table move update 15-11
multicast router interfaces 17-16
MVR 17-23
network traffic for analysis with probe 22-2
port
blocking 18-17
protection 18-17
SFP status 7-16, 29-12
speed and duplex mode 7-11
traffic flowing among switches 23-1
traffic suppression 18-17
traffic suppression
Index

monitoring (continued)

VLAN
  filters 26-29
  maps 26-29
VLANs 9-14
VMPS 9-30
VTP 10-16
more 6-41

MSTP
  boundary ports
    configuration guidelines 13-15
    described 13-6
  BPDU filtering
    described 14-3
    enabling 14-12
  BPDU guard
    described 14-2
    enabling 14-11
  CIST, described 13-3
  CIST regional root 13-3
  CIST root 13-5
  configuration guidelines 13-15, 14-10
  configuring
    forward-delay time 13-23
    hello time 13-22
    link type for rapid convergence 13-24
    maximum aging time 13-23
    maximum hop count 13-24
  MST region 13-16
  neighbor type 13-25
  path cost 13-20
  port priority 13-19
  root switch 13-17
  secondary root switch 13-18
  switch priority 13-21
  CST
    defined 13-3
    operations between regions 13-4

MSTP (continued)
  default configuration 13-14
  default optional feature configuration 14-9
  displaying status 13-26
  enabling the mode 13-16
  EtherChannel guard
    described 14-7
    enabling 14-14
  extended system ID
    effects on root switch 13-17
    effects on secondary root switch 13-18
    unexpected behavior 13-17
  IEEE 802.1s
    implementation 13-6
    port role naming change 13-7
    terminology 13-5
    instances supported 12-9
    interface state, blocking to forwarding 14-2
    interoperability and compatibility among modes 12-10
    interoperability with IEEE 802.1D
      described 13-8
      restarting migration process 13-25
  IST
    defined 13-3
    master 13-3
    operations within a region 13-3
    loop guard
      described 14-9
      enabling 14-15
  mapping VLANs to MST instance 13-16
  MST region
    CIST 13-3
    configuring 13-16
    described 13-2
    hop-count mechanism 13-5
    IST 13-3
    supported spanning-tree instances 13-2
    optional features supported 1-6
    overview 13-2
MSTP (continued)

Port Fast
  described 14-2
  enabling 14-10
preventing root switch selection
root guard
  described 14-8
  enabling 14-15
root switch
  configuring 13-17
  effects of extended system ID 13-17
  unexpected behavior 13-17
shutdown Port Fast-enabled port 14-2
status, displaying 13-26
multicast groups
  Immediate Leave 17-5
  joining 17-3
  leaving 17-5
  static joins 17-9
multicast packets
  blocking 18-7
multicast packets, blocking 18-7
multicast router interfaces, monitoring 17-16
multicast router ports, adding 17-9
multicast storm 18-1
multicast storm-control command 18-4
multicast television application 17-18
multicast VLAN 17-17
Multicast VLAN Registration
  See MVR

MVR (continued)

monitoring 17-23
multicast television application 17-18
setting global parameters 17-20
support for 1-3

N

NAC
  critical authentication 6-14, 6-33
  inaccessible authentication bypass 6-33
Layer 2 IEEE 802.1x validation 1-7
named IPv4 ACLs 26-12
native VLAN
  configuring 9-21
  default 9-21
Network Admission Control
  See NAC
Network Assistant
  benefits 1-2
  described 1-4
  downloading image files 1-2
  guide mode 1-2
  management options 1-2
  requirements xxx
  wizards 1-2
network configuration examples
  increasing network performance 1-12
  providing network services 1-12
  server aggregation and Linux server cluster 1-14
network design
  performance 1-12
  services 1-12
network management
  CDP 19-1
  RMON 23-1
  SNMP 25-1
Network Time Protocol
  See NTP
no commands 2-4
nonhierarchical policy maps
  configuration guidelines 27-32
  configuring 27-47
  described 27-9
non-IP traffic filtering 26-20
nontrunking mode 9-16
normal-range VLANs 9-4
  configuration guidelines 9-5
  configuration modes 9-6
  configuring 9-4
  defined 9-1
note, described xxx
NTP
associations
  authenticating 4-4
  defined 4-2
  enabling broadcast messages 4-6
  peer 4-5
  server 4-5
default configuration 4-4
displaying the configuration 4-11
overview 4-2
restricting access
  creating an access group 4-8
  disabling NTP services per interface 4-10
source IP address, configuring 4-10
stratum 4-2
support for 1-5
synchronizing devices 4-5
time
  services 4-2
  synchronizing 4-2

P

packet modification, with QoS 27-19
PAgP
  See EtherChannel
passwords
  default configuration 5-2
  disabling recovery of 5-5
  encrypting 5-3
  for security 1-7
  overview 5-1
  recovery of 29-3
  setting
    enable 5-3
    enable secret 5-3
    Telnet 5-6
    with usernames 5-6
    VTP domain 10-8
path cost
  MSTP 13-20
  STP 12-18
performance, network design 1-12
performance features 1-3
persistent self-signed certificate 5-43
per-VLAN spanning-tree plus
  See PVST+
physical ports 7-2
PIM-DVMRP, as snooping method 17-8
ping
  character output description 29-14
  executing 29-13
  overview 29-13
policed-DSCP map for QoS 27-60
policers
  configuring
    for each matched traffic class 27-47
    for more than one traffic class 27-55
  described 27-4
  displaying 27-75
policers (continued)
  number of  27-33
  types of  27-9
policing
  described  27-4
  hierarchical
    See hierarchical policy maps
token-bucket algorithm  27-9
policy maps for QoS
  characteristics of  27-47
  described  27-7
  displaying  27-76
  hierarchical  27-8
  hierarchical on SVIs
    configuration guidelines  27-32
    configuring  27-50
    described  27-11
  nonhierarchical on physical ports
    configuration guidelines  27-32
    configuring  27-47
    described  27-9
port ACLs
  defined  26-2
  types of  26-2
Port Aggregation Protocol
  See EtherChannel
port-based authentication
  accounting  6-9
  authentication server
    defined  6-2
    RADIUS server  6-2
  client, defined  6-2
  configuration guidelines  6-21
port-based authentication (continued)
  configuring
    802.1x authentication  6-23
    guest VLAN  6-31
    host mode  6-26
    inaccessible authentication bypass  6-33
    manual re-authentication of a client  6-27
    periodic re-authentication  6-26
    quiet period  6-27
    RADIUS server  6-25
    RADIUS server parameters on the switch  6-24
    restricted VLAN  6-32
    switch-to-client frame-retransmission number  6-29
    switch-to-client retransmission time  6-28
  default configuration  6-19
  described  6-1
  device roles  6-2
  displaying statistics  6-42
  EAPOL-start frame  6-5
  EAP-request/identity frame  6-5
  EAP-response/identity frame  6-5
  encapsulation  6-3
  guest VLAN
    configuration guidelines  6-13, 6-14
    described  6-12
    host mode  6-8
    inaccessible authentication bypass
      configuring  6-33
      described  6-14
      guidelines  6-22
    initiation and message exchange  6-5
    magic packet  6-16
    method lists  6-23
    multiple-hosts mode, described  6-8
port-based authentication (continued)

per-user ACLs
- AAA authorization 6-23
- configuration tasks 6-12
- described 6-11
- RADIUS server attributes 6-11

ports
- authorization state and dot1x port-control command 6-7
- authorized and unauthorized 6-7
- critical 6-14
- voice VLAN 6-15

port security
- and voice VLAN 6-16
- described 6-16
- interactions 6-16
- multiple-hosts mode 6-8

resetting to default values 6-42

statistics, displaying 6-42

switch
- as proxy 6-3
- RADIUS client 6-3

upgrading from a previous release 6-23

VLAN assignment
- AAA authorization 6-23
- characteristics 6-10
- configuration tasks 6-11
- described 6-10
- voice VLAN
- described 6-15
- PVID 6-15
- VVID 6-15

wake-on-LAN, described 6-16

port blocking 1-3, 18-6

port-channel
See EtherChannel

Port Fast
- described 14-2
- enabling 14-10
- mode, spanning tree 9-27
- support for 1-6

port membership modes, VLAN 9-3

port priority
- MSTP 13-19
- STP 12-16

ports
- access 7-2
- blocking 18-6
- dynamic access 9-3
- protected 18-5
- secure 18-7
- static-access 9-3, 9-10
- switch 7-2
- trunks 9-3, 9-14
- VLAN assignments 9-10

port security
- aging 18-16
- and QoS trusted boundary 27-37
- configuring 18-11
- default configuration 18-10
- described 18-7
- displaying 18-17
- on trunk ports 18-13
- sticky learning 18-8
- violations 18-9
- with other features 18-10

port-shutdown response, VMPS 9-26

preemption
- default configuration 15-5

preemption delay
- default configuration 15-5

preferential treatment of traffic
See QoS

preventing unauthorized access 5-1

primary links 15-2
priority
  overriding CoS 11-6
  trusting CoS 11-6
private VLAN edge ports
  See protected ports
privileged EXEC mode 2-2
privilege levels
  changing the default for lines 5-9
  exiting 5-9
  logging into 5-9
  overview 5-2, 5-7
  setting a command with 5-8
protected ports 1-7, 18-5
pruning, VTP
  disabling
    in VTP domain 10-14
    on a port 9-21
  enabling
    in VTP domain 10-14
    on a port 9-20
  examples 10-5
  overview 10-4
pruning-eligible list
  changing 9-20
  for VTP pruning 10-4
  VLANs 10-14
PVST+
  described 12-9
IEEE 802.1Q trunking interoperability 12-10
instance supported 12-9
Q
QoS
  and MQC commands 27-1
auto-QoS
  categorizing traffic 27-21
  configuration and defaults display 27-29
  configuration guidelines 27-25
  described 27-20
  disabling 27-26
  displaying generated commands 27-26
  displaying the initial configuration 27-29
  effects on running configuration 27-25
  egress queue defaults 27-21
  enabling for VoIP 27-26
  example configuration 27-27
  ingress queue defaults 27-21
  list of generated commands 27-22
  basic model 27-4
classification
  class maps, described 27-7
  defined 27-4
  DSCP transparency, described 27-39
  flowchart 27-6
  forwarding treatment 27-3
  in frames and packets 27-3
  IP ACLs, described 27-5, 27-7
  MAC ACLs, described 27-5, 27-7
  options for IP traffic 27-5
  options for non-IP traffic 27-5
  policy maps, described 27-7
  trust DSCP, described 27-5
  trusted CoS, described 27-5
  trust IP precedence, described 27-5
  class maps
    configuring 27-45
    displaying 27-75
QoS (continued)

configuration guidelines
  auto-QoS 27-25
  standard QoS 27-32
configuring
  aggregate policers 27-55
  auto-QoS 27-20
  default port CoS value 27-37
DSCP maps 27-57
DSCP transparency 27-39
DSCP trust states bordering another domain 27-39
egress queue characteristics 27-67
ingress queue characteristics 27-63
IP extended ACLs 27-43
IP standard ACLs 27-42
MAC ACLs 27-44
  policy maps, hierarchical 27-50
  policy maps on physical ports 27-47
  port trust states within the domain 27-35
  trusted boundary 27-37
default auto configuration 27-21
default standard configuration 27-30
displaying statistics 27-75
DSCP transparency 27-39
egress queues
  allocating buffer space 27-68
  buffer allocation scheme, described 27-18
  configuring shaped weights for SRR 27-72
  configuring shared weights for SRR 27-73
  described 27-4
  displaying the threshold map 27-71
  flowchart 27-17
  mapping DSCP or CoS values 27-70
  scheduling, described 27-4
  setting WTD thresholds 27-68
  WTD, described 27-19
  enabling globally 27-34
QoS (continued)

flowcharts
  classification 27-6
  egress queueing and scheduling 27-17
  ingress queueing and scheduling 27-15
  policing and marking 27-10
  implicit deny 27-7
ingress queues
  allocating bandwidth 27-65
  allocating buffer space 27-65
  buffer and bandwidth allocation, described 27-16
  configuring shared weights for SRR 27-65
  configuring the priority queue 27-66
  described 27-4
  displaying the threshold map 27-64
  flowchart 27-15
  mapping DSCP or CoS values 27-64
  priority queue, described 27-16
  scheduling, described 27-4
  setting WTD thresholds 27-64
  WTD, described 27-16
IP phones
  automatic classification and queueing 27-20
  detection and trusted settings 27-20, 27-37
limiting bandwidth on egress interface 27-74
mapping tables
  CoS-to-DSCP 27-58
  displaying 27-75
  DSCP-to-CoS 27-61
  DSCP-to-DSCP-mutation 27-62
  IP-precedence-to-DSCP 27-59
  policed-DSCP 27-60
  types of 27-12
  marked-down actions 27-49, 27-53
  marking, described 27-4, 27-8
overview 27-1
packet modification 27-19
QoS (continued)

policers
- described 27-8
- displaying 27-75
- number of 27-33
- types of 27-9

policies, attaching to an interface 27-8

policing
- described 27-4, 27-8
- token bucket algorithm 27-9

policy maps
- characteristics of 27-47
- displaying 27-76
- hierarchical 27-8
- hierarchical on SVIs 27-50
- nonhierarchical on physical ports 27-47

QoS label, defined 27-4

queues
- configuring egress characteristics 27-67
- configuring ingress characteristics 27-63
- high priority (expedite) 27-19, 27-74
- location of 27-13
- SRR, described 27-14
- WTD, described 27-13

rewrites 27-19

support for 1-8

trust states
- bordering another domain 27-39
- described 27-5
- trusted device 27-37
- within the domain 27-35

quality of service

See QoS

queries, IGMP 17-4

query solicitation, IGMP 17-12

R

RADIUS

attributes
- vendor-proprietary 5-31
- vendor-specific 5-29

configuring
- accounting 5-28
- authentication 5-23
- authorization 5-27
- communication, global 5-21, 5-29
- communication, per-server 5-20, 5-21
- multiple UDP ports 5-20
- default configuration 5-20
- defining AAA server groups 5-25
- displaying the configuration 5-31
- identifying the server 5-20
- limiting the services to the user 5-27
- method list, defined 5-19
- operation of 5-19
- overview 5-18
- suggested network environments 5-18
- support for 1-7
- tracking services accessed by user 5-28

range
- macro 7-7
- of interfaces 7-6

rapid convergence 13-10

rapid per-VLAN spanning-tree plus
- See rapid PVST+

rapid PVST+
- described 12-9
- IEEE 802.1Q trunking interoperability 12-10
- instances supported 12-9

Rapid Spanning Tree Protocol
- See RSTP
RCP
configuration files
  downloading  B-18
  overview  B-17
  preparing the server  B-17
  uploading  B-19
image files
  deleting old image  B-33
  downloading  B-31
  preparing the server  B-30
  uploading  B-33
reconfirmation interval, VMPS, changing  9-29
reconfirming dynamic VLAN membership  9-29
recovery procedures  29-1
redundancy
  EtherChannel  28-2
  STP
    backbone  12-8
    path cost  9-24
    port priority  9-22
redundant links and UplinkFast  14-13
reloading software  3-16
Remote Authentication Dial-In User Service
  See RADIUS
Remote Copy Protocol
  See RCP
Remote Network Monitoring
  See RMON
Remote SPAN
  See RSPAN
remote SPAN  22-2
report suppression, IGMP
  described  17-6
  disabling  17-15
recovery requirements
  cluster  xxx
  device manager  xxx
  Network Assistant  xxx
resequencing ACL entries  26-12
resetting a UDLD-shutdown interface  21-6
restricted VLAN
  configuring  6-32
  described  6-13
  using with IEEE 802.1x  6-13
restricting access
  NTP services  4-8
  overview  5-1
  passwords and privilege levels  5-2
  RADIUS  5-17
  TACACS+  5-10
retry count, VMPS, changing  9-29
RFC
  1112, IP multicast and IGMP  17-2
  1157, SNMPv1  25-2
  1305, NTP  4-2
  1757, RMON  23-2
  1901, SNMPv2C  25-2
  1902 to 1907, SNMPv2  25-2
  2236, IP multicast and IGMP  17-2
  2273-2275, SNMPv3  25-2
RMON
  default configuration  23-3
  displaying status  23-6
  enabling alarms and events  23-3
  groups supported  23-2
  overview  23-1
  statistics
    collecting group Ethernet  23-5
    collecting group history  23-5
  support for  1-9
root guard
  described  14-8
  enabling  14-15
  support for  1-6
root switch
  MSTP  13-17
  STP  12-14
RSPAN
  characteristics  22-7
  configuration guidelines  22-15
  default configuration  22-9
  defined  22-2
  destination ports  22-6
  displaying status  22-23
  interaction with other features  22-8
  monitored ports  22-5
  monitoring ports  22-6
  overview  1-9, 22-1
  received traffic  22-4
  sessions
    creating  22-16
    defined  22-3
    limiting source traffic to specific VLANs  22-22
    specifying monitored ports  22-16
    with ingress traffic enabled  22-20
  source ports  22-5
  transmitted traffic  22-5
  VLAN-based  22-6

RSTP
  active topology  13-9
  BPDU
    format  13-12
    processing  13-13
  designated port, defined  13-9
  designated switch, defined  13-9
  interoperability with IEEE 802.1D
    described  13-8
    restarting migration process  13-25
  topology changes  13-13
  overview  13-8
  port roles
    described  13-9
    synchronized  13-11
    proposal-agreement handshake process  13-10

RSTP (continued)
  rapid convergence
    described  13-10
  edge ports and Port Fast  13-10
  point-to-point links  13-10, 13-24
  root ports  13-10
  root port, defined  13-9
  See also MSTP
  running configuration, saving  3-11

S
  scheduled reloads  3-16
  secure HTTP client
    configuring  5-47
    displaying  5-48
  secure HTTP server
    configuring  5-46
    displaying  5-48
  secure MAC addresses
    deleting  18-15
    maximum number of  18-9
    types of  18-8
  secure ports
    configuring  18-7
  secure remote connections  5-38
  Secure Shell
    See SSH
  Secure Socket Layer
    See SSL
  security, port  18-7
  security features  1-7
  sequence numbers in log messages  24-7
  server mode, VTP  10-3
  service-provider network, MSTP and RSTP  13-1
  set-request operation  25-5
  setup program
    failed command switch replacement  29-10
    replacing failed command switch  29-8
severity levels, defining in system messages  24-8

SFPs
  monitoring status of  7-16, 28-12
  security and identification  29-12
  status, displaying  29-12

shaped round robin
  See SRR

show access-lists hw-summary command  26-18
show and more command output, filtering  2-10
show cdp traffic command  19-5
show configuration command  7-14
show forward command  29-20
show interfaces command  7-11, 7-14
show lldp traffic command  20-7
show platform forward command  29-20
show running-config command
  displaying ACLs  26-17, 26-24, 26-26
  interface description in  7-14
shutdown command on interfaces  7-17

Simple Network Management Protocol
  See SNMP

Smartports macros
  applying Cisco-default macros  8-6
  applying global parameter values  8-5, 8-6
  applying macros  8-5
  applying parameter values  8-5, 8-7
  configuration guidelines  8-3
  creating  8-4
  default configuration  8-2
  defined  8-1
  displaying  8-8
  tracing  8-3
  website  8-2

SNAP  19-1

SNMP
  accessing MIB variables with  25-4
  agent
    described  25-4
    disabling  25-8
  authentication level  25-11
  community strings
    configuring  25-8
    for cluster switches  25-4
    overview  25-4
  configuration examples  25-16
  default configuration  25-7
  engine ID  25-7
  groups  25-7, 25-10
  host  25-7
  ifIndex values  25-6
  in-band management  1-5
  informs
    and trap keyword  25-12
    described  25-5
    differences from traps  25-5
    disabling  25-15
    enabling  25-15
  limiting access by TFTP servers  25-16
  limiting system log messages to NMS  24-9
  manager functions  1-4, 25-3
  MIBs
    location of  A-3
    supported  A-1
    notifications  25-5
    overview  25-1, 25-4
    security levels  25-3
    status, displaying  25-17
    system contact and location  25-15
    trap manager, configuring  25-14
    traps
      described  25-3, 25-5
      differences from informs  25-5
      disabling  25-15
      enabling  25-12
      enabling MAC address notification  4-22
      overview  25-1, 25-5
      types of  25-12
SNMP (continued)
  users 25-7, 25-10
  versions supported 25-2
SNMPv1 25-2
SNMPv2C 25-2
SNMPv3 25-2
snooping, IGMP 17-1
software images
  location in flash B-21
  recovery procedures 29-2
  scheduling reloads 3-17
  tar file format, described B-21
See also downloading and uploading
source addresses, in IPv4 ACLs 26-9
source-and-destination-IP address based forwarding, EtherChannel 28-7
source-and-destination MAC address forwarding, EtherChannel 28-6
source-IP address based forwarding, EtherChannel 28-7
source-MAC address forwarding, EtherChannel 28-6
SPAN
  configuration guidelines 22-10
  default configuration 22-9
  destination ports 22-6
  displaying status 22-23
  interaction with other features 22-8
  monitored ports 22-5
  monitoring ports 22-6
  overview 1-9, 22-1
  ports, restrictions 18-11
  received traffic 22-4
  sessions
    configuring ingress forwarding 22-14, 22-21
    creating 22-10
    defined 22-3
    limiting source traffic to specific VLANs 22-14
    removing destination (monitoring) ports 22-12
    specifying monitored ports 22-10
    with ingress traffic enabled 22-13
  source ports 22-5
  transmitted traffic 22-5
  VLAN-based 22-6
spanning tree and native VLANs 9-17
Spanning Tree Protocol
  See STP
SPAN traffic 22-4
SRR
  configuring
    shaped weights on egress queues 27-72
    shared weights on egress queues 27-73
    shared weights on ingress queues 27-65
  described 27-14
  shaped mode 27-14
  shared mode 27-14
  support for 1-8, 1-9
SSH
  configuring
    cryptographic software image 5-37
    described 1-5, 5-38
    encryption methods 5-38
    user authentication methods, supported 5-38
SSL
  configuration guidelines 5-45
  configuring a secure HTTP client 5-47
  configuring a secure HTTP server 5-46
  described 5-42
  monitoring 5-48
  standby links 15-2
startup configuration
  booting
    manually 3-13
    specific image 3-14
  clearing B-20
  configuration file
    automatically downloading 3-13
    specifying the filename 3-13
    default boot configuration 3-12
static access ports
  assigning to VLAN 9-10
defined 7-2, 9-3
static addresses
  See addresses
static MAC addressing 1-7
static VLAN membership 9-2
statistics
  802.1x 6-42
  CDP 19-5
  interface 7-16
  LLDP 20-7
  LLDP-MED 20-7
  QoS ingress and egress 27-75
  RMON group Ethernet 23-5
  RMON group history 23-5
  SNMP input and output 25-17
  VTP 10-16
sticky learning 18-8
storm control
  configuring 18-3
described 18-1
  disabling 18-5
  displaying 18-17
  support for 1-3
  thresholds 18-1
STP
  accelerating root port selection 14-4
BackboneFast
  described 14-5
  disabling 14-14
  enabling 14-13
BPDU filtering
  described 14-3
  disabling 14-12
  enabling 14-12
STP (continued)
BPDU guard
  described 14-2
  disabling 14-12
  enabling 14-11
BPDU message exchange 12-3
configuration guidelines 12-12, 14-10
configuring
  forward-delay time 12-21
  hello time 12-20
  maximum aging time 12-21
  path cost 12-18
  port priority 12-16
  root switch 12-14
  secondary root switch 12-16
  spanning-tree mode 12-13
  switch priority 12-19
  transmit hold-count 12-22
  counters, clearing 12-22
default configuration 12-11
default optional feature configuration 14-9
designated port, defined 12-3
designated switch, defined 12-3
detecting indirect link failures 14-5
disabling 12-14
displaying status 12-22
EtherChannel guard
  described 14-7
disabling 14-14
  enabling 14-14
extended system ID
effects on root switch 12-14
effects on the secondary root switch 12-16
  overview 12-4
  unexpected behavior 12-14
features supported 1-5
IEEE 802.1D and bridge ID 12-4
IEEE 802.1D and multicast addresses 12-8
IEEE 802.1t and VLAN identifier 12-4
STP (continued)

inferior BPDU  12-3
instances supported  12-9
interface state, blocking to forwarding  14-2
interface states
  blocking  12-6
  disabled  12-7
  forwarding  12-5, 12-6
  learning  12-6
  listening  12-6
  overview  12-4
interoperability and compatibility among modes  12-10
limitations with IEEE 802.1Q trunks  12-10
load sharing
  overview  9-22
  using path costs  9-24
  using port priorities  9-22
loop guard
  described  14-9
  enabling  14-15
modes supported  12-9
multicast addresses, effect of  12-8
optional features supported  1-6
overview  12-2
path costs  9-24
Port Fast
  described  14-2
  enabling  14-10
port priorities  9-23
preventing root switch selection  14-8
protocols supported  12-9
redundant connectivity  12-8
root guard
  described  14-8
  enabling  14-15
root port, defined  12-3

STP (continued)

root switch
  configuring  12-14
  effects of extended system ID  12-4, 12-14
  election  12-3
  unexpected behavior  12-14
shutdown Port Fast-enabled port  14-2
status, displaying  12-22
superior BPDU  12-3
timers, described  12-20
UplinkFast
  described  14-3
  enabling  14-13
stratum, NTP  4-2
success response, VMPS  9-26
summer time  4-13
SunNet Manager  1-4
switch clustering technology
  See also clusters, switch
switch console port  1-5
Switched Port Analyzer
  See SPAN
switched ports  7-2
switchport block multicast command  18-7
switchport block unicast command  18-7
switchport protected command  18-6
switch priority
  MSTP  13-21
  STP  12-19
switch software features  1-1
syslog
  See system message logging
system clock
  configuring
    daylight saving time  4-13
    manually  4-11
    summer time  4-13
    time zones  4-12
displaying the time and date  4-12
system clock (continued)
  overview 4-1
  See also NTP
system message logging
  default configuration 24-3
  defining error message severity levels 24-8
  disabling 24-3
  displaying the configuration 24-12
  enabling 24-4
  facility keywords, described 24-11
  level keywords, described 24-9
  limiting messages 24-9
  message format 24-2
  overview 24-1
  sequence numbers, enabling and disabling 24-7
  setting the display destination device 24-4
  synchronizing log messages 24-5
  syslog facility 1-9
  time stamps, enabling and disabling 24-7
UNIX syslog servers
  configuring the daemon 24-10
  configuring the logging facility 24-11
  facilities supported 24-11
system name
  default configuration 4-15
  default setting 4-15
  manual configuration 4-15
  See also DNS
system prompt, default setting 4-14, 4-15

T

TACACS+
  accounting, defined 5-11
  authentication, defined 5-11
  authorization, defined 5-11
  configuring
    accounting 5-17
    authentication key 5-13
    authorization 5-16
    login authentication 5-14
    default configuration 5-13
    displaying the configuration 5-17
    identifying the server 5-13
    limiting the services to the user 5-16
    operation of 5-12
    overview 5-10
    support for 1-7
  tracking services accessed by user 5-17
tar files
  creating B-6
  displaying the contents of B-6
  extracting B-8
  image file format B-21
TDR 1-9
Telnet
  accessing management interfaces 2-10
  number of connections 1-5
  setting a password 5-6
  temporary self-signed certificate 5-43
  Terminal Access Controller Access Control System Plus
  See TACACS+
terminal lines, setting a password 5-6
TFTP
configuration files
downloading B-12
preparing the server B-11
uploading B-12
configuration files in base directory 3-6
configuring for autoconfiguration 3-6
image files
deleting B-24
downloading B-23
preparing the server B-23
uploading B-25
limiting access by servers 25-16
TFTP server 1-4
threshold, traffic level 18-2
time
See NTP and system clock
Time Domain Reflector
See TDR
time-range command 26-14
time ranges in ACLs 26-14
time stamps in log messages 24-7
time zones 4-12
tlvs
defined 20-1
LLDP 20-1
LLDP-MED 20-2
Token Ring VLANs
support for 9-5
VTP support 10-4
ToS 1-8
traceroute, Layer 2 (continued)
multiple devices on a port 29-15
unicast traffic 29-14
usage guidelines 29-15
traceroute command 29-17
See also IP traceroute
traffic
blocking flooded 18-7
fragmented 26-4
unfragmented 26-4
traffic policing 1-8
traffic suppression 18-1
transmit hold-count
see STP
transparent mode, VTP 10-3, 10-12
trap-door mechanism 3-2
traps
configuring MAC address notification 4-22
configuring managers 25-12
defined 25-3
enabling 4-22, 25-12
notification types 25-12
overview 25-1, 25-5
troubleshooting
connectivity problems 29-13, 29-14, 29-16
detecting unidirectional links 21-1
displaying crash information 29-22
setting packet forwarding 29-20
SFP security and identification 29-12
show forward command 29-20
with CiscoWorks 25-4
with debug commands 29-18
with ping 29-13
with system message logging 24-1
with traceroute 29-16
trunking encapsulation 1-6
trunk ports
  configuring 9-18
  defined 7-3, 9-3
  encapsulation 9-18, 9-23, 9-24
trunks
  allowed-VLAN list 9-19
  configuring 9-18, 9-23, 9-24
  ISL 9-14
load sharing
  setting STP path costs 9-24
  using STP port priorities 9-22, 9-23
native VLAN for untagged traffic 9-21
parallel 9-24
pruning-eligible list 9-20
to non-DTP device 9-15
trusted boundary for QoS 27-37
trusted port states
  between QoS domains 27-39
  classification options 27-5
  ensuring port security for IP phones 27-37
  support for 1-8
  within a QoS domain 27-35
trustpoints, CA 5-42
twisted-pair Ethernet, detecting unidirectional links 21-1
type of service
  See ToS
UDLD (continued)
  enabling
    globally 21-5
    per interface 21-5
  link-detection mechanism 21-1
  neighbor database 21-2
  overview 21-1
  resetting an interface 21-6
  status, displaying 21-6
  support for 1-5
unauthorized ports with IEEE 802.1x 6-7
unicast MAC address filtering 1-4
  and adding static addresses 4-25
  and broadcast MAC addresses 4-25
  and CPU packets 4-25
  and multicast addresses 4-25
  and router MAC addresses 4-25
  configuration guidelines 4-25
  described 4-25
unicast storm 18-1
unicast storm control command 18-4
unicast traffic, blocking 18-7
UniDirectional Link Detection protocol
  See UDLD
UNIX syslog servers
  daemon configuration 24-10
  facilities supported 24-11
  message logging configuration 24-11
unrecognized Type-Length-Value (TLV) support 10-4
upgrading information
  See release notes
upgrading software images
  See downloading
UplinkFast
  described 14-3
  disabling 14-13
  enabling 14-13
  support for 1-5
### Index

**uploading**
- configuration files
  - preparing B-11, B-14, B-17
  - reasons for B-9
  - using FTP B-15
  - using RCP B-19
  - using TFTP B-12
**image files**
  - preparing B-23, B-26, B-30
  - reasons for B-21
  - using FTP B-28
  - using RCP B-33
  - using TFTP B-25
**user EXEC mode** 2-2
**username-based authentication** 5-6

### V

**version-dependent transparent mode** 10-4
**vlan.dat file** 9-4
**VLAN 1, disabling on a trunk port** 9-19
**VLAN 1 minimization** 9-19
**VLAN ACLs**
  - See VLAN maps
**vlan-assignment response, VMPS** 9-25
**VLAN configuration**
  - at bootup 9-7
  - saving 9-7
**VLAN configuration mode** 2-2, 9-6
**VLAN database**
  - and startup configuration file 9-7
  - and VTP 10-1
  - VLAN configuration saved in 9-7
  - VLANs saved in 9-4
**vlan database command** 9-6
**VLAN filtering and SPAN** 22-6
**vlan global configuration command** 9-6
**VLAN ID, discovering** 4-26
**VLAN load balancing on flex links** 15-2
  - configuration guidelines 15-5
**VLAN management domain** 10-2
**VLAN Management Policy Server**
  - See VMPS
**VLAN map entries, order of** 26-23
**VLAN maps**
  - applying 26-26
  - common uses for 26-27
  - configuration guidelines 26-23
  - configuring 26-22
  - creating 26-24
  - defined 26-2, 26-3
  - denying access to a server example 26-28
  - denying and permitting packets 26-24
  - displaying 26-29
  - examples of ACLs and VLAN maps 26-24
  - removing 26-26
  - support for 1-7
  - wiring closet configuration example 26-27
**VLAN membership**
  - confirming 9-29
  - modes 9-3
**VLAN Query Protocol**
  - See VQP
**VLANs**
  - adding 9-8
  - adding to VLAN database 9-8
  - aging dynamic addresses 12-9
  - allowed on trunk 9-19
  - and spanning-tree instances 9-2, 9-6, 9-12
  - configuration guidelines, extended-range VLANs 9-12
  - configuration guidelines, normal-range VLANs 9-5
  - configuration options 9-6
  - configuring 9-1
  - configuring IDs 1006 to 4094 9-12
  - creating in config-vlan mode 9-8
  - creating in VLAN configuration mode 9-9
  - default configuration 9-7
VLANs (continued)
  deleting 9-10
  described 7-1, 9-1
  displaying 9-14
  extended-range 9-1, 9-11
  features 1-6
  illustrated 9-2
  limiting source traffic with RSPAN 22-22
  limiting source traffic with SPAN 22-14
  modifying 9-8
  multicast 17-17
  native, configuring 9-21
  normal-range 9-1, 9-4
  number supported 1-6
  parameters 9-4
  port membership modes 9-3
  static-access ports 9-10
  STP and IEEE 802.1Q trunks 12-10
  supported 9-2
  Token Ring 9-5
  traffic between 9-2
  VTP modes 10-3
VLAN Trunking Protocol
  See VTP
VLAN trunks 9-14
VMPS (continued)
  reconfirming membership 9-29
  retry count, changing 9-29
voice-over-IP 11-1
voice VLAN
  Cisco 7960 phone, port connections 11-1
  configuration guidelines 11-3
  configuring IP phones for data traffic
    override CoS of incoming frame 11-6
    trust CoS priority of incoming frame 11-6
  configuring ports for voice traffic in
    802.1p priority tagged frames 11-5
    802.1Q frames 11-5
  connecting to an IP phone 11-4
  default configuration 11-3
  described 11-1
  displaying 11-6
  IP phone data traffic, described 11-2
  IP phone voice traffic, described 11-2
VQP 1-6, 9-25
VTP
  adding a client to a domain 10-14
  advertisements 9-17, 10-3
  and extended-range VLANs 10-1
  and normal-range VLANs 10-1
  client mode, configuring 10-11
  configuration
    global configuration mode 10-7
    guidelines 10-8
    privileged EXEC mode 10-7
    requirements 10-9
    saving 10-7
    VLAN configuration mode 10-7
    configuration mode options 10-7
    configuration requirements 10-9
    configuration revision number
      guideline 10-14
      resetting 10-15
VTP (continued)
configuring
  client mode 10-11
  server mode 10-9
  transparent mode 10-12
consistency checks 10-4
default configuration described 10-1
disabling 10-12
domain names 10-8
domains 10-2
modes
  client 10-3, 10-11
  server 10-3, 10-9
  transitions 10-3
  transparent 10-3, 10-12
monitoring 10-16
passwords 10-8
pruning
  disabling 10-14
  enabling 10-14
  examples 10-5
  overview 10-4
  support for 1-6
pruning-eligible list, changing 9-20
server mode, configuring 10-9
statistics 10-16
support for 1-6
Token Ring support 10-4
transparent mode, configuring 10-12
using 10-1
version, guidelines 10-8
Version 1 10-4
Version 2
  configuration guidelines 10-8
  disabling 10-13
  enabling 10-13
  overview 10-4

W
  web authentication
    configuring 6-38 to 6-41
    described 6-18
    fallback for IEEE 802.1x 6-40
weighted tail drop
  See WTD
wizards 1-2
WTD
  described 27-13
  setting thresholds
    egress queue-sets 27-68
    ingress queues 27-64
  support for 1-8, 1-9

X
  Xmodem protocol 29-2