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Catalyst 4500 Series Switch Cisco IOS Software Configuration Guide

Release 12.2(20)EW

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Preface

This preface describes who should read this document, how it is organized, and its conventions. The book also tells you how to obtain Cisco documents as well as how to obtain technical assistance.

Audience

This guide is for experienced network administrators who are responsible for configuring and maintaining Catalyst 4500 series switches.

Organization

This guide is organized into the following chapters:

Chapter	Title	Description
Chapter 1	Product Overview	Presents an overview of the Cisco IOS software for the Catalyst 4500 series switches
Chapter 2	Command-Line Interfaces	Describes how to use the CLI
Chapter 3	Configuring the Switch for the First Time	Describes how to perform a baseline configuration of the switch
Chapter 4	Configuring Interfaces	Describes how to configure non-layer-specific features on Fast Ethernet and Gigabit Ethernet interfaces
Chapter 5	Checking Port Status and Connectivity	Describes how to check module and interface status
Chapter 6	Configuring Supervisor Engine Redundancy on the Catalyst 4507R and 4510R Switches	Describes how to configure RPR on the Catalyst 4507R and Catalyst 4510R switches.
Chapter 7	Understanding and Configuring VLANs	Describes how to set up and modify VLANs
Chapter 8	Configuring Dynamic VLAN Membership	Describes how to configure dynamic VLAN membership

Chapter	Title	Description
Chapter 9	Configuring Layer 2 Ethernet Interfaces	Describes how to configure interfaces to support Layer 2 features, including VLAN trunks
Chapter 10	Configuring SmartPort Macros	Describes how to configure SmartPort macros
Chapter 11	Understanding and Configuring STP	Describes how to configure the Spanning Tree Protocol (STP) and explains how spanning tree works
Chapter 12	Configuring STP Features	Describes how to configure the spanning-tree PortFast, UplinkFast, BackboneFast, and other STP features
Chapter 13	Understanding and Configuring Multiple Spanning Trees	Describes how to configure the Multiple Spanning Tree (MST) protocol and explains how it works
Chapter 14	Understanding and Configuring EtherChannel	Describes how to configure Layer 2 and Layer 3 EtherChannel port bundles
Chapter 15	Configuring IGMP Snooping and Filtering	Describes how to configure Internet Group Management Protocol (IGMP) snooping
Chapter 16	Configuring 802.1Q and Layer 2 Protocol Tunneling	Describes how to configure 802.1Q and Layer 2 protocol Tunneling
Chapter 17	Understanding and Configuring CDP	Describes how to configure the Cisco Discovery Protocol (CDP)
Chapter 18	Configuring UDLD	Describes how to configure the UniDirectional Link Detection (UDLD) protocol
Chapter 19	Configuring Unidirectional Ethernet	Describes how to configure unidirectional Ethernet
Chapter 20	Configuring Layer 3 Interfaces	Describes how to configure interfaces to support Layer 3 features
Chapter 21	Configuring Cisco Express Forwarding	Describes how to configure Cisco Express Forwarding (CEF) for IP unicast traffic
Chapter 22	Understanding and Configuring IP Multicast	Describes how to configure IP Multicast Multilayer Switching (MMLS)
Chapter 23	Configuring Policy-Based Routing	Describes how to configure policy-based routing
Chapter 24	Understanding and Configuring VTP	Describes how to configure the VLAN Trunking Protocol
Chapter 25	Configuring VRF-lite	Describes how to configure multiple VPN routing/forwarding (multi-VRF) instances in customer edge (CE) devices
Chapter 26	Configuring QoS	Describes how to configure quality of service (QoS)
Chapter 27	Configuring Voice Interfaces	Describes how to configure multi-VLAN access ports for use with Cisco IP phones
Chapter 28	Understanding and Configuring 802.1X Port-Based Authentication	Describes how to configure 802.1x port-based authentication
Chapter 29	Configuring Port Security	Describes how to configure the port security feature

Chapter	Title	Description
Chapter 30	Configuring DHCP Snooping and IP Source Guard	Describes how to configure DHCP snooping and display DHCP snooping information
Chapter 31	Understanding and Configuring Dynamic ARP Inspection	Describes how to configure Dynamic ARP Inspection
Chapter 32	Configuring Network Security with ACLs	Describes how to configure ACLS, VACLs, and MACLs
Chapter 33	Configuring Private VLANs	Describes how to set up and modify private VLANs
Chapter 34	Port Unicast and Multicast Flood Blocking	Describes how to configure unicast flood blocking on the Catalyst 4000 family switches
Chapter 35	Configuring Port-Based Traffic Control	Describes how to configure storm control suppression on the Catalyst 4500 series switches
Chapter 36	Environmental Monitoring and Power Management	Describes how to configure environmental monitoring, power redundancy, and inline power features
Chapter 37	Configuring SPAN and RSPAN	Describes how to configure the Switched Port Analyzer (SPAN)
Chapter 38	Configuring NetFlow Statistics Collection	Describes how to configure NetFlow statistics gathering
Appendix A	Acronyms	Defines acronyms used in this book

Related Documentation

The following publications are available for the Catalyst 4000 family and Catalyst 4500 series switches:

- *Catalyst 4000 Series Switch Cisco IOS Installation Guide*
- *Catalyst 4500 Series Switch Cisco IOS Installation Guide*
- *Catalyst 4500 Series Switch Cisco IOS Module Installation Guide*
- *Catalyst 4500 Series Switch Cisco IOS Command Reference*
- *Catalyst 4500 Series Switch Cisco IOS System Message Guide*
- Release Notes for the Catalyst 4500 Series
- Cisco IOS configuration guides and command references—Use these publications to help you configure Cisco IOS software features not described in the preceding publications:
  - *Configuration Fundamentals Configuration Guide*
  - *Configuration Fundamentals Command Reference*
  - *Interface Configuration Guide*
  - *Interface Command Reference*
  - *Network Protocols Configuration Guide*, Part 1, 2, and 3
  - *Network Protocols Command Reference*, Part 1, 2, and 3
  - *Security Configuration Guide*
  - *Security Command Reference*

  - *Switching Services Configuration Guide*
  - *Switching Services Command Reference*
  - *Voice, Video, and Fax Applications Configuration Guide*
  - *Voice, Video, and Fax Applications Command Reference*
  - *Cisco IOS IP Configuration Guide*
  - *Cisco IOS IP Command Reference*

  The Cisco IOS configuration guides and command references are at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm

- For information about MIBs, refer to http://www.cisco.com/public/sw-center/netmgmt/cmtk/mibs.shtml

Conventions

This document uses the following typographical conventions:

Convention	Description
boldface font	Commands, command options, and keywords are in **boldface**.
italic font	Command arguments for which you supply values are in *italics*.
[ ]	Command elements in square brackets are optional.
{ x | y | z }	Alternative keywords in command lines are grouped in braces and separated by vertical bars.
[x | y | z]	Optional alternative keywords are grouped in brackets and separated by vertical bars.
string	A nonquoted set of characters. Do not use quotation marks around the string because the string will include the quotation marks.
`screen` font	System displays are in `screen` font.
`boldface screen` font	Information you must enter verbatim is in **`boldface screen`** font.
`italic screen` font	Arguments for which you supply values are in *`italic screen`* font.
——→	This pointer highlights an important line of text in an example.
^	Represents the key labeled Control—for example, the key combination ^D in a screen display means hold down the Control key while you press the D key.
< >	Nonprinting characters such as passwords are in angle brackets.

Notes use the following conventions:

Note Means *reader take note*. Notes contain helpful suggestions or references to material not covered in the publication.

Cautions use the following conventions:

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

Commands in Task Tables

Commands listed in task tables show only the relevant information for completing the task and not all available options for the command. For a complete description of a command, refer to the command in the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Obtaining Documentation

Cisco documentation and additional literature are available on Cisco.com. Cisco also provides several ways to obtain technical assistance and other technical resources. These sections explain how to obtain technical information from Cisco Systems.

Cisco.com

You can access the most current Cisco documentation at this URL:

http://www.cisco.com/univercd/home/home.htm

You can access the Cisco website at this URL:

http://www.cisco.com

You can access international Cisco websites at this URL:

http://www.cisco.com/public/countries_languages.shtml

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You can find instructions for ordering documentation at this URL:

http://www.cisco.com/univercd/cc/td/doc/es_inpck/pdi.htm

You can order Cisco documentation in these ways:

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  http://www.cisco.com/en/US/partner/ordering/index.shtml

- Nonregistered Cisco.com users can order documentation through a local account representative by calling Cisco Systems Corporate Headquarters (California, USA) at 408 526-7208 or, elsewhere in North America, by calling 800 553-NETS (6387).

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We appreciate your comments.

Obtaining Technical Assistance

For all customers, partners, resellers, and distributors who hold valid Cisco service contracts, Cisco Technical Support provides 24-hour-a-day, award-winning technical assistance. The Cisco Technical Support Website on Cisco.com features extensive online support resources. In addition, Cisco Technical Assistance Center (TAC) engineers provide telephone support. If you do not hold a valid Cisco service contract, contact your reseller.

Cisco Technical Support Website

The Cisco Technical Support Website provides online documents and tools for troubleshooting and resolving technical issues with Cisco products and technologies. The website is available 24 hours a day, 365 days a year at this URL:

http://www.cisco.com/techsupport

Access to all tools on the Cisco Technical Support Website requires a Cisco.com user ID and password. If you have a valid service contract but do not have a user ID or password, you can register at this URL:

http://tools.cisco.com/RPF/register/register.do

Submitting a Service Request

Using the online TAC Service Request Tool is the fastest way to open S3 and S4 service requests. (S3 and S4 service requests are those in which your network is minimally impaired or for which you require product information.) After you describe your situation, the TAC Service Request Tool automatically provides recommended solutions. If your issue is not resolved using the recommended resources, your service request will be assigned to a Cisco TAC engineer. The TAC Service Request Tool is located at this URL:

http://www.cisco.com/techsupport/servicerequest

For S1 or S2 service requests or if you do not have Internet access, contact the Cisco TAC by telephone. (S1 or S2 service requests are those in which your production network is down or severely degraded.) Cisco TAC engineers are assigned immediately to S1 and S2 service requests to help keep your business operations running smoothly.

To open a service request by telephone, use one of the following numbers:

Asia-Pacific: +61 2 8446 7411 (Australia: 1 800 805 227)
EMEA: +32 2 704 55 55
USA: 1 800 553 2447

For a complete list of Cisco TAC contacts, go to this URL:

http://www.cisco.com/techsupport/contacts

Definitions of Service Request Severity

To ensure that all service requests are reported in a standard format, Cisco has established severity definitions.

Severity 1 (S1)—Your network is "down," or there is a critical impact to your business operations. You and Cisco will commit all necessary resources around the clock to resolve the situation.

Severity 2 (S2)—Operation of an existing network is severely degraded, or significant aspects of your business operation are negatively affected by inadequate performance of Cisco products. You and Cisco will commit full-time resources during normal business hours to resolve the situation.

Severity 3 (S3)—Operational performance of your network is impaired, but most business operations remain functional. You and Cisco will commit resources during normal business hours to restore service to satisfactory levels.

Severity 4 (S4)—You require information or assistance with Cisco product capabilities, installation, or configuration. There is little or no effect on your business operations.

Obtaining Additional Publications and Information

Information about Cisco products, technologies, and network solutions is available from various online and printed sources.

- Cisco Marketplace provides a variety of Cisco books, reference guides, and logo merchandise. Visit Cisco Marketplace, the company store, at this URL:

  http://www.cisco.com/go/marketplace/

- The Cisco *Product Catalog* describes the networking products offered by Cisco Systems, as well as ordering and customer support services. Access the Cisco Product Catalog at this URL:

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- *Cisco Press* publishes a wide range of general networking, training and certification titles. Both new and experienced users will benefit from these publications. For current Cisco Press titles and other information, go to Cisco Press at this URL:

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- *Packet* magazine is the Cisco Systems technical user magazine for maximizing Internet and networking investments. Each quarter, Packet delivers coverage of the latest industry trends, technology breakthroughs, and Cisco products and solutions, as well as network deployment and troubleshooting tips, configuration examples, customer case studies, certification and training information, and links to scores of in-depth online resources. You can access Packet magazine at this URL:

  http://www.cisco.com/packet

- *iQ Magazine* is the quarterly publication from Cisco Systems designed to help growing companies learn how they can use technology to increase revenue, streamline their business, and expand services. The publication identifies the challenges facing these companies and the technologies to help solve them, using real-world case studies and business strategies to help readers make sound technology investment decisions. You can access iQ Magazine at this URL:

  http://www.cisco.com/go/iqmagazine

- *Internet Protocol Journal* is a quarterly journal published by Cisco Systems for engineering professionals involved in designing, developing, and operating public and private internets and intranets. You can access the Internet Protocol Journal at this URL:

  http://www.cisco.com/ipj

- World-class networking training is available from Cisco. You can view current offerings at this URL:

  http://www.cisco.com/en/US/learning/index.html

Product Overview

This chapter provides an overview of Catalyst 4500 series switches and includes the following major sections:

Note For more information about the chassis, modules, and software features supported by the Catalyst 4500 series switch, refer to the *Release Notes for the Catalyst 4500 Series Switch, Cisco IOS Release 12.2(20)EW* at http://www.cisco.com/univercd/cc/td/doc/product/lan/cat4000/relnotes/

Layer 2 Software Features

The following subsections describe the key Layer 2 switching software features on the Catalyst 4500 series switch:

802.1Q and Layer 2 Protocol Tunneling

Dot1q tunneling is a 1q-in-1q technique that expands the VLAN space by retagging the tagged packets entering the service provider infrastructure. Dot1q tunneling allows service providers to assign a VLAN to each customer without losing the original customer VLAN IDs inside the tunnel. All data traffic entering the tunnel are encapsulated with the tunnel VLAN ID. Layer 2 Protocol Tunneling is similar technique for all Layer 2 control traffic. Dot1q tunneling and Layer 2 Protocol Tunneling are support on Supervisor Engine V only.

For information on configuring 802.1Q tunneling, see Chapter 16, "Configuring 802.1Q and Layer 2 Protocol Tunneling."

Storm Control

Broadcast suppression is used to prevent LANs from being disrupted by a broadcast storm on one or more switch ports. A LAN broadcast storm occurs when broadcast packets flood the LAN, creating excessive traffic and degrading network performance. Errors in the protocol-stack implementation or in the network configuration can cause a broadcast storm. Multicast and broadcast suppression measures how much broadcast traffic is passing through a port and compares the broadcast traffic with some configurable threshold value within a specific time interval. If the amount of broadcast traffic reaches the threshold during this interval, broadcast frames are dropped, and optionally the port is shut down.

For information on configuring broadcast suppression, see Chapter 35, "Configuring Port-Based Traffic Control."

CDP

The Cisco Discovery Protocol (CDP) is a device-discovery protocol that is both media- and protocol-independent. CDP is available on all Cisco products, including routers, switches, bridges, and access servers. Using CDP, a device can advertise its existence to other devices and receive information about other devices on the same LAN. CDP enables Cisco switches and routers to exchange information, such as their MAC addresses, IP addresses, and outgoing interfaces. CDP runs over the data-link layer only, allowing two systems that support different network-layer protocols to learn about each other. Each device configured for CDP sends periodic messages to a multicast address. Each device advertises at least one address at which it can receive Simple Network Management Protocol (SNMP) messages.

For information on configuring CDP, see Chapter 17, "Understanding and Configuring CDP."

DHCP Snooping

Dynamic Host Configuration Protocol (DHCP) snooping is a security feature that is a component of a DHCP server. DHCP snooping provides security by intercepting untrusted DHCP messages and by building and maintaining a DHCP snooping binding table. An untrusted message is a message that is received from outside the network or firewall that can cause traffic attacks within your network.

DHCP snooping acts like a firewall between untrusted hosts and DHCP servers. It also provides a way to differentiate between untrusted interfaces connected to the end-user and trusted interfaces connected to the DHCP server or another switch.

For DHCP server configuration information, refer to the chapter, "Configuring DHCP," in the *Cisco IOS IP and IP Routing Configuration Guide* at the following URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_c/ipcprt1/1cddhcp.htm

For information on configuring DHCP snooping, see Chapter 30, "Configuring DHCP Snooping and IP Source Guard."

EtherChannel Bundles

EtherChannel port bundles allow you to create high-bandwidth connections between two switches by grouping multiple ports into a single logical transmission path.

For information on configuring EtherChannel, see Chapter 14, "Understanding and Configuring EtherChannel."

IP Source Guard

Similar to DHCP snooping, this feature is enabled on an untrusted 12 port that is configured for DHCP snooping. Initially all IP traffic on the port is blocked except for the DHCP packets, which are captured by the DHCP snooping process. When a client receives a valid IP address from the DHCP server, a PVACL is installed on the port, which restricts the client IP traffic only to clients with assigned IP addresses; so any IP traffic with source IP addresses other than those assigned by the DHCP server will be filtered out. This filtering prevents a malicious host from attacking a network by hijacking neighbor host's IP address.

For information on configuring IP Source Guard, see Chapter 30, "Configuring DHCP Snooping and IP Source Guard."

Jumbo Frames

The jumbo frames feature allows the switch to forward packets as large as 9216 bytes (larger than the IEEE Ethernet MTU), rather than declare those frames "oversize" and discard them. This feature is typically used for large data transfers. The jumbo feature can be configured on a per-port basis on Layer 2 and Layer 3 interfaces and is supported only on non-blocking GB front ports.

For information on Jumbo Frames, see Chapter 4, "Configuring Interfaces."

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.

For information about Layer 2 Traceroute, see Chapter 5, "Checking Port Status and Connectivity."

MST

IEEE 802.1s Multiple Spanning Tree (MST) allows for multiple spanning tree instantiations within a single 802.1q or Inter-Switch Link (ISL) VLAN trunk. MST extends the IEEE 802.1w Rapid Spanning Tree (RST) algorithm to multiple spanning trees. This extension provides both rapid convergence and load balancing in a VLAN environment.

MST allows you to build multiple spanning trees over trunks. You can group and associate VLANs to spanning tree instances. Each instance can have a topology independent of other spanning tree instances. This new architecture provides multiple forwarding paths for data traffic and enables load balancing. Network fault tolerance is improved because a failure in one instance (forwarding path) does not affect other instances (forwarding paths).

For information on configuring MST, see Chapter 13, "Understanding and Configuring Multiple Spanning Trees."

PVRST+

Per-VLAN Rapid Spanning Tree (PVRST+) is the implementation of 802.1w on a per-VLAN basis. It is the same as PVST+ with respect to STP mode and runs RSTP protocol based on 802.1w.

For information on configuring PVRST+, see Chapter 11, "Understanding and Configuring STP."

Spanning Tree Protocol

The Spanning Tree Protocol (STP) allows you to create fault-tolerant internetworks that ensure an active, loop-free data path between all nodes in the network. STP uses an algorithm to calculate the best loop-free path throughout a switched network.

For information on configuring STP, see Chapter 11, "Understanding and Configuring STP."

The Catalyst 4500 series switch supports the following STP enhancements:

- Spanning tree PortFast—PortFast allows a port with a directly attached host to transition to the forwarding state directly, bypassing the listening and learning states.
- Spanning tree UplinkFast—UplinkFast provides fast convergence after a spanning-tree topology change and achieves load balancing between redundant links using uplink groups. Uplink groups provide an alternate path in case the currently forwarding link fails. UplinkFast is designed to decrease spanning-tree convergence time for switches that experience a direct link failure.
- Spanning tree BackboneFast—BackboneFast reduces the time needed for the spanning tree to converge after a topology change caused by an indirect link failure. BackboneFast decreases spanning-tree convergence time for any switch that experiences an indirect link failure.
- Spanning tree root guard—Root guard forces a port to become a designated port so that no switch on the other end of the link can become a root switch.

For information on the STP enhancements, see Chapter 12, "Configuring STP Features."

UDLD

The UniDirectional Link Detection (UDLD) protocol allows devices connected through fiber-optic or copper Ethernet cables to monitor the physical configuration of the cables and detect a unidirectional link.

For information about UDLD, see Chapter 18, "Configuring UDLD."

Unidirectional Ethernet

Unidirectional Ethernet uses only one strand of fiber for either transmitting or receiving one-way traffic for the Gigaport, instead of two strands of fiber for a full-duplex Gigaport Ethernet.

For information about Unidirectional Ethernet, see Chapter 19, "Configuring Unidirectional Ethernet."

VLANs

A VLAN configures switches and routers according to logical, rather than physical, topologies. Using VLANs, a network administrator can combine any collection of LAN segments within an internetwork into an autonomous user group, such that the segments appear as a single LAN in the network. VLANs logically segment the network into different broadcast domains so that packets are switched only between ports within the VLAN. Typically, a VLAN corresponds to a particular subnet, although not necessarily.

For more information about VLANs, see Chapter 7, "Understanding and Configuring VLANs."

The following VLAN-related features are also supported.

- VLAN Trunking Protocol (VTP)—VTP maintains VLAN naming consistency and connectivity between all devices in the VTP management domain. You can have redundancy in a domain by using multiple VTP servers, through which you can maintain and modify the global VLAN information. Only a few VTP servers are required in a large network.

  For more information about VTP, see Chapter 24, "Understanding and Configuring VTP."

- Private VLANs—Private VLANs are sets of ports that have the features of normal VLANs and also provide some Layer 2 isolation from other ports on the switch.

  For information about private VLANs, see Chapter 33, "Configuring Private VLANs."

- Private VLAN Trunk Ports—Private VLAN trunk ports allow a secondary port on a private VLAN to carry multiple secondary VLANs.

- Dynamic VLAN Membership—Dynamic VLAN Membership allows you to assign switch ports to VLANs dynamically, based on the source Media Access Control (MAC) address of the device connected to the port. When you move a host from a port on one switch in the network to a port on another switch in the network, that switch dynamically assigns the new port to the proper VLAN for that host.

For more information about Dynamic VLAN Membership, see Chapter 8, "Configuring Dynamic VLAN Membership."

Layer 3 Software Features

A Layer 3 switch is a high-performance switch that has been optimized for a campus LAN or intranet and that provides both wirespeed Ethernet routing and switching services. Layer 3 switching improves network performance with two software functions—route processing and intelligent network services.

Compared to conventional software-based switches, Layer 3 switches process more packets faster; they do so by using application-specific integrated circuit (ASIC) hardware instead of microprocessor-based engines.

The following subsections describe the key Layer 3 switching software features on the Catalyst 4500 series switch:

CEF

Cisco Express Forwarding (CEF) is an advanced Layer 3 IP-switching technology. CEF optimizes network performance and scalability in networks with large and dynamic traffic patterns, such as the Internet, and on networks that use intensive web-based applications, or interactive sessions. Although you can use CEF in any part of a network, it is designed for high-performance, highly resilient Layer 3 IP-backbone switching.

For information on configuring CEF, see Chapter 21, “Configuring Cisco Express Forwarding.”

HSRP

The Hot Standby Router Protocol (HSRP) provides high network availability by routing IP traffic from hosts on Ethernet networks without relying on the availability of any single Layer 3 switch. This feature is particularly useful for hosts that do not support a router discovery protocol and do not have the functionality to switch to a new router when their selected router reloads or loses power.

For information on configuring HSRP, refer to the following URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_c/ipcprt1/1cdip.htm

IP Routing Protocols

The following routing protocols are supported on the Catalyst 4500 series switch:

- RIP
- OSPF

- IS-IS
- IGRP
- EIGRP
- BGP

RIP

The Routing Information Protocol (RIP) is a distance-vector, intradomain routing protocol. RIP works well in small, homogeneous networks. In large, complex internetworks, it has many limitations, such as a maximum hop count of 15, lack of support for variable-length subnet masks (VLSMs), inefficient use of bandwidth, and slow convergence. (RIP II does support VLSMs.)

OSPF

The Open Shortest Path First (OSPF) protocol is a standards-based IP routing protocol designed to overcome the limitations of RIP. Because OSPF is a link-state routing protocol, it sends link-state advertisements (LSAs) to all other routers within the same hierarchical area. Information on the attached interfaces and their metrics is used in OSPF LSAs. As routers accumulate link-state information, they use the shortest path first (SPF) algorithm to calculate the shortest path to each node. Additional OSPF features include equal-cost multipath routing and routing based on the upper-layer type of service (ToS) requests.

OSPF employs the concept of an area, which is a group of contiguous OSPF networks and hosts. OSPF areas are logical subdivisions of OSPF autonomous systems in which the internal topology is hidden from routers outside the area. Areas allow an additional level of hierarchy different from that provided by IP network classes, and they can be used to aggregate routing information and mask the details of a network. These features make OSPF particularly scalable for large networks.

IS-IS

The IS-IS protocol uses a link-state routing algorithm. It closely follows the Open Shortest Path First (OSPF) routing protocol used within the TCP/IP environment. The operation of ISO IS-IS requires each router to maintain a full topology map of the network (that is, which ISs and ESs are connected to which other ISs and ESs). Periodically, the router runs an algorithm over its map to calculate the shortest path to all possible destinations.

IS-IS is a two-level hierarchy. Intermediate Systems (or routers) are classified as Level 1 and Level 2. Level 1 ISs deal with a single routing area. Traffic is relayed only within their area. Any other internetwork traffic is sent to nearest Level 2 ISs, which also acts as a Level 1 ISs. Level 2 ISs move traffic between different routing areas within the same domain.

An IS-IS with multiarea support allows multiple Level 1 areas within in a single IS, thus allowing an IS to be in multiple areas. A single Level 2 area is used as backbone for interarea traffic.

Only Ethernet frames are supported. The IS-IS does not support IPX.

IGRP

The Interior Gateway Routing Protocol (IGRP) is a robust distance-vector Interior Gateway Protocol (IGP) developed by Cisco to provide for routing within an autonomous system (AS). Distance vector routing protocols request that a switch send all or a portion of its routing table data in a routing update message at regular intervals to each of its neighboring routers. As routing information proliferates

through the network, routers can calculate distances to all nodes within the internetwork. IGRP uses a combination of metrics: internetwork delay, bandwidth, reliability, and load are all factored into the routing decision.

EIGRP

The Enhanced Interior Gateway Routing Protocol (EIGRP) is a version of IGRP that combines the advantages of link-state protocols with distance-vector protocols. EIGRP incorporates the Diffusing Update Algorithm (DUAL). EIGRP includes fast convergence, variable-length subnet masks, partially bounded updates, and multiple network-layer support.When a network topology change occurs, EIGRP checks its topology table for a suitable new route to the destination. If such a route exists in the table, EIGRP updates the routing table instantly.You can use the fast convergence and partial updates that EIGRP provides to route Internetwork Packet Exchange (IPX) packets.

EIGRP saves bandwidth by sending routing updates only when routing information changes. The updates contain information only about the link that changed, not the entire routing table. EIGRP also takes into consideration the available bandwidth when determining the rate at which it transmits updates.

Note Layer 3 switching does not support the Next Hop Resolution Protocol (NHRP).

BGP

The Border Gateway Protocol (BGP) is an exterior gateway protocol that allows you to set up an interdomain routing system to automatically guarantee the loop-free exchange of routing information between autonomous systems. In BGP, each route consists of a network number, a list of autonomous systems that information has passed through (called the autonomous system path), and a list of other path attributes.

The Catalyst 4500 series switch supports BGP version 4, including classless interdomain routing (CIDR). CIDR lets you reduce the size of your routing tables by creating aggregate routes, resulting in supernets. CIDR eliminates the concept of network classes within BGP and supports the advertising of IP prefixes. CIDR routes can be carried by OSPF, EIGRP, and RIP.

For BGP configuration information, refer to the chapter “Configuring BGP” in the *Cisco IOS IP and IP Routing Configuration Guide* at the following URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_c/ipcprt2/1cdbgp.htm

For a complete description of the BGP commands, refer to the chapter “BGP Commands” in the *Cisco IOS IP and IP Routing Command Reference* at the following URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_r/iprprt2/1rdbgp.htm

Multicast Services

Multicast services save bandwidth by forcing the network to replicate packets only when necessary and by allowing hosts to join and leave groups dynamically. The following multicast services are supported:

- Cisco Group Management Protocol (CGMP) server—CGMP server manages multicast traffic. Multicast traffic is forwarded only to ports with attached hosts that request the multicast traffic.
- Internet Group Management Protocol (IGMP) snooping—IGMP snooping manages multicast traffic. The switch software examines IP multicast packets and forwards packets based on their content. Multicast traffic is forwarded only to ports with attached hosts that request multicast traffic.

Support for IGMPv3 provides constrained flooding of multicast traffic in the presence of IGMPv3 hosts or routers. IGMPv3 snooping listens to IGMPv3 query and membership report messages to maintain host-to-multicast group associations. It enables a switch to propagate multicast data only to ports that need it. IGMPv3 snooping is fully interoperable with IGMPv1 and IGMPv2.

Explicit Host Tracking (EHT) is an extension to IGMPv3 snooping. EHT enables immediate leave operations on a per-port basis. EHT can be used to track per host membership information or to gather statistics about all IGMPv3 group members.

For information on configuring IGMP snooping, see Chapter 15, "Configuring IGMP Snooping and Filtering."

- Protocol Independent Multicast (PIM)—PIM is protocol-independent because it can leverage whichever unicast routing protocol is used to populate the unicast routing table, including EIGRP, OSPF, BGP, or static route. PIM also uses a unicast routing table to perform the Reverse Path Forwarding (RPF) check function instead of building a completely independent multicast routing table.

  For information on configuring multicast services, see Chapter 22, "Understanding and Configuring IP Multicast."

Network Security with ACLs

An access control list (ACL) filters network traffic by controlling whether routed packets are forwarded or blocked at the router interfaces. The Catalyst 4500 series switch examines each packet to determine whether to forward or drop the packet, based on the criteria you specified within the access lists.

MAC access control lists (MACLs) and VLAN access control lists (VACLs) are supported. VACLs are also known as VLAN maps in Cisco IOS.

The following security features are supported:

- MAC address filtering, which enables you to block unicast traffic for a MAC address on a VLAN interface.
- Port ACLs, which enable you to apply ACLs to Layer 2 interfaces on a switch for inbound traffic.

For information on ACLs, MACLs, VLAN maps, MAC address filtering, and Port ACLs, see Chapter 32, "Configuring Network Security with ACLs."

Policy-Based Routing

Traditional IP forwarding decisions are based purely on the destination IP address of the packet being forwarded. Policy Based Routing (PBR) enables forwarding based upon other information associated with a packet, such as the source interface, IP source address, Layer 4 ports, etc. This feature allows network managers more flexibility in how they configure and design their networks.

For more information on policy-based routing, see Chapter 23, "Configuring Policy-Based Routing."

Unidirectional Link Routing

Unidirectional link routing (UDLR) provides a way to forward multicast packets over a physical unidirectional interface (such as a satellite link of high bandwidth) to stub networks that have a back channel.

For information on configuring unidirectional link routing, refer to the chapter "Configuring Unidirectional Link Routing" in the *Cisco IP and IP Routing Configuration Guide*.

VRF-lite

VPN routing and forwarding (VRF-lite) is an extension of IP routing that provides multiple routing instances. Along with BGP, it enables the creation of a Layer 3 VPN service by keeping separate IP routing and forwarding tables for each VPN customer. VRF-lite uses input interfaces to distinguish routes for different VPNs. It forms virtual packet-forwarding tables by associating one or more Layer 3 interfaces with each VRF, allowing the creation of multiple Layer 3 VPNs on a single switch. Interfaces in a VRF could be either physical, such as an Ethernet port, or logical, such as a VLAN switch virtual interface (SVI). However, interfaces cannot belong to more than one VRF at any time.

For information on VRF-lite, see Chapter 25, "Configuring VRF-lite."

QoS Features

The quality of service (QoS) features prevent congestion by selecting network traffic and prioritizing it according to its relative importance. Implementing QoS in your network makes network performance more predictable and bandwidth use more effective.

The Catalyst 4500 series switch supports the following QoS features:

- Classification and marking
- Ingress and egress policing
- Sharing and shaping

Catalyst 4500 series switch supports trusted boundary, which uses the Cisco Discovery Protocol (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.

The Catalyst 4500 series switch also supports QoS Automation (Auto QoS), which simplifies the deployment of existing QoS features via automatic configuration.

For information on QoS and Auto QoS, see Chapter 26, "Configuring QoS."

Management and Security Features

The Catalyst 4500 series switch offers network management and control through the CLI or through alternative access methods, such as SNMP. The switch software supports these network management and security features:

- 802.1X protocol—This feature provides a means for a host connected to a switch port to be authenticated before it is given access to the switch services.
- 802.1X with VLAN assignment—This feature allows you to enable non-802.1X capable hosts to access networks that use 802.1X authentication.
- 802.1X authentication for guest VLANs—This feature allows you to use VLAN assignment to limit network access for certain users.
- 802.1X RADIUS accounting—This feature allows you to track the usage of network devices.

- Dynamic ARP inspection—This feature intercepts all ARP requests, replies on untrusted ports, and verifies each intercepted packet for valid IP to MAC bindings. Dynamic ARP Inspection helps to prevent attacks on a network by not relaying invalid ARP replies out to other ports in the same VLAN. Denied ARP packets are logged by the switch for auditing.
- Password-protected access (read-only and read-write)—This feature protects management interfaces against unauthorized configuration changes.
- Flood Blocking—This feature enables users to disable the flooding of unicast and multicast packets on a per-port basis. Occasionally, unknown unicast or multicast traffic from an unprotected port is flooded to a protected port because a MAC address has timed out or has not been learned by the switch.
- Port Security—This feature restricts traffic on a port based upon the MAC address of the workstation that accesses the port.
- Local Authentication, Remote Authentication Dial-In User Service (RADIUS), and Terminal Access Controller Access Control System Plus (TACACS+) authentication—These authentication methods control access to the switch. For additional information, refer to the chapter "Authentication, Authorization, and Accounting (AAA)," in *Cisco IOS Security Configuration Guide*, Release 12.1, at the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/secur_c/scprt1/index.htm
- Visual port status information—The switch LEDs provide visual management of port- and switch-level status.
- Secure Shell—Secure Shell (SSH) is a program that enables you to log into another computer over a network, to execute commands remotely, and to move files from one machine to another. The implementation will be limited to providing a remote login session to the switch, and will only function as a server; that is, the switch may not initiate SSH connections.
- NetFlow statistics—This feature is a global traffic monitoring feature that allows flow-level monitoring of all IPv4-routed traffic through the switch.
- Intelligent Power Management—Working with powered devices (PDs) from Cisco, this feature uses power negotiation to refine the power consumption of an 802.3af-compliant PD beyond the granularity of power consumption provided by the 802.3af class. Power negotiation also enables the backward compatibility of newer PDs with older modules that do not support either 802.3af or high-power levels as required by IEEE standard.
- Switched Port Analyzer (SPAN)—SPAN allows you to monitor traffic on any port for analysis by a network analyzer or Remote Monitoring (RMON) probe. You also can do the following:
  - Configure ACLs on SPAN sessions.
  - Allow incoming traffic on SPAN destination ports to be switched normally.
  - Explicitly configure the encapsulation type of packets that are spanned out of a destination port.
  - Restrict ingress sniffing depending on whether the packet is unicast, multicast, or broadcast, and depending on whether the packet is valid.
  - Mirror packets sent to or from the CPU out of a SPAN destination port for troubleshooting purposes.

  For information on SPAN, see Chapter 37, "Configuring SPAN and RSPAN."
- Remote SPAN (RSPAN)—RSPAN is an extension of SPAN, where source ports and destination ports are distributed across multiple switches, allowing remote monitoring of multiple switches across the network. The traffic for each RSPAN session is carried over a user-specified RSPAN VLAN that is dedicated for that RSPAN session on all participating switches.

  For information on RSPAN, see Chapter 37, "Configuring SPAN and RSPAN."

- Simple Network Management Protocol—SNMP facilitates the exchange of management information between network devices. The Catalyst 4500 series switch supports these SNMP types and enhancements:
  - SNMP—A full Internet standard
  - SNMP v2—Community-based administrative framework for version 2 of SNMP
  - SNMP v3—Security framework with three levels: noAuthNoPriv, authNoPriv, and authPriv (available only on a crypto image, like cat4000-i5k91s-mz)
  - SNMP trap message enhancements—Additional information with certain SNMP trap messages, including spanning-tree topology change notifications and configuration change notifications

  For information on SNMP, refer to the *Cisco IOS Configuration Fundamentals Configuration Guide* and *Cisco IOS Configuration Fundamentals Command Reference* at the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios121/121cgcr/index.htm
- Dynamic Host Control Protocol server—The Cisco IOS DHCP server feature is a full DHCP server implementation that assigns and manages IP addresses from specified address pools within the router to DHCP clients. If the Cisco IOS DHCP server cannot satisfy a DHCP request from its own database, it can forward the request to one or more secondary DHCP servers defined by the network administrator.

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

  For more information on configuring the DHCP server, refer to the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122newft/122t/122t1/easyip2.htm
- Debugging features—The Catalyst 4500 series switch has several commands to help you debug your initial setup. These commands include the following groups:
  - **platform**
  - **debug platform**

  For more information, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Configuring Embedded CiscoView Support

The Catalyst 4500 series switch supports CiscoView web-based administration through the Catalyst Web Interface (CWI) tool. CiscoView is a device management application that can be embedded on the switch flash and provides dynamic status, monitoring, and configuration information for your switch. CiscoView displays a physical view of your switch chassis, with color-coded modules and ports, and monitoring capabilities that display the switch status, performance, and other statistics. Configuration capabilities allow comprehensive changes to devices, given that the required security privileges have been granted. The configuration and monitoring capabilities for the Catalyst 4500 series of switches mirror those available in CiscoView in all server-based CiscoWorks solutions, including CiscoWorks LAN Management Solution (LMS) and CiscoWorks Routed WAN Management Solution (RWAN).

These sections describe the Embedded CiscoView support available with Release 12.1(20)EW and later releases:

- Understanding Embedded CiscoView, page 1-13
- Installing and Configuring Embedded CiscoView, page 1-13
- Displaying Embedded CiscoView Information, page 1-15

Understanding Embedded CiscoView

The Embedded CiscoView network management system is a web-based interface that uses HTTP and SNMP to provide a graphical representation of the switch and to provide a GUI-based management and configuration interface. You can download the Java Archive (JAR) files for Embedded CiscoView at this URL:
http://www.cisco.com/cgi-bin/tablebuild.pl/cview-cat4000

Installing and Configuring Embedded CiscoView

To install and configure Embedded CiscoView, perform this task:

	Command	Purpose
Step 1	`Router# dir device_name`	Displays the contents of the device. If you are installing Embedded CiscoView for the first time, or if the CiscoView directory is empty, skip to Step 5.
Step 2	`Switch# delete device_name:cv/*`	Removes existing files from the CiscoView directory.
Step 3	`Switch# squeeze device_name:`	Recovers the space in the file system.
Step 4	`Switch# acopy tftp bootflash`	Copies the tar file to bootflash.
Step 5	`Switch# archive tar /xtract tftp://ip address of tftp server/ciscoview.tar device_name:cv`	Extracts the CiscoView files from the tar file on the TFTP server to the CiscoView directory.
Step 6	`Switch# dir device_name:`	Displays the contents of the device. In a redundant configuration, repeat Step 1 through Step 6 for the file system on the redundant supervisor engine.
Step 7	`Switch# configure terminal`	Enters global configuration mode.
Step 8	`Switch(config)# ip http server`	Enables the HTTP web server.
Step 9	`Switch(config)# snmp-server community string ro`	Configures the SNMP password for read-only operation.
Step 10	`Switch(config)# snmp-server community string rw`	Configures the SNMP password for read/write operation.

Note The default password for accessing the switch web page is the enable-level password of the switch.

The following example shows how to install and configure Embedded CiscoView on your switch:

```
Switch# dir
Directory of bootflash:/

    1  -rw-     8620304  Dec 23 2002 23:27:49 +00:00  wickwire.EW1
    2  -rw-     9572396  Dec 30 2002 01:05:01 +00:00  cat4000-i9k2s-mz.121-19.EW
    3  -rw-     9604192   Jan 3 2003 07:46:49 +00:00  cat4000-i5k2s-mz.121-19.EW
    4  -rw-     1985024  Jan 21 2003 03:31:20 +00:00  Cat4000IOS.v4-0.tar
    5  -rw-     1910127  Jan 23 2003 04:23:39 +00:00  cv/Cat4000IOS-4.0.sgz
```

```
    6  -rw-        7258  Jan 23 2003 04:23:46 +00:00  cv/Cat4000IOS-4.0_ace.html
    7  -rw-         405  Jan 23 2003 04:23:46 +00:00  cv/Cat4000IOS-4.0_error.html
    8  -rw-        2738  Jan 23 2003 04:23:46 +00:00  cv/Cat4000IOS-4.0_install.html
    9  -rw-       20450  Jan 23 2003 04:23:46 +00:00  cv/Cat4000IOS-4.0_jks.jar
   10  -rw-       20743  Jan 23 2003 04:23:46 +00:00  cv/Cat4000IOS-4.0_nos.jar
   11  -rw-       12383  Jan 23 2003 04:23:46 +00:00  cv/applet.html
   12  -rw-         529  Jan 23 2003 04:23:46 +00:00  cv/cisco.x509
   13  -rw-        2523  Jan 23 2003 04:23:46 +00:00  cv/identitydb.obj
   14  -rw-     9630880  Feb 27 2003 01:25:16 +00:00  kurt70.devtest-enh
   15  -rw-        1173  Mar 19 2003 05:50:26 +00:00  post-2003.03.19.05.50.07-passed.txt
   16  -rw-    10511956  Mar 26 2003 04:24:12 +00:00  kurt_alpha_bas_crypto_103

61341696 bytes total (9436548 bytes free)
Switch#
Switch# del cv/*
Delete filename [cv/*]?
Delete bootflash:cv/Cat4000IOS-4.0.sgz? [confirm]y
Delete bootflash:cv/Cat4000IOS-4.0_ace.html? [confirm]y
Delete bootflash:cv/Cat4000IOS-4.0_error.html? [confirm]y
Delete bootflash:cv/Cat4000IOS-4.0_install.html? [confirm]y
Delete bootflash:cv/Cat4000IOS-4.0_jks.jar? [confirm]y
Delete bootflash:cv/Cat4000IOS-4.0_nos.jar? [confirm]y
Delete bootflash:cv/applet.html? [confirm]y
Delete bootflash:cv/cisco.x509? [confirm]y
Delete bootflash:cv/identitydb.obj? [confirm]y
Switch#

Switch# squeeze bootflash:
All deleted files will be removed. Continue? [confirm]y
Squeeze operation may take a while. Continue? [confirm]y
Squeeze of bootflash complete
Switch#
Switch# copy tftp bootflash
Address or name of remote host []? 10.5.5.5
Source filename []? Cat4000IOS.v5-1.tar
Destination filename [Cat4000IOS.v5-1.tar]?
Accessing tftp://10.5.5.5/Cat4000IOS.v5-1.tar...
Loading Cat4000IOS.v5-1.tar from 10.5.5.5 (via FastEthernet1):
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
[OK - 2031616 bytes]

2031616 bytes copied in 11.388 secs (178400 bytes/sec)
Switch#
Switch# dir
Directory of bootflash:/

    1  -rw-     8620304  Dec 23 2002 23:27:49 +00:00  wickwire.EW1
    2  -rw-     9572396  Dec 30 2002 01:05:01 +00:00  cat4000-i9k2s-mz.121-19.EW
    3  -rw-     9604192   Jan 3 2003 07:46:49 +00:00  cat4000-i5k2s-mz.121-19.EW
    4  -rw-     1985024  Jan 21 2003 03:31:20 +00:00  Cat4000IOS.v4-0.tar
    5  -rw-     9630880  Feb 27 2003 01:25:16 +00:00  kurt70.devtest-enh
    6  -rw-        1173  Mar 19 2003 05:50:26 +00:00  post-2003.03.19.05.50.07-passed.txt
    7  -rw-    10511956  Mar 26 2003 04:24:12 +00:00  kurt_alpha_bas_crypto_103
    8  -rw-     2031616  Mar 26 2003 05:33:12 +00:00  Cat4000IOS.v5-1.tar

61341696 bytes total (9383128 bytes free)
Switch#
Switch# archive tar /xtract Cat4000IOS.v5-1.tar /cv
extracting Cat4000IOS-5.1.sgz (1956591 bytes)
extracting Cat4000IOS-5.1_ace.html (7263 bytes)
extracting Cat4000IOS-5.1_error.html (410 bytes)
```

```
extracting Cat4000IOS-5.1_install.html (2743 bytes)
extracting Cat4000IOS-5.1_jks.jar (20450 bytes)
extracting Cat4000IOS-5.1_nos.jar (20782 bytes)
extracting applet.html (12388 bytes)
extracting cisco.x509 (529 bytes)
extracting identitydb.obj (2523 bytes)
Switch#
Switch# dir
Directory of bootflash:/

    1  -rw-     8620304  Dec 23 2002 23:27:49 +00:00  wickwire.EW1
    2  -rw-     9572396  Dec 30 2002 01:05:01 +00:00  cat4000-i9k2s-mz.121-19.EW
    3  -rw-     9604192   Jan 3 2003 07:46:49 +00:00  cat4000-i5k2s-mz.121-19.EW
    4  -rw-     1985024  Jan 21 2003 03:31:20 +00:00  Cat4000IOS.v4-0.tar
    5  -rw-     9630880  Feb 27 2003 01:25:16 +00:00  kurt70.devtest-enh
    6  -rw-        1173  Mar 19 2003 05:50:26 +00:00  post-2003.03.19.05.50.07-passed.txt
    7  -rw-    10511956  Mar 26 2003 04:24:12 +00:00  kurt_alpha_bas_crypto_103
    8  -rw-     2031616  Mar 26 2003 05:33:12 +00:00  Cat4000IOS.v5-1.tar
    9  -rw-     1956591  Mar 26 2003 05:36:11 +00:00  cv/Cat4000IOS-5.1.sgz
   10  -rw-        7263  Mar 26 2003 05:36:19 +00:00  cv/Cat4000IOS-5.1_ace.html
   11  -rw-         410  Mar 26 2003 05:36:19 +00:00  cv/Cat4000IOS-5.1_error.html
   12  -rw-        2743  Mar 26 2003 05:36:19 +00:00  cv/Cat4000IOS-5.1_install.html
   13  -rw-       20450  Mar 26 2003 05:36:19 +00:00  cv/Cat4000IOS-5.1_jks.jar
   14  -rw-       20782  Mar 26 2003 05:36:19 +00:00  cv/Cat4000IOS-5.1_nos.jar
   15  -rw-       12388  Mar 26 2003 05:36:19 +00:00  cv/applet.html
   16  -rw-         529  Mar 26 2003 05:36:19 +00:00  cv/cisco.x509
   17  -rw-        2523  Mar 26 2003 05:36:19 +00:00  cv/identitydb.obj

61341696 bytes total (7358284 bytes free)
Switch#
Switch# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip http server
Switch(config)# snmp-server community public ro
Switch(config)# snmp-server community public rw
Switch(config)# exit
Switch# wr
Building configuration...
Compressed configuration from 2735 bytes to 1169 bytes[OK]
Switch# show ciscoview ?
  package  ADP Package Details
  version  ADP version
  |        Output modifiers
  <
```

For more information about web access to the switch, refer to the "Using the Cisco Web Browser" chapter in the *Cisco IOS Configuration Fundamentals Configuration Guide* at this URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fun_c/fcprt1/fcd105.htm

Displaying Embedded CiscoView Information

To display the Embedded CiscoView information, enter the following commands:

Command	Purpose
`Switch# show ciscoview package`	Displays information about the Embedded CiscoView files.
`Switch# show ciscoview version`	Displays the Embedded CiscoView version.

The following example shows how to display the Embedded CiscoView file and version information:

```
Switch# show ciscoview package
File source:
CVFILE                          SIZE(in bytes)
-------------------------------------------------
Cat4000IOS-5.1.sgz               1956591
Cat4000IOS-5.1_ace.html          7263
Cat4000IOS-5.1_error.html        410
Cat4000IOS-5.1_install.html      2743
Cat4000IOS-5.1_jks.jar           20450
Cat4000IOS-5.1_nos.jar           20782
applet.html                      12388
cisco.x509                       529
identitydb.obj                   2523

Switch# show ciscoview version
Engine Version: 5.3.4 ADP Device: Cat4000IOS ADP Version: 5.1 ADK: 49
Switch#
```

Command-Line Interfaces

This chapter describes the CLIs you use to configure the Catalyst 4500 series switch. This chapter includes the following major sections:

Note For complete syntax and usage information for the commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm

Accessing the Switch CLI

The following sections describe how to access the switch CLI:

Accessing the CLI Using the EIA/TIA-232 Console Interface

Note EIA/TIA-232 was known as recommended standard 232 (RS-232) before its acceptance as a standard by the Electronic Industries Alliance (EIA) and Telecommunications Industry Association (TIA).

Perform the initial switch configuration over a connection to the EIA/TIA-232 console interface. Refer to the *Catalyst 4500 Series Switch Module Installation Guide* for console interface cable connection procedures.

To access the switch through the console interface, perform this task:

	Command	Purpose
Step 1	`Switch> enable`	From the user EXEC prompt (>), enter **enable** to change to enable mode (also known as privileged mode or privileged EXEC mode).

Step 2	`Password: password`
	
	`Switch#`
		At the password prompt, enter the system password. The prompt (#) appears, indicating that you have accessed the CLI in enabled mode.

Step 3	`Switch# quit`	When you are finished executing the task command, exit the session.

After accessing the switch through the EIA/TIA-232 interface, you see this display:

```
Press Return for Console prompt

Switch> enable
Password:< >
Switch#
```

Accessing the CLI Through Telnet

Note Before you make a Telnet connection to the switch, you must set the IP address for the switch. See the "Configuring Physical Layer 3 Interfaces" section on page 20-4.

The switch supports up to eight simultaneous Telnet sessions. Telnet sessions disconnect automatically after remaining idle for the period specified by the **exec-timeout** command.

To make a Telnet connection to the switch, perform this task:

	Command	Purpose
Step 1	**telnet** {*hostname* | *ip_addr*}	From the remote host, enter the **telnet** command and the name or IP address of the switch you want to access.

Step 2	`Password: password`
	
	`Switch#`
		At the prompt, enter the password for the CLI. If no password has been configured, press **Return**.

Step 3		Enter the necessary commands to complete your desired tasks.
Step 4	`Switch# quit`	When finished, exit the Telnet session.

This example shows how to open a Telnet session to the switch:

```
unix_host% telnet Switch_1
Trying 172.20.52.40...
Connected to 172.20.52.40.
Escape character is '^]'.
User Access Verification
Password:< >
Switch_1> enable
Password:
Switch_1#
```

Performing Command-Line Processing

Switch commands are not case sensitive. You can abbreviate commands and parameters if the abbreviations contain enough letters to be different from any other currently available commands or parameters.

You can scroll through the last 20 commands stored in the history buffer and enter or edit a command at the prompt. Table 2-1 lists the keyboard shortcuts for entering and editing switch commands.

Table 2-1 Keyboard Shortcuts

Keystrokes	Result
Press **Ctrl-B** or press the **Left Arrow** key[1]	Moves the cursor back one character.
Press **Ctrl-F** or press the **Right Arrow** key[1]	Moves the cursor forward one character.
Press **Ctrl-A**	Moves the cursor to the beginning of the command line.
Press **Ctrl-E**	Moves the cursor to the end of the command line.
Press **Esc-B**	Moves the cursor back one word.
Press **Esc-F**	Moves the cursor forward one word.

1. The Arrow keys function only on ANSI-compatible terminals, such as VT100s.

Performing History Substitution

The history buffer stores the last 20 command lines you entered. History substitution allows you to access these command lines without retyping them. Table 2-2 lists the history substitution commands.

Table 2-2 History Substitution Commands

Command	Purpose
Ctrl-P or the **Up Arrow** key[1]	Recalls commands in the history buffer, beginning with the most recent command. Repeat the key sequence to recall older commands successively.

Table 2-2 History Substitution Commands (continued)

Command	Purpose
Ctrl-N or the **Down Arrow** key[1]	Returns to more recent commands in the history buffer after commands have been recalled with **Ctrl-P** or the **Up Arrow** key. Repeat the key sequence to recall more recent commands.
`Switch# show history`	Lists the last several commands you have entered in EXEC mode.

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

Understanding Cisco IOS Command Modes

Note For complete information about Cisco IOS command modes, refer to the *Cisco IOS Configuration Fundamentals Configuration Guide* and the *Cisco IOS Configuration Fundamentals Command Reference* at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm

The Cisco IOS user interface has many different modes: user EXEC, privileged EXEC (enable), global configuration, interface, subinterface, and protocol-specific. The commands available to you depend on which mode you are in. To get a list of the commands in a given mode, enter a question mark (?) at the system prompt. See the "Getting a List of Commands and Syntax" section on page 2-5 for more information.

When you start a session on the switch, you begin in user mode, also called user EXEC mode. Only a small subset of commands are available in EXEC mode. To have access to all commands, you must enter privileged EXEC mode, also called enable mode. To access the privileged EXEC mode, you must enter a password. When you are in the privileged EXEC mode, you can enter any EXEC command or access global configuration mode. Most EXEC commands are one-time commands, such as **show** commands, which display the current configuration status, and **clear** commands, which reset counters or interfaces. The EXEC commands are not saved when the switch is rebooted.

The configuration modes allow you to make changes to the running configuration. If you save the configuration, these commands are stored when you reboot the switch. You must start in global configuration mode. From global configuration mode, you can enter interface configuration mode, subinterface configuration mode, and a variety of protocol-specific modes.

You would use a separate mode called ROMMON when the switch cannot boot up properly. For example, the switch might enter ROMMON mode if it does not find a valid system image when it is booting, or if its configuration file is corrupted. For more information, see the "ROMMOM Command-Line Interface" section on page 2-6.

Table 2-3 lists and describes frequently used Cisco IOS modes.

Table 2-3 Frequently Used Cisco IOS Command Modes

Mode	What You Use It For	How to Access	Prompt
User EXEC	To connect to remote devices, change terminal settings on a temporary basis, perform basic tests, and display system information.	Log in.	`Switch>`
Privileged EXEC (enable)	To set operating parameters. The privileged command set includes the commands in user EXEC mode, as well as the **configure** command. Use the **configure** command to access the other command modes.	From user EXEC mode, enter the **enable** command and the enable password (if a password has been configured).	`Switch#`
Global configuration	To configure features that affect the system as a whole, such as the system time or switch name.	From privileged EXEC mode, enter the **configure terminal** command.	`Switch(config)#`
Interface configuration	To enable or modify the operation of a Gigabit Ethernet or Fast Ethernet interface with **interface** commands.	From global configuration mode, enter the **interface** *type location* command.	`Switch(config-if)#`
Console configuration	To configure the console interface; from the directly connected console or the virtual terminal; used with Telnet.	From global configuration mode, enter the **line console 0** command.	`Switch(config-line)#`

The Cisco IOS command interpreter, called the EXEC, interprets and runs the commands you enter. You can abbreviate commands and keywords by entering just enough characters to make the command unique from other commands. For example, you can abbreviate the **show** command to **sh** and the **configure terminal** command to **config t**.

When you type **exit**, the switch backs out one level. To exit configuration mode completely and return to privileged EXEC mode, press **Ctrl-Z**.

Getting a List of Commands and Syntax

In any command mode, you can get a list of available commands by entering a question mark (?).

```
Switch> ?
```

To obtain a list of commands that begin with a particular character sequence, enter those characters followed by the question mark (?). Do not include a space before the question mark. This form of help is called word help, because it completes a word for you.

To list keywords or arguments, enter a question mark in place of a keyword or argument. Include a space before the question mark. This form of help is called command syntax help, because it reminds you which keywords or arguments are applicable based on the command, keywords, and arguments you have already entered.

```
Switch# configure ?
  memory             Configure from NV memory
  network            Configure from a TFTP network host
  overwrite-network  Overwrite NV memory from TFTP network host
  terminal           Configure from the terminal
  <cr>
```

To redisplay a command you previously entered, press the **Up Arrow** key or **Ctrl-P**. You can continue to press the **Up Arrow** key to see the last 20 commands you entered.

Tip If you are having trouble entering a command, check the system prompt and enter the question mark (?) for a list of available commands. You might be in the wrong command mode or using incorrect syntax.

Type **exit** to return to the previous mode. Press **Ctrl-Z** or enter the **end** command in any mode to immediately return to privileged EXEC mode.

ROMMOM Command-Line Interface

ROMMON is a ROM-based program that is involved at power-up or reset, or when a fatal exception error occurs. The switch enters ROMMON mode if the switch does not find a valid software image, if the NVRAM configuration is corrupted, or if the configuration register is set to enter ROMMON mode. From the ROMMON mode, you can load a software image manually from Flash memory, from a network server file, or from bootflash.

You can also enter ROMMON mode by restarting the switch and pressing **Ctrl-C** during the first five seconds of startup.

Note **Ctrl-C** is always enabled for 60 seconds after you reboot the switch, even if **Ctrl-C** is configured to be off in the configuration register settings.

When you enter ROMMON mode, the prompt changes to **rommon 1>**. Use the **?** command to see the available ROMMON commands.

For more information about the ROMMON commands, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Configuring the Switch for the First Time

This chapter describes how to initially configure a Catalyst 4500 series switch. The information presented here supplements the administration information and procedures in these publications:

- *Cisco IOS Configuration Fundamentals Configuration Guide*, Release 12.2, at this URL:

  http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fun_c/index.htm
- *Cisco IOS Configuration Fundamentals Configuration Command Reference*, Release 12.2, at this URL:

  http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fun_r/index.htm

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm

Default Switch Configuration

This section describes the default configurations for the Catalyst 4500 series switch. Table 3-1 shows the default configuration settings for each feature.

Table 3-1 Default Switch Configuration

Feature	Default Settings
Administrative connection	Normal mode
Global switch information	No default value for system name, system contact, and location
System clock	No value for system clock time

Table 3-1 Default Switch Configuration (continued)

Feature	Default Settings
Passwords	No passwords are configured for normal mode or enable mode (press the **Return** key)
Switch prompt	`Switch>`
Interfaces	Enabled, with speed and flow control autonegotiated, and without IP addresses

Configuring DHCP-Based Autoconfiguration

These sections describe how to configure DHCP-based autoconfiguration.

If your DHCP server is a Cisco device, or if you are configuring the switch as a DHCP server, refer to the "*IP Addressing and Services*" section in the *Cisco IOS IP and IP Routing Configuration Guide for Cisco IOS Release 12.1* for additional information about configuring DHCP.

Understanding DHCP-Based Autoconfiguration

Note Starting with Release 12.2(20)EW, you can enable DHCP AutoConfiguration by issuing the **write erase** command. This command clears the startup-config in NVRAM. In images prior to Release 12.2(20)EW, this command will not enable autoconfiguration.

DHCP provides configuration information to Internet hosts and internetworking devices. This protocol consists of two components: one component for delivering configuration parameters from a DHCP server to a device and another component that is 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.

With DHCP-based autoconfiguration, no DHCP client-side configuration is needed on your switch because your switch (the DHCP client) is automatically configured at startup with IP address information and a configuration file. However, you need to configure the DHCP server or the DHCP server feature on your switch 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.

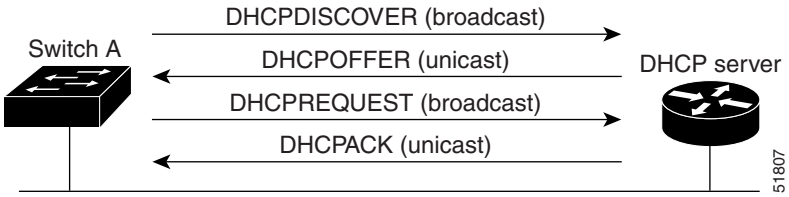
DHCP-based autoconfiguration replaces the BOOTP client functionality on your switch.

DHCP Client Request Process

At startup the switch automatically requests configuration information from a DHCP server if a configuration file is not present on the switch.

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, 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 the configuration information that it 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 DHCP Server" section on page 3-3.

If the configuration parameters sent to the client in the DHCPOFFER unicast message are invalid (if 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 might have assigned the parameters to another client).

A DHCP client might receive offers from multiple DHCP servers and can accept any of them; however, the client usually accepts the first offer it receives. The offer from the DHCP server is not a guarantee that the IP address will be allocated to the client; however, the server usually reserves the address until the client has had a chance to formally request the address.

Configuring the DHCP Server

A switch can act as both the DHCP client and the DHCP server. By default, the Cisco IOS DHCP server and relay agent features are enabled on your switch.

You should configure the DHCP server, or the DHCP server feature running on your switch, 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 (required)

Note The router IP address is the default gateway address for the switch.

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 or IP address (required)
- Boot filename (the name of the configuration file that the client needs) (recommended)
- Host name (optional)

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

If you do not configure the DHCP server, or the DHCP server feature running on your switch, with the lease options described earlier, the switch replies to client requests with only those parameters that are configured. If the IP address and subnet mask are not in the reply, the switch is not configured. If the router IP address or TFTP server name (or IP address) are not found, the switch might send broadcast, instead of unicast, TFTP requests. Unavailability of other lease options does not impact autoconfiguration.

The DHCP server, or the DHCP server feature running on 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, which 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. For more information on relay devices, see the "Configuring the Relay Device" section on page 3-5.

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 or the TFTP server name, or if the configuration file could not be downloaded, the switch attempts to download a configuration file using various combinations of filenames and TFTP server addresses. The files include the specified configuration filename (if any) and the following files: network-confg, cisconet.cfg, *hostname*.confg, or *hostname*.cfg, where *hostname* is the current hostname of the switch and router-confg and ciscortr.cfg. 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 the following:

- The configuration file named in the DHCP reply (the actual switch configuration file).
- The network-confg or the cisconet.cfg file (known as the default configuration files).
- The router-confg 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 you plan to use 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 earlier), 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 3-5. The preferred solution is to configure either the DHCP server or the DHCP server feature running on your switch with all the required information.

Configuring the DNS Server

The DHCP server, or the DHCP server feature running on your switch, 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 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 to forward received broadcast packets to the destination host whenever a switch sends broadcast packets to which a host on a different LAN must respond. Examples of such broadcast packets are DHCP, DNS, and in some cases, TFTP packets.

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

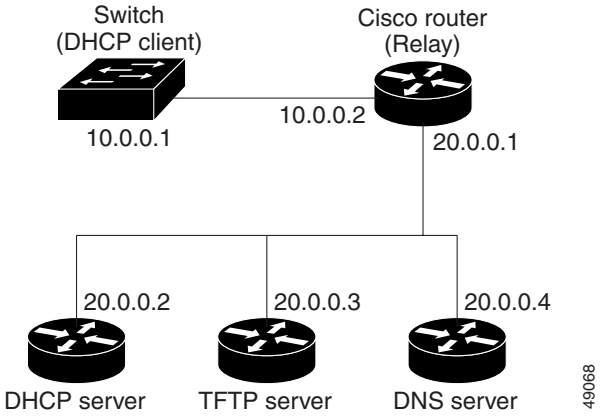
On interface 10.0.0.2:

```
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 are 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 either the DHCP server or the DHCP server feature running on your switch. 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, completes its boot-up 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 either the DHCP server or the DHCP server feature running on your switch. 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, completes its boot-up 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 either the DHCP server or the DHCP server feature running on your switch. The switch sends a unicast message to the TFTP server to retrieve the network-confg or cisconet.cfg default configuration file. (If the network-confg file cannot be read, the switch reads the cisconet.cfg file.)

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

  After obtaining its host name from the default configuration file or the DHCP reply, the switch reads the configuration file that has the same name as its host name (*hostname*-confg or *hostname*.cfg, depending on whether or not the network-confg file or the cisconet.cfg file 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-confg, cisconet.cfg, or the hostname file, it reads the router-confg file. If the switch cannot read the router-confg file, it reads the ciscortr.cfg file.

Note The switch broadcasts TFTP server requests provided that either 1) the TFTP server is not obtained from the DHCP replies, 2) all attempts to read the configuration file through unicast transmissions fail, or 3) the TFTP server name cannot be resolved to an IP address.

Example Configuration

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

Figure 3-3 DHCP-Based Autoconfiguration Network Example

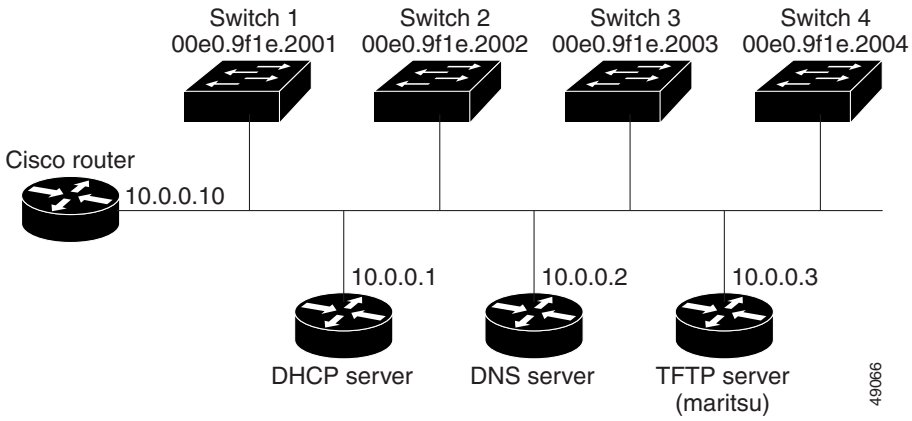


Table 3-2 shows the configuration of the reserved leases on either the DHCP server or the DHCP server feature running on your switch.

Table 3-2 DHCP Server Configuration

	Switch-1	Switch-2	Switch-3	Switch-4
Binding key (hardware address)	00e0.9f1e.2001	00e0.9f1e.2002	00e0.9f1e.2003	00e0.9f1e.2004
IP address	10.0.0.21	10.0.0.22	10.0.0.23	10.0.0.24
Subnet mask	255.255.255.0	255.255.255.0	255.255.255.0	255.255.255.0
Router address	10.0.0.10	10.0.0.10	10.0.0.10	10.0.0.10
DNS server address	10.0.0.2	10.0.0.2	10.0.0.2	10.0.0.2
TFTP server name	maritsu or 10.0.0.3	maritsu or 10.0.0.3	maritsu or 10.0.0.3	maritsu or 10.0.0.3
Boot filename (configuration file) (optional)	switch1-confg	switch2-confg	switch3-confg	switch4-confg
Host name (optional)	switch1	switch2	switch3	switch4

DNS Server Configuration

The DNS server maps the TFTP server name *maritsu* 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 host name to be assigned to the switch based on its IP address. The base directory also contains a configuration file for each switch (*switch1-confg*, *switch2-confg*, and so forth) as shown in the following display:

```
prompt> cd /tftpserver/work/
prompt> ls
network-confg
switch1-confg
switch2-confg
switch3-confg
switch4-confg
prompt> cat network-confg
ip host switch1 10.0.0.21
ip host switch2 10.0.0.22
ip host switch3 10.0.0.23
ip host switch4 10.0.0.24
```

DHCP Client Configuration

No configuration file is present on Switch 1 through Switch 4.

Configuration Explanation

In Figure 3-3, Switch 1 reads its configuration file as follows:

- Switch 1 obtains its IP address 10.0.0.21 from the DHCP server.
- If no configuration filename is given in the DHCP server reply, Switch 1 reads the network-confg file from the base directory of the TFTP server.
- Switch 1 adds the contents of the network-confg file to its host table.
- Switch 1 reads its host table by indexing its IP address 10.0.0.21 to its host name (switch1).
- Switch 1 reads the configuration file that corresponds to its host name; for example, it reads *switch1-confg* from the TFTP server.

Switches 2 through 4 retrieve their configuration files and IP addresses in the same way.

Configuring the Switch

The following sections describe how to configure your switch:

Using Configuration Mode to Configure Your Switch

To configure your switch from configuration mode, perform this procedure:

Step 1 Connect a console terminal to the console interface of your supervisor engine.

Step 2 After a few seconds, you will see the user EXEC prompt (`Switch>`). Now, you may want to enter privileged EXEC mode, also known as enable mode. Type **enable** to enter enable mode:

```
Switch> enable
```

Note You must be in enable mode to make configuration changes.

The prompt will change to the enable prompt (#):

```
Switch#
```

Step 3 At the enable prompt (#), enter the **configure terminal** command to enter global configuration mode:

```
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#
```

Step 4 At the global configuration mode prompt, enter the **interface** *type slot/interface* command to enter interface configuration mode:

```
Switch(config)# interface fastethernet 5/1
Switch(config-if)#
```

Step 5 In either of these configuration modes, enter changes to the switch configuration.

Step 6 Enter the **end** command to exit configuration mode.

Step 7 Save your settings. (See the "Saving the Running Configuration Settings to Your Start-up File" section on page 3-10.)

Your switch is now minimally configured and can boot with the configuration you entered. To see a list of the configuration commands, enter **?** at the prompt or press the **help** key in configuration mode.

Checking the Running Configuration Settings

To verify the configuration settings you entered or the changes you made, enter the **show running-config** command at the enable prompt (#), as shown in this example:

```
Switch# show running-config
Building configuration...

Current configuration:
!
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname Switch
```

```
<...output truncated...>

!
line con 0
 transport input none
line vty 0 4
 exec-timeout 0 0
 password lab
 login
 transport input lat pad dsipcon mop telnet rlogin udptn nasi
!
end
Switch#
```

Saving the Running Configuration Settings to Your Start-up File

Caution This command saves the configuration settings that you created in configuration mode. If you fail to do this step, your configuration will be lost the next time you reload the system.

To store the configuration, changes to the configuration, or changes to the startup configuration in NVRAM, enter the **copy running-config startup-config** command at the enable prompt (#), as follows:

```
Switch# copy running-config startup-config
```

Reviewing the Configuration in NVRAM

To display information stored in NVRAM, enter the **show startup-config** EXEC command.

The following example shows a typical system configuration:

```
Switch# show startup-config
Using 1579 out of 491500 bytes, uncompressed size = 7372 bytes
Uncompressed configuration from 1579 bytes to 7372 bytes
!
version 12.1
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
service compress-config
!
hostname Switch
!
!
ip subnet-zero
!
!
!
!
interface GigabitEthernet1/1
 no snmp trap link-status
!
interface GigabitEthernet1/2
 no snmp trap link-status
!--More--

<...output truncated...>
```

```
!
line con 0
 exec-timeout 0 0
 transport input none
line vty 0 4
 exec-timeout 0 0
 password lab
 login
 transport input lat pad dsipcon mop telnet rlogin udptn nasi
!
end

Switch#
```

Configuring a Default Gateway

Note The switch uses the default gateway only when it is not configured with a routing protocol.

Configure a default gateway to send data to subnets other than its own when the switch is not configured with a routing protocol. The default gateway must be the IP address of an interface on a router that is directly connected to the switch.

To configure a default gateway, perform this task:

	Command	Purpose
Step 1	`Switch(config)# ip default-gateway` *IP-address*	Configures a default gateway.
Step 2	`Switch# show ip route`	Verifies that the default gateway is correctly displayed in the IP routing table.

This example shows how to configure a default gateway and how to verify the configuration:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip default-gateway 172.20.52.35
Switch(config)# end
3d17h: %SYS-5-CONFIG_I: Configured from console by console
Switch# show ip route
Default gateway is 172.20.52.35

Host               Gateway           Last Use    Total Uses  Interface
ICMP redirect cache is empty
Switch#
```

Configuring a Static Route

If your Telnet station or SNMP network management workstation is on a different network from your switch and a routing protocol has not been configured, you might need to add a static routing table entry for the network where your end station is located.

To configure a static route, perform this task:

	Command	Purpose
Step 1	`Switch(config)# ip route dest_IP_address mask {forwarding_IP | vlan vlan_ID}`	Configures a static route to the remote network.
Step 2	`Switch# show running-config`	Verifies that the static route is displayed correctly.

This example shows how to use the **ip route** command to configure a static route to a workstation at IP address 171.10.5.10 on the switch with a subnet mask and IP address 172.20.3.35 of the forwarding router:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip route 171.10.5.10 255.255.255.255 172.20.3.35
Switch(config)# end
Switch#
```

This example shows how to use the **show running-config** command to confirm the configuration of the static route:

```
Switch# show running-config
Building configuration...
.
<...output truncated...>
.
ip default-gateway 172.20.52.35
ip classless
ip route 171.10.5.10 255.255.255.255 172.20.3.35
no ip http server
!
line con 0
 transport input none
line vty 0 4
 exec-timeout 0 0
 password lab
 login
 transport input lat pad dsipcon mop telnet rlogin udptn nasi
!
end

Switch#
```

This example shows how to use the **ip route** command to configure the static route IP address 171.20.5.3 with subnet mask and connected over VLAN 1 to a workstation on the switch:

```
Switch# configure terminal
Switch(config)# ip route 171.20.5.3 255.255.255.255 vlan 1
Switch(config)# end
Switch#
```

This example shows how to use the **show running-config** command to confirm the configuration of the static route:

```
Switch# show running-config
Building configuration...
.
<...output truncated...>
.
```

```
ip default-gateway 172.20.52.35
ip classless
ip route 171.20.5.3 255.255.255.255 Vlan1
no ip http server
!
!
x25 host z
!
line con 0
 transport input none
line vty 0 4
 exec-timeout 0 0
 password lab
 login
 transport input lat pad dsipcon mop telnet rlogin udptn nasi
!
end

Switch#
```

Controlling Access to Privileged EXEC Commands

The procedures in these sections let you control access to the system configuration file and privileged EXEC commands:

Setting or Changing a Static enable Password

To set or change a static password that controls access to the enable mode, perform this task:

Command	Purpose
`Switch(config)# enable password` *password*	Sets a new password or changes an existing password for the privileged EXEC mode.

This example shows how to configure an enable password as “lab” at the privileged EXEC mode:

```
Switch# configure terminal
Switch(config)# enable password lab
Switch(config)#
```

For instructions on how to display the password or access level configuration, see the “Displaying the Password, Access Level, and Privilege Level Configuration” section on page 3-17.

Using the enable Password and enable secret Commands

To provide an additional layer of security, particularly for passwords that cross the network or that are stored on a TFTP server, you can use either the **enable password** or **enable secret** commands. Both commands configure an encrypted password that you must enter to access the enable mode (the default) or any other privilege level that you specify.

We recommend that you use the **enable secret** command.

If you configure the **enable secret** command, it takes precedence over the **enable password** command; the two commands cannot be in effect simultaneously.

To configure the switch to require an enable password, perform either one of these tasks:

Command	Purpose
`Switch(config)# enable password [level level] {password | encryption-type encrypted-password}`	Establishes a password for the privileged EXEC mode.
`Switch(config)# enable secret [level level] {password | encryption-type encrypted-password}`	Specifies a secret password that will be saved using a nonreversible encryption method. (If **enable password** and **enable secret** commands are both set, users must enter the enable secret password.)

When you enter either of these password commands with the **level** option, you 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** configuration command to specify commands accessible at various levels.

If you enable the **service password-encryption** command, the password you enter is encrypted. When you display the password with the **more system:running-config** command, the password displays the password in encrypted form.

If you specify an encryption type, you must provide an encrypted password—an encrypted password you copy from another Catalyst 4500 series switch configuration.

Note You cannot recover a lost encrypted password. You must clear NVRAM and set a new password. See the "Recovering a Lost Enable Password" section on page 3-18 for more information.

For information on how to display the password or access level configuration, see the "Displaying the Password, Access Level, and Privilege Level Configuration" section on page 3-17.

Setting or Changing a Privileged Password

To set or change a privileged password, perform this task:

Command	Purpose
`Switch(config-line)# password password`	Sets a new password or changes an existing password for the privileged level.

For information on how to display the password or access level configuration, see the "Displaying the Password, Access Level, and Privilege Level Configuration" section on page 3-17.

Setting TACACS+ Password Protection for Privileged EXEC Mode

For complete information about TACACS+ and RADIUS, refer to these publications:

- The "Authentication, Authorization, and Accounting (AAA)" chapter in the *Cisco IOS Security Configuration Guide*, Release 12.2, at the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/secur_c/scprt1/index.htm
- *Cisco IOS Security Command Reference*, Release 12.2, at the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/secur_r/index.htm

To set the TACACS+ protocol to determine whether a user can access privileged EXEC mode, perform this task:

Command	Purpose
`Switch(config)# enable use-tacacs`	Sets the TACACS-style user ID and password-checking mechanism for the privileged EXEC mode.

When you set TACACS password protection at the privileged EXEC mode, the **enable** EXEC command prompts you for a new username and a new password. This information is then passed to the TACACS+ server for authentication. If you are using the extended TACACS, another extension to the older TACACS protocol that provides additional functionality, it also passes any existing UNIX user identification code to the TACACS+ server.

An extension to the older TACACS protocol, supplying additional functionality to TACACS. Extended TACACS provides information about protocol translator and router use. This information is used in UNIX auditing trails and accounting files.

Note When used without extended TACACS, the **enable use-tacacs** command allows anyone with a valid username and password to access the privileged EXEC mode, creating a potential security risk. This problem occurs because the query resulting from entering the **enable** command is indistinguishable from an attempt to log in without extended TACACS.

Encrypting Passwords

Because protocol analyzers can examine packets (and read passwords), you can increase access security by configuring the Cisco IOS software to encrypt passwords. Encryption prevents the password from being readable in the configuration file.

To configure the Cisco IOS software to encrypt passwords, perform this task:

Command	Purpose
`Switch(config)# service password-encryption`	Encrypts a password.

Encryption occurs when the current configuration is written or when a password is configured. Password encryption is applied to all passwords, including authentication key passwords, the privileged command password, console and virtual terminal line access passwords, and Border Gateway Protocol (BGP) neighbor passwords. The **service password-encryption** command keeps unauthorized individuals from viewing your password in your configuration file.

Caution The **service password-encryption** command does not provide a high level of network security. If you use this command, you should also take additional network security measures.

Although you cannot recover a lost encrypted password (that is, you cannot get the original password back), you can regain control of the switch after having lost or forgotten the encrypted password. See the "Recovering a Lost Enable Password" section on page 3-18 for more information.

For information on how to display the password or access level configuration, see the "Displaying the Password, Access Level, and Privilege Level Configuration" section on page 3-17.

Configuring Multiple Privilege Levels

By default, the Cisco IOS software has two modes of password security: user EXEC mode and privileged EXEC mode. 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. If you want more restricted access to the **configure** command, you can assign it level 3 security and distribute that password to fewer users.

The procedures in the following sections describe how to configure additional levels of security:

Setting the Privilege Level for a Command

To set the privilege level for a command, perform this task:

	Command	Purpose
Step 1	`Switch(config)# privilege mode level level command`	Sets the privilege level for a command.
Step 2	`Switch(config)# enable password level level [encryption-type] password`	Specifies the enable password for a privilege level.

For information on how to display the password or access level configuration, see the "Displaying the Password, Access Level, and Privilege Level Configuration" section on page 3-17.

Changing the Default Privilege Level for Lines

To change the default privilege level for a given line or a group of lines, perform this task:

Command	Purpose
`Switch(config-line)# privilege level level`	Changes the default privilege level for the line.

For information on how to display the password or access level configuration, see the "Displaying the Password, Access Level, and Privilege Level Configuration" section on page 3-17.

Logging In to a Privilege Level

To log in at a specified privilege level, perform this task:

Command	Purpose
`Switch# enable level`	Logs in to a specified privilege level.

Exiting a Privilege Level

To exit to a specified privilege level, perform this task:

Command	Purpose
`Switch# disable level`	Exits to a specified privilege level.

Displaying the Password, Access Level, and Privilege Level Configuration

To display detailed password information, perform this task:

	Command	Purpose
Step 1	`Switch# show running-config`	Displays the password and access level configuration.
Step 2	`Switch# show privilege`	Shows the privilege level configuration.

This example shows how to display the password and access level configuration:

```
Switch# show running-config
Building configuration...

Current configuration:
!
version 12.0
service timestamps debug datetime localtime
service timestamps log datetime localtime
no service password-encryption
!
hostname Switch
!
boot system flash sup-bootflash
enable password lab
!
<...output truncated...>
```

This example shows how to display the privilege level configuration:

```
Switch# show privilege
Current privilege level is 15
Switch#
```

Recovering a Lost Enable Password

Note For more information on the configuration register which is preconfigured in NVRAM, see "Configuring the Software Configuration Register" section on page 3-19.

Perform these steps to recover a lost enable password:

Step 1 Connect to the console interface.

Step 2 Stop the boot sequence and enter ROM monitor by pressing **Ctrl-C** during the first 5 seconds of bootup.

Step 3 Configure the switch to boot-up without reading the configuration memory (NVRAM).

Step 4 Reboot the system.

Step 5 Access enable mode (this can be done without a password if a password has not been configured).

Step 6 View or change the password, or erase the configuration.

Step 7 Reconfigure the switch to boot-up and read the NVRAM as it normally does.

Step 8 Reboot the system.

Modifying the Supervisor Engine Startup Configuration

These sections describe how the startup configuration on the supervisor engine works and how to modify the configuration register and BOOT variable:

Understanding the Supervisor Engine Boot Configuration

The supervisor engine boot process involves two software images: ROM monitor and supervisor engine software. When the switch is booted or reset, the ROMMON code is executed. Depending on the NVRAM configuration, the supervisor engine either stays in ROMMON mode or loads the supervisor engine software.

Two user-configurable parameters determine how the switch boots: the configuration register and the BOOT environment variable. The configuration register is described in the "Modifying the Boot Field and Using the boot Command" section on page 3-21. The BOOT environment variable is described in the "Specifying the Startup System Image" section on page 3-23.

Understanding the ROM Monitor

The ROM monitor (ROMMON) is invoked at switch bootup, reset, or when a fatal exception occurs. The switch enters ROMMON mode if the switch does not find a valid software image, if the NVRAM configuration is corrupted, or if the configuration register is set to enter ROMMON mode. From ROMMON mode, you can manually load a software image from bootflash or a Flash disk, or you can boot up from the management interface. ROMMON mode loads a primary image from which you can configure a secondary image to boot up from a specified source either locally or through the network using the BOOTLDR environment variable. This variable is described in the "Switch#" section on page 3-24.

You can also enter ROMMON mode by restarting the switch and then pressing **Ctrl-C** during the first five seconds of startup. If you are connected through a terminal server, you can escape to the Telnet prompt and enter the **send break** command to enter ROMMON mode.

Note **Ctrl-C** is always enabled for five seconds after you reboot the switch, regardless of whether the configuration-register setting has **Ctrl-C** disabled.

The ROM monitor has these features:

- Power-on confidence test
- Hardware initialization
- Boot capability (manual bootup and autoboot)
- File system (read-only while in ROMMON)

Configuring the Software Configuration Register

The switch uses a 16-bit software configuration register, which allows you to set specific system parameters. Settings for the software configuration register are preconfigured in NVRAM.

Following are some reasons you might want to change the software configuration register settings:

- To select a boot source and default boot filename
- To control broadcast addresses
- To set the console terminal baud rate
- To load operating software from Flash memory
- To recover a lost password
- To manually boot the system using the **boot** command at the bootstrap program prompt
- To force an automatic bootup from the system bootstrap software (boot image) or from a default system image in onboard Flash memory, and read any **boot system** commands that are stored in the configuration file in NVRAM

Caution To avoid possibly halting the Catalyst 4500 series switch switch, remember that valid configuration register settings might be combinations of settings and not just the individual settings listed in Table 3-3. For example, the factory default value of 0x2101 is a combination of settings.

Table 3-3 lists the meaning of each of the software configuration memory bits. Table 3-4 defines the *boot field*.

Table 3-3 Software Configuration Register Bits

Bit Number[1]	Hexadecimal	Meaning
00 to 03	0x0000 to 0x000F	Boot field (see Table 3-4)
04	0x0010	Unused
05	0x0020	Bit two of console line speed
06	0x0040	Causes system software to ignore NVRAM contents
07	0x0080	OEM[2] bit enabled
08	0x0100	Unused
09	0x0200	Unused
10	0x0400	IP broadcast with all zeros
11 to 12	0x0800 to 0x1000	Bits one and zero of Console line speed (default is 9600 baud)
13	0x2000	Loads ROM monitor after netboot fails
14	0x4000	IP broadcasts do not have network numbers

1. The factory default value for the configuration register is 0x0102. This value is a combination of the following: binary bit 13, bit 8 = 0x0100 and binary bits 00 through 03 = 0x0001 (see Table 3-4).
2. OEM = original equipment manufacturer.

Table 3-4 Explanation of Boot Field (Configuration Register Bits 00 to 03)

Boot Field	Meaning
00	Stays at the system bootstrap prompt (does not autoboot).
01	Boots the first system image in onboard Flash memory.
02 to 0F	Autoboots using image(s) specified by the BOOT environment variable. If more than one image is specified, the switch attempts to boot the first image specified in the BOOT variable. As long as the switch can successfully boot from this image, the same image will be used on a reboot. If the switch fails to boot from the image specified in the BOOT variable, the switch will try to boot from the next image listed in the BOOT variable. If the end of the BOOT variable is reached without the switch booting successfully, the switch attempts the boot from the beginning of the BOOT variable. The autoboot continues until the switch successfully boots from one of the images specified in the BOOT variable.

Modifying the Boot Field and Using the boot Command

The configuration register boot field determines whether the switch loads an operating system image and, if so, where it obtains this system image. The following sections describe how to use and set the configuration register boot field and the procedures you must perform to modify the configuration register boot field. In ROMMON, you can use the **confreg** command to modify the configuration register and change boot settings.

Bits 0 through 3 of the software configuration register contain the boot field.

Note The factory default configuration register setting for systems and spares is 0x2101. However, the recommended value is 0x0102.

When the boot field is set to either 00 or 01 (0-0-0-0 or 0-0-0-1), the system ignores any boot instructions in the system configuration file and the following occurs:

- When the boot field is set to 00, you must boot up the operating system manually by issuing the **boot** command at the system bootstrap or ROMMON prompt.
- When the boot field is set to 01, the system boots the first image in the bootflash single in-line memory module (SIMM).
- When the entire boot field equals a value between 0-0-1-0 and 1-1-1-1, the switch loads the system image specified by **boot system** commands in the startup configuration file.

Caution If you set bootfield to a value between 0-0-1-0 and 1-1-1-1, you must specify a value in the **boot system** command, else the switch cannot boot up and will remain stuck in ROMMON.

You can enter the **boot** command only, or enter the command and include additional boot instructions, such as the name of a file stored in Flash memory, or a file that you specify for booting from a network server. If you use the **boot** command without specifying a file or any other boot instructions, the system boots from the default Flash image (the first image in onboard Flash memory). Otherwise, you can instruct the system to boot up from a specific Flash image (using the **boot system flash** *filename* command).

You can also use the **boot** command to boot up images stored in the compact Flash cards located in slot 0 on the supervisor engine.

Modifying the Boot Field

Modify the boot field from the software configuration register. To modify the software configuration register boot field, perform this task:

	Command	Purpose
Step 1	`Switch# show version`	Determines the current configuration register setting.
Step 2	`Switch# configure terminal`	Enters configuration mode, and specify the **terminal** option.
Step 3	`Switch(config)# config-register` *value*	Modifies the existing configuration register setting to reflect the way you want the switch to load a system image.

	Command	Purpose
Step 4	`Switch(config)# end`	Exits configuration mode.
Step 5	`Switch# reload`	Reboots the switch to make your changes take effect.

To modify the configuration register while the switch is running Cisco IOS software, follow these steps:

Step 1 Enter the **enable** command and your password to enter privileged level, as follows:

```
Switch> enable
Password:
Switch#
```

Step 2 Enter the **configure terminal** command at the EXEC mode prompt (#), as follows:

```
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#
```

Step 3 Configure the configuration register to 0x102 as follows:

```
Switch(config)# config-register 0x102
```

Set the contents of the configuration register by specifying the *value* command variable, where *value* is a hexadecimal number preceded by 0x (see Table 3-3 on page 3-20).

Step 4 Enter the **end** command to exit configuration mode. The new value settings are saved to memory; however, the new settings do not take effect until the system is rebooted.

Step 5 Enter the **show version** EXEC command to display the configuration register value currently in effect; it will be used at the next reload. The value is displayed on the last line of the screen display, as shown in this sample output:

```
Configuration register is 0x141 (will be 0x102 at next reload)
```

Step 6 Save your settings. (See the "Saving the Running Configuration Settings to Your Start-up File" section on page 3-10. Note that configuration register changes take effect only after the system reloads, such as when you enter a **reload** command from the console.)

Step 7 Reboot the system. The new configuration register value takes effect with the next system boot up.

Verifying the Configuration Register Setting

Enter the **show version** EXEC command to verify the current configuration register setting. In ROMMON mode, enter the **show version** command to verify the configuration register setting.

To verify the configuration register setting for the switch, perform this task:

Command	Purpose
`Switch# show version`	Displays the configuration register setting.

In this example, the **show version** command indicates that the current configuration register is set so that the switch does not automatically load an operating system image. Instead, it enters ROMMON mode and waits for you to enter ROM monitor commands.

```
Switch#show version
Cisco Internetwork Operating System Software
IOS (tm) Catalyst 4000 L3 Switch Software (cat4000-IS-M), Experimental
Version 12.1(20010828:211314) [cisco 105]
Copyright (c) 1986-2001 by cisco Systems, Inc.
Compiled Thu 06-Sep-01 15:40 by
Image text-base:0x00000000, data-base:0x00ADF444

ROM:1.15
Switch uptime is 10 minutes
System returned to ROM by reload
Running default software

cisco Catalyst 4000 (MPC8240) processor (revision 3) with 262144K bytes
of memory.
Processor board ID Ask SN 12345
Last reset from Reload
Bridging software.
49 FastEthernet/IEEE 802.3 interface(s)
20 Gigabit Ethernet/IEEE 802.3 interface(s)
271K bytes of non-volatile configuration memory.

Configuration register is 0xEC60

Switch#
```

Specifying the Startup System Image

You can enter multiple boot commands in the startup configuration file or in the BOOT environment variable to provide backup methods for loading a system image.

The BOOT environment variable is also described in the "Specify the Startup System Image in the Configuration File" section in the "Loading and Maintaining System Images and Microcode" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide*.

Use the following sections to configure your switch to boot from Flash memory. Flash memory can be either single in-line memory modules (SIMMs) or Flash disks. Check the appropriate hardware installation and maintenance guide for information about types of Flash memory.

Using Flash Memory

Flash memory allows you to do the following:

- Copy the system image to Flash memory using TFTP
- Boot the system from Flash memory either automatically or manually
- Copy the Flash memory image to a network server using TFTP or RCP

Flash Memory Features

Flash memory allows you to do the following:

- Remotely load multiple system software images through TFTP or RCP transfers (one transfer for each file loaded)
- Boot a switch manually or automatically from a system software image stored in Flash memory (you can also boot directly from ROM)

Security Precautions

Note the following security precaution when loading from Flash memory:

Caution You can only change the system image stored in Flash memory from privileged EXEC level on the console terminal.

Configuring Flash Memory

To configure your switch to boot from Flash memory, perform the following procedure. (Refer to the appropriate hardware installation and maintenance publication for complete instructions on installing the hardware.)

Step 1 Copy a system image to Flash memory using TFTP or other protocols. Refer to the "Cisco IOS File Management" and "Loading and Maintaining System Images" chapters in the *Cisco IOS Configuration Fundamentals Configuration Guide*, Release 12.2, at the following URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fun_c/fcprt2/fcd203.htm

Step 2 Configure the system to boot automatically from the desired file in Flash memory. You might need to change the configuration register value. See the "Modifying the Boot Field and Using the boot Command" section on page 3-21, for more information on modifying the configuration register.

Step 3 Save your configurations.

Step 4 Power cycle and reboot your system to verify that all is working as expected.

Controlling Environment Variables

Although the ROM monitor controls environment variables, you can create, modify, or view them with certain commands. To create or modify the BOOT and BOOTLDR variables, use the **boot system** and **boot bootldr** global configuration commands, respectively. Refer to the "Specify the Startup System Image in the Configuration File" section in the "Loading and Maintaining System Images and Microcode" chapter of the *Configuration Fundamentals Configuration Guide* for details on setting the BOOT environment variable.

Note When you use the **boot system** and **boot bootldr** global configuration commands, you affect only the running configuration. To save the configuration for future use, you must save the environment variable settings to your startup configuration, which places the information under ROM monitor control. Enter the **copy system:running-config nvram:startup-config** command to save the environment variables from your running configuration to your startup configuration.

You can view the contents of the BOOT and BOOTLDR variables using the **show bootvar** command. This command displays the settings for these variables as they exist in the startup configuration and in the running configuration if a running configuration setting differs from a startup configuration setting. This example shows how to check the BOOT and BOOTLDR variables on the switch:

```
Switch# show bootvar
BOOTLDR variable = bootflash:cat4000-is-mz,1;
Configuration register is 0x0
Switch#
```

Configuring Interfaces

This chapter describes how to configure interfaces for the Catalyst 4500 series switches. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Interface Configuration

By default, all interfaces are enabled. The 10/100-Mbps Ethernet interfaces autonegotiate connection speed and duplex. The 10/100/1000-Mbps Ethernet interfaces negotiate speed, duplex, and flow control. The 1000-Mbps Ethernet interfaces negotiate flow control only. Autonegotiation automatically selects the fastest speed possible on that port for the given pair. If a speed is explicitly stated for an interface, that interface will default to half duplex unless it is explicitly set for full duplex.

Many features are enabled on a per-interface basis. When you enter the **interface** command, you must specify the following:

- Interface type:
  - Fast Ethernet (use the **fastethernet** keyword)
  - Gigabit Ethernet (use the **gigabitethernet** keyword)

- Slot number—The slot in which the interface module is installed. Slots are numbered starting with 1, from top to bottom.
- Interface number—The interface number on the module. The interface numbers always begin with 1. When you are facing the front of the switch, the interfaces are numbered from left to right.

You can identify interfaces by physically checking the slot/interface location on the switch. You can also use the Cisco IOS **show** commands to display information about a specific interface or all the interfaces.

Using the interface Command

These general instructions apply to all interface configuration processes.

Step 1 At the privileged EXEC prompt, enter the **configure terminal** command to enter global configuration mode:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)#
```

Step 2 In global configuration mode, enter the **interface** command. Identify the interface type and the number of the connector on the interface card. The following example shows how to select Fast Ethernet, slot 5, interface 1:

```
Switch(config)# interface fastethernet 5/1
Switch(config-if)#
```

Step 3 Interface numbers are assigned at the factory at the time of installation or when modules are added to a system. Enter the **show interfaces** EXEC command to see a list of all interfaces installed on your switch. A report is provided for each interface that your switch supports, as shown in this display:

```
Switch(config-if)#Ctrl-Z
Switch#show interfaces
Vlan1 is up, line protocol is down
  Hardware is Ethernet SVI, address is 0004.dd46.7aff (bia 0004.dd46.7aff)
  MTU 1500 bytes, BW 1000000 Kbit, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 interface resets
     0 output buffer failures, 0 output buffers swapped out
GigabitEthernet1/1 is up, line protocol is down
  Hardware is Gigabit Ethernet Port, address is 0004.dd46.7700 (bia 0004.dd46.7700)
  MTU 1500 bytes, BW 1000000 Kbit, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Auto-duplex, Auto-speed
  ARP type: ARPA, ARP Timeout 04:00:00
```

```
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/2000/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 input packets with dribble condition detected
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 babbles, 0 late collision, 0 deferred
     0 lost carrier, 0 no carrier
     0 output buffer failures, 0 output buffers swapped out
GigabitEthernet1/2 is up, line protocol is down
  Hardware is Gigabit Ethernet Port, address is 0004.dd46.7701 (bia 0004.dd46.7701)
  MTU 1500 bytes, BW 1000000 Kbit, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Auto-duplex, Auto-speed
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/2000/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 input packets with dribble condition detected
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 babbles, 0 late collision, 0 deferred
     0 lost carrier, 0 no carrier
     0 output buffer failures, 0 output buffers swapped out
--More--
<...output truncated...>
```

Step 4 To begin configuring Fast Ethernet interface 5/5, as shown in the following example, enter the **interface** keyword, interface type, slot number, and interface number in global configuration mode:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/5
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 **fastethernet 5/5 or fastethernet5/5**.

Step 5 Follow each **interface** command with the interface configuration commands your particular interface requires. The commands you enter define the protocols and applications that will run on the interface. The commands are collected and applied to the **interface** command until you enter another **interface** command or press **Ctrl-Z** to exit interface configuration mode and return to privileged EXEC mode.

Step 6 After you configure an interface, check its status by using the EXEC **show** commands listed in "Monitoring and Maintaining the Interface" section on page 4-13.

Configuring a Range of Interfaces

The interface-range configuration mode allows you to configure multiple interfaces with the same configuration parameters. When you enter the interface-range configuration mode, all command parameters you enter are attributed to all interfaces within that range until you exit interface-range configuration mode.

To configure a range of interfaces with the same configuration, perform this task:

Command	Purpose
`Switch(config)# interface range {vlan vlan_ID - vlan_ID} | {{fastethernet | gigabitethernet | macro macro_name} slot/interface - interface} [, {vlan vlan_ID - vlan_ID} {{fastethernet | gigabitethernet | macro macro_name} slot/interface - interface}]`	Selects the range of interfaces to be configured. Note the following: • You are required to enter a space before the dash. • You can enter up to five comma-separated ranges. • You are not required to enter spaces before or after the comma.

Note When you use the **interface range** command, you must add a space between the **vlan**, **fastethernet**, **gigabitethernet**, or **macro** keyword and the dash. For example, the command **interface range fastethernet 5/1 - 5** specifies a valid range; the command **interface range fastethernet 1-5** does not contain a valid range command.

Note The **interface range** command works only with VLAN interfaces that have been configured with the **interface vlan** command (the **show running-configuration** command displays the configured VLAN interfaces). VLAN interfaces that are not displayed by the **show running-configuration** command cannot be used with the **interface range** command.

This example shows how to reenable all Fast Ethernet interfaces 5/1 to 5/5:

```
Switch(config)# interface range fastethernet 5/1 - 5
Switch(config-if-range)# no shutdown
Switch(config-if-range)#
*Oct  6 08:24:35: %LINK-3-UPDOWN: Interface FastEthernet5/1, changed state to up
*Oct  6 08:24:35: %LINK-3-UPDOWN: Interface FastEthernet5/2, changed state to up
*Oct  6 08:24:35: %LINK-3-UPDOWN: Interface FastEthernet5/3, changed state to up
*Oct  6 08:24:35: %LINK-3-UPDOWN: Interface FastEthernet5/4, changed state to up
*Oct  6 08:24:35: %LINK-3-UPDOWN: Interface FastEthernet5/5, changed state to up
*Oct  6 08:24:36: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
5, changed state to up
*Oct  6 08:24:36: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
3, changed state to up
*Oct  6 08:24:36: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
4, changed state to up
Switch(config-if)#
```

This example shows how to use a comma to add different interface type strings to the range to reenable all Fast Ethernet interfaces in the range 5/1 to 5/5 and both Gigabit Ethernet interfaces 1/1 and 1/2:

```
Switch(config-if)# interface range fastethernet 5/1 - 5, gigabitethernet 1/1 - 2
Switch(config-if)# no shutdown
Switch(config-if)#
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface FastEthernet5/1, changed state to up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface FastEthernet5/2, changed state to up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface FastEthernet5/3, changed state to up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface FastEthernet5/4, changed state to up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface FastEthernet5/5, changed state to up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface GigabitEthernet1/1, changed state to
 up
*Oct  6 08:29:28: %LINK-3-UPDOWN: Interface GigabitEthernet1/2, changed state to
 up
*Oct  6 08:29:29: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
5, changed state to up
*Oct  6 08:29:29: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
3, changed state to up
*Oct  6 08:29:29: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet5/
4, changed state to up
Switch(config-if)#
```

If you enter multiple configuration commands while you are in interface-range configuration mode, each command is run as it is entered (they are not batched together and run after you exit interface-range configuration mode). If you exit interface-range configuration mode while the commands are being run, some commands might not be run on all interfaces in the range. Wait until the command prompt is displayed before exiting interface-range configuration mode.

Defining and Using Interface-Range Macros

You can define 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 command string, you must define the macro.

To define an interface-range macro, perform this task:

Command	Purpose
`Switch(config)# define interface-range macro_name {vlan vlan_ID - vlan_ID} | {{fastethernet | gigabitethernet} slot/interface - interface} [, {vlan vlan_ID - vlan_ID} {{fastethernet | gigabitethernet} slot/interface - interface}]`	Defines the interface-range macro and saves it in the running configuration file.

This example shows how to define an interface-range macro named **enet_list** to select Fast Ethernet interfaces 5/1 through 5/4:

```
Switch(config)# define interface-range enet_list fastethernet 5/1 - 4
```

To show the defined interface-range macro configuration, perform this task:

Command	Purpose
`Switch# show running-config`	Shows the defined interface-range macro configuration.

This example shows how to display the defined interface-range macro named **enet_list**:

```
Switch# show running-config | include define
define interface-range enet_list FastEthernet5/1 - 4
Switch#
```

To use an interface-range macro in the **interface range** command, perform this task:

Command	Purpose
`Switch(config)# interface range macro name`	Selects the interface range to be configured using the values saved in a named interface-range macro.

This example shows how to change to the interface-range configuration mode using the interface-range macro **enet_list**:

```
Switch(config)# interface range macro enet_list
Switch(config-if)#
```

Configuring Optional Interface Features

The following subsections describe optional procedures:

Configuring Ethernet Interface Speed and Duplex Mode

Speed and Duplex Mode Configuration Guidelines

You can configure the interface speed and duplex mode parameters to **auto** and allow the Catalyst 4500 series switch to negotiate the interface speed and duplex mode between interfaces. If you decide to configure the interface **speed** and **duplex** commands manually, consider the following:

- If you set the interface **speed** to **auto**, the switch automatically sets the **duplex** mode to **auto**.
- If you enter the **no speed** command, the switch automatically configures both interface **speed** and **duplex** to **auto**.
- When you set the interface speed to 1000 Mbps, the duplex mode is full duplex. You cannot change the duplex mode.
- If the interface speed is set to 10 or 100 mbps, the duplex mode is set to half duplex by default unless you explicitly configure it.

Caution Changing the interface speed and duplex mode configuration might shut down and restart the interface during the reconfiguration.

Setting the Interface Speed

If you set the interface speed to **auto** on a 10/100-Mbps Ethernet interface, speed and duplex are autonegotiated.

To set the port speed for a 10/100-Mbps Ethernet interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface fastethernet slot/interface`	Specifies the interface to be configured.
Step 2	`Switch(config-if)# speed [10 | 100 | auto]`	Sets the interface speed of the interface.

This example shows how to set the interface speed to 100 Mbps on the Fast Ethernet interface 5/4:

```
Switch(config)# interface fastethernet 5/4
Switch(config-if)# speed 100
```

Turning off autonegotiation on a Gigabit Ethernet interface will result in the port being forced into 1000 Mbps and full-duplex mode. To turn off the port speed autonegotiation for Gigabit Ethernet interface 1/1, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface gigabitethernet1/1`	Specifies the interface to be configured.
Step 2	`Switch(config-if)# speed nonegotiate`	Disables autonegotiation on the interface.

To restore autonegotiation, enter the **no speed nonegotiate** command in the interface configuration mode.

Note For the blocking ports on the WS-X4416 module, do not set the speed to autonegotiate.

Setting the Interface Duplex Mode

Note When the interface is set to 1000 Mbps, you cannot change the duplex mode from full duplex to half duplex.

Note If you set the port speed to **auto** on a 10/100-Mbps Ethernet interface, both speed and duplex mode are autonegotiated. The configured duplex mode is not applied on autonegotiation interfaces.

To set the duplex mode of a Fast Ethernet interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface fastethernet` *slot/interface*	Specifies the interface to be configured.
Step 2	`Switch(config-if)# duplex [auto | full | half]`	Sets the duplex mode of the interface.

This example shows how to set the interface duplex mode to full on Fast Ethernet interface 5/4:

```
Switch(config)# interface fastethernet 5/4
Switch(config-if)# duplex full
```

Displaying the Interface Speed and Duplex Mode Configuration

To display the interface speed and duplex mode configuration for an interface, perform this task:

Command	Purpose
`Switch# show interfaces [fastethernet | gigabitethernet] slot/interface`	Displays the interface speed and duplex mode configuration.

This example shows how to display the interface speed and duplex mode of Fast Ethernet interface 6/1:

```
Switch# show interface fastethernet 6/1
FastEthernet6/1 is up, line protocol is up
  Hardware is Fast Ethernet Port, address is 0050.547a.dee0 (bia 0050.547a.dee0)
  MTU 1500 bytes, BW 100000 Kbit, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full-duplex, 100Mb/s
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input 00:00:54, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 50/2000/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     50 packets input, 11300 bytes, 0 no buffer
     Received 50 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 input packets with dribble condition detected
     1456 packets output, 111609 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 babbles, 0 late collision, 0 deferred
     1 lost carrier, 0 no carrier
     0 output buffer failures, 0 output buffers swapped out
Switch#
```

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 the following commands: **show configuration**, **show running-config**, and **show interfaces**.

To add a description for an interface, enter the following command:

Command	Purpose
`Switch(config-if)# description` *string*	Adds a description for an interface.

This example shows how to add a description on Fast Ethernet interface 5/5:

```
Switch(config)# interface fastethernet 5/5
Switch(config-if)# description Channel-group to "Marketing"
```

Configuring Jumbo Frame Support

These subsections describe jumbo frame support:

Ports and Modules that Support Jumbo Frames

The following ports and modules support jumbo frames:

- Supervisor uplink ports
- WS-X4306-GB: all ports
- WS-X4232-GB-RJ: ports 1-2
- WS-X4418-GB: ports 1-2
- WS-X4412-2GB-TX: ports 13-14

  Each of the last three modules has two non-blocking ports that can support jumbo frames. Other ports are over-subscribed ports and cannot support jumbo frames.

Understanding Jumbo Frame Support

These sections describe jumbo frame support:

- Jumbo Frame Support Overview, page 4-10
- Ethernet Ports, page 4-10
- VLAN Interfaces, page 4-11

Jumbo Frame Support Overview

A jumbo frame is a frame larger than the default Ethernet size. Enable jumbo frame support by configuring a larger-than-default maximum transmission unit (MTU) size on a port or interface.

Catalyst 4500 series switch Ethernet LAN ports configured with a nondefault MTU size accept frames containing packets with a size between 1500 and 9198 bytes. With a nondefault MTU size configured, the packet size of ingress frames is checked. If the packet is larger than the configured MTU, it is dropped.

For traffic that needs to be routed, the MTU of the egress port is checked. If the MTU is smaller than the packet size, the packet is forwarded to the CPU. If the "do not fragment bit" is not set, it is fragmented. Otherwise, the packet is dropped.

Note Jumbo frame support does not fragment Layer 2 switched packets.

The Catalyst 4500 series switch does not compare the packet size with the MTU at the egress port, but jumbo frames are dropped in ports that do not support them. The frames can be transmitted in ports that do support jumbo frames, even though the MTU is not configured to jumbo size.

Note Jumbo frame support is only configured per interface; jumbo frame support cannot be configured globally.

Ethernet Ports

These sections describe configuring nondefault MTU sizes on Ethernet ports:

- Ethernet Port Overview, page 4-11
- Layer 3 and Layer 2 EtherChannels, page 4-11

Ethernet Port Overview

With Cisco IOS Release 12.2(20)EW, configuring a nondefault MTU size on certain Ethernet port limits the size of ingress packets. The MTU does not impact the egress packets.

With releases earlier than Cisco IOS Release 12.1(13)EW, you can configure the MTU size only on Gigabit Ethernet and 10-Gigabit Ethernet ports.

Layer 3 and Layer 2 EtherChannels

With Release Cisco IOS Release 12.2(20)EW and later releases, you can configure all the interfaces in an EtherChannel provided that they have the same MTU. Changing the MTU of an EtherChannel changes the MTU of all member ports. If the MTU of a member port cannot be changed to the new value, that port is suspended (administratively shut down). A port cannot join an EtherChannel if the port has a different MTU. If a member port of an EtherChannel changes MTU, the member port is suspended.

VLAN Interfaces

If switch ports reside in the same VLAN, either configure all of the switch ports to handle jumbo frames and support the same MTU size, or configure none of them. However, such uniformity of MTU size in the same VLAN is not enforced.

When a VLAN has switch ports with different MTU size, packets received from a port with a larger MTU might be dropped when they are forwarded to a port with a smaller MTU.

If the switch ports in a VLAN have jumbo frames enabled, the corresponding SVI can have jumbo frames enabled. The MTU of an SVI should always be smaller than the smallest MTU among all the switch ports in the VLAN, but this condition is not enforced.

The MTU of a packet is not checked on the ingress side for an SVI; it is checked on the egress side of an SVI. If the MTU of a packet is larger than the MTU of the egress SVI, the packet will be sent to the CPU for fragmentation processing. If the “do not fragment” bit is not set, the packet is fragmented. Otherwise, the packet is dropped.

Configuring MTU Sizes

To configure the MTU size, perform this task:

	Command	Purpose
Step 1	`Router(config)# interface {{vlan vlan_ID} | {{type[1] slot/port} | {port-channel port_channel_number} slot/port}}`	Selects the interface to configure.
Step 2	`Router(config-if)# mtu mtu_size`	Configures the MTU size.
	`Router(config-if)# no mtu`	Reverts to the default MTU size (1500 bytes).
Step 3	`Router(config-if)# end`	Exits configuration mode.
Step 4	`Router# show running-config interface [{fastethernet | gigabitethernet} slot/port]`	Displays the running configuration.

1. *type* = **fastethernet** or **gigabitethernet**

Note When configuring the MTU size for VLAN interfaces and Layer 3 and Layer 2 Ethernet ports, note that the supported MTU values are from 1500 to 9198 bytes.

This example shows how to configure the MTU size on Gigabit Ethernet port 1/2:

```
switch# conf t
switch(config)# int gi1/1
switch(config-if)# mtu 9198
switch(config-if)# end
```

This example shows how to verify the configuration:

```
switch# show interface gigabitethernet 1/2
GigabitEthernet1/2 is administratively down, line protocol is down
  Hardware is C6k 1000Mb 802.3, address is 0030.9629.9f88 (bia 0030.9629.9f88)
  MTU 9216 bytes, BW 1000000 Kbit, DLY 10 usec,
<...Output Truncated...>
switch#
```

Interacting with the Baby Giants Feature

The baby giants feature, introduced in Cisco IOS Release 12.1(12c)EW, uses the global command **system mtu <size>** to set the global baby giant MTU. This feature also allows certain interfaces to support Ethernet payload size of up to 1552 bytes.

Both the **system mtu** command and the per-interface **mtu** command can operate on interfaces that can support jumbo frames, but the per-interface **mtu** command takes precedence.

For example, let's say that before setting the per-interface MTU for interface gi1/1, you issue the **system mtu 1550** command to change the MTU for gi1/1 to 1550 bytes. Next, you issue the per-interface **mtu** command to change the MTU for gi1/1 to 9198 bytes. Now, if you change the baby giant MTU to 1540 bytes with the command **system mtu 1540**, the MTU for gi1/1 remains unchanged at 9198 bytes.

Understanding Online Insertion and Removal

The online insertion and removal (OIR) feature supported on the Catalyst 4500 series switch allows you to remove and replace modules while the system is online. You can shut down the module before removal and restart it after insertion without causing other software or interfaces to shut down.

You do not need to enter a command to notify the software that you are going to remove or install a module. The system notifies the supervisor engine that a module has been removed or installed and scans the system for a configuration change. The newly installed module is initialized, and each interface type is verified against the system configuration; then the system runs diagnostics on the new interface. There is no disruption to normal operation during module insertion or removal.

If you remove a module and then replace it, or insert a different module of the same type into the same slot, no change to the system configuration is needed. An interface of a type that has been configured previously will be brought online immediately. If you remove a module and insert a module of a different type, the interface(s) on that module will be administratively up with the default configuration for that module.

Monitoring and Maintaining the Interface

The following sections describe how to monitor and maintain the interfaces:

Monitoring Interface and Controller Status

The Cisco IOS software for the Catalyst 4500 series switch contains commands that you can enter at the EXEC prompt to display information about the interface, including the version of the software and the hardware, the controller status, and statistics about the interfaces. The following table lists some of the interface monitoring commands. (You can display the full list of **show** commands by entering the **show ?** command at the EXEC prompt.) These commands are fully described in the *Interface Command Reference*.

To display information about the interface, perform this task:

	Command	Purpose
Step 1	`Switch# show interfaces [type slot/interface]`	Displays the status and configuration of all interfaces or of a specific interface.
Step 2	`Switch# show running-config`	Displays the configuration currently running in RAM.
Step 3	`Switch# show protocols [type slot/interface]`	Displays the global (system-wide) and interface-specific status of any configured protocol.
Step 4	`Switch# show version`	Displays the hardware configuration, software version, the names and sources of configuration files, and the boot images.

This example shows how to display the status of Fast Ethernet interface 5/5:

```
Switch# show protocols fastethernet 5/5
FastEthernet5/5 is up, line protocol is up
Switch#
```

Clearing and Resetting the Interface

To clear the interface counters shown with the **show interfaces** command, enter the following command:

Command	Purpose
`Switch# clear counters {type slot/interface}`	Clears interface counters.

This example shows how to clear and reset the counters on Fast Ethernet interface 5/5:

```
Switch# clear counters fastethernet 5/5
Clear "show interface" counters on this interface [confirm] y
Switch#
*Sep 30 08:42:55: %CLEAR-5-COUNTERS: Clear counter on interface FastEthernet5/5
by vty1 (171.69.115.10)
Switch#
```

The **clear counters** command (without any arguments) clears all the current interface counters from all interfaces.

Note The **clear counters** command does not clear counters retrieved with SNMP; it clears only those counters displayed with the EXEC **show interfaces** command.

Shutting Down and Restarting an Interface

You can disable an interface, which 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 will not be mentioned in any routing updates.

To shut down an interface and then restart it, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {vlan vlan_ID} | {{fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}`	Specifies the interface to be configured.
Step 2	`Switch(config-if)# shutdown`	Shuts down the interface.
Step 3	`Switch(config-if)# no shutdown`	Reenables the interface.

This example shows how to shut down Fast Ethernet interface 5/5:

```
Switch(config)# interface fastethernet 5/5
Switch(config-if)# shutdown
Switch(config-if)#
*Sep 30 08:33:47: %LINK-5-CHANGED: Interface FastEthernet5/5, changed state to a
administratively down
Switch(config-if)#
```

This example shows how to reenable Fast Ethernet interface 5/5:

```
Switch(config-if)# no shutdown
Switch(config-if)#
*Sep 30 08:36:00: %LINK-3-UPDOWN: Interface FastEthernet5/5, changed state to up
Switch(config-if)#
```

To check whether or not an interface is disabled, enter the EXEC **show interfaces** command. An interface that has been shut down is shown as being administratively down when you enter the **show interfaces** command.

Checking Port Status and Connectivity

This chapter describes how to check switch port status and connectivity on the Catalyst 4500 series switch.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Checking Module Status

The Catalyst 4500 series switch is a multimodule system. You can see which modules are installed, as well as the MAC address ranges and version numbers for each module, by using the **show module** command. You can use the [*mod_num*] argument to specify a particular module number to see detailed information on that module.

This example shows how to check module status for all modules on your switch:

```
Switch# show module all

Mod  Ports Card Type                                  Model              Serial No.
---+-----+--------------------------------------+------------------+-----------
 1     2   1000BaseX (GBIC) Supervisor Module     WS-X4014         JAB012345AB
 5    24   10/100/1000BaseTX (RJ45)               WS-X4424-GB-RJ45 JAB045304EY
 6    48   10/100BaseTX (RJ45)                    WS-X4148         JAB023402QK

 M MAC addresses                   Hw  Fw                Sw               Stat
--+--------------------------------+---+-----------------+----------------+-----
 1 0004.dd46.9f00 to 0004.dd46.a2ff 0.0 12.1(10r)EW(1.21) 12.1(10)EW(1)    Ok
 5 0050.3e7e.1d70 to 0050.3e7e.1d87 0.0                                    Ok
 6 0050.0f10.2370 to 0050.0f10.239f 1.0                                    Ok
Switch#
```

Checking Interfaces Status

You can view summary or detailed information on the switch ports using the **show interfaces status** command. To see summary information on all of the ports on the switch, enter the **show interfaces status** command with no arguments. Specify a particular module number to see information on the ports on that module only. Enter both the module number and the port number to see detailed information about the specified port.

To apply configuration commands to a particular port, you must specify the appropriate logical module. For more information, see the "Checking Module Status" section on page 5-1.

This example shows how to display the status of all interfaces on a Catalyst 4500 series switch:

```
Switch#show interfaces status

Port    Name               Status       Vlan       Duplex  Speed Type
Gi1/1                      notconnect   1            auto   auto No Gbic
Gi1/2                      notconnect   1            auto   auto No Gbic
Gi5/1                      notconnect   1            auto   auto 10/100/1000-TX
Gi5/2                      notconnect   1            auto   auto 10/100/1000-TX
Gi5/3                      notconnect   1            auto   auto 10/100/1000-TX
Gi5/4                      notconnect   1            auto   auto 10/100/1000-TX
Fa6/1                      connected    1          a-full  a-100 10/100BaseTX
Fa6/2                      connected    2          a-full  a-100 10/100BaseTX
Fa6/3                      notconnect   1            auto   auto 10/100BaseTX
Fa6/4                      notconnect   1            auto   auto 10/100BaseTX

Switch#
```

This example shows how to display the status of interfaces in error-disabled state:

```
Switch# show interfaces status err-disabled
Port    Name               Status         Reason
Fa9/4                      err-disabled   link-flap
informational error message when the timer expires on a cause
-----------------------------------------------------------
5d04h:%PM-SP-4-ERR_RECOVER:Attempting to recover from link-flap err-disable state on Fa9/4
Switch#
```

Checking MAC Addresses

In addition to displaying the MAC address range for a module using the **show module** command, you can display the MAC address table information of a specific MAC address or a specific interface in the switch using the **show mac-address-table address** and **show mac-address-table interface** commands.

This example shows how to display MAC address table information for a specific MAC address:

```
Switch# show mac-address-table address 0050.3e8d.6400
vlan   mac address     type    protocol  qos             ports
-----+---------------+--------+---------+---+--------------------------------
 200  0050.3e8d.6400  static   assigned  --  Switch
 100  0050.3e8d.6400  static   assigned  --  Switch
   5  0050.3e8d.6400  static   assigned  --  Switch
   4  0050.3e8d.6400  static        ipx  --  Switch
   1  0050.3e8d.6400  static        ipx  --  Switch
   1  0050.3e8d.6400  static   assigned  --  Switch
   4  0050.3e8d.6400  static   assigned  --  Switch
   5  0050.3e8d.6400  static        ipx  --  Switch
 100  0050.3e8d.6400  static        ipx  --  Switch
 200  0050.3e8d.6400  static        ipx  --  Switch
 100  0050.3e8d.6400  static      other  --  Switch
 200  0050.3e8d.6400  static      other  --  Switch
   5  0050.3e8d.6400  static      other  --  Switch
   4  0050.3e8d.6400  static         ip  --  Switch
   1  0050.3e8d.6400  static         ip  --  Route
   1  0050.3e8d.6400  static      other  --  Switch
   4  0050.3e8d.6400  static      other  --  Switch
   5  0050.3e8d.6400  static         ip  --  Switch
 200  0050.3e8d.6400  static         ip  --  Switch
 100  0050.3e8d.6400  static         ip  --  Switch
Switch#
```

This example shows how to display MAC address table information for a specific interface:

```
Switch# show mac-address-table interface gigabit 1/1
Multicast Entries
 vlan    mac address     type    ports
-------+---------------+-------+-----------------------------------------
   1    ffff.ffff.ffff system Switch,Gi6/1,Gi6/2,Gi6/9,Gi1/1
Switch#
```

Using Telnet

You can access the switch command-line interface (CLI) using Telnet. In addition, you can use Telnet from the switch to access other devices in the network. You can have up to eight simultaneous Telnet sessions.

Before you can open a Telnet session to the switch, you must first set the IP address (and in some cases the default gateway) for the switch. For information about setting the IP address and default gateway, see Chapter 3, “Configuring the Switch for the First Time.”

Note To establish a Telnet connection to a host by using the hostname, configure and enable DNS.

To establish a Telnet connection to another device on the network from the switch, perform this task:

Command	Purpose
Switch# **telnet** *host* [*port*]	Opens a Telnet session to a remote host.

This example shows how to establish a Telnet connection from the switch to the remote host named labsparc:

```
Switch# telnet labsparc
Trying 172.16.10.3...
Connected to labsparc.
Escape character is '^]'.

UNIX(r) System V Release 4.0 (labsparc)

login:
```

Changing the Logout Timer

The logout timer automatically disconnects a user from the switch when the user is idle for longer than the specified time. To set the logout timer, perform this task:

Command	Purpose
Switch# **logoutwarning** *number*	Changes the logout timer value (a timeout value of 0 prevents idle sessions from being disconnected automatically). Use the **no** keyword to return to the default value.

Monitoring User Sessions

You can display the currently active user sessions on the switch using the **show users** command. The command output lists all active console port and Telnet sessions on the switch.

To display the active user sessions on the switch, perform this task in privileged EXEC mode:

Command	Purpose
Switch# **show users** [**all**]	Displays the currently active user sessions on the switch.

This example shows the output of the **show users** command when local authentication is enabled for console and Telnet sessions (the asterisk [*] indicates the current session):

```
Switch#show users
    Line       User       Host(s)              Idle       Location
*  0 con 0                 idle                 00:00:00

  Interface      User        Mode                    Idle     Peer Address

Switch#show users all
    Line       User       Host(s)              Idle       Location
*  0 con 0                 idle                 00:00:00
   1 vty 0                                     00:00:00
   2 vty 1                                     00:00:00
   3 vty 2                                     00:00:00
   4 vty 3                                     00:00:00
   5 vty 4                                     00:00:00

  Interface      User        Mode                    Idle     Peer Address
Switch#
```

To disconnect an active user session, perform this task:

Command	Purpose
`Switch# disconnect {console | ip_addr}`	Disconnects an active user session on the switch.

This example shows how to disconnect an active console port session and an active Telnet session:

```
Switch> disconnect console
Console session disconnected.
Console> (enable) disconnect tim-nt.bigcorp.com
Telnet session from tim-nt.bigcorp.com disconnected. (1)
Switch# show users
  Session  User             Location
  -------- ---------------- -------------------------
  telnet   jake             jake-mac.bigcorp.com
* telnet   suzy             suzy-pc.bigcorp.com
Switch#
```

Using Ping

These sections describe how to use IP ping:

- Understanding How Ping Works, page 5-5
- Running Ping, page 5-6

Understanding How Ping Works

You can use the **ping** command to verify connectivity to remote hosts. If you attempt to ping a host in a different IP subnetwork, you must define a static route to the network or configure a router to route between those subnets.

The **ping** command is configurable from normal executive and privileged EXEC mode. Ping returns one of the following 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.

To stop a ping in progress, press **Ctrl-C**.

Running Ping

To ping another device on the network from the switch, perform this task:

Command	Purpose
`Switch# ping host`	Checks connectivity to a remote host.

This example shows how to ping a remote host from normal executive mode:

```
Switch# ping labsparc
labsparc is alive
Switch> ping 72.16.10.3
12.16.10.3 is alive
Switch#
```

This example shows how to enter a **ping** command in privileged EXEC mode specifying the number of packets, the packet size, and the timeout period:

```
Switch# ping
Target IP Address []: 12.20.5.19
Number of Packets [5]: 10
Datagram Size [56]: 100
Timeout in seconds [2]: 10
Source IP Address [12.20.2.18]: 12.20.2.18
!!!!!!!!!!

----12.20.2.19 PING Statistics----
10 packets transmitted, 10 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 1/1/1
Switch
```

Using IP Traceroute

These sections describe how to use IP traceroute feature:

Understanding How IP Traceroute Works

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.

Layer 2 switches can participate as the source or destination of the **trace** command but will not appear as a hop in the **trace** command output.

The **trace** 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 back an Internet Control Message Protocol (ICMP) Time-Exceeded message to the sender. Traceroute determines the address of the first hop by examining the source address field of the ICMP Time-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-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 determine when a datagram reaches its destination, traceroute sets the UDP destination port in the datagram to a very large value that the destination host is unlikely to be using. When a host receives a datagram with an unrecognized port number, it sends an ICMP Port Unreachable error message to the source. The Port Unreachable error message indicates to traceroute that the destination has been reached.

Running IP Traceroute

To trace the path that packets take through the network, perform this task in EXEC or privileged EXEC mode:

Command	Purpose
`Switch# trace [protocol] [destination]`	Runs IP traceroute to trace the path that packets take through the network.

This example shows use the **trace** command to display the route a packet takes through the network to reach its destination:

```
Switch# trace ip ABA.NYC.mil

Type escape sequence to abort.
Tracing the route to ABA.NYC.mil (26.0.0.73)
  1 DEBRIS.CISCO.COM (192.180.1.6) 1000 msec 8 msec 4 msec
  2 BARRNET-GW.CISCO.COM (192.180.16.2) 8 msec 8 msec 8 msec
  3 EXTERNAL-A-GATEWAY.STANFORD.EDU (192.42.110.225) 8 msec 4 msec 4 msec
  4 BB2.SU.BARRNET.NET (192.200.254.6) 8 msec 8 msec 8 msec
  5 SU.ARC.BARRNET.NET (192.200.3.8) 12 msec 12 msec 8 msec
  6 MOFFETT-FLD-MB.in.MIL (192.52.195.1) 216 msec 120 msec 132 msec
  7 ABA.NYC.mil (26.0.0.73) 412 msec 628 msec 664 msec
Switch#
```

Using Layer 2 Traceroute

These sections describe how to use the Layer 2 traceroute feature:

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 determines 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.

If you want the switch to trace the path from a host on a source device to a host on a destination device, the switch can identify only 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.

Layer 2 Traceroute Usage Guidelines

These are the Layer 2 traceroute usage guidelines:

- CDP must be enabled on all the devices in the network. For Layer 2 traceroute to functional properly, do not disable CDP.

  If any devices in the physical path are transparent to CDP, the switch cannot identify the path through these devices.

  Note For more information about enabling CDP, see Chapter 17, "Understanding and Configuring CDP."

- All switches in the physical path must have IP connectivity. When a switch is reachable from another switch, you can test connectivity by using the **ping** command in privileged EXEC mode.

- The maximum number of hops identified in the path is ten.
- You can enter the **traceroute mac** or the **traceroute mac ip** command in privileged EXEC mode 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 Address Resolution Protocol (ARP) to associate the IP address with the corresponding MAC address and the VLAN ID.
  - 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.

Running Layer 2 Traceroute

To display the physical path that a packet takes from a source device to a destination device, perform either one of these tasks in privileged EXEC mode:

Command	Purpose
`Switch# traceroute mac {source-mac-address} {destination-mac-address}`	Runs Layer 2 traceroute to trace the path that packets take through the network.

or

Command	Purpose
`Switch# traceroute mac ip {source-mac-address} {destination-mac-address}`	Runs IP traceroute to trace the path that packets take through the network.

These examples show how to use the **traceroute mac** and **traceroute mac ip** commands to display the physical path a packet takes through the network to reach its destination:

```
Switch# traceroute mac 0000.0201.0601 0000.0201.0201

Source 0000.0201.0601 found on con6[WS-C2950G-24-EI] (2.2.6.6)
con6 (2.2.6.6) :Fa0/1 => Fa0/3
con5                 (2.2.5.5        )  :    Fa0/3 => Gi0/1
con1                 (2.2.1.1        )  :    Gi0/1 => Gi0/2
con2                 (2.2.2.2        )  :    Gi0/2 => Fa0/1
Destination 0000.0201.0201 found on con2[WS-C3550-24] (2.2.2.2)
Layer 2 trace completed
Switch#

Switch# traceroute mac ip 2.2.66.66 2.2.22.22 detail
Translating IP to mac .....
2.2.66.66 => 0000.0201.0601
2.2.22.22 => 0000.0201.0201

Source 0000.0201.0601 found on con6[WS-C2950G-24-EI] (2.2.6.6)
con6 / WS-C2950G-24-EI / 2.2.6.6 :
        Fa0/1 [auto, auto] => Fa0/3 [auto, auto]
con5 / WS-C2950G-24-EI / 2.2.5.5 :
        Fa0/3 [auto, auto] => Gi0/1 [auto, auto]
con1 / WS-C3550-12G / 2.2.1.1 :
        Gi0/1 [auto, auto] => Gi0/2 [auto, auto]
con2 / WS-C3550-24 / 2.2.2.2 :
        Gi0/2 [auto, auto] => Fa0/1 [auto, auto]
Destination 0000.0201.0201 found on con2[WS-C3550-24] (2.2.2.2)
Layer 2 trace completed.
Switch#
```

Configuring ICMP

Internet Control Message Protocol (ICMP) provides many services that control and manage IP connections. ICMP messages are sent by routers or access servers to hosts or other routers when a problem is discovered with the Internet header. For detailed information on ICMP, refer to RFC 792.

Enabling ICMP Protocol Unreachable Messages

If the Cisco IOS software receives a nonbroadcast packet that uses an unknown protocol, it sends an ICMP Protocol Unreachable message back to the source.

Similarly, if the software receives a packet that it is unable to deliver to the ultimate destination because it knows of no route to the destination address, it sends an ICMP Host Unreachable message to the source. This feature is enabled by default.

To enable the generation of ICMP Protocol Unreachable and Host Unreachable messages, enter the following command in interface configuration mode:

Command	Purpose
`Switch (config-if)# [no] ip unreachables`	Enables ICMP destination unreachable messages. Use the **no** keyword to disable the ICMP destination unreachable messages.

To limit the rate that Internet Control Message Protocol (ICMP) destination unreachable messages are generated, perform this task:

Command	Purpose
`Switch (config)# [no] ip icmp rate-limit unreachable [df] milliseconds`	Limits the rate that ICMP destination messages are generated. Use the **no** keyword to remove the rate limit and reduce the CPU usage.

Enabling ICMP Redirect Messages

Data routes are sometimes less than optimal. For example, it is possible for the router to be forced to resend a packet through the same interface on which it was received. If this occurs, the Cisco IOS software sends an ICMP Redirect message to the originator of the packet telling the originator that the router is on a subnet directly connected to the receiving device, and that it must forward the packet to another system on the same subnet. The software sends an ICMP Redirect message to the packet's originator because the originating host presumably could have sent that packet to the next hop without involving this device at all. The Redirect message instructs the sender to remove the receiving device from the route and substitute a specified device representing a more direct path. This feature is enabled by default.

However, when Hot Standby Router Protocol (HSRP) is configured on an interface, ICMP Redirect messages are disabled (by default) for the interface. For more information on HSRP, refer to the following URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios121/121cgcr/ip_c/ipcprt1/1cdip.htm

To enable the sending of ICMP Redirect messages if the Cisco IOS software is forced to resend a packet through the same interface on which it was received, enter the following command in interface configuration mode:

Command	Purpose
`Switch (config-if)# [no] ip redirects`	Enables ICMP Redirect messages. Use the **no** keyword to disable the ICMP Redirect messages and reduce CPU usage.

Enabling ICMP Mask Reply Messages

Occasionally, network devices must know the subnet mask for a particular subnetwork in the internetwork. To obtain this information, devices can send ICMP Mask Request messages. These messages are responded to by ICMP Mask Reply messages from devices that have the requested information. The Cisco IOS software can respond to ICMP Mask Request messages if the ICMP Mask Reply function is enabled.

To have the Cisco IOS software respond to ICMP mask requests by sending ICMP Mask Reply messages, perform this task:

Command	Purpose
`Switch (config-if)# [no] ip mask-reply`	Enables response to ICMP destination mask requests. Use the **no** keyword to disable this functionality.

Configuring Supervisor Engine Redundancy on the Catalyst 4507R and 4510R Switches

This chapter describes how to configure supervisor engine redundancy on the Catalyst 4507R and Catalyst 4510R switches.

This chapter consists of the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Supervisor Engine Redundancy

Catalyst 4500 series switches allow a standby supervisor engine to take over if the primary supervisor engine fails, thereby allowing the switch to resume operation quickly in the event of a supervisor engine failure. This capability is called supervisor engine redundancy. In software, this capability is enabled by route processor redundancy (RPR) operating mode.

The standby supervisor engine runs in RPR mode. When RPR mode is used, the standby supervisor engine partially boots and keeps synchronized copies of the active configuration, which shortens the time needed to bring up the standby supervisor engine and have it start handling traffic from 1.5 minutes (for a cold boot on the standby) to 30 seconds (to finish the boot and reestablish links).

In addition to the reduced switchover time, supervisor engine redundancy supports the following:

- Online insertion and removal (OIR) of the standby supervisor engine.
- Software upgrade. (See the "Performing a Software Upgrade" section on page 6-6.)
- Auto-startup and bootvar synchronization.

- Hardware signals that detect and decide the active or standby status of supervisor engine.
- Automatic switchover to the standby supervisor engine if the active supervisor engine ever fails.

When the switch is powered on, the two supervisor engines determine which will serve as the primary and which will be the standby. Usually, the supervisor engine that boots first, either in slot 1 or 2, becomes the active supervisor engine.

A switchover will occur when one or more of the following events take place:

- The active supervisor engine fails or is removed.
- A user forces a switchover.
- A user reloads the active supervisor engine.
- A core dump occurs.

Note In a switchover, there is a disruption of traffic because some address states are lost and then restored after they are dynamically redetermined.

Table 6-1 lists the chassis and supervisor support for redundancy.

Table 6-1 Chassis and Supervisor Support

Chassis (Product Number)	Supported Supervisor Engines
Catalyst 4507R (WS-C4507R)	Supports redundant Supervisor Engine II-Plus and (WS-X4013+) and redundant Supervisor Engine V, Supervisor Engine IV (WS-X4515)
Catalyst 4510R (WS-C4510R)	Supports redundant Supervisor Engine VSupervisor Engine V, (WS-X4516)

Understanding Supervisor Engine Redundancy

These sections describe supervisor engine redundancy:

Operation

With supervisor engine redundancy enabled, the standby supervisor engine automatically takes over for the primary supervisor engine if the active supervisor engine fails or if a manual switchover occurs. The standby supervisor engine has already been automatically initialized and configured, shortening the switchover time. Supervisor engine redundancy provides these additional benefits:

- Online insertion and removal (OIR) of the standby supervisor engine

  Supervisor engine redundancy allows OIR of the standby supervisor engine for maintenance. When the standby supervisor engine is inserted, the active supervisor engine detects its presence and begins to transition the standby supervisor engine to the fully initialized state.

- Software upgrade

  To minimize software upgrade and downgrade times, you can preload the standby supervisor engine with the software version you want to upgrade or downgrade to and then configure the system to switch over to the standby supervisor engine.

Supervisor engine redundancy also supports manual user-initiated switchover. You can initiate a switchover with the **redundancy force-switchover** command.

Supervisor Engine Synchronization

Because the standby supervisor engine is not fully initialized, it interacts with the active supervisor engine only to receive configuration changes as they occur, keeping the configuration information on both supervisor engines identical. This synchronization of the startup configuration file is enabled by default in RPR mode. You cannot enter CLI commands on the standby supervisor engine.

When a standby supervisor engine is running in RPR mode, the following operations trigger synchronization of the configuration information:

- When a standby supervisor engine first comes online, the configuration information is synchronized from the active supervisor engine to the standby supervisor engine. This synchronization overwrites any existing startup configuration file on the standby supervisor engine.
- If the **auto-synch** command is enabled, changes to the startup configuration on the active supervisor engine are automatically synchronized on the standby supervisor.

Supervisor Engine Redundancy Guidelines and Restrictions

The following guidelines and restrictions apply to supervisor engine redundancy:

- Supervisor engine redundancy does not provide supervisor engine load balancing or any other feature requiring two active supervisor engines. Only one supervisor engine is active. Network services are disrupted until the standby supervisor engine takes over and the switch recovers.
- When using RPR mode with WS-4513+ and WS-X4515 supervisor engines, only the Gig 1/1 and Gig 2/1 Gigabit Ethernet interfaces on each supervisor engine are available. The Gig 1/2 and Gig 2/2 interfaces are not available.

Note This restriction applies only to the WS-4513+ and WS-X4515 supervisor engines. The WS-X4516 supervisor engines support all four Gigabit Ethernet interfaces in RPR mode.

- With supervisor engine redundancy enabled, the supervisor engines may run different releases of Cisco IOS software if both releases are Cisco IOS Release 12.1(12c)EW or later.
- The Forwarding Information Base (FIB) tables are cleared on a switchover. As a result, routed traffic is interrupted until route tables reconverge.
- Static IP routes are maintained across a switchover because they are configured from entries in the configuration file.
- Information about dynamic states maintained on the active supervisor engine is not synchronized to the standby supervisor engine and is lost on switchover. Dynamic state information (such as border gateway protocol [BGP] session information) is lost at switchover.
- The Catalyst 4507R switch and the 4510R switches are the only Catalyst 4500 series switch that support supervisor engine redundancy.
- The Catalyst 4510R switch supports the WS-X4516 supervisor engine only. The Catalyst 4507R switch supports the other redundant supervisor engines (Supervisor Engine II-Plus and Supervisor Engine IV and WS-X4516). Do not mix and match different supervisor models in a redundancy configuration.
- The active and standby supervisor engines must be in slots 1 and 2.
- Both the active and standby supervisor engines must support redundancy (Supervisor Engine II-Plus, Supervisor Engine IV, and Supervisor Engine V). Earlier versions are not supported.
- Each supervisor engine must have the resources to run the switch on its own, which means that each supervisor engine has its own Flash device and console port connections.
- Make separate console connections to each supervisor engine. Do not connect a Y cable to the console ports.
- You must set the configuration register in the startup-config to autoboot. (See the "Modifying the Boot Field" section on page 3-21.)
- With redundancy enabled, the supervisor engines can run different releases of Cisco IOS software provided both releases are Release 12.1(12c)EW or later.

Note There is no support for booting from the network.

If these requirements are met, the switch functions in RPR mode by default.

Configuring Supervisor Engine Redundancy

Supervisor engine redundancy is configured by default when a second supervisor engine is detected.

This example shows how to display the redundancy state:

```
Switch#show redundancy states
       my state = 13 -ACTIVE
     peer state = 4  -STANDBY COLD
           Mode = Duplex
           Unit = Primary
        Unit ID = 1

Redundancy Mode (Operational) = RPR
Redundancy Mode (Configured)  = RPR
     Split Mode = Disabled
   Manual Swact = Enabled
 Communications = Up
```

```
   client count = 4
 client_notification_TMR = 30000 milliseconds
          keep_alive TMR = 4000 milliseconds
        keep_alive count = 1
    keep_alive threshold = 7
           RF debug mask = 0x0
Switch#
```

Synchronizing the Supervisor Engine Configurations

During normal operation, the startup-config, boot variables, config-registers, and VLAN database configuration are synchronized by default between the two supervisor engines. In a switchover, the new active supervisor engine uses the current configuration.

To manually synchronize the configurations used by the two supervisor engines, perform this task on the active supervisor engine:

	Command	Purpose
Step 1	`Switch(config)# redundancy`	Enters redundancy configuration mode.
Step 2	`Switch(config-red)# main-cpu`	Enters main-cpu configuration submode.
Step 3	`Switch(config-r-mc)# auto-sync {startup-config | config-register | bootvar | standard}`	Synchronizes the configuration elements.
Step 4	`Switch(config-r-mc)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# copy running-config startup-config`	Forces a manual synchronization of the configuration files in NVRAM. **Note** This step is not required to synchronize the running configuration file in dynamic random-access memory (DRAM).

Note The **auto-sync** command controls the synchronization of the CONFIG-REG, BOOTVAR and STARTUP/PRIVATE configuration files only. The calendar and **vlan** database files are always synchronized when they change.

This example shows how to reenable the default automatic synchronization feature using the **auto-sync standard** command to synchronize the **startup-config** and **config-register** configuration of the active supervisor engine with the standby supervisor engine: updates for the boot variables are automatic and cannot be disabled.

```
Switch(config)# redundancy
Switch(config-red)# main-cpu
Switch(config-r-mc)# auto-sync standard
Switch(config-r-mc)# end
Switch# copy running-config startup-config
```

Note To manually synchronize individual elements of the standard auto-sync configuration, disable the default automatic synchronization feature.

This example shows how to disable default automatic synchronization and allow only automatic synchronization of the config-registers of the active supervisor engine to the standby supervisor engine, while disallowing synchronization of the startup configuration:

```
Switch(config)# redundancy
Switch(config-red)# main-cpu
Switch(config-r-mc)# no auto-sync standard
Switch(config-r-mc)# auto-sync config-register
Switch(config-r-mc)# end
```

Performing a Software Upgrade

The software upgrade procedure supported by supervisor engine redundancy allows you to upgrade the Cisco IOS software image on the supervisor engines without reloading the system.

To perform a software upgrade, perform this task:

	Command	Purpose

Step 1	`Switch# copy source_device:source_filename slot0:target_filename`
	
	Or:
	
	`Switch# copy source_device:source_filename bootflash:target_filename`
	
	Or:
	
	`Switch# copy source_device:source_filename slaveslot0:target_filename`
	
	Or:
	
	`Switch# copy source_device:source_filename slavebootflash:target_filename`
		Copies the new Cisco IOS software image to bootflash on both supervisor engines.

Step 2	`Switch# config terminal`
	`Switch(config)# config-register 0x2`
	`Switch(config)# boot system flash device:file_name`
		Configures the supervisor engines to boot the new image.

Step 3	`Switch# copy running-config start-config`	Saves the configuration.

	Command	Purpose
Step 4	`Switch# redundancy reload peer`	Reloads the standby supervisor engine and bring it back online (running the new version of the Cisco IOS software). **Note** Before reloading the standby supervisor engine, make sure you wait long enough to ensure that all configuration synchronization changes have completed.
Step 5	`Switch# redundancy force-switchover`	Conducts a manual switchover to the standby supervisor engine. The standby supervisor engine becomes the new active supervisor engine running the new Cisco IOS software image. The modules reload and the module software downloads from the new active supervisor engine. The old active supervisor engine reboots with the new image and becomes the standby supervisor engine.

This example shows how to perform a software upgrade:

```
Switch# config terminal
Switch(config)# config-register 0x2
Switch(config)# boot system flash slot0: cat4000-is-mz.121-11b.EW
Switch# copy running-config start-config
Switch# redundancy reload peer
Switch# redundancy force-switchover
Switch#
```

Copying Files to the Standby Supervisor Engine

If you want to manually copy a file from the active supervisor engine to the **slot0:** device on the standby supervisor engine, use this command:

```
Switch# copy source_device:source_filename slaveslot0:target_filename
```

To copy a file to the **bootflash:** device on a standby supervisor engine, use this command:

```
Switch# copy source_device:source_filename slavebootflash:target_filename
```

Understanding and Configuring VLANs

This chapter describes VLANs on Catalyst 4500 series switches. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of VLANs

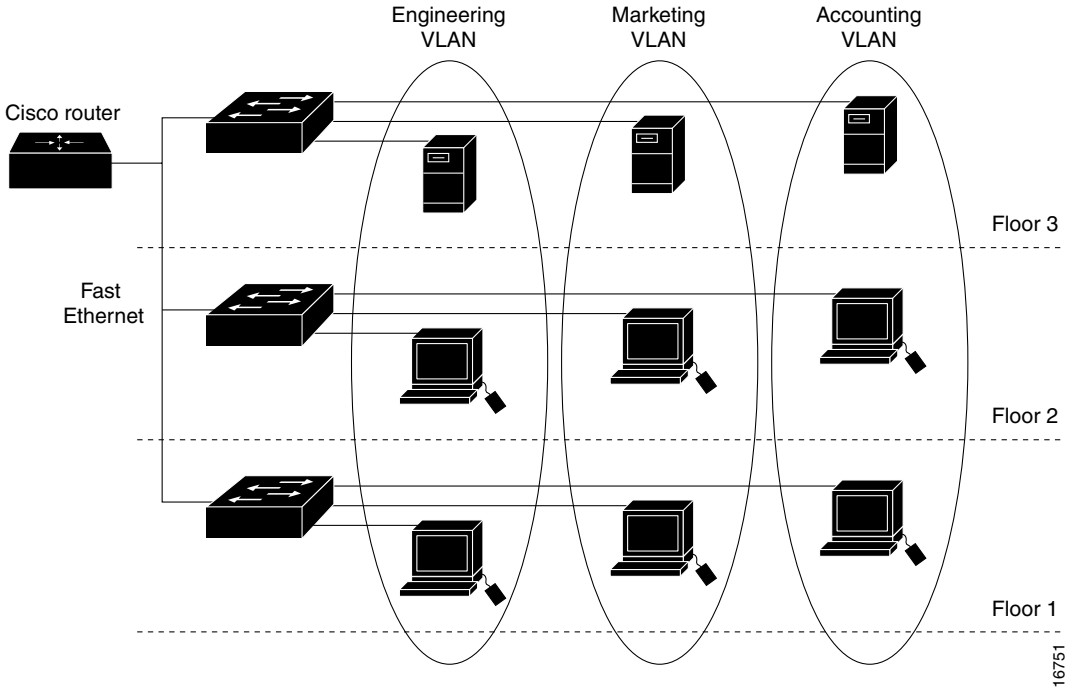
A VLAN is a group of devices on one or more LANs that are configured to communicate as if they were attached to the same wire, when in fact they are located on a number of different LAN segments. Because VLANs are based on logical instead of physical connections, they are extremely flexible.

VLANs define broadcast domains in a Layer 2 network. A broadcast domain is the set of all devices that will receive broadcast frames originating from any device within the set. Broadcast domains are typically bounded by routers because routers do not forward broadcast frames. Layer 2 switches create broadcast domains based on the configuration of the switch. Switches are multiport bridges that allow you to create multiple broadcast domains. Each broadcast domain is like a distinct virtual bridge within a switch.

You can define one or many virtual bridges within a switch. Each virtual bridge you create in the switch defines a new broadcast domain (VLAN). Traffic cannot pass directly to another VLAN (between broadcast domains) within the switch or between two switches. To interconnect two different VLANs, you must use routers or Layer 3 switches. See the "Overview of Layer 3 Interfaces" section on page 20-1 for information on inter-VLAN routing on Catalyst 4500 series switches.

Figure 7-1 shows an example of three VLANs that create logically defined networks.

Figure 7-1 Sample VLANs



VLANs are often associated with IP subnetworks. For example, all of the end stations in a particular IP subnet belong to the same VLAN. Traffic between VLANs must be routed. You must assign LAN interface VLAN membership on an interface-by-interface basis (this is known as interface-based or static VLAN membership).

You can set the following parameters when you create a VLAN in the management domain:

- VLAN number
- VLAN name
- VLAN type
- VLAN state (active or suspended)
- Maximum transmission unit (MTU) for the VLAN
- Security Association Identifier (SAID)
- VLAN number to use when translating from one VLAN type to another

Note When the software translates from one VLAN type to another, it requires a different VLAN number for each media type.

VLAN Configuration Guidelines and Restrictions

Follow these guidelines and restrictions when creating and modifying VLANs in your network:

- Before creating a VLAN, put the Catalyst 4500 series switch in VTP server mode or VTP transparent mode. If the Catalyst 4500 series switch is a VTP server, you must define a VTP domain. For information on configuring VTP, see Chapter 24, "Understanding and Configuring VTP."
- The Cisco IOS **end** command is not supported in VLAN database mode.
- You cannot use **Ctrl-Z** to exit VLAN database mode.

VLAN Ranges

Note You must enable the extended system ID to use 4094 VLANs. See the "Understanding the Bridge ID" section on page 11-2.

With Cisco IOS Release 12.2(20)EW and later, Catalyst 4500 series switches support 4096 VLANs in compliance with the IEEE 802.1Q standard. These VLANs are organized into three ranges: reserved, normal, and extended.

Some of these VLANs are propagated to other switches in the network when you use the VLAN Trunking Protocol (VTP). The extended-range VLANs are not propagated, so you must configure extended-range VLANs manually on each network device.

Table 7-1 describes the uses for VLAN ranges.

Table 7-1 VLAN Ranges

VLANs	Range	Usage	Propagated by VTP
0, 4095	Reserved	For system use only. You cannot see or use these VLANs.	N/A
1	Normal	Cisco default. You can use this VLAN but you cannot delete it.	Yes
2–1001	Normal	Used for Ethernet VLANs; you can create, use, and delete these VLANs.	Yes
1002–1005	Normal	Cisco defaults for FDDI and Token Ring. You cannot delete VLANs 1002–1005.	Yes
1006–4094	Extended	For Ethernet VLANs only. When configuring extended-range VLANs, note the following: • Layer 3 ports and some software features require internal VLANs. Internal VLANs are allocated from 1006 and up. You cannot use a VLAN that has been allocated for such use. To display the VLANs used internally, enter the **show vlan internal usage** command. • Switches running Catalyst product family software do not support configuration of VLANs 1006–1024. If you configure VLANs 1006–1024, ensure that the VLANs do not extend to any switches running Catalyst product family software. • You must enable the extended system ID to use extended range VLANs. See the "Enabling the Extended System ID" section on page 11-8.	No

Configurable Normal-Range VLAN Parameters

Note Ethernet VLANs 1 and 1006 through 4094 use only default values.

You can configure the following parameters for VLANs 2 through 1001:

- VLAN name
- VLAN type
- VLAN state (active or suspended)
- SAID
- STP type for VLANs

VLAN Default Configuration

Table 7-2 shows the default VLAN configuration values.

Table 7-2 Ethernet VLAN Defaults and Ranges

Parameter	Default	Valid Values
VLAN ID	1	1–4094
VLAN name	VLAN*x*, where *x* is a number assigned by the software.	No range
802.10 SAID	100,001	1–4,294,967,294
MTU size	1500	1500–18,190
Translational bridge 1	1002	0–1005
Translational bridge 2	1003	0–1005
VLAN state	active	active; suspend; shutdown

Note Catalyst 4500 series switches do 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 via VTP. The software reserves parameters for these media types, but they are not truly supported.

Configuring VLANs

Note Before you configure VLANs, you must use VLAN Trunking Protocol (VTP) to maintain global VLAN configuration information for your network. For complete information on VTP, see Chapter 24, "Understanding and Configuring VTP."

Note VLANs support a number of parameters that are not discussed in detail in this section. For complete information, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Note The VLAN configuration is stored in the **vlan.dat** file, which is stored in nonvolatile memory. You can cause inconsistency in the VLAN database if you manually delete the **vlan.dat** file. If you want to modify the VLAN configuration or VTP, use the commands described in the following sections and in the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

These sections describe how to configure VLANs:

- Configuring VLANs in Global Configuration Mode, page 7-5
- Configuring VLANs in VLAN Database Mode, page 7-7
- Assigning a Layer 2 LAN Interface to a VLAN, page 7-8

Configuring VLANs in Global Configuration Mode

If the switch is in VTP server or transparent mode (see the "Configuring VTP" section on page 24-6), you can configure VLANs in global and VLAN configuration modes. When you configure VLANs in global and config-vlan configuration modes, the VLAN configuration is saved in the **vlan.dat** files, not the **running-config** or **startup-config** files. To display the VLAN configuration, enter the **show vlan** command.

If the switch is in VLAN transparent mode, use the **copy running-config startup-config** command to save the VLAN configuration to the **startup-config** file. After you save the running configuration as the startup configuration, the **show running-config** and **show startup-config** commands display the VLAN configuration.

Note When the switch boots, if the VTP domain name and VTP mode in the **startup-config** and **vlan.dat** files do not match, the switch uses the configuration in the **vlan.dat** file.

You use the interface configuration command mode to define the port membership mode and add and remove ports from a VLAN. The results of these commands are written to the **running-config** file, and you can display the contents of the file by entering the **show running-config** command.

User-configured VLANs have unique IDs from 1 to 4094. To create a VLAN, enter the **vlan** command with an unused ID. To verify whether a particular ID is in use, enter the **show vlan id** *ID* command. To modify a VLAN, enter the **vlan** command for an existing VLAN.

See the "VLAN Default Configuration" section on page 7-4 for the list of default parameters that are assigned when you create a VLAN. If you do not use the **media** keyword when specifying the VLAN type, the VLAN is an Ethernet VLAN.

To create a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# vlan vlan_ID` `Switch(config-vlan)#`	Adds an Ethernet VLAN. **Note** You cannot delete the default VLANs for these media types: Ethernet VLAN 1 and FDDI or Token Ring VLANs 1002 to 1005. When you delete a VLAN, any LAN interfaces configured as access ports assigned to that VLAN become inactive. They remain associated with the VLAN (and thus inactive) until you assign them to a new VLAN. You can use the **no** keyword to delete a VLAN. When the prompt reads `Switch(config-vlan)#`, you are in vlan-configuration mode. If you wish to change any of the parameters for the newly created VLAN, use this mode.
Step 3	`Switch(config-vlan)# end`	Returns to enable mode from vlan-configuration mode.
Step 4	`Switch# show vlan [id | name] vlan_name`	Verifies the VLAN configuration.

When you create or modify an Ethernet VLAN, note the following:

- Because Layer 3 ports and some software features require internal VLANs allocated from 1006 and up, configure extended-range VLANs starting with 4094 and work downward.
- You can configure extended-range VLANs only in global configuration mode. You cannot configure extended-range VLANs in VLAN database mode.
- Layer 3 ports and some software features use extended-range VLANs. If the VLAN you are trying to create or modify is being used by a Layer 3 port or a software feature, the switch displays a message and does not modify the VLAN configuration.

This example shows how to create an Ethernet VLAN in global configuration mode and verify the configuration:

```
Switch# configure terminal
Switch(config)# vlan 3
Switch(config-vlan)# end
Switch# show vlan id 3
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
3    VLAN0003                         active
VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
3    enet  100003     1500  -      -      -        -    -        0      0
Primary Secondary Type              Interfaces
------- --------- ----------------- ------------------------------------------
Switch#
```

Configuring VLANs in VLAN Database Mode

When the switch is in VTP server or transparent mode, you can configure VLANs in the VLAN database mode. When you configure VLANs in VLAN database mode, the VLAN configuration is saved in the **vlan.dat** file, not the **running-config** or **startup-config** files. To display the VLAN configuration, enter the **show running-config vlan** command.

User-configurable VLANs have unique IDs from 1 to 4094. Database mode supports configuration of IDs from 1 to 1001, but not the extended addresses from 1006 to 4094. To create a VLAN, enter the **vlan** command with an unused ID. To verify whether a particular ID is in use, enter the **show vlan id** *ID* command. To modify a VLAN, enter the **vlan** command for an existing VLAN.

See the "VLAN Default Configuration" section on page 7-4 for a listing of the default parameters that are assigned when you create a VLAN. If you do not use the **media** keyword when specifying the VLAN type, the VLAN is an Ethernet VLAN.

To create a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch# vlan database`	Enters VLAN database mode.
Step 2	`Switch(vlan)# vlan vlan_ID`	Adds an Ethernet VLAN. **Note** You cannot delete the default VLANs for these media types: Ethernet VLAN 1 and FDDI or Token Ring VLANs 1002 to 1005. When you delete a VLAN, any LAN interfaces configured as access ports assigned to that VLAN become inactive. They remain associated with the VLAN (and thus inactive) until you assign them to a new VLAN. You can use the **no** keyword to delete a VLAN.
Step 3	`Switch(vlan)# exit`	Returns to enable mode.
Step 4	`Switch# show vlan [id | name] vlan_name`	Verifies the VLAN configuration.

This example shows how to create an Ethernet VLAN in VLAN database mode and verify the configuration:

```
Switch# vlan database
Switch(vlan)# vlan 3
VLAN 3 added:
    Name: VLAN0003
Switch(vlan)# exit
APPLY completed.
Exiting....
Switch# show vlan name VLAN0003
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------

3    VLAN0003                         active

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- ------ ------
3    enet  100003     1500  -      -      -        -    0      0
Switch#
```

Assigning a Layer 2 LAN Interface to a VLAN

A VLAN created in a management domain remains unused until you assign one or more LAN interfaces to the VLAN.

Note Makes sure you assign LAN interfaces to a VLAN of the proper type. Assign Fast Ethernet and Gigabit Ethernet interfaces to Ethernet-type VLANs.

To assign one or more LAN interfaces to a VLAN, complete the procedures in the "Configuring Ethernet Interfaces for Layer 2 Switching" section on page 9-5.

Configuring Dynamic VLAN Membership

This chapter describes how to configure dynamic port VLAN membership by using the VLAN Membership Policy Server (VMPS).

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Understanding VMPS

This section includes the following subsections:

With the VMPS, you can dynamically assign switch ports to VLANs based on the source Media Access Control (MAC) address of the device connected to the port. When you move a host from a port on one switch in the network to a port on another switch in the network, that switch dynamically assigns the new port to the proper VLAN for that host.

A Catalyst 4500 series switch can be a member switch or a command switch in a cluster of switches managed as a single entity. The communication between VMPS and a member switch is managed by the command switch. In this description, the VMPS client is always the command switch.

A Catalyst 4500 series switch acts as a client to the VMPS and communicates with it by using the VLAN Query Protocol (VQP). When the VMPS receives a VQP request from a client switch, the VMPS searches its database for a MAC address-to-VLAN mapping. The server response is based on this mapping. If the server is in secure mode, the server shuts down the port when a VLAN is not allowed on it, or the server simply denies the port access to the VLAN.

In response to a request, the VMPS takes one of the following actions:

- If the assigned VLAN is restricted to a group of ports, the VMPS verifies the requesting port against this group and responds as follows:
  - If the VLAN is allowed on the port, the VMPS sends the VLAN name to the client in response.
  - If the VLAN is not allowed on the port, and the VMPS is not in secure 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 VLAN in the database does not match the current VLAN on the port, and there are active hosts 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, the switch continues to block traffic from the MAC address to or from the port. The switch continues to monitor the packets directed to the port and sends a query to the VMPS when it identifies a new address. If the switch receives a *port-shutdown* response from the VMPS, the switch disables the port. The port must be manually reenabled by using the CLI, Cisco Visual Switch Manager (CVSM), or SNMP.

  You can also use an explicit entry in the configuration table to deny access to specific MAC addresses for security reasons. If you enter the **none** keyword for the VLAN name, the VMPS sends an *access-denied* or *port-shutdown* response.

Entering Port Names in the VMPS

A VMPS database configuration file must use the Catalyst 4500 series convention for naming ports. For example, Fa0/5 is fixed-port number 5.

If the switch is a cluster member, the command switch adds the name of the switch before the “Fa” in the port name. For example, es3%Fa02 refers to fixed 10/100 port 2 on member switch 3. These naming conventions must be used in the VMPS database configuration file when the VMPS is configured to support a cluster.

You can configure a fallback VLAN name. If you connect a device with a MAC address that is not in the database, the VMPS sends the fallback VLAN name to the client. If you do not configure a fallback VLAN name and the MAC address does not exist in the database, the VMPS sends an *access-denied* response. If the VMPS is in secure mode, it sends a *port-shutdown* response.

Dynamic Port VLAN Membership

A dynamic (nontrunking) port can belong to only one VLAN. When the link comes up, the switch does not forward traffic to or from this port until the port is assigned to a VLAN. The source MAC address from the first packet of a new host on the dynamic port is sent to the VMPS, which 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 there is no match, the VMPS either denies the request or shuts down the port (depending on the VMPS secure mode setting). See the “Understanding VMPS” section on page 8-1 for a complete description of possible VMPS responses.

Multiple hosts (MAC addresses) can be active on a dynamic port if they are all in the same VLAN. If the link goes down on a dynamic 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 with the VMPS before the port is assigned to a VLAN.

Note The VMPS shuts down a dynamic port if more than 20 hosts are active on that port.

VMPS Configuration Guidelines

The following guidelines and restrictions apply to dynamic port VLAN membership:

- You must configure the VMPS before you configure ports as dynamic.
- The communication between a cluster of switches and the VMPS is managed by the command switch and includes port-naming conventions that are different from standard port names. See "Entering Port Names in the VMPS" section on page 8-2 for the cluster-based port-naming conventions.
- When you configure a port as dynamic, the spanning-tree PortFast feature is automatically enabled for that port. The PortFast mode accelerates the process of bringing the port into the forwarding state. You can disable PortFast mode on a dynamic port.
- Secure ports cannot be dynamic ports. You must disable port security on the port before it becomes dynamic.
- Trunk ports cannot be dynamic ports, but it is possible to enter the **switchport access VLAN dynamic** 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 ports cannot be network ports or monitor ports.

Note The VTP management domain of the VMPS client and the VMPS server must match.

Default VMPS Configuration

Table 8-1 shows the default VMPS and dynamic port configuration on client switches.

Table 8-1 Default VMPS Client and Dynamic Port Configuration

Feature	Default Configuration
VMPS domain server	None
VMPS reconfirm interval	60 minutes
VMPS server retry count	3
Dynamic ports	None configured

Configuring Dynamic VLAN Membership

These subsections describe how to configure a switch as a VMPS client and configure its ports for dynamic VLAN membership.

The following topics are included:

Entering the IP Address of the VMPS

To configure the switch as a client, you must enter the IP address of the Catalyst 4500 series switch or the other device acting as the VMPS.

To define a VMPS for a cluster of switches, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# vmps server` *ipaddress* `primary`	Enters the IP address of the switch acting as the primary VMPS server.
Step 3	`Switch(config)# vmps server` *ipaddress*	Enters the IP address for the switch acting as a secondary VMPS server.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show vmps`	Verifies the VMPS server entry.

This example shows how to enter the primary and backup VMPS devices:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# vmps server 172.20.128.179 primary
Switch(config)# vmps server 172.20.128.178
Switch(config)# end

Switch# show vmps
VQP Client Status:
--------------------
VMPS VQP Version:   1
Reconfirm Interval: 60 min
Server Retry Count: 3
VMPS domain server: 172.20.128.179 (primary, current)
                    172.20.128.178

Reconfirmation status
---------------------
VMPS Action:         No Dynamic Port
```

Configuring Dynamic Ports on VMPS Clients

To configure dynamic ports on the VMPS client switches, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface*	Enters interface configuration mode and the port to be configured.
Step 3	`Switch(config-if)# switchport mode access`	Sets the port to access mode.
Step 4	`Switch(config-if)# switchport access vlan dynamic`	Configures the port as eligible for dynamic VLAN access.
Step 5	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show interface` *interface* `switchport`	Verifies the entry.

This example shows how to configure a port as a dynamic access port and then verify the entry:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fa0/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan dynamic
Switch(config-if)# end

Switch# show interface fa0/1 switchport
Name: Fa0/1
Switchport: Enabled
Administrative mode: dynamic access
Operational Mode: dynamic access
Administrative Trunking Encapsulation: isl
Operational Trunking Encapsulation: isl
Negotiation of Trunking: Disabled
Access Mode VLAN: 0 ((Inactive))
Trunking Native Mode VLAN: 1 (default)
Trunking VLANs Enabled: NONE
Pruning VLANs Enabled: NONE
```

Administering and Monitoring the VMPS

You can display information about the VMPS by using the **show vmps** command in mode privileged EXEC.

The switch displays the following information about the VMPS:

VMPS VQP Version	The version of VQP used to communicate with the VMPS. The switch queries the VMPS using version 1 of VQP.
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 currently 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. This can happen automatically when the reconfirmation interval expired, or you can force it by entering the privileged EXEC **vmps reconfirm** command or its CVSM or SNMP equivalent.

The following example shows how to display VMPS information. You can enter this information on a command or member switch:

```
Switch# show vmps
VQP Client Status:
-------------------
VMPS VQP Version:   1
Reconfirm Interval: 60 min
Server Retry Count: 3
VMPS domain server:

Reconfirmation status
---------------------
VMPS Action:         other

The following example shows how to display VMPS statistics:
Switch# show vmps statistics
VMPS Client Statistics
----------------------
VQP  Queries:               0
VQP  Responses:             0
VMPS Changes:               0
VQP  Shutdowns:             0
VQP  Denied:                0
VQP  Wrong Domain:          0
VQP  Wrong Version:         0
VQP  Insufficient Resource: 0
```

Note Refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* for details on the VMPS statistics.

Configuring the Reconfirmation Interval

VMPS clients periodically reconfirm the VLAN membership information received from the VMPS. You can set the interval at which the reconfirmation will occur.

To configure the reconfirmation interval, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# vmps reconfirm` *minutes*	Enters the number of minutes between reconfirmations of the dynamic VLAN membership.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show vmps`	Verifies the dynamic VLAN reconfirmation status.

This example shows how to change the reconfirmation interval to 60 minutes and verify the change by displaying the VMPS information:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# vmps reconfirm 60
Switch(config)# end

Switch# show vmps
VQP Client Status:
---------------------
VMPS VQP Version:   1
Reconfirm Interval: 60 min
Server Retry Count: 10
VMPS domain server: 172.20.130.50 (primary, current)

Reconfirmation status
---------------------
VMPS Action:         No Host
```

Reconfirming VLAN Memberships

To confirm the dynamic port VLAN membership assignments that the switch has received from the VMPS, perform this task in privileged EXEC mode:

	Command	Purpose
Step 1	`Switch(config)# vmps reconfirm`	Reconfirms dynamic port VLAN membership.
Step 2	`Switch# show vmps`	Verifies the dynamic VLAN reconfirmation status.

Troubleshooting Dynamic Port VLAN Membership

The VMPS shuts down a dynamic port under these conditions:

- The VMPS is in secure mode, and it will 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 port.

  To reenable a shut-down dynamic port, enter the **no shutdown** command in interface configuration mode.

Configuring Layer 2 Ethernet Interfaces

This chapter describes how to use the command-line interface (CLI) to configure Fast Ethernet and Gigabit Ethernet interfaces for Layer 2 switching on Catalyst 4500 series switches. It also provides guidelines, procedures, and configuration examples. The configuration tasks in this chapter apply to Fast Ethernet and Gigabit Ethernet interfaces on any module, including the uplink ports on the supervisor engine.

This chapter includes the following major sections:

Note To configure Layer 3 interfaces, see Chapter 20, "Configuring Layer 3 Interfaces."

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Layer 2 Ethernet Switching

The following sections describe how Layer 2 Ethernet switching works on Catalyst 4500 series switches:

Understanding Layer 2 Ethernet Switching

Catalyst 4500 series switches support simultaneous, parallel connections between Layer 2 Ethernet segments. Switched connections between Ethernet segments last only for the duration of the packet. New connections can be made between different segments for successive packets.

Note With release 12.1(13)EW, the Catalyst 4500 series switches can handle packets of 1600 bytes, rather than treat them as "oversized" and discard them. This size is larger than the usual IEEE Ethernet Maximum Transmission Unit (MTU) (1518 bytes) and 802.1q MTU (1522 bytes). The ability to handle larger packets is required to support two nested 802.1q headers and Multiprotocol Label Switching (MPLS) on a network.

The Catalyst 4500 series solves congestion problems caused by high-bandwidth devices and a large number of users by assigning each device (for example, a server) to its own 10-, 100-, or 1000-Mbps segment. Because each Ethernet interface on the switch represents a separate Ethernet segment, servers in a properly configured switched environment achieve full access to the bandwidth.

Because collisions are a major bottleneck in Ethernet networks, an effective solution is full-duplex communication. Normally, Ethernet operates in half-duplex mode, which means that stations can either receive or transmit. In full-duplex mode, two devices can transmit and receive at the same time. When packets can flow in both directions simultaneously, effective Ethernet bandwidth doubles to 20 Mbps for 10-Mbps interfaces and to 200 Mbps for Fast Ethernet interfaces. Gigabit Ethernet interfaces on the Catalyst 4500 series switch are full-duplex mode only, providing 2-Gbps effective bandwidth.

Switching Frames Between Segments

Each Ethernet interface on a Catalyst 4500 series switch can connect to a single workstation or server, or to a hub through which workstations or servers connect to the network.

On a typical Ethernet hub, all ports connect to a common backplane within the hub, and the bandwidth of the network is shared by all devices attached to the hub. If two devices establish a session that uses a significant level of bandwidth, the network performance of all other stations attached to the hub is degraded.

To reduce degradation, the switch treats each interface as an individual segment. When stations on different interfaces need to communicate, the switch forwards frames from one interface to the other at wire speed to ensure that each session receives full bandwidth.

To switch frames between interfaces efficiently, the switch maintains an address table. When a frame enters the switch, it associates the MAC address of the sending station with the interface on which it was received.

Building the MAC Address Table

The Catalyst 4500 series builds the MAC address table by using the source address of the frames received. When the switch receives a frame for a destination address not listed in its MAC address table, it floods the frame to all interfaces of the same VLAN except the interface that received the frame. When the destination device replies, the switch adds its relevant source address and interface ID to the address table. The switch then forwards subsequent frames to a single interface without flooding to all interfaces.

The address table can store at least 32,000 address entries without flooding any entries. The switch uses an aging mechanism, defined by a configurable aging timer, so if an address remains inactive for a specified number of seconds, it is removed from the address table.

Understanding VLAN Trunks

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. Trunks carry the traffic of multiple VLANs over a single link and allow you to extend VLANs across an entire network.

Two trunking encapsulations are available on all Ethernet interfaces:

- Inter-Switch Link (ISL) Protocol—ISL is a Cisco-proprietary trunking encapsulation.

Note The blocking Gigabit ports on the WS-X4418-GB and WS-X4412-2GB-T modules do not support ISL. Ports 3 to 18 are blocking Gigabit ports on the WS-X4418-GB module. Ports 1to 12 are blocking Gigabit ports on the WS-X4412-2GB-T module.

- 802.1Q—802.1Q is an industry-standard trunking encapsulation.

You can configure a trunk on a single Ethernet interface or on an EtherChannel bundle. For more information about EtherChannel, see Chapter 14, "Understanding and Configuring EtherChannel."

Ethernet trunk interfaces support different trunking modes (see Table 9-2). You can specify whether the trunk uses ISL encapsulation, 802.1Q encapsulation, or if the encapsulation type is autonegotiated.

To autonegotiate trunking, make sure your interfaces are in the same VTP domain. Use the **trunk** or **nonegotiate** keywords to force interfaces in different domains to trunk. For more information on VTP domains, see Chapter 24, "Understanding and Configuring VTP."

Trunk negotiation is managed by the Dynamic Trunking Protocol (DTP). DTP supports autonegotiation of both ISL and 802.1Q trunks.

Encapsulation Types

Table 9-1 lists the Ethernet trunk encapsulation types.

Table 9-1 Ethernet Trunk Encapsulation Types

Encapsulation Type	Encapsulation Command	Purpose
ISL	**switchport trunk encapsulation isl**	Specifies ISL encapsulation on the trunk link.
802.1Q	**switchport trunk encapsulation dot1q**	Specifies 802.1Q encapsulation on the trunk link.
Negotiate	**switchport trunk encapsulation negotiate**	Specifies that the interface negotiate with the neighboring interface to become an ISL (preferred) or 802.1Q trunk, depending on the configuration and capabilities of the neighboring interface.

The trunking mode, the trunk encapsulation type, and the hardware capabilities of the two connected interfaces determine whether a link becomes an ISL or 802.1Q trunk.

Layer 2 Interface Modes

Table 9-2 lists the Layer 2 interface modes and describes how they function on Ethernet interfaces.

Table 9-2 Layer 2 Interface Modes

Mode	Purpose
switchport mode access	Puts the interface into permanent nontrunking mode and negotiates to convert the link into a nontrunking link. The interface becomes a nontrunk interface even if the neighboring interface does not change.
switchport mode dynamic desirable	Makes the interface actively attempt to convert the link to a trunking link. The interface becomes a trunk interface if the neighboring interface is set to **trunk**, **desirable**, or **auto** mode. This is the default mode for all Ethernet interfaces.
switchport mode dynamic auto	Makes the interface convert the link to a trunking link if the neighboring interface is set to **trunk** or **desirable** mode. This is the default mode for all Ethernet interfaces.
switchport mode trunk	Puts the interface into permanent trunking mode and negotiates to convert the link into a trunking link. The interface becomes a trunk interface even if the neighboring interface does not change.
switchport nonegotiate	Puts the interface into permanent trunking mode but prevents the interface from generating DTP frames. You must configure the neighboring interface manually as a trunk interface to establish a trunking link.

Note DTP is a point-to-point protocol. However, some internetworking devices might forward DTP frames improperly. To avoid this problem, ensure that interfaces connected to devices that do not support DTP are configured with the **access** keyword if you do not intend to trunk across those links. To enable trunking to a device that does not support DTP, use the **nonegotiate** keyword to cause the interface to become a trunk without generating DTP frames.

Default Layer 2 Ethernet Interface Configuration

Table 9-3 shows the Layer 2 Ethernet interface default configuration.

Table 9-3 Layer 2 Ethernet Interface Default Configuration

Feature	Default Value
Interface mode	switchport mode dynamic auto
Trunk encapsulation	switchport trunk encapsulation negotiate
Allowed VLAN range	VLANs 1–1005
VLAN range eligible for pruning	VLANs 2–1001
Default VLAN (for access ports)	VLAN 1

Table 9-3 Layer 2 Ethernet Interface Default Configuration (continued)

Feature	Default Value
Native VLAN (for 802.1Q only trunks)	VLAN 1
STP[1]	Enabled for all VLANs
STP port priority	128
STP port cost	• 19 for 10/100-Mbps Fast Ethernet interfaces • 19 for 100-Mbps Fast Ethernet interfaces • 4 for 1000-Mbps Gigabit Ethernet interfaces

1. STP = Spanning Tree Protocol

Layer 2 Interface Configuration Guidelines and Restrictions

Keep the following guidelines and restrictions in mind when you configure Layer 2 interfaces:

- In a network of Cisco switches connected through 802.1Q trunks, the switches maintain one instance of spanning tree for each VLAN allowed on the trunks. Non-Cisco 802.1Q switches maintain only one instance of spanning tree for all VLANs allowed on the trunks.

  When you connect a Cisco switch to a non-Cisco device through an 802.1Q trunk, the Cisco switch combines the spanning tree instance of the native VLAN of the trunk with the spanning tree instance of the non-Cisco 802.1Q switch. However, spanning tree information for each VLAN is maintained by Cisco switches separated by a cloud of non-Cisco 802.1Q switches. The non-Cisco 802.1Q cloud separating the Cisco switches is treated as a single trunk link between the switches.
- Make sure the native VLAN for an 802.1Q trunk is the same on both ends of the trunk link. If the VLAN on one end of the trunk is different from the VLAN on the other end, spanning tree loops might result.
- Disabling spanning tree on any VLAN of an 802.1Q trunk can cause spanning tree loops.

Configuring Ethernet Interfaces for Layer 2 Switching

The following sections describe how to configure Layer 2 switching on a Catalyst 4500 series switch:

- Configuring an Ethernet Interface as a Layer 2 Trunk, page 9-6
- Configuring an Interface as a Layer 2 Access Port, page 9-8
- Clearing Layer 2 Configuration, page 9-9

Configuring an Ethernet Interface as a Layer 2 Trunk

Note The default for Layer 2 interfaces is **switchport mode dynamic auto**. If the neighboring interface supports trunking and is configured to trunk mode or dynamic desirable mode, the link becomes a Layer 2 trunk. By default, trunks negotiate encapsulation. If the neighboring interface supports ISL and 802.1Q encapsulation and both interfaces are set to negotiate the encapsulation type, the trunk uses ISL encapsulation.

To configure an interface as a Layer 2 trunk, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to configure.
Step 2	`Switch(config-if)# shutdown`	(Optional) Shuts down the interface to prevent traffic flow until configuration is complete.
Step 3	`Switch(config-if)# switchport trunk encapsulation {isl | dot1q | negotiate}`	(Optional) Specifies the encapsulation. **Note** You must enter this command with either the **isl** or **dot1q** keyword to support the **switchport mode trunk** command, which is not supported by the default mode (**negotiate**).
Step 4	`Switch(config-if)# switchport mode {dynamic {auto | desirable} | trunk}`	Configures the interface as a Layer 2 trunk. (Required only if the interface is a Layer 2 access port or to specify the trunking mode.)
Step 5	`Switch(config-if)# switchport access vlan vlan_num`	(Optional) Specifies the access VLAN, which is used if the interface stops trunking. The access VLAN is not used as the native VLAN. **Note** The *vlan_num* parameter is either a single VLAN number from 1 to 1005 or a range of VLANs described by two VLAN numbers, the lesser one first, separated by a dash. Do not enter any spaces between comma-separated *vlan* parameters or in dash-specified ranges.
Step 6	`Switch(config-if)# switchport trunk native vlan vlan_num`	For 802.1Q trunks, specifies the native VLAN. **Note** If you do not set the native VLAN, the default is used (VLAN 1).
Step 7	`Switch(config-if)# switchport trunk allowed vlan {add | except | all | remove} vlan_num[,vlan_num[,vlan_num[,....]]]`	(Optional) Configures the list of VLANs allowed on the trunk. All VLANs are allowed by default. You cannot remove any of the default VLANs from a trunk.
Step 8	`Switch(config-if)# switchport trunk pruning vlan {add | except | none | remove} vlan_num[,vlan_num[,vlan_num[,....]]]`	(Optional) Configures the list of VLANs allowed to be pruned from the trunk (see the "Understanding VTP Pruning" section on page 24-3). The default list of VLANs allowed to be pruned contains all VLANs, except for VLAN 1.
Step 9	`Switch(config-if)# no shutdown`	Activates the interface. (Required only if you shut down the interface.)
Step 10	`Switch(config-if)# end`	Exits interface configuration mode.

	Command	Purpose
Step 11	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port`	Displays the running configuration of the interface.
Step 12	`Switch# show interfaces [fastethernet | gigabitethernet] slot/port switchport`	Displays the switch port configuration of the interface.
Step 13	`Switch# show interfaces [{fastethernet | gigabitethernet} slot/port] trunk`	Displays the trunk configuration of the interface.

This example shows how to configure the Fast Ethernet interface 5/8 as an 802.1Q trunk. This example assumes that the neighbor interface is configured to support 802.1Q trunking and that the native VLAN defaults to VLAN 1:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/8
Switch(config-if)# shutdown
Switch(config-if)# switchport mode dynamic desirable
Switch(config-if)# switchport trunk encapsulation dot1q
Switch(config-if)# no shutdown
Switch(config-if)# end
Switch# exit
```

This example shows how to verify the running configuration:

```
Switch# show running-config interface fastethernet 5/8
Building configuration...
Current configuration:
!
interface FastEthernet5/8
 switchport mode dynamic desirable
 switchport trunk encapsulation dot1q
end
```

This example shows how to verify the switch port configuration:

```
Switch# show interfaces fastethernet 5/8 switchport
Name: Fa5/8
Switchport: Enabled
Administrative Mode: dynamic desirable
Operational Mode: trunk
Administrative Trunking Encapsulation: negotiate
Operational Trunking Encapsulation: dot1q
Negotiation of Trunking: Enabled
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Trunking VLANs Enabled: ALL
Pruning VLANs Enabled: 2-1001
```

This example shows how to verify the trunk configuration:

```
Switch# show interfaces fastethernet 5/8 trunk

Port      Mode         Encapsulation  Status        Native vlan
Fa5/8     desirable    n-802.1q       trunking      1

Port      Vlans allowed on trunk
Fa5/8 1-1005

Port      Vlans allowed and active in management domain
Fa5/8 1-6,10,20,50,100,152,200,300,303-305,349-351,400,500,521,524,570,801-8
02,850,917,999,1002-1005

Port      Vlans in spanning tree forwarding state and not pruned
Fa5/8 1-6,10,20,50,100,152,200,300,303-305,349-351,400,500,521,524,570,801-8
02,850,917,999,1002-1005

Switch#
```

Configuring an Interface as a Layer 2 Access Port

Note If you assign an interface to a VLAN that does not exist, the interface is not operational until you create the VLAN in the VLAN database (see the "Configuring VLANs in Global Configuration Mode" section on page 7-5).

To configure an interface as a Layer 2 access port, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to configure.
Step 2	`Switch(config-if)# shutdown`	(Optional) Shuts down the interface to prevent traffic flow until configuration is complete.
Step 3	`Switch(config-if)# switchport`	Configures the interface for Layer 2 switching: • You must enter the **switchport** command once without any keywords to configure the interface as a Layer 2 port before you can enter additional **switchport** commands with keywords. • Required only if you previously entered the **no switchport** command for the interface.
Step 4	`Switch(config-if)# switchport mode access`	Configures the interface as a Layer 2 access port.
Step 5	`Switch(config-if)# switchport access vlan vlan_num`	Place the interface in a VLAN.
Step 6	`Switch(config-if)# no shutdown`	Activates the interface. (Required only if you had shut down the interface.)
Step 7	`Switch(config-if)# end`	Exits interface configuration mode.
Step 8	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port`	Displays the running configuration of the interface.
Step 9	`Switch# show interfaces [{fastethernet | gigabitethernet} slot/port] switchport`	Displays the switch port configuration of the interface.

This example shows how to configure the Fast Ethernet interface 5/6 as an access port in VLAN 200:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/6
Switch(config-if)# shutdown
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 200
Switch(config-if)# no shutdown
Switch(config-if)# end
Switch# exit
```

This example shows how to verify the running configuration:

```
Switch# show running-config interface fastethernet 5/6
Building configuration...
!
Current configuration :33 bytes
interface FastEthernet 5/6
 switchport access vlan 200
 switchport mode access
end
```

This example shows how to verify the switch port configuration:

```
Switch# show running-config interface fastethernet 5/6 switchport
Name:Fa5/6
Switchport:Enabled
Administrative Mode:dynamic auto
Operational Mode:static access
Administrative Trunking Encapsulation:negotiate
Operational Trunking Encapsulation:native
Negotiation of Trunking:On
Access Mode VLAN:1 (default)
Trunking Native Mode VLAN:1 (default)
Administrative private-vlan host-association:none
Administrative private-vlan mapping:none
Operational private-vlan:none
Trunking VLANs Enabled:ALL
Pruning VLANs Enabled:2-1001
Switch#
```

Clearing Layer 2 Configuration

To clear the Layer 2 configuration on an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# default interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to clear.
Step 2	`Switch(config-if)# end`	Exits interface configuration mode.
Step 3	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port`	Displays the running configuration of the interface.
Step 4	`Switch# show interfaces [{fastethernet | gigabitethernet} slot/port] switchport`	Displays the switch port configuration of the interface.

This example shows how to clear the Layer 2 configuration on the Fast Ethernet interface 5/6:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# default interface fastethernet 5/6
Switch(config)# end
Switch# exit
```

This example shows how to verify that the Layer 2 configuration was cleared:

```
Switch# show running-config interface fastethernet 5/6
Building configuration...
Current configuration:
!
interface FastEthernet5/6
end
```

This example shows how to verify the switch port configuration:

```
Switch# show interfaces fastethernet 5/6 switchport
Name: Fa5/6
Switchport: Enabled
Switch#
```

Configuring SmartPort Macros

This chapter describes how to configure and apply SmartPort macros on your switch.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

This chapter consists of these sections:

Understanding SmartPort Macros

SmartPort macros provide a convenient way to save and share common configurations. You can use SmartPort 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 SmartPort macro is a set of CLI commands that you define. SmartPort macro sets do not contain new CLI commands; Each SmartPort macro is a group of existing CLI commands.

When you apply a SmartPort macro on an interface, the CLI commands contained 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 interface and are saved in the running configuration file.

Configuring Smart-Port Macros

You can create a new SmartPort 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 to an interface or a range of interfaces.

This section includes information about these topics:

Default SmartPort Macro Configuration

This section illustrates the default configurations for the four supported macros. These macros can only be viewed and applied; they cannot be modified by the user.

cisco-desktop

```
# 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
# Ensure port-security age is greater than one minute
# and use inactivity timer
# “Port-security maximum 1” is the default and will not
# Show up in the config
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
```

cisco-phone

```
# VoIP enabled interface - Enable data VLAN
# and voice VLAN (VVID)
# Recommended value for access vlan (AVID) should not be 1\
switchport access vlan $AVID
switchport mode access
# Update the Voice VLAN (VVID) value which should be
# different from data VLAN
# Recommended value for voice vlan (VVID) should not be 1
switchport voice vlan $VVID
# Enable port security limiting port to a 3 MAC
```

```
# addressess -- One for desktop and two for phone
switchport port-security
switchport port-security maximum 3
# 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
# Enable auto-qos to extend trust to attached Cisco phone
auto qos voip cisco-phone
# Configure port as an edge network port
spanning-tree portfast
spanning-tree bpduguard enable@
```

cisco-switch

```
# Access Uplink to Distribution
switchport trunk encapsulation dot1q
# Define unique Native VLAN on trunk ports
# Recommended value for native vlan (NVID) should not be 1
switchport trunk native vlan $NVID
# Update the allowed VLAN range (VRANGE) such that it
# includes data, voice and native VLANs
# switchport trunk allowed vlan $VRANGE
# Hardcode trunk and disable negotiation to
# speed up convergence
switchport mode trunk
switchport nonegotiate
# Configure qos to trust this interface
auto qos voip trust
# 802.1w defines the link as pt-pt for rapid convergence
spanning-tree link-type point-to-point
```

cisco-router

```
# Access Uplink to Distribution
switchport trunk encapsulation dot1q
# Define unique Native VLAN on trunk ports
# Recommended value for native vlan (NVID) should not be 1
switchport trunk native vlan $NVID
# Update the allowed VLAN range (VRANGE) such that it
# includes data, voice and native VLANs
# switchport trunk allowed vlan $VRANGE
# Hardcode trunk and disable negotiation to
# speed up convergence
# Hardcode speed and duplex to router
switchport mode trunk
switchport nonegotiate
speed 100
duplex full
# Configure qos to trust this interface
auto qos voip trust
qos trust dscp
# Ensure fast access to the network when enabling the interface.
# Ensure that switch devices cannot become active on the interface.
spanning-tree portfast
spanning-tree bpduguard enable
```

SmartPort Macro Configuration Guidelines

Follow these guidelines when configuring macros on your switch:

- Do not use **exit** or **end** commands when creating a macro. This action could cause commands that follow **exit** or **end** to execute in a different command mode.
- When creating a macro, all CLI commands should be interface configuration mode commands.
- Some CLI commands are specific to certain interface types. The macro will fail the syntax check or the configuration check, and the switch will return an error message if it is applied to an interface that does not accept the configuration.
- When a macro is applied to an interface, all existing configuration on the interface is retained. This is helpful when applying an incremental configuration to an interface.
- 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 trace** *macro-name* interface configuration command to show what macros are running on an interface or to debug the macro to determine any syntax or configuration errors.
- If a command fails when you apply a macro, either due to a syntax error or to a configuration error, the macro continues to apply the remaining commands to the interface.
- 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 individual interface within the range. If a macro command fails on one interface, it is still applied to the remaining interfaces.

Creating and Applying SmartPort Macros

To create and apply a SmartPort macro, perform the following task:

	Command	Purpose
Step 1	`Switch # configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# macro name` *macro-name*	Creates a macro definition, and enters a macro name. A macro definition can contain up to 3000 characters. Enters the macro commands with one command per line. Use the @ character to end the macro. Use the **#** character at the beginning of a line to enter comment text within the macro. Do not use the **exit** or **end** commands in a macro. This action could cause any commands following **exit** or **end** to execute in a different command mode. For best results, all commands in a macro should be interface configuration mode commands.
Step 3	`Switch(config)# interface` *interface-id*	Enters interface configuration mode and specifies the interface on which to apply the macro.
Step 4	`Switch(config-if)# macro {apply | trace}` *macro-name*	Applies each command defined in the macro to the interface.
Step 5	`Switch(config-if)# macro description` *text*	(Optional) Enters a description about the macro that is applied to the interface.
Step 6	`Switch(config-if)# end`	Returns to privileged EXEC mode.

	Command	Purpose
Step 7	`Switch# show parser macro`	Verifies that the macro was created.
Step 8	`Switch# show running-config interface` *interface-id*	Verifies that the macro is applied to an interface.
Step 9	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

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. You can delete a macro-applied configuration on an interface by entering the **default interface** *interface-id* interface configuration command. Alternatively, you can create an *anti-macro* for an existing macro that contains the **no** form of all the corresponding commands in the original macro. Then apply the anti-macro to the interface.

The following sections illustrate how to apply and display the attachments on each of the supported macros:

- cisco-desktop, page 10-5
- cisco-phone, page 10-6
- cisco-switch, page 10-6
- cisco-router, page 10-7

cisco-desktop

This example shows how to apply the cisco-desktop macro to interface Fast Ethernet interface 2/9:

```
Switch(config)# interface fastethernet2/9
Switch(config-if)# macro apply cisco-desktop $AVID 35
Switch(config-if)# end
Switch# show parser macro name cisco-desktop
Macro name : cisco-desktop
Macro type : customizable

# Basic interface - Enable data VLAN only
# Recommended value for access vlan (AVID) should not be 1
switchport access vlan $AVID [access_vlan_id]
switchport mode access
# Enable port security limiting port to a single
# MAC address -- that of desktop
switchport port-security
# Ensure port-security age is greater than one minute
# and use inactivity timer
# "Port-security maximum 1" is the default and will not
# Show up in the config
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# show parser macro description
Interface    Macro Description
---------------------------------------------------------------
Fa2/9        cisco-desktop
---------------------------------------------------------------
```

cisco-phone

This example shows how to apply the cisco-phone macro to interface Fast Ethernet interface 2/9:

```
Switch(config)# interface fastethernet2/9
Switch(config-if)# macro apply cisco-phone
Switch(config-if)# macro description cisco-phone $AVID 35 $VVID 56
Switch(config-if)# end
Switch# show parser macro name cisco-phone
Macro name : cisco-phone
Macro type : customizable

# VoIP enabled interface - Enable data VLAN
# and voice VLAN (VVID)
# Recommended value for access vlan (AVID) should not be 1\
switchport access vlan $AVID [access_vlan_id]
switchport mode access
# Update the Voice VLAN (VVID) value which should be
# different from data VLAN
# Recommended value for voice vlan (VVID) should not be 1
switchport voice vlan $VVID [voice_vlan_id]
# Enable port security limiting port to a 3 MAC
# addressess -- One for desktop and two for phone
switchport port-security
switchport port-security maximum 3
# 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
# Enable auto-qos to extend trust to attached Cisco phone
auto qos voip cisco-phone
# Configure port as an edge network port
spanning-tree portfast
spanning-tree bpduguard enable@

Switch# show parser macro description
Interface    Macro Description
---------------------------------------------------------------
Fa2/9        cisco-phone
---------------------------------------------------------------
```

cisco-switch

This example shows how to apply the cisco-switch macro to interface Fast Ethernet interface 2/9:

```
Switch(config)# interface fastethernet2/9
Switch(config-if)# macro apply cisco-switch
Switch(config-if)# macro description cisco-switch $NVID 38
Switch(config-if)# end
Switch# show parser macro name cisco-switch
Macro name : cisco-switch
Macro type : customizable

# Access Uplink to Distribution
switchport trunk encapsulation dot1q
# Define unique Native VLAN on trunk ports
# Recommended value for native vlan (NVID) should not be 1
switchport trunk native vlan $NVID [native_vlan_id]
```

```
# Update the allowed VLAN range (VRANGE) such that it
# includes data, voice and native VLANs
# switchport trunk allowed vlan $VRANGE [vlan_range]
# Hardcode trunk and disable negotiation to
# speed up convergence
switchport mode trunk
switchport nonegotiate
# Configure qos to trust this interface
auto qos voip trust
# 802.1w defines the link as pt-pt for rapid convergence
spanning-tree link-type point-to-point

Switch# show parser macro description
Interface    Macro Description
---------------------------------------------------------------
Fa2/9        cisco-switch
---------------------------------------------------------------
```

cisco-router

This example shows how to apply the cisco-router macro to interface Fast Ethernet interface 2/9:

```
Switch(config)# interface fastethernet2/9
Switch(config-if)# macro apply cisco-router
Switch(config-if)# macro description cisco-router $NVID 45I
Switch(config-if)# end
Switch# show parser macro name cisco-router
Macro name : cisco-router
Macro type : customizable

# Access Uplink to Distribution
switchport trunk encapsulation dot1q
# Define unique Native VLAN on trunk ports
# Recommended value for native vlan (NVID) should not be 1
switchport trunk native vlan $NVID [native_vlan_id]
# Update the allowed VLAN range (VRANGE) such that it
# includes data, voice and native VLANs
# switchport trunk allowed vlan $VRANGE [vlan_range]
# Hardcode trunk and disable negotiation to
# speed up convergence
# Hardcode speed and duplex to router
switchport mode trunk
switchport nonegotiate
speed 100
duplex full
# Configure qos to trust this interface
auto qos voip trust
qos trust dscp
# Ensure fast access to the network when enabling the interface.
# Ensure that switch devices cannot become active on the interface.
spanning-tree portfast
spanning-tree bpduguard enable

Switch# show parser macro description
Interface    Macro Description
---------------------------------------------------------------
Fa2/9        cisco-router
---------------------------------------------------------------
```

Displaying SmartPort Macros

To display the SmartPort macros, use one or more of the privileged EXEC commands in Table 10-1.

Table 10-1 Commands for Displaying SmartPort Macros

Command	Purpose
show parser macro	Displays all configured macros.
show parser macro name *macro-name*	Displays a specific macro.
show parser macro brief	Displays the configured macro names.
show parser macro description [**interface** *interface-id*]	Displays the macro description for all interfaces or for a specified interface.

Understanding and Configuring STP

This chapter describes how to configure the Spanning Tree Protocol (STP) on a Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For information on configuring the PortFast, UplinkFast, and BackboneFast, and other spanning tree enhancements, see Chapter 12, "Configuring STP Features."

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of STP

STP is a Layer 2 link management protocol that provides path redundancy while preventing undesirable loops in the network. For a Layer 2 Ethernet network to function properly, only one active path can exist between any two stations. A loop-free subset of a network topology is called a spanning tree. The operation of a spanning tree is transparent to end stations, which cannot detect whether they are connected to a single LAN segment or a switched LAN of multiple segments.

A Catalyst 4500 series switch use STP (the IEEE 802.1D bridge protocol) on all VLANs. By default, a single spanning tree runs on each configured VLAN (provided you do not manually disable the spanning tree). You can enable and disable a spanning tree on a per-VLAN basis.

When you create fault-tolerant internetworks, you must have a loop-free path between all nodes in a network. The spanning tree algorithm calculates the best loop-free path throughout a switched Layer 2 network. Switches send and receive spanning tree frames at regular intervals. The switches do not forward these frames, but use the frames to construct a loop-free path.

Multiple active paths between end stations cause loops in the network. If a loop exists in the network, end stations might receive duplicate messages and switches might learn end station MAC addresses on multiple Layer 2 interfaces. These conditions result in an unstable network.

A spanning tree defines a tree with a root switch and a loop-free path from the root to all switches in the Layer 2 network. A 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.

When two ports on a switch are part of a loop, the spanning tree port priority and port path cost setting determine which port is put in the forwarding state and which port is put in the blocking state. The spanning tree port priority value represents the location of an interface in the network topology and how well located it is to pass traffic. The spanning tree port path cost value represents media speed.

Understanding the Bridge ID

Each VLAN on each network device has a unique 64-bit bridge ID consisting of a bridge priority value, an extended system ID, and an STP MAC address allocation.

Bridge Priority Value

The bridge priority value determines whether a given redundant link will be given priority and considered part of a given span in a spanning tree. Preference is given to lower values, and if you want to manually configure a preference, assign a lower bridge priority value to a link than to its redundant possibility. With releases prior to 12.1(12c)EW, the bridge priority is a 16-bit value (see Table 11-1).With Release 12.1(12c)EW and later releases, the bridge priority is a 4-bit value when the extended system ID is enabled (see Table 11-2). See the "Configuring the Bridge Priority of a VLAN" section on page 11-16.

Extended System ID

Extended system IDs are VLAN IDs between 1025 and 4096. Releases 12.1(12c)EW and later releases support a 12-bit extended system ID field as part of the bridge ID (see Table 11-2). Chassis that support only 64 MAC addresses always use the 12-bit extended system ID. On chassis that support 1024 MAC addresses, you can enable use of the extended system ID. STP uses the VLAN ID as the extended system ID. See the "Enabling the Extended System ID" section on page 11-8.

Table 11-1 Bridge Priority Value with the Extended System ID Disabled

Bridge Priority Value															
Bit 16	**Bit 15**	**Bit 14**	**Bit 13**	**Bit 12**	**Bit 11**	**Bit 10**	**Bit 9**	**Bit 8**	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**
32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1

Table 11-2 Bridge Priority Value and Extended System ID with the Extended System ID Enabled

Bridge Priority Value				Extended System ID (Set Equal to the VLAN ID)											
Bit 16	**Bit 15**	**Bit 14**	**Bit 13**	**Bit 12**	**Bit 11**	**Bit 10**	**Bit 9**	**Bit 8**	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**
32768	16384	8192	4096	VLAN ID											

STP MAC Address Allocation

A Catalyst 4500 series switch chassis has either 64 or 1024 MAC addresses available to support software features like STP. Enter the **show module** command to view the MAC address range on your chassis.

Release 12.1(12c)EW and later releases support chassis with 64 or 1024 MAC addresses. For chassis with 64 MAC addresses, STP uses the extended system ID plus a MAC address to make the bridge ID unique for each VLAN.

Earlier releases support chassis with 1024 MAC addresses. With earlier releases, STP uses one MAC address per VLAN to make the bridge ID unique for each VLAN.

Bridge Protocol Data Units

The following elements determine the stable active spanning tree topology of a switched network:

- The unique bridge ID (bridge priority and MAC address) associated with each VLAN on each switch
- The spanning tree path cost (or bridge priority value) to the root bridge
- The port identifier (port priority and MAC address) associated with each Layer 2 interface

Bridge protocol data units (BPDUs) contain information about the transmitting bridge and its ports, including the bridge and MAC addresses, bridge priority, port priority, and path cost. The system computes the spanning tree topology by transmitting BPDUs among connecting switches, and in one direction from the root switch. Each configuration BPDU contains at least the following:

- The unique bridge ID of the switch that the transmitting switch believes to be the root switch
- The spanning tree path cost to the root
- The bridge ID of the transmitting bridge
- The age of the message
- The identifier of the transmitting port
- Values for the *hello*, *forward delay*, and *max-age* protocol timers

When a switch transmits a BPDU frame, all switches connected to the LAN on which the frame is transmitted receive the BPDU. When a switch receives a BPDU, it does not forward the frame but instead uses the information in the frame to calculate a BPDU and, if the topology changes, initiate a BPDU transmission.

A BPDU exchange results in the following:

- One switch is elected as the root bridge.
- The shortest distance to the root bridge is calculated for each switch based on the path cost.
- A designated bridge for each LAN segment is selected. This is the switch closest to the root bridge through which frames are forwarded to the root.
- A root port is selected. This is the port providing the best path from the bridge to the root bridge.
- Ports included in the spanning tree are selected.

Election of the Root Bridge

For each VLAN, the switch with the highest bridge priority (the lowest numerical priority value) is elected as the root bridge. If all switches are configured with the default priority value (32,768), the switch with the lowest MAC address in the VLAN becomes the root bridge.

The spanning tree root bridge is the logical center of the spanning tree topology in a switched network. All paths that are not required to reach the root bridge from anywhere in the switched network are placed in spanning tree blocking mode.

A spanning tree uses the information provided by BPDUs to elect the root bridge and root port for the switched network, as well as the root port and designated port for each switched segment.

STP Timers

Table 11-3 describes the STP timers that affect the performance of the entire spanning tree.

Table 11-3 Spanning Tree Protocol Timers

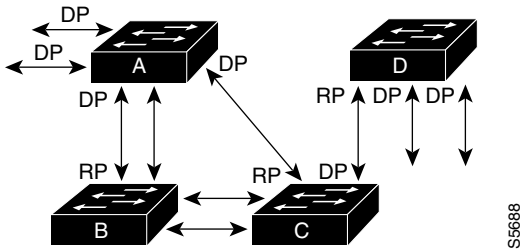
Variable	Description
hello_time	Determines how often the switch broadcasts hello messages to other switches.
forward_time	Determines how long each of the listening and learning states will last before the port begins forwarding.
max_age	Determines the amount of time that protocol information received on a port is stored by the switch.

Creating the STP Topology

The goal of the spanning tree algorithm is to make the most direct link the root port. 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 optimal according to link speed. For instance, connecting higher-speed links to a port that has a higher number than the current root port can cause a root-port change.

In Figure 11-1, Switch A is elected as the root bridge. (This could happen if the bridge priority of all the switches is set to the default value [32,768] and Switch A has the lowest MAC address.) However, due to traffic patterns, the number of forwarding ports, or link types, Switch A might not be the ideal root bridge. By increasing the STP port priority (lowering the numerical value) of the ideal switch so that it becomes the root bridge, you force a spanning tree recalculation to form a new spanning tree topology with the ideal switch as the root.

Figure 11-1 Spanning Tree Topology



RP = Root Port
DP = Designated Port

For example, assume that one port on Switch B is a fiber-optic link, and another port on Switch B (an unshielded twisted-pair [UTP] link) is the root port. Network traffic might be more efficient over the high-speed fiber-optic link. By changing the spanning tree port priority on the fiber-optic port to a higher priority (lower numerical value) than the priority set for the root port, the fiber-optic port becomes the new root port.

STP Port 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 a Layer 2 interface transitions directly from nonparticipation in the spanning tree topology to the forwarding state, it can create temporary data loops. Ports 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 frames that have been forwarded under the old topology.

Each Layer 2 interface on a switch that uses spanning tree exists in one of the following five states:

- Blocking—In this state, the Layer 2 interface does not participate in frame forwarding.
- Listening—This state is the first transitional state after the blocking state when spanning tree determines that the Layer 2 interface should participate in frame forwarding.
- Learning—In this state, the Layer 2 interface prepares to participate in frame forwarding.
- Forwarding—In this state, the Layer 2 interface forwards frames.
- Disabled—In this state, the Layer 2 interface does not participate in spanning tree and does not forward frames.

MAC Address Allocation

The supervisor engine has a pool of 1024 MAC addresses that are used as the bridge IDs for the VLAN spanning trees. You can use the **show module** command to view the MAC address range (allocation range for the supervisor) that the spanning tree uses for the algorithm.

MAC addresses for the Catalyst 4506 switch are allocated sequentially, with the first MAC address in the range assigned to VLAN 1, the second MAC address in the range assigned to VLAN 2, and so forth. For example, if the MAC address range is 00-e0-1e-9b-2e-00 to 00-e0-1e-9b-31-ff, the VLAN 1 bridge ID is 00-e0-1e-9b-2e-00, the VLAN 2 bridge ID is 00-e0-1e-9b-2e-01, the VLAN 3 bridge ID is 00-e0-1e-9b-2e-02, and so on. On other Catalyst 4500 series platforms, all VLANS map to the same MAC address rather than mapping to separate MAC addresses.

STP and IEEE 802.1Q Trunks

802.1Q VLAN trunks impose some limitations on the spanning tree strategy for a network. In a network of Cisco switches connected through 802.1Q trunks, the switches maintain one instance of spanning tree for each VLAN allowed on the trunks. However, non-Cisco 802.1Q switches maintain only one instance of spanning tree for all VLANs allowed on the trunks.

When you connect a Cisco switch to a non-Cisco device (that supports 802.1Q) through an 802.1Q trunk, the Cisco switch combines the spanning tree instance of the 802.1Q native VLAN of the trunk with the spanning tree instance of the non-Cisco 802.1Q switch. However, all per-VLAN spanning tree information is maintained by Cisco switches separated by a network of non-Cisco 802.1Q switches. The non-Cisco 802.1Q network separating the Cisco switches is treated as a single trunk link between the switches.

Note For more information on 802.1Q trunks, see Chapter 9, "Configuring Layer 2 Ethernet Interfaces."

Per-VLAN Rapid Spanning Tree

Per-VLAN Rapid Spanning Tree (PVRST+) is the same as PVST+, although PVRST+ utilizes a rapid STP based on IEEE 802.1w rather than 802.1D to provide faster convergence. PVRST+ uses roughly the same configuration as PVST+ and needs only minimal configuration. In PVRST+, dynamic CAM entries are flushed immediately on a per-port basis when any topology change is made. UplinkFast and BackboneFast are enabled but not active in this mode, since the functionality is built into the Rapid STP. PVRST+ provides for rapid recovery of connectivity following the failure of a bridge, bridge port, or LAN.

For enabling information, see "Enabling Per-VLAN Rapid Spanning Tree" on page 20.

Default STP Configuration

Table 11-4 shows the default spanning tree configuration.

Table 11-4 Spanning Tree Default Configuration Values

Feature	Default Value
Enable state	Spanning tree enabled for all VLANs
Bridge priority value	32,768
Spanning tree port priority value (configurable on a per-interface basis—used on interfaces configured as Layer 2 access ports)	128
Spanning tree port cost (configurable on a per-interface basis—used on interfaces configured as Layer 2 access ports)	• Gigabit Ethernet: 4 • Fast Ethernet: 19 • Fast Ethernet 10/100: 19
Spanning tree VLAN port priority value (configurable on a per-VLAN basis—used on interfaces configured as Layer 2 trunk ports)	128

Table 11-4 Spanning Tree Default Configuration Values (continued)

Feature	Default Value
Spanning tree VLAN port cost (configurable on a per-VLAN basis—used on interfaces configured as Layer 2 trunk ports)	• Gigabit Ethernet: 4 • Fast Ethernet: 19
Hello time	2 sec
Forward delay time	15 sec
Maximum aging time	20 sec

Configuring STP

The following sections describe how to configure spanning tree on VLANs:

Note The spanning tree commands described in this chapter can be configured on any interface except those configured with the **no switchport** command.

Enabling STP

Note By default, spanning tree is enabled on all the VLANs.

You can enable a spanning tree on a per-VLAN basis. The switch maintains a separate instance of spanning tree for each VLAN (except on VLANs on which you have disabled a spanning tree).

To enable a spanning tree on a per-VLAN basis, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# spanning-tree vlan vlan_ID`	Enables spanning tree for VLAN *vlan_id*. The *vlan_ID* value can range from 1 to 4094.
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show spanning-tree vlan vlan_ID`	Verifies that spanning tree is enabled.

This example shows how to enable a spanning tree on VLAN 200:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 200
Switch(config)# end
Switch#
```

Note Because spanning tree is enabled by default, issuing a **show running** command to view the resulting configuration will not display the command you entered to enable spanning tree.

This example shows how to verify that spanning tree is enabled on VLAN 200:

```
Switch# show spanning-tree vlan 200

 VLAN200 is executing the ieee compatible Spanning Tree protocol
  Bridge Identifier has priority 32768, address 0050.3e8d.6401
  Configured hello time 2, max age 20, forward delay 15
  Current root has priority 16384, address 0060.704c.7000
  Root port is 264 (FastEthernet5/8), cost of root path is 38
  Topology change flag not set, detected flag not set
  Number of topology changes 0 last change occurred 01:53:48 ago
  Times:  hold 1, topology change 24, notification 2
          hello 2, max age 14, forward delay 10
  Timers: hello 0, topology change 0, notification 0

 Port 264 (FastEthernet5/8) of VLAN200 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 129.9.
   Designated root has priority 16384, address 0060.704c.7000
   Designated bridge has priority 32768, address 00e0.4fac.b000
   Designated port id is 128.2, designated path cost 19
   Timers: message age 3, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 3, received 3417

Switch#
```

Enabling the Extended System ID

Note The extended system ID is enabled permanently on chassis that support 64 MAC addresses.

You can use the **spanning-tree extend system-id** command to enable the extended system ID on chassis that support 1024 MAC addresses. See the "Understanding the Bridge ID" section on page 11-2.

To enable the extended system ID, perform this task:

	Command	Purpose
Step 1	`Switch(config)# spanning-tree extend system-id`	Enables the extended system ID. Disables the extended system ID. **Note** You cannot disable the extended system ID on chassis that support 64 MAC addresses or when you have configured extended range VLANs (see "Table 11-4Spanning Tree Default Configuration Values" section on page 11-6).
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID`	Verifies the configuration.

Note When you enable or disable the extended system ID, the bridge IDs of all active STP instances are updated, which might change the spanning tree topology.

This example shows how to enable the extended system ID:

```
Switch# configure terminal
Switch(config)# spanning-tree extend system-id
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree summary | include extended
Extended system ID is enabled.
```

Configuring the Root Bridge

A Catalyst 4000 family switch maintains an instance of spanning tree for each active VLAN configured on the switch. A bridge ID, consisting of the bridge priority and the bridge MAC address, is associated with each instance. For each VLAN, the switch with the lowest bridge ID will become the root bridge for that VLAN. Whenever the bridge priority changes, the bridge ID also changes. This results in the recomputation of the root bridge for the VLAN.

To configure a switch to become the root bridge for the specified VLAN, use the **spanning-tree vlan** *vlan-ID* **root** command to modify the bridge priority from the default value (32,768) to a significantly lower value. The bridge priority for the specified VLAN is set to 8192 if this value will cause the switch to become the root for the VLAN. If any bridge for the VLAN has a priority lower than 8192, the switch sets the priority to 1 less than the lowest bridge priority.

For example, assume that all the switches in the network have the bridge priority for VLAN 100 set to the default value of 32,768. Entering the **spanning-tree vlan 100 root primary** command on a switch will set the bridge priority for VLAN 100 to 8192, causing this switch to become the root bridge for VLAN 100.

Note The root switch for each instance of spanning tree 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 (the maximum number of bridge hops between any two end stations in the network). When you specify the network diameter, a switch automatically picks an optimal hello time, forward delay time, and maximum age time for a network of that diameter. This can significantly reduce the spanning tree convergence time.

Use the **hello-time** keyword to override the automatically calculated hello time.

Note We recommend that you avoid manually configuring the hello time, forward delay time, and maximum age time after configuring the switch as the root bridge.

To configure a switch as the root switch, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID root primary [diameter hops [hello-time seconds]]`	Configures a switch as the root switch. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.

This example shows how to configure a switch as the root bridge for VLAN 10, with a network diameter of 4:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 10 root primary diameter 4
Switch(config)# end
Switch#
```

This example shows how the configuration changes when a switch becomes a spanning tree root. This is the configuration before the switch becomes the root for VLAN 1:

```
Switch#show spanning-tree vlan 1

VLAN1 is executing the ieee compatible Spanning Tree protocol
  Bridge Identifier has priority 32768, address 0030.94fc.0a00
  Configured hello time 2, max age 20, forward delay 15
  Current root has priority 32768, address 0001.6445.4400
  Root port is 323 (FastEthernet6/3), cost of root path is 19
  Topology change flag not set, detected flag not set
  Number of topology changes 2 last change occurred 00:02:19 ago
          from FastEthernet6/1
  Times: hold 1, topology change 35, notification 2
          hello 2, max age 20, forward delay 15
  Timers:hello 0, topology change 0, notification 0, aging 300

 Port 323 (FastEthernet6/3) of VLAN1 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 129.67.
   Designated root has priority 32768, address 0001.6445.4400
   Designated bridge has priority 32768, address 0001.6445.4400
   Designated port id is 129.67, designated path cost 0
   Timers:message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   BPDU:sent 3, received 91
```

```
 Port 324 (FastEthernet6/4) of VLAN1 is blocking
   Port path cost 19, Port priority 128, Port Identifier 129.68.
   Designated root has priority 32768, address 0001.6445.4400
   Designated bridge has priority 32768, address 0001.6445.4400
   Designated port id is 129.68, designated path cost 0
   Timers:message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state:0
   BPDU:sent 1, received 89
```

Now, you can set the switch as the root:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 1 root primary
Switch(config)# spanning-tree vlan 1 root primary
 VLAN 1 bridge priority set to 8192
 VLAN 1 bridge max aging time unchanged at 20
 VLAN 1 bridge hello time unchanged at 2
 VLAN 1 bridge forward delay unchanged at 15
Switch(config)# end
```

This is the configuration after the switch becomes the root:

```
Switch# show spanning-tree vlan 1

VLAN1 is executing the ieee compatible Spanning Tree protocol
  Bridge Identifier has priority 8192, address 0030.94fc.0a00
  Configured hello time 2, max age 20, forward delay 15
  We are the root of the spanning tree
  Topology change flag set, detected flag set
  Number of topology changes 3 last change occurred 00:00:09 ago
  Times: hold 1, topology change 35, notification 2
         hello 2, max age 20, forward delay 15
  Timers:hello 0, topology change 25, notification 0, aging 15

Port 323 (FastEthernet6/3) of VLAN1 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 129.67.
   Designated root has priority 8192, address 0030.94fc.0a00
   Designated bridge has priority 8192, address 0030.94fc.0a00
   Designated port id is 129.67, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   BPDU:sent 9, received 105

 Port 324 (FastEthernet6/4) of VLAN1 is listening
   Port path cost 19, Port priority 128, Port Identifier 129.68.
   Designated root has priority 8192, address 0030.94fc.0a00
   Designated bridge has priority 8192, address 0030.94fc.0a00
   Designated port id is 129.68, designated path cost 0
   Timers:message age 0, forward delay 5, hold 0
   Number of transitions to forwarding state:0
   BPDU:sent 6, received 102

Switch#
```

Note Because the bridge priority is now set at 8192, this switch becomes the root of the spanning tree.

Configuring a Secondary Root Switch

When you configure a switch as the secondary root, the spanning tree bridge priority is modified from the default value (32,768) to 16,384. This means that the switch is likely to become the root bridge for the specified VLANs if the primary root bridge fails (assuming the other switches in the network use the default bridge priority of 32,768).

You can run 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 configuring the primary root switch.

Note We recommend that you avoid manually configuring the hello time, forward delay time, and maximum age time after configuring the switch as the root bridge.

To configure a switch as the secondary root switch, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID root secondary [diameter hops [hello-time seconds]]`	Configures a switch as the secondary root switch. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.

This example shows how to configure the switch as the secondary root switch for VLAN 10, with a network diameter of 4:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 10 root secondary diameter 4
VLAN 10 bridge priority set to 16384
 VLAN 10 bridge max aging time set to 14
 VLAN 10 bridge hello time unchanged at 2
 VLAN 10 bridge forward delay set to 10
Switch(config)# end
Switch#
```

This example shows how to verify the configuration of VLAN 1:

```
Switch#sh spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32768
             Address     0003.6b10.e800
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32768
             Address     0003.6b10.e800
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa3/1            Desg FWD 19        128.129  P2p
Fa3/2            Desg FWD 19        128.130  P2p
Fa3/48           Desg FWD 19        128.176  Edge P2p

Switch#
```

Configuring STP Port Priority

In the event of a loop, a spanning tree considers port priority when selecting an interface to put into the forwarding state. You can assign higher priority values to interfaces that you want a spanning tree to select first and lower priority values to interfaces that you want a spanning tree to select last. If all interfaces have the same priority value, a spanning tree puts the interface with the lowest interface number in the forwarding state and blocks other interfaces. The possible priority range is 0 through 240, configurable in increments of 16 (the default is 128).

Note The Cisco IOS software uses the port priority value when the interface is configured as an access port and uses VLAN port priority values when the interface is configured as a trunk port.

To configure the spanning tree port priority of an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {{fastethernet |gigabitethernet} slot/port} | {port-channel port_channel_number}`	Specifies an interface to configure.
Step 2	`Switch(config-if)# [no] spanning-tree port-priority port_priority`	Configures the port priority for an interface. The *port_priority* value can be from 0 to 240, in increments of 16. You can use the **no** keyword to restore the defaults.
Step 3	`Switch(config-if)# [no] spanning-tree vlan vlan_ID port-priority port_priority`	Configures the VLAN port priority for an interface. The *port_priority* value can be from 0 to 240, in increments of 16. You can use the **no** keyword to restore the defaults.
Step 4	`Switch(config-if)# end`	Exits configuration mode.
Step 5	`Switch# show spanning-tree interface {{fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}` `show spanning-tree vlan vlan_ID`	Verifies the configuration.

This example shows how to configure the spanning tree port priority of a Fast Ethernet interface:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree port-priority 100
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration of a Fast Ethernet interface when it is configured as an access port:

```
Switch# show spanning-tree interface fastethernet 3/1

Vlan             Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
VLAN0001         Desg FWD 19        128.129  P2p
VLAN1002         Desg FWD 19        128.129  P2p
VLAN1003         Desg FWD 19        128.129  P2p
VLAN1004         Desg FWD 19        128.129  P2p
VLAN1005         Desg FWD 19        128.129  P2p
Switch#
```

This example shows how to display the details of the interface configuration when the interface is configured as an access port:

```
Switch# show spanning-tree interface fastethernet 3/1 detail
Port 129 (FastEthernet3/1) of VLAN0001 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.129.
   Designated root has priority 32768, address 0003.6b10.e800
   Designated bridge has priority 32768, address 0003.6b10.e800
   Designated port id is 128.129, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   Link type is point-to-point by default
   BPDU:sent 187, received 1

 Port 129 (FastEthernet3/1) of VLAN1002 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.129.
   Designated root has priority 32768, address 0003.6b10.ebe9
   Designated bridge has priority 32768, address 0003.6b10.ebe9
   Designated port id is 128.129, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   Link type is point-to-point by default
   BPDU:sent 94, received 2

 Port 129 (FastEthernet3/1) of VLAN1003 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.129.
   Designated root has priority 32768, address 0003.6b10.ebea
   Designated bridge has priority 32768, address 0003.6b10.ebea
   Designated port id is 128.129, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   Link type is point-to-point by default
   BPDU:sent 94, received 2

 Port 129 (FastEthernet3/1) of VLAN1004 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.129.
   Designated root has priority 32768, address 0003.6b10.ebeb
   Designated bridge has priority 32768, address 0003.6b10.ebeb
   Designated port id is 128.129, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   Link type is point-to-point by default
   BPDU:sent 95, received 2

 Port 129 (FastEthernet3/1) of VLAN1005 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.129.
   Designated root has priority 32768, address 0003.6b10.ebec
   Designated bridge has priority 32768, address 0003.6b10.ebec
   Designated port id is 128.129, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   Link type is point-to-point by default
   BPDU:sent 95, received 2
Switch#
```

Note The **show spanning-tree port-priority** command displays only information for ports with an active link. If there is no port with an active link, enter a **show running-config interface** command to verify the configuration.

This example shows how to configure the spanning tree VLAN port priority of a Fast Ethernet interface:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree vlan 200 port-priority 64
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration of VLAN 200 on the interface when it is configured as a trunk port:

```
Switch# show spanning-tree vlan 200
<...output truncated...>

Port 264 (FastEthernet5/8) of VLAN200 is forwarding
Port path cost 19, Port priority 64, Port Identifier 129.8.
   Designated root has priority 32768, address 0010.0d40.34c7
   Designated bridge has priority 32768, address 0010.0d40.34c7
   Designated port id is 128.1, designated path cost 0
   Timers: message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 0, received 13513

<...output truncated...>
Switch#
```

Configuring STP Port Cost

The default value for spanning tree port path cost is derived from the interface media speed. In the event of a loop, spanning tree considers port cost when selecting an interface to put into the forwarding state. You can assign lower cost values to interfaces that you want spanning tree to select first, and higher cost values to interfaces that you want spanning tree to select 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 other interfaces. The possible cost range is 1 through 200,000,000 (the default is media-specific).

Spanning tree uses the port cost value when the interface is configured as an access port and uses VLAN port cost values when the interface is configured as a trunk port.

To configure the spanning tree port cost of an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {{fastethernet |gigabitethernet} slot/port} | {port-channel port_channel_number}`	Specifies an interface to configure.
Step 2	`Switch(config-if)# [no] spanning-tree cost port_cost`	Configures the port cost for an interface. The *port_cost* value can be from 1 to 200,000,000. You can use the **no** keyword to restore the defaults.
Step 3	`Switch(config-if)# [no] spanning-tree vlan vlan_ID cost port_cost`	Configures the VLAN port cost for an interface. The *port_cost* value can be from 1 to 200,000,000. You can use the **no** keyword to restore the defaults.
Step 4	`Switch(config-if)# end`	Exits configuration mode.
Step 5	`Switch# show spanning-tree interface {{fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}` `show spanning-tree vlan vlan_ID`	Verifies the configuration.

This example shows how to change the spanning tree port cost of a Fast Ethernet interface:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree cost 18
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration of the interface when it is configured as an access port:

```
Switch# show spanning-tree interface fastethernet 5/8
 Port 264 (FastEthernet5/8) of VLAN200 is forwarding
   Port path cost 18, Port priority 100, Port Identifier 129.8.
   Designated root has priority 32768, address 0010.0d40.34c7
   Designated bridge has priority 32768, address 0010.0d40.34c7
   Designated port id is 128.1, designated path cost 0
   Timers: message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 0, received 13513
Switch#
```

This example shows how to configure the spanning tree VLAN port cost of a Fast Ethernet interface:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree vlan 200 cost 17
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration of VLAN 200 on the interface when it is configured as a trunk port:

```
Switch# show spanning-tree vlan 200
<...output truncated...>
Port 264 (FastEthernet5/8) of VLAN200 is forwarding
Port path cost 17, Port priority 64, Port Identifier 129.8.
   Designated root has priority 32768, address 0010.0d40.34c7
   Designated bridge has priority 32768, address 0010.0d40.34c7
   Designated port id is 128.1, designated path cost 0
   Timers: message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 0, received 13513

<...output truncated...>
Switch#
```

Note The **show spanning-tree** command displays only information for ports with an active link (green light is on). If there is no port with an active link, you can issue a **show running-config** command to confirm the configuration.

Configuring the Bridge Priority of a VLAN

Note Exercise care when configuring the bridge priority of a VLAN. In most cases, we recommend that you enter the **spanning-tree vlan** *vlan_ID* **root primary** and the **spanning-tree vlan** *vlan_ID* **root secondary** commands to modify the bridge priority.

To configure the spanning tree bridge priority of a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID priority bridge_priority`	Configures the bridge priority of a VLAN. The *bridge_priority* value can be from 1 to 65,535. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID bridge [brief]`	Verifies the configuration.

This example shows how to configure the bridge priority of VLAN 200 to 33,792:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 200 priority 33792
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree vlan 200 bridge brief
                                     Hello Max  Fwd
Vlan                  Bridge ID      Time  Age Delay  Protocol
---------------- -------------------- ---- ---- -----  --------
VLAN200          33792 0050.3e8d.64c8    2   20    15  ieee
Switch#
```

Configuring the Hello Time

Note Exercise care when configuring the hello time. In most cases, we recommend that you use the **spanning-tree vlan** *vlan_ID* **root primary** and the **spanning-tree vlan** *vlan_ID* **root secondary** commands to modify the hello time.

To configure the spanning tree hello time of a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID hello-time hello_time`	Configures the hello time of a VLAN. The *hello_time* value can be from 1 to 10 seconds. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID bridge [brief]`	Verifies the configuration.

This example shows how to configure the hello time for VLAN 200 to 7 seconds:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 200 hello-time 7
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree vlan 200 bridge brief
                                     Hello Max  Fwd
Vlan                 Bridge ID       Time  Age Delay  Protocol
---------------- -------------------- ---- ---- -----  --------
VLAN200          49152 0050.3e8d.64c8    7   20    15  ieee
Switch#
```

Configuring the Maximum Aging Time for a VLAN

Note Exercise care when configuring aging time. In most cases, we recommend that you use the **spanning-tree vlan** *vlan_ID* **root primary** and the **spanning-tree vlan** *vlan_ID* **root secondary** commands to modify the maximum aging time.

To configure the spanning tree maximum aging time for a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID max-age max_age`	Configures the maximum aging time of a VLAN. The *max_age* value can be from 6 to 40 seconds. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID bridge [brief]`	Verifies the configuration.

This example shows how to configure the maximum aging time for VLAN 200 to 36 seconds:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 200 max-age 36
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree vlan 200 bridge brief
                                     Hello Max  Fwd
Vlan                 Bridge ID       Time  Age Delay  Protocol
---------------- -------------------- ---- ---- -----  --------
VLAN200          49152 0050.3e8d.64c8    2   36    15  ieee
Switch#
```

Configuring the Forward-Delay Time for a VLAN

Note Exercise care when configuring forward-delay time. In most cases, we recommend that you use the **spanning-tree vlan** *vlan_ID* **root primary** and the **spanning-tree vlan** *vlan_ID* **root secondary** commands to modify the forward delay time.

To configure the spanning tree forward delay time for a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree vlan vlan_ID forward-time forward_time`	Configures the forward time of a VLAN. The *forward_time* value can be from 4 to 30 seconds. You can use the **no** keyword to restore the defaults.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID bridge [brief]`	Verifies the configuration.

This example shows how to configure the forward delay time for VLAN 200 to 21 seconds:

```
Switch# configure terminal
Switch(config)# spanning-tree vlan 200 forward-time 21
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree vlan 200 bridge brief
                                     Hello Max  Fwd
Vlan                  Bridge ID      Time  Age Delay  Protocol
---------------- -------------------- ---- ---- -----  --------
VLAN200          49152 0050.3e8d.64c8    2   20    21  ieee
Switch#
```

This example shows how to display spanning tree information for the bridge:

```
Switch# show spanning-tree bridge

                                                 Hello  Max  Fwd
Vlan                          Bridge ID           Time  Age  Dly  Protocol
---------------- --------------------------------- -----  ---  ---  --------
VLAN200               49152 0050.3e8d.64c8           2    20   15  ieee
VLAN202               49152 0050.3e8d.64c9           2    20   15  ieee
VLAN203               49152 0050.3e8d.64ca           2    20   15  ieee
VLAN204               49152 0050.3e8d.64cb           2    20   15  ieee
VLAN205               49152 0050.3e8d.64cc           2    20   15  ieee
VLAN206               49152 0050.3e8d.64cd           2    20   15  ieee
Switch#
```

Disabling Spanning Tree Protocol

To disable spanning tree on a per-VLAN basis, perform this task:

	Command	Purpose
Step 1	`Switch(config)# no spanning-tree vlan vlan_ID`	Disables spanning tree on a per-VLAN basis.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID`	Verifies that spanning tree is disabled.

This example shows how to disable spanning tree on VLAN 200:

```
Switch# configure terminal
Switch(config)# no spanning-tree vlan 200
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show spanning-tree vlan 200
Spanning tree instance for VLAN 200 does not exist.
Switch#
```

Enabling Per-VLAN Rapid Spanning Tree

Per-VLAN Rapid Spanning Tree (PVRST+) uses the existing PVST+ framework for configuration purposes and for interaction with other features. It also supports some of the PVST+ extensions.

To configure PVRST+, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spantree mode rapid-pvst`	Enables rapid-PVST+.
Step 2	`Switch(config)# interface` *interface/port*	Switches to interface configuration mode.
Step 3	`Switch(config)# spanning-tree link-type point-to-point`	Sets the link-type to point-to-point mode for the port.
Step 4	`Switch(config-if)# end`	Exits interface mode.
Step 5	`Switch(config)# end`	Exits configuration mode.
Step 6	`Switch(config-if)# clear spantree detected-protocols` *mod/port*	Detects any legacy bridges on the port
Step 7	`Switch# show spanning-tree summary totals`	Verifies the rapid-PVST+ configuration.

The following example shows how to configure Rapid-PVST+:

```
Switch# config t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# spanning-tree mode rapid-pvst
Switch(config)# interface fa 6/4
Switch(config-if)# spanning-tree link-type point-to-point
Switch(config-if)# end
Switch(config)# end
Switch#
23:55:32:%SYS-5-CONFIG_I:Configured from console by console
Switch# clear spanning-tree detected-protocols
```

The following example shows how to verify the configuration:

```
Switch# show spanning-tree summary totals
Switch is in rapid-pvst mode
Root bridge for:VLAN0001
Extended system ID           is disabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
EtherChannel misconfig guard is enabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Pathcost method used         is short
Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
1 vlan                        0         0        0          2          2
Switch#
```

Specifying the Link Type

Rapid connectivity is established only on point-to-point links. Spanning tree views a point-to-point link as a segment connecting only two switches running the spanning tree algorithm. Because the switch assumes that all full-duplex links are point-to-point links and that half-duplex links are shared links, you can avoid explicitly configuring the link type. To configure a specific link type, use the **spanning-tree linktype** command.

Restarting Protocol Migration

A switch running both MSTP and RSTP supports a built-in protocol migration process that enables the switch to interoperate with legacy 802.1D switches. If this switch receives a legacy 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only 802.1D BPDUs on that port. Furthermore, when an MSTP switch receives a legacy BPDU, it can also detect the following:

- that a port is at the boundary of a region
- an MST BPDU (version 3) associated with a different region, or
- an RST BPDU (version 2).

The switch, however, does not automatically revert to the MSTP mode if it no longer receives 802.1D BPDUs because it cannot determine whether or not 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 on the entire switch (that is, to force renegotiation with neighboring switches), use the **clear spanning-tree detected-protocols** commands in privileged EXEC mode. To restart the protocol migration process on a specific interface, enter the **clear spanning-tree detected-protocols interface** command *in interface-id* privileged EXEC mode.

CHAPTER 12

Configuring STP Features

This chapter describes the Spanning Tree Protocol (STP) features supported on the Catalyst 4500 series switches. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For information on configuring STP, see Chapter 11, "Understanding and Configuring STP."

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Root Guard

Spanning Tree root guard forces an interface to become a designated port, to protect the current root status and prevent surrounding switches from becoming the root switch.

When you enable root guard on a per-port basis, it is automatically applied to all of the active VLANs to which that port belongs. When you disable root guard, it is disabled for the specified port and the port automatically goes into the listening state.

When a switch that has ports with root guard enabled detects a new root, the ports will go into root-inconsistent state. Then, when the switch no longer detects a new root, its ports will automatically go into the listening state.

Overview of Loop Guard

Loop guard helps prevent bridging loops that could occur because of a unidirectional link failure on a point-to-point link. When enabled globally, loop guard applies to all point-to-point ports on the system. Loop guard detects root ports and blocked ports and ensures that they keep receiving BPDUs from their designated port on the segment. If a loop-guard-enabled root or blocked port stop receiving BPDUs from its designated port, it transitions to the blocking state, assuming there is a physical link error on this port. The port recovers from this state as soon as it receives a BPDU.

You can enable loop guard on a per-port basis. When you enable loop guard, it is automatically applied to all of the active instances or VLANs to which that port belongs. When you disable loop guard, it is disabled for the specified ports. Disabling loop guard moves all loop-inconsistent ports to the listening state.

If you enable loop guard on a channel and the first link becomes unidirectional, loop guard blocks the entire channel until the affected port is removed from the channel. Figure 12-1 shows loop guard in a triangular switch configuration.

Figure 12-1 Triangular Switch Configuration with Loop Guard

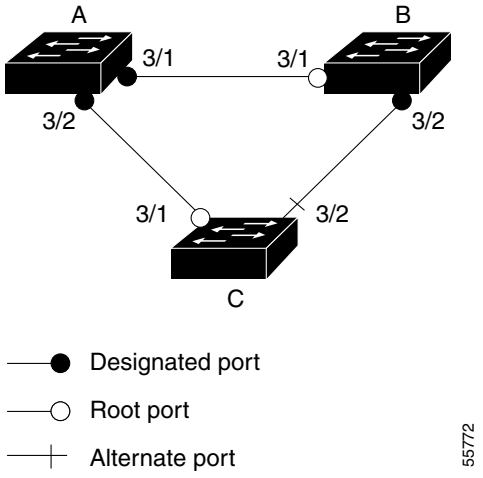


Figure 12-1 illustrates the following configuration:

- Switches A and B are distribution switches.
- Switch C is an access switch.
- Loop guard is enabled on ports 3/1 and 3/2 on Switches A, B, and C.

Enabling loop guard on a root switch has no effect but provides protection when a root switch becomes a nonroot switch.

Follow these guidelines when using loop guard:

- Do not enable loop guard on PortFast-enabled or dynamic VLAN ports.
- Do not enable loop guard if root guard is enabled.

Loop guard interacts with other features as follows:

- Loop guard does not affect the functionality of UplinkFast or BackboneFast.
- Enabling loop guard on ports that are not connected to a point-to-point link will not work.
- Root guard forces a port to always be the root port. Loop guard is effective only if the port is a root port or an alternate port. You cannot enable loop guard and root guard on a port at the same time.
- Loop guard uses the ports known to spanning tree. Loop guard can take advantage of logical ports provided by the Port Aggregation Protocol (PAgP). However, to form a channel, all the physical ports grouped in the channel must have compatible configurations. PAgP enforces uniform configurations of root guard or loop guard on all the physical ports to form a channel.

  These caveats apply to loop guard:

  - Spanning tree always chooses the first operational port in the channel to send the BPDUs. If that link becomes unidirectional, loop guard blocks the channel, even if other links in the channel are functioning properly.
  - If a set of ports that are already blocked by loop guard are grouped together to form a channel, spanning tree loses all the state information for those ports and the new channel port may obtain the forwarding state with a designated role.
  - If a channel is blocked by loop guard and the channel breaks, spanning tree loses all the state information. The individual physical ports may obtain the forwarding state with the designated role, even if one or more of the links that formed the channel are unidirectional.

  Note You can enable UniDirectional Link Detection (UDLD) to help isolate the link failure. A loop may occur until UDLD detects the failure, but loop guard will not be able to detect it.

- Loop guard has no effect on a disabled spanning tree instance or a VLAN.

Overview of PortFast

Spanning Tree PortFast causes an interface configured as a Layer 2 access port to enter the forwarding state immediately, bypassing the listening and learning states. You can use PortFast on Layer 2 access ports connected to a single workstation or server to allow those devices to connect to the network immediately, rather than waiting for spanning tree to converge. If the interface receives a bridge protocol data unit (BPDU), which should not happen if the interface is connected to a single workstation or server, spanning tree puts the port into the blocking state.

Note Because the purpose of PortFast is to minimize the time that access ports must wait for spanning tree to converge, it is most effective when used on access ports. If you enable PortFast on a port connecting to another switch, you risk creating a spanning tree loop.

Overview of BPDU Guard

Spanning Tree BPDU guard shuts down PortFast-configured interfaces that receive BPDUs, rather than putting them into the spanning tree blocking state. In a valid configuration, PortFast-configured interfaces do not receive BPDUs. Reception of a BPDU by a PortFast-configured interface signals an invalid configuration, such as connection of an unauthorized device. BPDU guard provides a secure response to invalid configurations, because the administrator must manually put the interface back in service.

Note When the BPDU guard feature is enabled, spanning tree applies the BPDU guard feature to all PortFast-configured interfaces.

Overview of PortFast BPDU Filtering

Cisco IOS Release 12.2(20)EW and later support PortFast BPDU filtering, which allows the administrator to prevent the system from sending or even receiving BPDUs on specified ports.

When configured globally, PortFast BPDU filtering applies to all operational PortFast ports. Ports in an operational PortFast state are supposed to be connected to hosts that typically drop BPDUs. If an operational PortFast port receives a BPDU, it immediately loses its operational PortFast status. In that case, PortFast BPDU filtering is disabled on this port and STP resumes sending BPDUs on this port.

PortFast BPDU filtering can also be configured on a per-port basis. When PortFast BPDU filtering is explicitly configured on a port, it does not send any BPDUs and drops all BPDUs it receives.

Caution Explicitly configuring PortFast BPDU filtering on a port that is not connected to a host can result in bridging loops, because the port will ignore any BPDU it receives and go to the forwarding state.

When you enable PortFast BPDU filtering globally and set the port configuration as the default for PortFast BPDU filtering (see the "Enabling PortFast BPDU Filtering" section on page 12-12), PortFast enables or disables PortFast BPDU filtering.

If the port configuration is not set to default, then the PortFast configuration will not affect PortFast BPDU filtering. Table 12-1 lists all the possible PortFast BPDU filtering combinations. PortFast BPDU filtering allows access ports to move directly to the forwarding state as soon as the end hosts are connected.

Table 12-1 PortFast BPDU Filtering Port Configurations

Per-Port Configuration	Global Configuration	PortFast State	PortFast BPDU Filtering State
Default	Enable	Enable	Enable[1]
Default	Enable	Disable	Disable
Default	Disable	Not applicable	Disable
Disable	Not applicable	Not applicable	Disable
Enable	Not applicable	Not applicable	Enable

1. The port transmits at least 10 BPDUs. If this port receives any BPDUs, then PortFast and PortFast BPDU filtering are disabled.

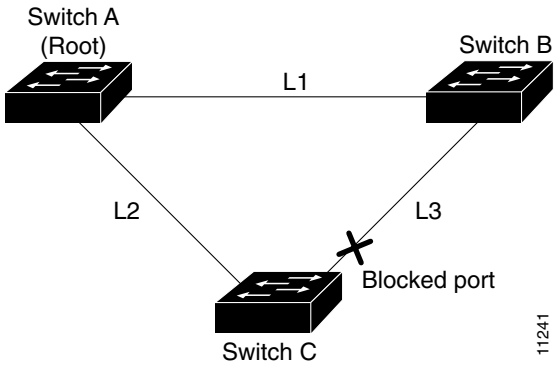
Overview of UplinkFast

Note UplinkFast is most useful in wiring-closet switches. This feature might not be useful for other types of applications.

Spanning Tree UplinkFast provides fast convergence after a direct link failure and uses uplink groups to achieve load balancing between redundant Layer 2 links. Convergence is the speed and ability of a group of internetworking devices running a specific routing protocol to agree on the topology of an internetwork after a change in that topology. 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.

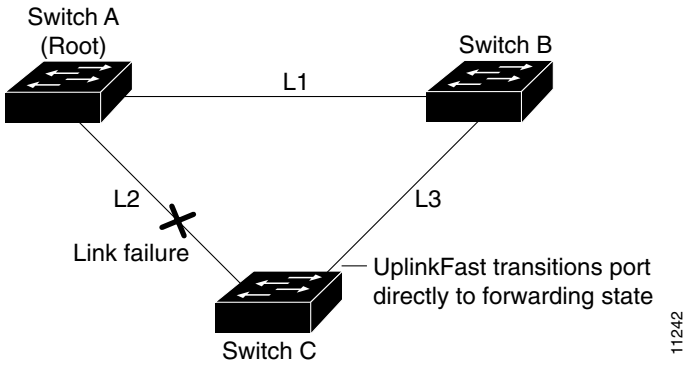
Figure 12-2 shows an example of a topology with no link failures. Switch A, the root switch, is connected directly to Switch B over link L1 and to Switch C over link L2. The Layer 2 interface on Switch C that is connected directly to Switch B is in the blocking state.

Figure 12-2 UplinkFast Before Direct Link Failure



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 port on Switch C and transitions it to the forwarding state without going through the listening and learning states, as shown in Figure 12-3. This switchover takes approximately one to five seconds.

Figure 12-3 UplinkFast After Direct Link Failure



Overview of BackboneFast

BackboneFast is a complementary technology to UplinkFast. Whereas UplinkFast is designed to quickly respond to failures on links directly connected to leaf-node switches, it does not help with indirect failures in the backbone core. BackboneFast optimizes based on the Max Age setting. It allows the default convergence time for indirect failures to be reduced from 50 seconds to 30 seconds. However, it never eliminates forward delays and offers no assistance for direct failures.

Note BackboneFast should be enabled on every switch in your network.

Sometimes a switch receives a BPDU from a designated switch that identifies the root bridge and the designated bridge as the same switch. Because this shouldn't happen, the BPDU is considered inferior.

BPDUs are considered inferior when a link from the designated switch has lost its link to the root bridge. The designated switch transmits the BPDUs with the information that it is now the root bridge as well as the designated bridge. The receiving switch will ignore the inferior BPDU for the time defined by the Max Age setting.

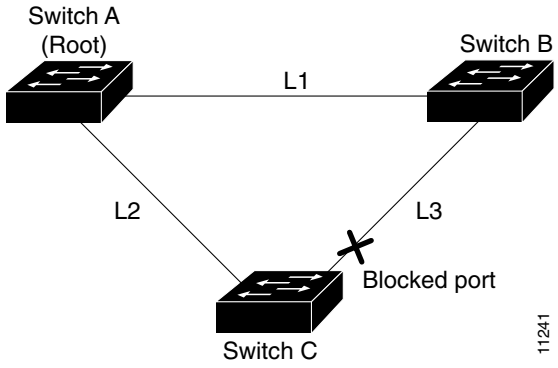
After receiving inferior BPDUs, the receiving switch will try to determine if there is an alternate path to the root bridge.

- If the port that the inferior BPDUs are received on is already in blocking mode, then the root port and other blocked ports on the switch become alternate paths to the root bridge.
- If the inferior BPDUs are received on a root port, then all presently blocking ports become the alternate paths to the root bridge. Also, if the inferior BPDUs are received on a root port and there are no other blocking ports on the switch, the receiving switch assumes that the link to the root bridge is down and the time defined by the Max Age setting expires, which turns the switch into the root switch.

If the switch finds an alternate path to the root bridge, it will use this new alternate path. This new path, and any other alternate paths, will be used to send a Root Link Query (RLQ) BPDU. When BackboneFast is enabled, the RLQ BPDUs are sent out as soon as an inferior BPDU is received. This process can enable faster convergence in the event of a backbone link failure.

Figure 12-4 shows an example of a 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. In this example, because switch B has a lower priority than A but higher than C, switch B becomes the designated bridge for L3. Consequently, the Layer 2 interface on Switch C that connects directly to Switch B must be in the blocking state.

Figure 12-4 BackboneFast Before Indirect Link Failure



Next, assume that L1 fails. Switch A and Switch B, the switches directly connected to this segment, instantly know that the link is down. The blocking interface on Switch C must enter the forwarding state for the network to recover by itself. However, because L1 is not directly connected to Switch C, Switch C does not start sending any BPDUs on L3 under the normal rules of STP until the time defined by the Max Age setting has expired.

In an STP environment without BackboneFast, if L1 should fail, Switch C cannot detect this failure because it is not connected directly to link L1. However, because Switch B is directly connected to the root switch over L1, Switch B detects the failure and elects itself the root. Then Switch B begins sending configuration BDPUs to Switch C, listing itself as the root.

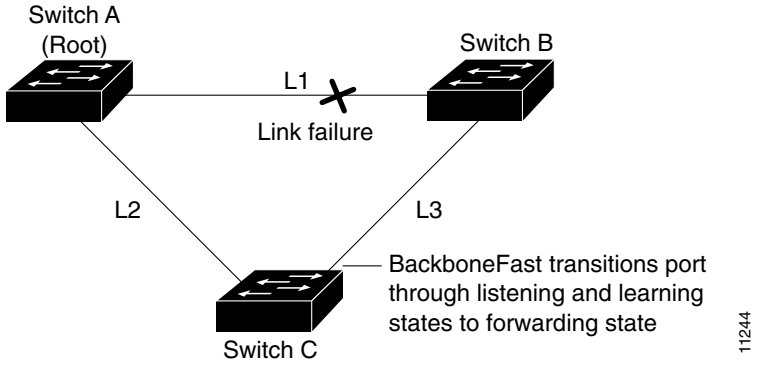
Here is what happens additionally when you use BackboneFast to eliminate the time defined by the Max Age setting (20-second) delay:

1. When Switch C receives the inferior configuration BPDUs from Switch B, Switch C infers that an indirect failure has occurred.
2. Switch C then sends out an RLQ.
3. Switch A receives the RLQ. Because Switch A is the root bridge, it replies with an RLQ response, listing itself as the root bridge.
4. When Switch C receives the RLQ response on its existing root port, it knows that it still has a stable connection to the root bridge. Because Switch C originated the RLQ request, it does not need to forward the RLQ response on to other switches.
5. BackboneFast allows the blocked port on Switch C to move immediately to the listening state without waiting for the time defined by the Max Age setting for the port to expire.
6. BackboneFast transitions the Layer 2 interface on Switch C to the forwarding state, providing a path from Switch B to Switch A.

This switchover takes approximately 30 seconds, twice the Forward Delay time if the default forward delay time of 15 seconds is set.

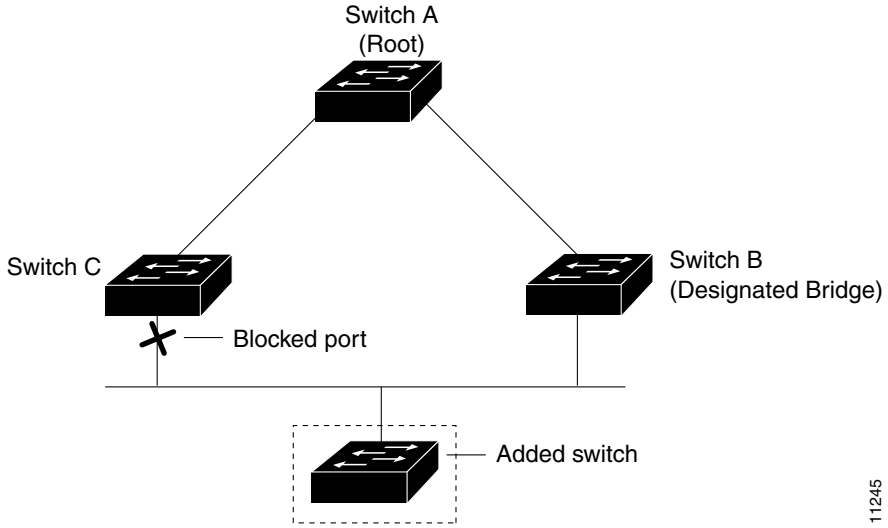
Figure 12-5 shows how BackboneFast reconfigures the topology to account for the failure of link L1.

Figure 12-5 BackboneFast after Indirect Link Failure



If a new switch is introduced into a shared-medium topology as shown in Figure 12-6, BackboneFast is not activated, because the inferior BPDUs did not come from the recognized designated bridge (Switch B). The new switch begins sending inferior BPDUs that say it is the root switch. However, the other switches ignore these inferior BPDUs, and the new switch learns that Switch B is the designated bridge to Switch A, the root switch.

Figure 12-6 Adding a Switch in a Shared-Medium Topology



Enabling Root Guard

To enable root guard on a Layer 2 access port (to force it to become a designated port), perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {{fastethernet | gigabitethernet} slot/port}`	Specifies an interface to configure.
Step 2	`Switch(config-if)# [no] spanning-tree guard root`	Enables root guard. You can use the **no** keyword to disable Root Guard.

	Command	Purpose
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show spanning-tree`	Verifies the configuration.

This example shows how to enable root guard on Fast Ethernet interface 5/8:

```
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree guard root
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show running-config interface fastethernet 5/8
Building configuration...

Current configuration: 67 bytes
!
interface FastEthernet5/8
 switchport mode access
 spanning-tree guard root
end

Switch#
```

This example shows how to determine whether any ports are in root inconsistent state:

```
Switch# show spanning-tree inconsistentports

Name                 Interface              Inconsistency
-------------------- ---------------------- ------------------
VLAN0001             FastEthernet3/1        Port Type Inconsistent
VLAN0001             FastEthernet3/2        Port Type Inconsistent
VLAN1002             FastEthernet3/1        Port Type Inconsistent
VLAN1002             FastEthernet3/2        Port Type Inconsistent
VLAN1003             FastEthernet3/1        Port Type Inconsistent
VLAN1003             FastEthernet3/2        Port Type Inconsistent
VLAN1004             FastEthernet3/1        Port Type Inconsistent
VLAN1004             FastEthernet3/2        Port Type Inconsistent
VLAN1005             FastEthernet3/1        Port Type Inconsistent
VLAN1005             FastEthernet3/2        Port Type Inconsistent

Number of inconsistent ports (segments) in the system :10
```

Enabling Loop Guard

You can enable loop guard globally or per port.

To enable loop guard globally on the switch, perform this task:

	Command	Purpose
Step 1	`Switch(config)# spanning-tree loopguard default`	Enables loop guard globally on the switch.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning tree interface 4/4 detail`	Verifies the configuration impact on a port.

This example shows how to enable loop guard globally:

```
Switch(config)# spanning-tree loopguard default
Switch(config)# Ctrl-Z
```

This example shows how to verify the previous configuration of port 4/4:

```
Switch# show spanning-tree interface fastethernet 4/4 detail
 Port 196 (FastEthernet4/4) of VLAN0010 is forwarding
   Port path cost 1000, Port priority 160, Port Identifier 160.196.
   Designated root has priority 32768, address 00d0.00b8.140a
   Designated bridge has priority 32768, address 00d0.00b8.140a
   Designated port id is 160.196, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   The port is in the portfast mode by portfast trunk configuration
   Link type is point-to-point by default
   Bpdu filter is enabled
   Loop guard is enabled by default on the port
   BPDU:sent 0, received 0
```

To enable loop guard on an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface` {*type slot/port*} | {**port-channel** *port_channel_number*}	Selects an interface to configure.
Step 2	`Switch(config-if)# spanning-tree guard loop`	Configures loop guard.
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show spanning tree interface 4/4 detail`	Verifies the configuration impact on that port.

This example shows how to enable loop guard on port 4/4:

```
Switch(config)# interface fastEthernet 4/4
Switch(config-if)# spanning-tree guard loop
Switch(config-if)# ^Z
```

This example shows how to verify the configuration impact on port 4/4:

```
Switch# show spanning-tree interface fastEthernet 4/4 detail
 Port 196 (FastEthernet4/4) of VLAN0010 is forwarding
   Port path cost 1000, Port priority 160, Port Identifier 160.196.
   Designated root has priority 32768, address 00d0.00b8.140a
   Designated bridge has priority 32768, address 00d0.00b8.140a
   Designated port id is 160.196, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   The port is in the portfast mode by portfast trunk configuration
   Link type is point-to-point by default
   Bpdu filter is enabled
   Loop guard is enabled on the port
   BPDU:sent 0, received 0
Switch#
```

Enabling PortFast

Caution Use PortFast *only* when connecting a single end station to a Layer 2 access port. Otherwise, you might create a network loop.

To enable PortFast on a Layer 2 access port to force it to enter the forwarding state immediately, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {{fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}`	Specifies an interface to configure.
Step 2	`Switch(config-if)# [no] spanning-tree portfast`	Enables PortFast on a Layer 2 access port connected to a single workstation or server. You can use the **no** keyword to disable PortFast.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show running interface {{fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}`	Verifies the configuration.

This example shows how to enable PortFast on Fast Ethernet interface 5/8:

```
Switch(config)# interface fastethernet 5/8
Switch(config-if)# spanning-tree portfast
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show running-config interface fastethernet 5/8
Building configuration...

Current configuration:
!
interface FastEthernet5/8
 no ip address
 switchport
 switchport access vlan 200
 switchport mode access
 spanning-tree portfast
end

Switch#
```

Enabling BPDU Guard

To enable BPDU guard to shut down PortFast-configured interfaces that receive BPDUs, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree portfast bpduguard`	Enables BPDU guard on all the switch's PortFast-configured interfaces. You can use the **no** keyword to disable BPDU guard.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree summary totals`	Verifies the BPDU configuration.

This example shows how to enable BPDU guard:

```
Switch(config)# spanning-tree portfast bpduguard
Switch(config)# end
Switch#
```

This example shows how to verify the BPDU configuration:

```
Switch# show spanning-tree summary totals

Root bridge for: none.
PortFast BPDU Guard is enabled
Etherchannel misconfiguration guard is enabled
UplinkFast is disabled
BackboneFast is disabled
Default pathcost method used is short

Name                 Blocking Listening Learning Forwarding STP Active
-------------------- -------- --------- -------- ---------- ----------
            34 VLANs 0        0         0        36         36
Switch#
```

Enabling PortFast BPDU Filtering

To enable PortFast BPDU filtering globally, perform this task:

	Command	Purpose
Step 1	`Switch(config)# spanning-tree portfast bpdufilter default`	Enables BPDU filtering globally on the switch.
Step 2	`Switch# show spanning-tree summary totals`	Verifies the BPDU configuration.

This example shows how to enable PortFast BPDU filtering on a port:

```
Switch(config)# spanning-tree portfast bpdufilter default
Switch(config)# Ctrl-Z
```

This example shows how to verify the BPDU configuration in PVST+ mode:

```
Switch# show spanning-tree summary totals
Root bridge for:VLAN0010
EtherChannel misconfiguration guard is enabled
Extended system ID   is disabled
Portfast             is enabled by default
PortFast BPDU Guard  is disabled by default
Portfast BPDU Filter is enabled by default
Loopguard            is disabled by default
UplinkFast           is disabled
BackboneFast         is disabled
Pathcost method used is long

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
2 vlans                   0        0         0        3          3

Switch#
```

Note For PVST+ information, see Chapter 13, "Understanding and Configuring Multiple Spanning Trees."

To enable PortFast BPDU filtering, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface fastEthernet 4/4`	Selects the interface to configure.
Step 2	`Switch(config-if)# spanning-tree bpdufilter enable`	Enables BPDU filtering.
Step 3	`Switch# show spanning-tree interface fastethernet 4/4`	Verifies the configuration.

This example shows how to enable PortFast BPDU filtering on port 4/4:

```
Switch(config)# interface fastethernet 4/4
Switch(config-if)# spanning-tree bpdufilter enable
Switch(config-if)# ^Z
```

This example shows how to verify that PortFast BPDU filtering is enabled:

```
Switch# show spanning-tree interface fastethernet 4/4

Vlan             Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
VLAN0010         Desg FWD 1000      160.196  Edge P2p
```

This example shows more detail on the port:

```
Switch# show spanning-tree interface fastEthernet 4/4 detail
 Port 196 (FastEthernet4/4) of VLAN0010 is forwarding
   Port path cost 1000, Port priority 160, Port Identifier 160.196.
   Designated root has priority 32768, address 00d0.00b8.140a
   Designated bridge has priority 32768, address 00d0.00b8.140a
   Designated port id is 160.196, designated path cost 0
   Timers:message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state:1
   The port is in the portfast mode by portfast trunk configuration
   Link type is point-to-point by default
   Bpdu filter is enabled
   BPDU:sent 0, received 0
Switch#
```

Enabling UplinkFast

UplinkFast increases the bridge priority to 49,152 and adds 3000 to the spanning tree port cost of all interfaces on the switch, making it unlikely that the switch will become the root switch. The *max_update_rate* value represents the number of multicast packets transmitted per second (the default is 150 packets per second [pps]).

UplinkFast cannot be enabled on VLANs that have been configured for bridge priority. To enable UplinkFast on a VLAN with bridge priority configured, restore the bridge priority on the VLAN to the default value by entering a **no spanning-tree vlan** *vlan_ID* **priority** command in global configuration mode.

Note When you enable UplinkFast, it affects all VLANs on the switch. You cannot configure UplinkFast on an individual VLAN.

To enable UplinkFast, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree uplinkfast [max-update-rate max_update_rate]`	Enables UplinkFast. You can use the **no** keyword to disable UplinkFast and restore the default rate, use the command
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree vlan vlan_ID`	Verifies that UplinkFast is enabled on that VLAN.

This example shows how to enable UplinkFast with a maximum update rate of 400 pps:

```
Switch(config)# spanning-tree uplinkfast max-update-rate 400
Switch(config)# exit
Switch#
```

This example shows how to verify which VLANS have UplinkFast enabled:

```
Switch# show spanning-tree uplinkfast
UplinkFast is enabled

Station update rate set to 150 packets/sec.

UplinkFast statistics
-----------------------
Number of transitions via uplinkFast (all VLANs)            :14
Number of proxy multicast addresses transmitted (all VLANs) :5308
```

```
Name                 Interface List
-------------------- ------------------------------------
VLAN1                Fa6/9(fwd), Gi5/7
VLAN2                Gi5/7(fwd)
VLAN3                Gi5/7(fwd)
VLAN4
VLAN5
VLAN6
VLAN7
VLAN8
VLAN10
VLAN15
VLAN1002             Gi5/7(fwd)
VLAN1003             Gi5/7(fwd)
VLAN1004             Gi5/7(fwd)
VLAN1005             Gi5/7(fwd)
Switch#
```

Enabling BackboneFast

Note For BackboneFast to work, you must enable it on all switches in the network. BackboneFast is supported for use with third-party switches but it is not supported on Token Ring VLANs.

To enable BackboneFast, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] spanning-tree backbonefast`	Enables BackboneFast. You can use the **no** keyword to disable BackboneFast.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show spanning-tree backbonefast`	Verifies that BackboneFast is enabled.

This example shows how to enable BackboneFast:

```
Switch(config)# spanning-tree backbonefast
Switch(config)# end
Switch#
```

This example shows how to verify that BackboneFast is enabled:

```
Switch# show spanning-tree backbonefast
BackboneFast is enabled

BackboneFast statistics
-----------------------
Number of transition via backboneFast (all VLANs) : 0
Number of inferior BPDUs received (all VLANs)     : 0
Number of RLQ request PDUs received (all VLANs)   : 0
Number of RLQ response PDUs received (all VLANs)  : 0
Number of RLQ request PDUs sent (all VLANs)       : 0
Number of RLQ response PDUs sent (all VLANs)      : 0
Switch#
```

This example shows how to display a summary of port states:

```
Switch#show spanning-tree summary
Root bridge for:VLAN0001, VLAN1002-VLAN1005
Extended system ID   is disabled
Portfast             is enabled by default
PortFast BPDU Guard  is disabled by default
Portfast BPDU Filter is enabled by default
Loopguard            is disabled by default
EtherChannel misconfiguration guard is enabled
UplinkFast           is enabled
BackboneFast         is enabled
Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                  0        0         0        3          3
VLAN1002                  0        0         0        2          2
VLAN1003                  0        0         0        2          2
VLAN1004                  0        0         0        2          2
VLAN1005                  0        0         0        2          2
---------------------- -------- --------- -------- ---------- ----------
5 vlans                   0        0         0        11         11

BackboneFast statistics
-----------------------
Number of transition via backboneFast (all VLANs)           :0
Number of inferior BPDUs received (all VLANs)               :0
Number of RLQ request PDUs received (all VLANs)             :0
Number of RLQ response PDUs received (all VLANs)            :0
Number of RLQ request PDUs sent (all VLANs)                 :0
Number of RLQ response PDUs sent (all VLANs)                :0
Switch#
```

This example shows how to display the total lines of the spanning tree state section:

```
Switch#show spanning-tree summary totals
Root bridge for:VLAN0001, VLAN1002-VLAN1005
Extended system ID   is disabled
Portfast             is enabled by default
PortFast BPDU Guard  is disabled by default
Portfast BPDU Filter is enabled by default
Loopguard            is disabled by default
EtherChannel misconfiguration guard is enabled
UplinkFast           is enabled
BackboneFast         is enabled
Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
5 vlans                   0        0         0        11         11

BackboneFast statistics
-----------------------
Number of transition via backboneFast (all VLANs)           :0
Number of inferior BPDUs received (all VLANs)               :0
Number of RLQ request PDUs received (all VLANs)             :0
Number of RLQ response PDUs received (all VLANs)            :0
Number of RLQ request PDUs sent (all VLANs)                 :0
Number of RLQ response PDUs sent (all VLANs)                :0
Switch#
```

CHAPTER 13

Understanding and Configuring Multiple Spanning Trees

This chapter describes how to configure the IEEE 802.1s Multiple Spanning Tree (MST) protocol on the Catalyst 4500 series switch. MST is a new IEEE standard derived from Cisco's proprietary Multi-Instance Spanning-Tree Protocol (MISTP) implementation. With MST, you can map a single spanning-tree instance to several VLANs.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of MST

The following sections describe how MST works on a Catalyst 4500 series switch:

IEEE 802.1s MST

MST extends the IEEE 802.1w rapid spanning tree (RST) algorithm to multiple spanning trees. This extension provides both rapid convergence and load balancing in a VLAN environment. MST converges faster than Per VLAN Spanning Tree Plus (PVST+) and is backward compatible with 802.1D STP, 802.1w (Rapid Spanning Tree Protocol [RSTP]), and the Cisco PVST+ architecture.

MST allows you to build multiple spanning trees over trunks. You can group and associate VLANs to spanning tree instances. Each instance can have a topology independent of other spanning tree instances. This architecture provides multiple forwarding paths for data traffic and enables load balancing. Network fault tolerance is improved because a failure in one instance (forwarding path) does not affect other instances.

In large networks, you can more easily administer the network and use redundant paths by locating different VLAN and spanning tree instance assignments in different parts of the network. A spanning tree instance can exist only on bridges that have compatible VLAN instance assignments. You must configure a set of bridges with the same MST configuration information, which allows them to participate in a specific set of spanning tree instances. Interconnected bridges that have the same MST configuration are referred to as an MST region.

MST uses the modified RSTP, MSTP. MST has the following characteristics:

- MST runs a variant of spanning tree called Internal Spanning Tree (IST). IST augments Common Spanning Tree (CST) information with internal information about the MST region. The MST region appears as a single bridge to adjacent single spanning tree (SST) and MST regions.
- A bridge running MST provides interoperability with SST bridges as follows:
  - MST bridges run IST, which augments CST information with internal information about the MST region.
  - IST connects all the MST bridges in the region and appears as a subtree in the CST that includes the whole bridged domain. The MST region appears as a virtual bridge to adjacent SST bridges and MST regions.
  - The Common and Internal Spanning Tree (CIST) is the collection of the following: ISTs in each MST region, the CST that interconnects the MST regions, and the SST bridges. CIST is identical to an IST inside an MST region and identical to a CST outside an MST region. The STP, RSTP, and MSTP together elect a single bridge as the root of the CIST.
- MST establishes and maintains additional spanning trees within each MST region. These spanning trees are termed MST instances (MSTIs). The IST is numbered 0, and the MSTIs are numbered 1, 2, 3, and so on. Any MSTI is local to the MST region and is independent of MSTIs in another region, even if the MST regions are interconnected.

  MST instances combine with the IST at the boundary of MST regions to become the CST as follows:
  - Spanning tree information for an MSTI is contained in an MSTP record (M-record).

    M-records are always encapsulated within MST bridge protocol data units (BPDUs). The original spanning trees computed by MSTP are called M-trees, which are active only within the MST region. M-trees merge with the IST at the boundary of the MST region and form the CST.
- MST provides interoperability with PVST+ by generating PVST+ BPDUs for the non-CST VLANs.
- MST supports some of the PVST+ extensions in MSTP as follows:
  - UplinkFast and BackboneFast are not available in MST mode; they are part of RSTP.
  - PortFast is supported.
  - BPDU filter and BPDU guard are supported in MST mode.
  - Loop guard and root guard are supported in MST. MST preserves the VLAN 1 disabled functionality except that BPDUs are still transmitted in VLAN 1.

  - MST switches operate as if MAC reduction is enabled.
  - For private VLANs (PVLANs), you must map a secondary VLAN to the same instance as the primary.

IEEE 802.1w RSTP

RSTP, specified in 802.1w, supersedes STP specified in 802.1D, but remains compatible with STP. You configure RSTP when you configure the MST feature. For more information, see the "Configuring MST" section on page 13-9.

RSTP provides the structure on which the MST operates, significantly reducing the time to reconfigure the active topology of a network when its physical topology or configuration parameters change. RSTP selects one switch as the root of a spanning-tree-connected active topology and assigns port roles to individual ports of the switch, depending on whether that port is part of the active topology.

RSTP provides rapid connectivity following the failure of a switch, switch port, or a LAN. A new root port and the designated port on the other side of the bridge transition to the forwarding state through an explicit handshake between them. RSTP allows switch port configuration so the ports can transition to forwarding directly when the switch reinitializes.

RSTP provides backward compatibility with 802.1D bridges as follows:

- RSTP selectively sends 802.1D-configured BPDUs and Topology Change Notification (TCN) BPDUs on a per-port basis.
- When a port initializes, the migration delay timer starts and RSTP BPDUs are transmitted. While the migration delay timer is active, the bridge processes all BPDUs received on that port.
- If the bridge receives an 802.1D BPDU after a port's migration delay timer expires, the bridge assumes it is connected to an 802.1D bridge and starts using only 802.1D BPDUs.
- When RSTP uses 802.1D BPDUs on a port and receives an RSTP BPDU after the migration delay expires, RSTP restarts the migration delay timer and begins using RSTP BPDUs on that port.

RSTP Port Roles

In RSTP, the port roles are defined as follows:

- Root—A forwarding port elected for the spanning tree topology.
- Designated—A forwarding port elected for every switched LAN segment.
- Alternate—An alternate path to the root bridge to that provided by the current root port.
- Backup—A backup for the path provided by a designated port toward the leaves of the spanning tree. Backup ports can exist only where two ports are connected together in a loopback mode or bridge with two or more connections to a shared LAN segment.
- Disabled—A port that has no role within the operation of spanning tree.

The system assigns port roles as follows:

- A root port or designated port role includes the port in the active topology.
- An alternate port or backup port role excludes the port from the active topology.

RSTP Port States

The port state controls the forwarding and learning processes and provides the values of discarding, learning, and forwarding. Table 13-1 shows the STP port states and RSTP port states.

Table 13-1 Comparison Between STP and RSTP Port States

Operational Status	STP Port State	RSTP Port State	Port Included in Active Topology
Enabled	Blocking[1]	Discarding[2]	No
Enabled	Listening	Discarding	No
Enabled	Learning	Learning	Yes
Enabled	Forwarding	Forwarding	Yes
Disabled	Disabled	Discarding	No

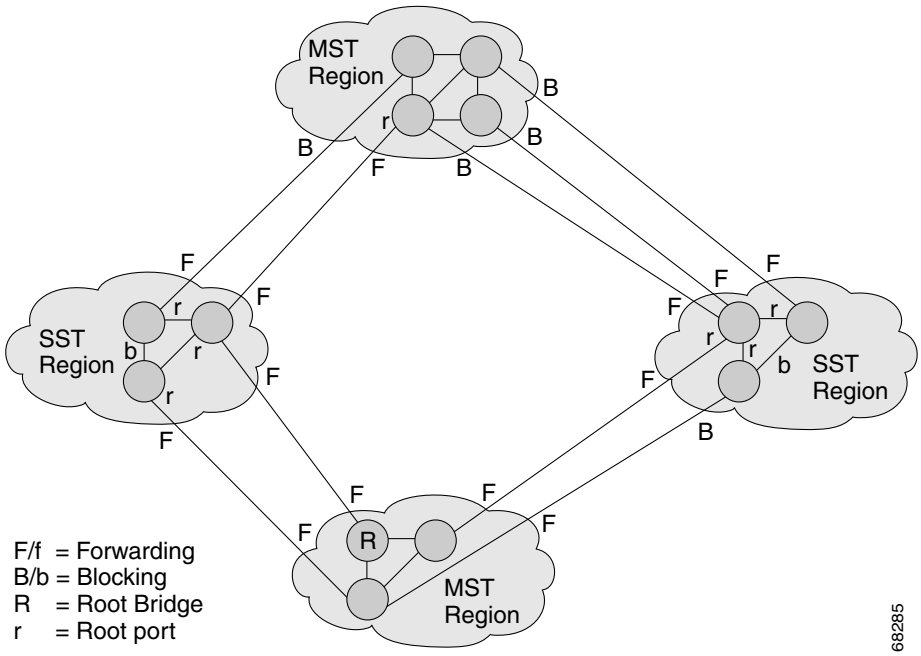
1. IEEE 802.1D port state designation.
2. IEEE 802.1w port state designation. Discarding is the same as blocking in MST.

In a stable topology, RSTP ensures that every root port and designated port transitions to the forwarding state while all alternate ports and backup ports are always in the discarding state.

MST-to-SST Interoperability

A virtual bridged LAN may contain interconnected regions of SST and MST bridges. Figure 13-1 shows this relationship.

Figure 13-1 Network with Interconnected SST and MST Regions



To STP running in the SST region, an MST region appears as a single SST or pseudobridge, which operates as follows:

- Although the values for root identifiers and root path costs match for all BPDUs in all pseudobridges, a pseudobridge differs from a single SST bridge as follows:
  - The pseudobridge BPDUs have different bridge identifiers. This difference does not affect STP operation in the neighboring SST regions because the root identifier and root cost are the same.
  - BPDUs sent from the pseudobridge ports may have significantly different message ages. Because the message age increases by one second for each hop, the difference in the message age is measured in seconds.
- Data traffic from one port of a pseudobridge (a port at the edge of a region) to another port follows a path entirely contained within the pseudobridge or MST region. Data traffic belonging to different VLANs might follow different paths within the MST regions established by MST.
- The system prevents looping by doing either of the following:
  - Blocking the appropriate pseudobridge ports by allowing one forwarding port on the boundary and blocking all other ports.
  - Setting the CST partitions to block the ports of the SST regions.

Common Spanning Tree

CST (802.1Q) is a single spanning tree for all the VLANs. In a Catalyst 4000 family switch running PVST+, the VLAN 1 spanning tree corresponds to CST. In a Catalyst 4000 family switch running MST, IST (instance 0) corresponds to CST.

MST Instances

This release supports up to 16 instances; each spanning tree instance is identified by an instance ID that ranges from 0 to 15. Instance 0 is mandatory and is always present. Instances 1 through 15 are optional.

MST Configuration Parameters

MST configuration has three parts, as follows:

- Name—A 32-character string (null padded) that identifies the MST region.
- Revision number—An unsigned 16-bit number that identifies the revision of the current MST configuration.

Note You must set the revision number when required as part of the MST configuration. The revision number is not incremented automatically each time you commit the MST configuration.

- MST configuration table—An array of 4096 bytes. Each byte, interpreted as an unsigned integer, corresponds to a VLAN. The value is the instance number to which the VLAN is mapped. The first byte that corresponds to VLAN 0 and the 4096th byte that corresponds to VLAN 4095 are unused and always set to zero.

You must configure each byte manually. You can use SNMP or the CLI to perform the configuration.

MST BPDUs contain the MST configuration ID and the checksum. An MST bridge accepts an MST BPDU only if the MST BPDU configuration ID and the checksum match its own MST region configuration ID and checksum. If either value is different, the MST BPDU is considered to be an SST BPDU.

MST Regions

These sections describe MST regions:

MST Region Overview

Interconnected bridges that have the same MST configuration are referred to as an MST region. There is no limit on the number of MST regions in the network.

To form an MST region, bridges can be either of the following:

- An MST bridge that is the only member of the MST region.
- An MST bridge interconnected by a LAN. A LAN's designated bridge has the same MST configuration as an MST bridge. All the bridges on the LAN can process MST BPDUs.

If you connect two MST regions with different MST configurations, the MST regions do the following:

- Load balance across redundant paths in the network. If two MST regions are redundantly connected, all traffic flows on a single connection with the MST regions in a network.
- Provide an RSTP handshake to enable rapid connectivity between regions. However, the handshaking is not as fast as between two bridges. To prevent loops, all the bridges inside the region must agree upon the connections to other regions. This situation introduces a delay. We do not recommend partitioning the network into a large number of regions.

Boundary Ports

A boundary port is a port that connects to a LAN, the designated bridge of which is either an SST bridge or a bridge with a different MST configuration. A designated port knows that it is on the boundary if it detects an STP bridge or receives an agreement message from an RST or MST bridge with a different configuration.

At the boundary, the role of MST ports do not matter; their state is forced to be the same as the IST port state. If the boundary flag is set for the port, the MSTP Port Role selection mechanism assigns a port role to the boundary and the same state as that of the IST port. The IST port at the boundary can take up any port role except a backup port role.

IST Master

The IST master of an MST region is the bridge with the lowest bridge identifier and the least path cost to the CST root. If an MST bridge is the root bridge for CST, then it is the IST master of that MST region. If the CST root is outside the MST region, then one of the MST bridges at the boundary is selected as the IST master. Other bridges on the boundary that belong to the same region eventually block the boundary ports that lead to the root.

If two or more bridges at the boundary of a region have an identical path to the root, you can set a slightly lower bridge priority to make a specific bridge the IST master.

The root path cost and message age inside a region stay constant, but the IST path cost is incremented and the IST remaining hops are decremented at each hop. Enter the **show spanning-tree mst** command to display the information about the IST master, path cost, and remaining hops for the bridge.

Edge Ports

A port that is connected to a nonbridging device (for example, a host or a switch) is an edge port. A port that connects to a hub is also an edge port if the hub or any LAN that is connected to it does not have a bridge. An edge port can start forwarding as soon as the link is up.

MST requires that you configure each port connected to a host. To establish rapid connectivity after a failure, you need to block the non-edge designated ports of an intermediate bridge. If the port connects to another bridge that can send back an agreement, then the port starts forwarding immediately. Otherwise, the port needs twice the forward delay time to start forwarding again. You must explicitly configure the ports that are connected to the hosts and switches as edge ports while using MST.

To prevent a misconfiguration, the PortFast operation is turned off if the port receives a BPDU. You can display the configured and operational status of PortFast by using the **show spanning-tree mst** *interface* command.

Link Type

Rapid connectivity is established only on point-to-point links. You must configure ports explicitly to a host or switch. However, cabling in most networks meets this requirement, and you can avoid explicit configuration by treating all full-duplex links as point-to-point links by entering the **spanning-tree linktype** command.

Message Age and Hop Count

IST and MST instances do not use the message age and maximum age timer settings in the BPDU. IST and MST use a separate hop count mechanism that is very similar to the IP time-to live (TTL) mechanism. You can configure each MST bridge with a maximum hop count. The root bridge of the instance sends a BPDU (or M-record) with the remaining hop count that is equal to the maximum hop count. When a bridge receives a BPDU (or M-record), it decrements the received remaining hop count by one. The bridge discards the BPDU (M-record) and ages out the information held for the port if the count reaches zero after decrementing. The nonroot bridges propagate the decremented count as the remaining hop count in the BPDUs (M-records) they generate.

The message age and maximum age timer settings in the RST portion of the BPDU remain the same throughout the region, and the same values are propagated by the region's designated ports at the boundary.

MST-to-PVST+ Interoperability

Keep these guidelines in mind when you configure MST switches (in the same region) to interact with PVST+ switches:

- Configure the root for all VLANs inside the MST region as shown in this example:

```
Switch# show spanning-tree mst interface gigabitethernet 1/1

GigabitEthernet1/1 of MST00 is root forwarding
Edge port: no             (trunk)          port guard : none        (default)
Link type: point-to-point (auto)           bpdu filter: disable     (default)
Boundary : boundary       (PVST)           bpdu guard : disable     (default)
Bpdus sent 10, received 310

Instance Role Sts Cost      Prio.Nbr Vlans mapped
-------- ---- --- --------- -------- --------------------------------
0        Root FWD 20000     128.1    1-2,4-2999,4000-4094
3        Boun FWD 20000     128.1    3,3000-3999
```

  The ports that belong to the MST switch at the boundary simulate PVST+ and send PVST+ BPDUs for all the VLANs.

  If you enable loop guard on the PVST+ switches, the ports might change to a loop-inconsistent state when the MST switches change their configuration. To correct the loop-inconsistent state, you must disable and renewable loop guard on that PVST+ switch.

- Do not locate the root for some or all of the VLANs inside the PVST+ side of the MST switch because when the MST switch at the boundary receives PVST+ BPDUs for all or some of the VLANs on its designated ports, root guard sets the port to the blocking state.

When you connect a PVST+ switch to two different MST regions, the topology change from the PVST+ switch does not pass beyond the first MST region. In such a case, the topology changes are propagated only in the instance to which the VLAN is mapped. The topology change stays local to the first MST region, and the Cisco Access Manager (CAM) entries in the other region are not flushed. To make the topology change visible throughout other MST regions, you can map that VLAN to IST or connect the PVST+ switch to the two regions through access links.

MST Configuration Restrictions and Guidelines

Follow these restrictions and guidelines to avoid configuration problems:

- Do not disable spanning tree on any VLAN in any of the PVST bridges.
- Do no use PVST bridges as the root of CST.
- Do not connect switches with access links, because access links may partition a VLAN.
- Ensure that all PVST root bridges have lower (numerically higher) priority than the CST root bridge.
- Ensure that trunks carry all of the VLANs mapped to an instance or do not carry any VLANs at all for this instance.
- Complete any MST configuration that incorporates a large number of either existing or new logical VLAN ports during a maintenance window because the complete MST database gets reinitialized for any incremental change (such as adding new VLANs to instances or moving VLANs across instances).

Configuring MST

The following sections describe how to configure MST:

Enabling MST

To enable and configure MST on a Catalyst 4006 switch with Supervisor Engine III, perform this task:

	Command	Purpose
Step 1	`Switch(config)# spanning-tree mode mst`	Enters MST mode.
Step 2	`Switch(config)# spanning-tree mst configuration`	Enters MST configuration submode. You can use the **no** keyword to clear the MST configuration.
Step 3	`Switch(config-mst)# show current`	Displays the current MST configuration.
Step 4	`Switch(config-mst)# name` *name*	Sets the MST region name.
Step 5	`Switch(config-mst)# revision` *revision_number*	Sets the MST configuration revision number.
Step 6	`Switch(config-mst)# instance` *instance_number* `vlan` *vlan_range*	Maps the VLANs to an MST instance. If you do not specify the **vlan** keyword, you can use the **no** keyword to unmap all the VLANs that were mapped to an MST instance. If you specify the **vlan** keyword, you can use the **no** keyword to unmap a specified VLAN from an MST instance.
Step 7	`Switch(config-mst)# show pending`	Displays the new MST configuration to be applied.
Step 8	`Switch(config-mst)# end`	Applies the configuration and exit MST configuration submode.
Step 9	`Switch# show spanning-tree mst configuration`	Displays the current MST configuration.

This example show how to enable MST:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# spanning-tree mode mst

Switch(config)# spanning-tree mst configuration
```

```
Switch(config-mst)# show current
Current MST configuration
Name      []
Revision  0
Instance  Vlans mapped
--------  ---------------------------------------------------------------------
0         1-4094
-------------------------------------------------------------------------------
Switch(config-mst)# name cisco
Switch(config-mst)# revision 2
Switch(config-mst)# instance 1 vlan 1
Switch(config-mst)# instance 2 vlan 1-1000
Switch(config-mst)# show pending
Pending MST configuration
Name      [cisco]
Revision  2
Instance  Vlans mapped
--------  ---------------------------------------------------------------------
0         1001-4094
2         1-1000
-------------------------------------------------------------------------------
Switch(config-mst)# no instance 2
Switch(config-mst)# show pending
Pending MST configuration
Name      [cisco]
Revision  2
Instance  Vlans mapped
--------  ---------------------------------------------------------------------
0         1-4094
-------------------------------------------------------------------------------
Switch(config-mst)# instance 1 vlan 2000-3000
Switch(config-mst)# no instance 1 vlan 1500
Switch(config-mst)# show pending
Pending MST configuration
Name      [cisco]
Revision  2
Instance  Vlans mapped
--------  ---------------------------------------------------------------------
0         1-1999,2500,3001-4094
1         2000-2499,2501-3000
-------------------------------------------------------------------------------
Switch(config-mst)# end
Switch(config)# no spanning-tree mst configuration
Switch(config)# end
Switch# show spanning-tree mst configuration
Name      []
Revision  0
Instance  Vlans mapped
--------  ---------------------------------------------------------------------
0         1-4094
-------------------------------------------------------------------------------
```

Configuring MST Instance Parameters

To configure MST instance parameters, perform this task:

	Command	Purpose
Step 1	`Switch(config)# spanning-tree mst X priority Y`	Configures the priority for an MST instance.
Step 2	`Switch(config)# spanning-tree mst X root [primary | secondary]`	Configures the bridge as root for an MST instance.
Step 3	`Switch(config)# Ctrl-Z`	Exits configuration mode.
Step 4	`Switch# show spanning-tree mst`	Verifies the configuration.

This example shows how to configure MST instance parameters:

```
Switch(config)# spanning-tree mst 1 priority ?
 <0-61440>  bridge priority in increments of 4096

Switch(config)# spanning-tree mst 1 priority 1
% Bridge Priority must be in increments of 4096.
% Allowed values are:
  0     4096  8192  12288 16384 20480 24576 28672
  32768 36864 40960 45056 49152 53248 57344 61440

Switch(config)# spanning-tree mst 1 priority 49152
Switch(config)#

Switch(config)# spanning-tree mst 0 root primary
 mst 0 bridge priority set to 24576
 mst bridge max aging time unchanged at 20
 mst bridge hello time unchanged at 2
 mst bridge forward delay unchanged at 15
Switch(config)# ^Z
Switch#

Switch# show spanning-tree mst

###### MST00        vlans mapped:  11-4094
Bridge      address 00d0.00b8.1400  priority  24576 (24576 sysid 0)
Root        this switch for CST and IST
Configured  hello time 2, forward delay 15, max age 20, max hops 20

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      240.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p
Fa4/48           Desg FWD 200000    128.240  P2p Bound(STP)

###### MST01        vlans mapped:  1-10
Bridge      address 00d0.00b8.1400  priority  49153 (49152 sysid 1)
Root        this switch for MST01

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      160.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p
Fa4/48           Boun FWD 200000    128.240  P2p Bound(STP)

Switch#
```

Configuring MST Instance Port Parameters

To configure MST instance port parameters, perform this task:

	Command	Purpose
Step 1	`Switch(config-if)# spanning-tree mst x cost y`	Configures the MST instance port cost.
Step 2	`Switch(config-if)# spanning-tree mst x port-priority y`	Configures the MST instance port priority.
Step 3	`Switch(config-if)# Ctrl-Z`	Exits configuration mode.
Step 4	`Switch# show spanning-tree mst x interface y`	Verifies the configuration.

This example shows how to configure MST instance port parameters:

```
Switch(config)# interface fastethernet 4/4
Switch(config-if)# spanning-tree mst 1 ?
  cost           Change the interface spanning tree path cost for an instance
  port-priority  Change the spanning tree port priority for an instance

Switch(config-if)# spanning-tree mst 1 cost 1234567

Switch(config-if)# spanning-tree mst 1 port-priority 240
Switch(config-if)# ^Z

Switch# show spanning-tree mst 1 interface fastethernet 4/4

FastEthernet4/4 of MST01 is backup blocking
Edge port:no             (default)        port guard :none        (default)
Link type:point-to-point (auto)           bpdu filter:disable     (default)
Boundary :internal                        bpdu guard :disable     (default)
Bpdus (MRecords) sent 125, received 1782

Instance Role Sts Cost      Prio.Nbr Vlans mapped
-------- ---- --- --------- -------- --------------------------------
1        Back BLK 1234567   240.196  1-10

Switch#
```

Restarting Protocol Migration

RSTP and MST have built-in compatibility mechanisms that allow them to interact properly with other regions or other versions of IEEE spanning-tree. For example, an RSTP bridge connected to a legacy bridge can send 802.1D BPDUs on one of its ports. Similarly, when an MST bridge receives a legacy BPDU or an MST BPDU associated with a different region, it is also to detect that a port is at the boundary of a region.

Unfortunately, these mechanisms cannot always revert to the most efficient mode. For example, an RSTP bridge designated for a legacy 802.1D will stay in 802.1D mode even after the legacy bridge has been removed from the link. Similarly, an MST port still assumes that it is a boundary port when the bridge(s) to which it is connected have joined the same region. To force a Catalyst 4000 family switch to renegotiate with the neighbors (that is, to restart protocol migration), you must enter the **clear spanning-tree detected-protocols** command, as follows:

```
Switch# clear spanning-tree detected-protocols fastethernet 4/4
Switch#
```

Displaying MST Configurations

To display MST configurations, perform this task:

	Command	Purpose
Step 1	`Switch# show spanning-tree mst configuration`	Displays the active region configuration information.
Step 2	`Switch# show spanning-tree mst [detail]`	Displays detailed MST protocol information.
Step 3	`Switch# show spanning-tree mst instance-id [detail]`	Displays information about a specific MST instance.
Step 4	`Switch# show spanning-tree mst interface interface [detail]`	Displays information for a given port.
Step 5	`Switch# show spanning-tree mst instance-id interface interface [detail]`	Displays MST information for a given port and a given instance.
Step 6	`Switch# show spanning-tree vlan vlan_ID`	Displays VLAN information in MST mode.

The following examples show how to display spanning tree VLAN configurations in MST mode:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)# instance 1 vlan 1-10
Switch(config-mst)# name cisco
Switch(config-mst)# revision 1
Switch(config-mst)# Ctrl-D

Switch# show spanning-tree mst configuration
Name      [cisco]
Revision  1
Instance  Vlans mapped
--------  ------------------------------------------------------------------------
0         11-4094
1         1-10
-------------------------------------------------------------------------------

Switch# show spanning-tree mst

###### MST00        vlans mapped:  11-4094
Bridge      address 00d0.00b8.1400  priority  32768 (32768 sysid 0)
Root        address 00d0.004a.3c1c  priority  32768 (32768 sysid 0)
            port    Fa4/48          path cost 203100
IST master  this switch
Operational hello time 2, forward delay 15, max age 20, max hops 20
Configured  hello time 2, forward delay 15, max age 20, max hops 20

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      240.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p
Fa4/48           Root FWD 200000    128.240  P2p Bound(STP)

###### MST01        vlans mapped:  1-10
Bridge      address 00d0.00b8.1400  priority  32769 (32768 sysid 1)
Root        this switch for MST01

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      240.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p
Fa4/48           Boun FWD 200000    128.240  P2p Bound(STP)
```

```
Switch# show spanning-tree mst 1

###### MST01        vlans mapped:  1-10
Bridge      address 00d0.00b8.1400  priority  32769 (32768 sysid 1)
Root        this switch for MST01

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      240.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p
Fa4/48           Boun FWD 200000    128.240  P2p Bound(STP)

Switch# show spanning-tree mst interface fastethernet 4/4

FastEthernet4/4 of MST00 is backup blocking
Edge port:no             (default)        port guard :none        (default)
Link type:point-to-point (auto)           bpdu filter:disable     (default)
Boundary :internal                        bpdu guard :disable     (default)
Bpdus sent 2, received 368

Instance Role Sts Cost      Prio.Nbr Vlans mapped
-------- ---- --- --------- -------- --------------------------------
0        Back BLK 1000      240.196  11-4094
1        Back BLK 1000      240.196  1-10


Switch# show spanning-tree mst 1 interface fastethernet 4/4

FastEthernet4/4 of MST01 is backup blocking
Edge port:no             (default)        port guard :none        (default)
Link type:point-to-point (auto)           bpdu filter:disable     (default)
Boundary :internal                        bpdu guard :disable     (default)
Bpdus (MRecords) sent 2, received 364

Instance Role Sts Cost      Prio.Nbr Vlans mapped
-------- ---- --- --------- -------- --------------------------------
1        Back BLK 1000      240.196  1-10

Switch# show spanning-tree mst 1 detail

###### MST01        vlans mapped:  1-10
Bridge      address 00d0.00b8.1400  priority  32769 (32768 sysid 1)
Root        this switch for MST01

FastEthernet4/4 of MST01 is backup blocking
Port info             port id        240.196  priority    240  cost        1000
Designated root       address 00d0.00b8.1400  priority  32769  cost           0
Designated bridge     address 00d0.00b8.1400  priority  32769  port id  128.197
Timers:message expires in 5 sec, forward delay 0, forward transitions 0
Bpdus (MRecords) sent 123, received 1188

FastEthernet4/5 of MST01 is designated forwarding
Port info             port id        128.197  priority    128  cost      200000
Designated root       address 00d0.00b8.1400  priority  32769  cost           0
Designated bridge     address 00d0.00b8.1400  priority  32769  port id  128.197
Timers:message expires in 0 sec, forward delay 0, forward transitions 1
Bpdus (MRecords) sent 1188, received 123
```

```
FastEthernet4/48 of MST01 is boundary forwarding
Port info             port id        128.240  priority    128  cost      200000
Designated root       address 00d0.00b8.1400  priority  32769  cost           0
Designated bridge     address 00d0.00b8.1400  priority  32769  port id  128.240
Timers:message expires in 0 sec, forward delay 0, forward transitions 1
Bpdus (MRecords) sent 78, received 0

Switch# show spanning-tree vlan 10

MST01
  Spanning tree enabled protocol mstp
  Root ID    Priority    32769
             Address     00d0.00b8.1400
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     00d0.00b8.1400
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface        Role Sts Cost      Prio.Nbr Status
---------------- ---- --- --------- -------- --------------------------------
Fa4/4            Back BLK 1000      240.196  P2p
Fa4/5            Desg FWD 200000    128.197  P2p

Switch# show spanning-tree summary
Root bridge for:MST01
EtherChannel misconfiguration guard is enabled
Extended system ID   is enabled
Portfast             is disabled by default
PortFast BPDU Guard  is disabled by default
Portfast BPDU Filter is disabled by default
Loopguard            is disabled by default
UplinkFast           is disabled
BackboneFast         is disabled
Pathcost method used is long

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
MST00                     1        0         0        2          3
MST01                     1        0         0        2          3
---------------------- -------- --------- -------- ---------- ----------
2 msts                    2        0         0        4          6
Switch#
```

Understanding and Configuring EtherChannel

This chapter describes how to use the command-line interface (CLI) to configure EtherChannel on the Catalyst 4500 series switch Layer 2 or Layer 3 interfaces. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note The commands in the following sections can be used on all Ethernet interfaces on a Catalyst 4500 series switch, including the uplink ports on the supervisor engine.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of EtherChannel

These subsections describe how EtherChannel works:

EtherChannel bundles individual Ethernet links into a single logical link that provides bandwidth up to 1600 Mbps (Fast EtherChannel full duplex) or 16 Gbps (Gigabit EtherChannel) between a Catalyst 4500 series switch and another switch or host.

A Catalyst 4500 series switch supports a maximum of 64 EtherChannels. You can form an EtherChannel with up to eight compatibly configured Ethernet interfaces across modules in a Catalyst 4500 series switch. All interfaces in each EtherChannel must be the same speed and must be configured as either Layer 2 or Layer 3 interfaces.

Note The network device to which a Catalyst 4500 series switch is connected may impose its own limits on the number of interfaces in an EtherChannel.

If a segment within an EtherChannel fails, traffic previously carried over the failed link switches to the remaining segments within the EtherChannel. Once the segment fails, an SNMP trap is sent, identifying the switch, the EtherChannel, and the failed link. Inbound broadcast and multicast packets on one segment in an EtherChannel are blocked from returning on any other segment of the EtherChannel.

Understanding Port-Channel Interfaces

Each EtherChannel has a numbered port-channel interface. A configuration applied to the port-channel interface affects all physical interfaces assigned to that interface.

Note QoS does not propagate to members. The defaults, QoS cos = 0 and QoS dscp = 0, apply on the port-channel. Input or output policies applied on individual interfaces will be ignored.

After you configure an EtherChannel, the configuration that you apply to the port-channel interface affects the EtherChannel; the configuration that you apply to the physical interfaces affects only the interface where you apply the configuration. To change the parameters of all ports in an EtherChannel, apply configuration commands to the port-channel interface (such commands can be STP commands or commands to configure a Layer 2 EtherChannel as a trunk).

Understanding How EtherChannels Are Configured

These subsections describe how EtherChannels are configured:

EtherChannel Configuration Overview

You can configure EtherChannels manually or you can use the Port Aggregation Control Protocol (PAgP) or, with Release Cisco IOS Release 12.2(20)EW and later, the Link Aggregation Control Protocol (LACP) to form EtherChannels. The EtherChannel protocols allow ports with similar characteristics to form an EtherChannel through dynamic negotiation with connected network devices. PAgP is a Cisco-proprietary protocol and LACP is defined in IEEE 802.3ad.

PAgP and LACP do not interoperate with each other. Ports configured to use PAgP cannot form EtherChannels with ports configured to use LACP and vice versa.

Table 14-1 lists the user-configurable EtherChannel modes.

Table 14-1 EtherChannel Modes

Mode	Description
on	Mode that forces the LAN port to channel unconditionally. In the **on** mode, a usable EtherChannel exists only when a LAN port group in the **on** mode is connected to another LAN port group in the **on** mode. Because ports configured in the **on** mode do not negotiate, there is no negotiation traffic between the ports.
auto	PAgP mode that places a LAN port into a passive negotiating state, in which the port responds to PAgP packets it receives but does not initiate PAgP negotiation.
desirable	PAgP mode that places a LAN port into an active negotiating state, in which the port initiates negotiations with other LAN ports by sending PAgP packets.
passive	LACP mode that places a port into a passive negotiating state, in which the port responds to LACP packets it receives but does not initiate LACP negotiation.
active	LACP mode that places a port into an active negotiating state, in which the port initiates negotiations with other ports by sending LACP packets.

Understanding Manual EtherChannel Configuration

Manually configured EtherChannel ports do not exchange EtherChannel protocol packets. A manually configured EtherChannel forms only when you enter configure all ports in the EtherChannel compatibly.

Understanding PAgP EtherChannel Configuration

PAgP supports the automatic creation of EtherChannels by exchanging PAgP packets between LAN ports. PAgP packets are exchanged only between ports in **auto** and **desirable** modes.

The protocol learns the capabilities of LAN port groups dynamically and informs the other LAN ports. Once PAgP identifies correctly matched Ethernet links, it facilitates grouping the links into an EtherChannel. The EtherChannel is then added to the spanning tree as a single bridge port.

Both the **auto** and **desirable** modes allow PAgP to negotiate between LAN ports to determine if they can form an EtherChannel, based on criteria such as port speed and trunking state. Layer 2 EtherChannels also use VLAN numbers.

LAN ports can form an EtherChannel when they are in different PAgP modes if the modes are compatible. For example:

- A LAN port in **desirable** mode can form an EtherChannel successfully with another LAN port that is in **desirable** mode.
- A LAN port in **desirable** mode can form an EtherChannel with another LAN port in **auto** mode.
- A LAN port in **auto** mode cannot form an EtherChannel with another LAN port that is also in **auto** mode, because neither port will initiate negotiation.

Understanding IEEE 802.3ad LACP EtherChannel Configuration

Release Cisco IOS Release 12.2(20)EW and later releases support IEEE 802.3ad LACP EtherChannels. LACP supports the automatic creation of EtherChannels by exchanging LACP packets between LAN ports. LACP packets are exchanged only between ports in **passive** and **active** modes.

The protocol learns the capabilities of LAN port groups dynamically and informs the other LAN ports. Once LACP identifies correctly matched Ethernet links, it facilitates grouping the links into an EtherChannel. The EtherChannel is then added to the spanning tree as a single bridge port.

Both the **passive** and **active** modes allow LACP to negotiate between LAN ports to determine if they can form an EtherChannel, based on criteria such as port speed and trunking state. Layer 2 EtherChannels also use VLAN numbers.

LAN ports can form an EtherChannel when they are in different LACP modes as long as the modes are compatible. For example:

- A LAN port in **active** mode can form an EtherChannel successfully with another LAN port that is in **active** mode.
- A LAN port in **active** mode can form an EtherChannel with another LAN port in **passive** mode.
- A LAN port in **passive** mode cannot form an EtherChannel with another LAN port that is also in **passive** mode, because neither port will initiate negotiation.

LACP uses the following parameters:

- LACP system priority—You may configure an LACP system priority on each switch running LACP. The system priority can be configured automatically or through the CLI. See the "Configuring the LACP System Priority and System ID" section on page 14-11. LACP uses the system priority with the switch MAC address to form the system ID and also during negotiation with other systems.

  Note The LACP system ID is the combination of the LACP system priority value and the MAC address of the switch.

- LACP port priority—You must configure an LACP port priority on each port configured to use LACP. The port priority can be configured automatically or through the CLI. See the "Configuring Layer 2 EtherChannels" section on page 14-9. LACP uses the port priority with the port number to form the port identifier.

Note Standby and "sub-channeling" are not supported in LACP and PagP.

- LACP administrative key—LACP automatically configures an administrative key value equal to the channel group identification number on each port configured to use LACP. The administrative key defines the ability of a port to aggregate with other ports. A port's ability to aggregate with other ports is determined by these factors:
  - Port physical characteristics, such as data rate, duplex capability, and point-to-point or shared medium
  - Configuration restrictions that you establish

LACP tries to configure the maximum number of compatible ports in an EtherChannel, up to the maximum allowed by the hardware (eight ports). If a port can not be actively included in a channel, it will not be included automatically if a channelled port fails.

Understanding Load Balancing

EtherChannel can balance the traffic load across the links in the channel. It does this by reducing part of the binary pattern formed from the addresses or ports in the frame to a numerical value that selects one of the links in the channel. To balance the load, EtherChannel uses MAC addresses, IP addresses, or Layer 4 port numbers, and either the message source or message destination, or both.

Use the option that provides the greatest variety in your configuration. For example, if the traffic on a channel is going only 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.

Note Load balancing can only be configured globally. As a result, all channels (manually configured, PagP, or LACP) will use the same load balancing method.

For additional information on load balancing, see the "Configuring EtherChannel Load Balancing" section on page 14-12.

EtherChannel Configuration Guidelines and Restrictions

If improperly configured, some EtherChannel interfaces are disabled automatically to avoid network loops and other problems. Follow these guidelines and restrictions to avoid configuration problems:

- All Ethernet interfaces on all modules support EtherChannel (maximum of eight interfaces) with no requirement that interfaces be physically contiguous or on the same module.
- Configure all interfaces in an EtherChannel to operate at the same speed and duplex mode.
- Enable all interfaces in an EtherChannel. If you shut down an interface in an EtherChannel, it is treated as a link failure and its traffic is transferred to one of the remaining interfaces in the EtherChannel.
- An EtherChannel will not form if one of the interfaces is a Switched Port Analyzer (SPAN) destination port.
- For Layer 3 EtherChannels:
  - Assign Layer 3 addresses to the port-channel logical interface, not to the physical interfaces in the channel.
- For Layer 2 EtherChannels:
  - Assign all interfaces in the EtherChannel to the same VLAN, or configure them as trunks.
  - If you configure an EtherChannel from trunk interfaces, verify that the trunking mode is the same on all the trunks. Interfaces in an EtherChannel with different trunk modes can have unexpected results.
  - An EtherChannel supports the same allowed range of VLANs on all the interfaces in a trunking Layer 2 EtherChannel. If the allowed range of VLANs is not the same, the interfaces do not form an EtherChannel.
  - Interfaces with different Spanning Tree Protocol (STP) port path costs can form an EtherChannel as long they are otherwise compatibly configured. Setting different STP port path costs does not, by itself, make interfaces incompatible for the formation of an EtherChannel.

- After you configure an EtherChannel, any configuration that you apply to the port-channel interface affects the EtherChannel; any configuration that you apply to the physical interfaces affects only the interface where you apply the configuration.
- You cannot configure a 802.1x port in an EtherChannel.

Configuring EtherChannel

These sections describe how to configure EtherChannel:

Note Ensure that the interfaces are configured correctly (see the "EtherChannel Configuration Guidelines and Restrictions" section on page 14-5).

Configuring Layer 3 EtherChannels

To configure Layer 3 EtherChannels, create the port-channel logical interface and then put the Ethernet interfaces into the port-channel.

These sections describe Layer 3 EtherChannel configuration:

Creating Port-Channel Logical Interfaces

Note To move an IP address from a physical interface to an EtherChannel, you must delete the IP address from the physical interface before configuring it on the port-channel interface.

To create a port-channel interface for a Layer 3 EtherChannel, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface port-channel port_channel_number`	Creates the port-channel interface. The value for *port_channel_number* can range from 1 to 64
Step 2	`Switch(config-if)# ip address ip_address mask`	Assigns an IP address and subnet mask to the EtherChannel.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show running-config interface port-channel port_channel_number`	Verifies the configuration.

This example shows how to create port-channel interface 1:

```
Switch# configure terminal
Switch(config)# interface port-channel 1
Switch(config-if)# ip address 172.32.52.10 255.255.255.0
Switch(config-if)# end
```

This example shows how to verify the configuration of port-channel interface 1:

```
Switch# show running-config interface port-channel 1
Building configuration...

Current configuration:
!
interface Port-channel1
 ip address 172.32.52.10 255.255.255.0
 no ip directed-broadcast
end

Switch#
```

Configuring Physical Interfaces as Layer 3 EtherChannels

To configure physical interfaces as Layer 3 EtherChannels, perform this task for each interface:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects a physical interface to configure.
Step 2	`Switch(config-if)# no switchport`	Makes this a Layer 3 routed port.
Step 3	`Switch(config-if)# no ip address`	Ensures that there is no IP address assigned to the physical interface.
Step 4	`Switch(config-if)# channel-group port_channel_number mode {active | on | auto | passive | desirable}`	Configures the interface in a port-channel and specify the PAgP or LACP mode. If you use PAgP, select the keywords **auto** and **desirable**. If you use LACP, select the keywords **active** and **passive**.

	Command	Purpose
Step 5	`Switch(config-if)# end`	Exits configuration mode.

Step 6	`Switch# show running-config interface port-channel port_channel_number`
	
	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port`
	
	`Switch# show interfaces {fastethernet | gigabitethernet} slot/port etherchannel`
	
	`Switch# show etherchannel 1 port-channel`
		Verifies the configuration.

This example shows how to configure Fast Ethernet interfaces 5/4 and 5/5 into port-channel 1 with PAgP mode **desirable**:

```
Switch# configure terminal
Switch(config)# interface range fastethernet 5/4 - 5 (Note: Space is mandatory.)
Switch(config-if)# no switchport
Switch(config-if)# no ip address
Switch(config-if)# channel-group 1 mode desirable
Switch(config-if)# end
```

Note See the "Configuring a Range of Interfaces" section on page 4-4 for information about the **range** keyword.

The following two examples shows how to verify the configuration of Fast Ethernet interface 5/4:

```
Switch# show running-config interface fastethernet 5/4
Building configuration...

Current configuration:
!
interface FastEthernet5/4
 no ip address
 no switchport
 no ip directed-broadcast
 channel-group 1 mode desirable
end

Switch# show interfaces fastethernet 5/4 etherchannel
Port state    = EC-Enbld Up In-Bndl Usr-Config
Channel group = 1           Mode = Desirable     Gcchange = 0
Port-channel  = Po1         GC   = 0x00010001    Pseudo-port-channel = Po1
Port indx     = 0           Load = 0x55

Flags:  S - Device is sending Slow hello.  C - Device is in Consistent state.
        A - Device is in Auto mode.        P - Device learns on physical port.
Timers: H - Hello timer is running.        Q - Quit timer is running.
        S - Switching timer is running.    I - Interface timer is running.

Local information:
                              Hello    Partner  PAgP     Learning  Group
Port      Flags State   Timers  Interval Count   Priority   Method  Ifindex
Fa5/4     SC    U6/S7           30s      1        128        Any      55
```

```
Partner's information:

          Partner              Partner          Partner         Partner Group
Port      Name                 Device ID        Port       Age  Flags   Cap.
Fa5/4     JAB031301            0050.0f10.230c   2/45         1s SAC     2D

Age of the port in the current state: 00h:54m:52s

Switch#
```

This example shows how to verify the configuration of port-channel interface 1 after the interfaces have been configured:

```
Switch# show etherchannel 1 port-channel

                Channel-group listing:
                ----------------------
Group: 1
------------

                Port-channels in the group:
                ----------------------
Port-channel: Po1
------------

Age of the Port-channel   = 01h:56m:20s
Logical slot/port   = 10/1           Number of ports = 2
GC                  = 0x00010001      HotStandBy port = null
Port state          = Port-channel L3-Ag Ag-Inuse

Ports in the Port-channel:

Index   Load   Port
--------------------
  1     00      Fa5/6
  0     00      Fa5/7

Time since last port bundled:    00h:23m:33s    Fa5/6

Switch#
```

Configuring Layer 2 EtherChannels

To configure Layer 2 EtherChannels, configure the Ethernet interfaces with the **channel-group** command. This creates the port-channel logical interface.

Note Cisco IOS software creates port-channel interfaces for Layer 2 EtherChannels when you configure Layer 2 Ethernet interfaces with the **channel-group** command.

To configure Layer 2 Ethernet interfaces as Layer 2 EtherChannels, perform this task for each interface:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects a physical interface to configure.
Step 2	`Switch(config-if)# channel-group port_channel_number mode {active | on | auto | passive | desirable}`	Configures the interface in a port-channel and specify the PAgP or LACP mode. If you use PAgP, select the keywords **active** and **desirable**. If you use LACP, select the keywords **active** and **passive**.
Step 3	`Switch(config-if)# end`	Exits configuration mode.

Step 4	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port`
	
	`Switch# show interface {fastethernet | gigabitethernet} slot/port etherchannel`
		Verifies the configuration.

This example shows how to configure Fast Ethernet interfaces 5/6 and 5/7 into port-channel 2 with PAgP mode **desirable**:

```
Switch# configure terminal
Switch(config)# interface range fastethernet 5/6 - 7 (Note: Space is mandatory.)
Switch(config-if-range)# channel-group 2 mode desirable
Switch(config-if-range)# end
```

Note See the "Configuring a Range of Interfaces" section on page 4-4 for information about the **range** keyword.

This example shows how to verify the configuration of port-channel interface 2:

```
Switch# show running-config interface port-channel 2
Building configuration...

Current configuration:
!
interface Port-channel2
 switchport access vlan 10
 switchport mode access
end

Switch#
```

The following two examples show how to verify the configuration of Fast Ethernet interface 5/6:

```
Switch# show running-config interface fastethernet 5/6
Building configuration...

Current configuration:
!
interface FastEthernet5/6
 switchport access vlan 10
 switchport mode access
 channel-group 2 mode desirable
end
```

```
Switch# show interfaces fastethernet 5/6 etherchannel
Port state    = EC-Enbld Up In-Bndl Usr-Config
Channel group = 1           Mode = Desirable     Gcchange = 0
Port-channel  = Po1         GC   = 0x00010001
Port indx     = 0           Load = 0x55

Flags:  S - Device is sending Slow hello.  C - Device is in Consistent state.
        A - Device is in Auto mode.        P - Device learns on physical port.
        d - PAgP is down.
Timers: H - Hello timer is running.        Q - Quit timer is running.
        S - Switching timer is running.    I - Interface timer is running.
Local information:
                              Hello    Partner  PAgP     Learning  Group
Port      Flags State   Timers  Interval Count   Priority   Method  Ifindex
Fa5/6     SC    U6/S7           30s      1        128        Any      56

Partner's information:

          Partner              Partner          Partner         Partner Group
Port      Name                 Device ID        Port       Age  Flags   Cap.
Fa5/6     JAB031301            0050.0f10.230c   2/47        18s SAC     2F

Age of the port in the current state: 00h:10m:57s
```

This example shows how to verify the configuration of port-channel interface 2 after the interfaces have been configured:

```
Switch# show etherchannel 2 port-channel
               Port-channels in the group:
               ----------------------

Port-channel: Po2
------------

Age of the Port-channel   = 00h:23m:33s
Logical slot/port   = 10/2           Number of ports in agport = 2
GC                  = 0x00020001      HotStandBy port = null
Port state          = Port-channel Ag-Inuse

Ports in the Port-channel:

Index   Load   Port
-------------------
  1     00      Fa5/6
  0     00      Fa5/7

Time since last port bundled:    00h:23m:33s    Fa5/6

Switch#
```

Configuring the LACP System Priority and System ID

The LACP system ID is the combination of the LACP system priority value and the MAC address of the switch.

To configure the LACP system priority and system ID, perform this task:

	Command	Purpose
Step 1	`Router(config)# lacp system-priority` *priority_value*	(Optional for LACP) Valid values are 1 through 65535. Higher numbers have lower priority. The default is 32768.
	`Router(config)# no system port-priority`	Reverts to the default.
Step 2	`Router(config)# end`	Exits configuration mode.
Step 3	`Router# show lacp sys-id`	Verifies the configuration.

This example shows how to configure the LACP system priority:

```
Switch# configure terminal
Switch(config)# lacp system-priority 23456
Switch(config)# end
Switch(config)#
Switch>show module

Mod  Ports Card Type                              Model             Serial No.
---+-----+--------------------------------------+------------------+-----------
 1      2  1000BaseX (GBIC) Supervisor(active)    WS-X4014          JAB063808YZ
 2     48  10/100BaseTX (RJ45)                    WS-X4148-RJ       JAB0447072W
 3     48  10/100BaseTX (RJ45)V                   WS-X4148-RJ45V    JAE061704J6
 4     48  10/100BaseTX (RJ45)V                   WS-X4148-RJ45V    JAE061704ML

 M MAC addresses                    Hw  Fw           Sw               Status
--+--------------------------------+---+------------+----------------+---------
 1 0005.9a39.7a80 to 0005.9a39.7a81 2.1 12.1(12r)EW  12.1(13)EW(0.26) Ok
 2 0002.fd80.f530 to 0002.fd80.f55f 0.1                               Ok
 3 0009.7c45.67c0 to 0009.7c45.67ef 1.6                               Ok
 4 0009.7c45.4a80 to 0009.7c45.4aaf 1.6                               Ok
```

This example shows how to verify the configuration:

```
Switch# show lacp sys-id
23456,0050.3e8d.6400
Switch#
```

The system priority is displayed first, followed by the MAC address of the switch.

Configuring EtherChannel Load Balancing

Note Load balancing can only be configured globally. As a result, all channels (manually configured, PagP, or LACP) will use the same load balancing method.

To configure EtherChannel load balancing, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] port-channel load-balance {src-mac | dst-mac | src-dst-mac | src-ip | dst-ip | src-dst-ip | src-port | dst-port | src-dst-port}`	Configures EtherChannel load balancing. Use the **no** keyword to return EtherChannel load balancing to the default configuration.

	Command	Purpose
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show etherchannel load-balance`	Verifies the configuration.

The load-balancing keywords are:

- **src-mac**—Source MAC addresses
- **dst-mac**—Destination MAC addresses
- **src-dst-mac**—Source and destination MAC addresses
- **src-ip**—Source IP addresses
- **dst-ip**—Destination IP addresses
- **src-dst-ip**—Source and destination IP addresses (Default)
- **src-port**—Source Layer 4 port
- **dst-port**—Destination Layer 4 port
- **src-dst-port**—Source and destination Layer 4 port

This example shows how to configure EtherChannel to use source and destination IP addresses:

```
Switch# configure terminal
Switch(config)# port-channel load-balance dst-mac
Switch(config)# end
Switch(config)#
```

This example shows how to verify the configuration:

```
Switch# show etherchannel load-balance
Source XOR Destination IP address
Switch#
```

Removing an Interface from an EtherChannel

To remove an Ethernet interface from an EtherChannel, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects a physical interface to configure.
Step 2	`Switch(config-if)# no channel-group`	Removes the interface from the port-channel interface.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show running-config interface {fastethernet | gigabitethernet} slot/port` `Switch# show interface {fastethernet | gigabitethernet} slot/port etherchannel`	Verifies the configuration.

This example shows how to remove Fast Ethernet interfaces 5/4 and 5/5 from port-channel 1:

```
Switch# configure terminal
Switch(config)# interface range fastethernet 5/4 - 5 (Note: Space is mandatory.)
Switch(config-if)# no channel-group 1
Switch(config-if)# end
```

Removing an EtherChannel

If you remove an EtherChannel, the member ports are shut down and removed from the Channel group.

Note You must remove an EtherChannel before changing a port from Layer 2 to Layer 3, or Layer 3 to Layer 2.

To remove an EtherChannel, perform this task:

	Command	Purpose
Step 1	`Switch(config)# no interface port-channel` *port_channel_number*	Removes the port-channel interface.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show etherchannel summary`	Verifies the configuration.

This example shows how to remove port-channel 1:

```
Switch# configure terminal
Switch(config)# no interface port-channel 1
Switch(config)# end
```

CHAPTER 15

Configuring IGMP Snooping and Filtering

This chapter describes how to configure Internet Group Management Protocol (IGMP) snooping on the Catalyst 4500 series switch. It provides guidelines, procedures, and configuration examples.

This chapter consists of the following major sections:

Note To support Cisco Group Management Protocol (CGMP) client devices, configure the switch as a CGMP server. For more information, see the chapters "IP Multicast" and "Configuring IP Multicast Routing" in the *Cisco IOS IP and IP Routing Configuration Guide*, Release 12.2 at this URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_c/ipcprt3/1cdmulti.htm

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of IGMP Snooping

This section includes the following subsections:

Note Quality of service does not apply to IGMP packets.

IGMP snooping allows a switch to snoop or capture information from IGMP packets transmitted between hosts and a router. Based on this information, a switch will add or delete multicast addresses from its address table, thereby enabling (or disabling) multicast traffic from flowing to individual host ports. IGMP snooping supports all versions of IGMP: IGMPv1, IGMPv2, and IGMPv3.

In contrast to IGMPv1 and IGMPv2, IGMPv3 snooping provides immediate-leave processing by default. It provides Explicit Host Tracking (EHT) and allows network administrators to deploy SSM functionality on Layer 2 devices that truly support IGMPv3. (See Explicit Host Tracking, page 15-3.)

In subnets where IGMP is configured, IGMP snooping manages multicast traffic at Layer 2. You can configure interfaces to dynamically forward multicast traffic only to those interfaces that are interested in receiving it by using the **switchport** keyword.

IGMP snooping restricts traffic in MAC multicast groups 0100.5e00.0001 to 01-00-5e-ff-ff-ff. IGMP snooping does not restrict Layer 2 multicast packets generated by routing protocols.

Note For more information on IP multicast and IGMP, refer to RFC 1112, RFC 2236, RFC 3376 (for IGMPv3).

IGMP (configured on a router) periodically sends out IGMP general queries. A host responds to these queries with IGMP membership reports for groups that it is interested in. When IGMP snooping is enabled, the switch creates one entry per VLAN in the Layer 2 forwarding table for each Layer 2 multicast group from which it receives an IGMP join request. All hosts interested in this multicast traffic send IGMP membership reports and are added to the forwarding table entry.

Layer 2 multicast groups learned through IGMP snooping are dynamic. However, you can statically configure Layer 2 multicast groups using the **ip igmp snooping static** command. If you specify group membership statically, your setting supersedes any automatic manipulation by IGMP snooping. Multicast group membership lists can contain both user-defined and IGMP snooping settings.

Groups with IP addresses in the range 224.0.0.0 to 224.0.0.255, which map to the multicast MAC address range 0100.5E00.0001 to 0100.5E00.00FF, are reserved for routing control packets. These groups are flooded to all forwarding ports of the VLAN with the exception of 224.0.0.22, which is used for IGMPv3 membership reports.

Note If a VLAN experiences a spanning-tree topology change, IP multicast traffic floods on all VLAN ports where PortFast is not enabled, as well as on ports with the **no igmp snooping tcn flood** command configured for a period of TCN query count.

For a Layer 2 IGMPv2 host interface to join an IP multicast group, a host sends an IGMP membership report for the IP multicast group. For a host to leave a multicast group, it can either ignore the periodic IGMP general queries or it can send an IGMP leave message. When the switch receives an IGMP leave message from a host, it sends out an IGMP group-specific query to determine whether any devices connected to that interface are interested in traffic for the specific multicast group. The switch then updates the table entry for that Layer 2 multicast group so that only those hosts interested in receiving multicast traffic for the group are listed.

In contrast, IGMPv3 hosts send IGMPv3 membership reports (with the **allow** group record mode) to join a specific multicast group. When IGMPv3 hosts send membership reports (with the **block** group record) to reject traffic from all sources in the previous source list, the last host on the port will be removed by immediate-leave if EHT is enabled.

Immediate-Leave Processing

IGMP snooping immediate-leave processing allows the switch to remove an interface from the forwarding-table entry without first sending out IGMP group-specific queries to the interface. The VLAN interface is pruned from the multicast tree for the multicast group specified in the original IGMP leave message. Immediate-leave processing ensures optimal bandwidth management for all hosts on a switched network, even when multiple multicast groups are being used simultaneously.

When a switch with IGMP snooping enabled receives an IGMPv2 or IGMPv3 leave message, it sends an IGMP group-specific query from the interface where the leave message was received to determine when there are other hosts attached to that interface that are interested in joining the MAC multicast group. If the switch does not receive an IGMP join message within the query response interval, the interface is removed from the port list of the (MAC-group, VLAN) entry in the Layer 2 forwarding table.

Note By default all IGMP joins are forwarded to all multicast router ports.

With immediate-leave processing enabled on the VLAN, an interface can be removed immediately from the port list of the Layer 2 entry when the IGMP leave message is received, unless a multicast router was learned on the port.

Note When using IGMPv2 snooping, use immediate-leave processing only on VLANs where just one host is connected to each interface. If immediate-leave processing is enabled on VLANs where multiple hosts are connected to an interface, some hosts might be dropped inadvertently. When using IGMPv3, immediate-leave processing is enabled by default, and due to Explicit Host Tracking (see below), the switch can detect when a port has single or multiple hosts maintained by the switch for IGMPv3 hosts. As a result, the switch can perform immediate-leave processing when it detects a single host behind a given port.

Note IGMPv3 is interoperable with older versions of IGMP.

Use the **show ip igmp snooping querier vlan** command to display the IGMP version on a particular VLAN.

Use the **show ip igmp snooping vlan** command to display whether or not the switch supports IGMPv3 snooping.

Use the **ip igmp snooping immediate-leave** command to enable immediate-leave for IGMPv2.

Note Immediate-leave processing is enabled by default for IGMPv3.

Explicit Host Tracking

Explicit Host Tracking (EHT) monitors group membership by tracking hosts that are sending IGMPv3 membership reports. This tracking enables a switch to detect host information associated with the groups of each port. Furthermore, EHT enables the user to track the membership and various statistics.

EHT enables a switch to track membership on a per-port basis. Consequently, a switch is aware of the hosts residing on each port and can perform immediate-leave processing when there is only one host behind a port.

To determine whether or not EHT is enabled on a VLAN, use the **show ip igmp snoop vlan** command.

Configuring IGMP Snooping

Note When configuring IGMP, configure the VLAN in the VLAN database mode. (See Chapter 7, "Understanding and Configuring VLANs".)

IGMP snooping allows switches to examine IGMP packets and make forwarding decisions based on their content.

These sections describe how to configure IGMP snooping:

Default IGMP Snooping Configuration

Table 15-1 shows the IGMP snooping default configuration values.

Table 15-1 IGMP Snooping Default Configuration Values

Feature	Default Value
IGMP snooping	Enabled
Multicast routers	None configured
Explicit Host Tracking	Enabled for IGMPv3; Not available for IGMPv2
Immediate-leave processing	Enabled for IGMPv3; Disabled for IGMPv2
Report Suppression	Enabled
IGMP snooping learning method	PIM/DVMRP[1]

1. PIM/DVMRP = Protocol Independent Multicast/Distance Vector Multicast Routing Protocol

Enabling IGMP Snooping

To enable IGMP snooping globally, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] ip igmp snooping`	Enables IGMP snooping. Use the **no** keyword to disable IGMP snooping.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show ip igmp snooping | include`	Verifies the configuration.

This example shows how to enable IGMP snooping globally and verify the configuration:

```
Switch(config)# ip igmp snooping
Switch(config)# end
Switch# show ip igmp snooping
Global IGMP Snooping configuration:
-----------------------------------
IGMP snooping             : Enabled
IGMPv3 snooping           : Enabled
Report suppression        : Enabled
TCN solicit query         : Disabled
TCN flood query count     : 2

Vlan 1:
--------
IGMP snooping                  : Enabled
IGMPv2 immediate leave         : Disabled
Explicit host tracking         : Enabled
Multicast router learning mode : pim-dvmrp
CGMP interoperability mode     : IGMP_ONLY

Vlan 2:
--------
IGMP snooping                  : Enabled
IGMPv2 immediate leave         : Disabled
Explicit host tracking         : Enabled
Multicast router learning mode : pim-dvmrp
CGMP interoperability mode     : IGMP_ONLY
```

To enable IGMP snooping on a VLAN, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] ip igmp snooping vlan` *vlan_ID*	Enables IGMP snooping. Use the **no** keyword to disable IGMP snooping.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show ip igmp snooping vlan` *vlan_ID*	Verifies the configuration.

This example shows how to enable IGMP snooping on VLAN 2 and verify the configuration:

```
Switch# configure terminal
Switch(config)# ip igmp snooping vlan 2
Switch(config)# end
Switch# show ip igmp snooping vlan 2
Global IGMP Snooping configuration:
-----------------------------------
IGMP snooping             : Enabled
IGMPv3 snooping           : Enabled
Report suppression        : Enabled
TCN solicit query         : Disabled
TCN flood query count     : 2

Vlan 2:
--------
IGMP snooping                  : Enabled
IGMPv2 immediate leave         : Disabled
Explicit host tracking         : Enabled
Multicast router learning mode : pim-dvmrp
CGMP interoperability mode     : IGMP_ONLY
```

Configuring Learning Methods

The following sections describe IGMP snooping learning methods:

- Configuring PIM/DVMRP Learning, page 15-6
- Configuring CGMP Learning, page 15-6

Configuring PIM/DVMRP Learning

To configure IGMP snooping to learn from PIM/DVMRP packets, perform this task:

Command	Purpose
`Switch(config)# ip igmp snooping vlan` *vlan_ID* `mrouter learn [cgmp | pim-dvmrp]`	Specifies the learning method for the VLAN.

This example shows how to configure IP IGMP snooping to learn from PIM/DVMRP packets:

```
Switch(config)# ip igmp snooping vlan 1 mrouter learn pim-dvmrp
Switch(config)# end
Switch#
```

Configuring CGMP Learning

To configure IGMP snooping to learn from CGMP self-join packets, perform this task:

Command	Purpose
`Switch(config)# ip igmp snooping vlan` *vlan_ID* `mrouter learn [cgmp | pim-dvmrp]`	Specifies the learning method for the VLAN.

This example shows how to configure IP IGMP snooping to learn from CGMP self-join packets:

```
Switch(config)# ip igmp snooping vlan 1 mrouter learn cgmp
Switch(config)# end
Switch#
```

Configuring a Multicast Router Port Statical

To configure a static connection to a multicast router, enter the **ip igmp snooping mrouter** command on the switch.

To configure a static connection to a multicast router, perform this task:

	Command	Purpose
Step 1	`Switch(config)# ip igmp snooping vlan` *vlan_ID* `mrouter interface` *interface_num*	Specifies a static connection to a multicast router for the VLAN. **Note** The interface to the router must be in the VLAN where you are entering the command. The router must be administratively up, and the line protocol must be up.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show ip igmp snooping mrouter vlan` *vlan_ID*	Verifies the configuration.

This example shows how to configure a static connection to a multicast router:

```
Switch(config)# ip igmp snooping vlan 200 mrouter interface fastethernet 2/10
Switch# show ip igmp snooping mrouter vlan 200
vlan   ports
-----+---------------------------------------
 200   Fa2/10
Switch#
```

Enabling IGMP Immediate-Leave Processing

When you enable IGMP immediate-leave processing on a VLAN, a switch will remove an interface from the multicast group when it detects an IGMPv2 leave message on that interface.

Note For IGMPv3, immediate-leave processing is enabled by default with EHT.

To enable immediate-leave processing on an IGMPv2 interface, perform this task:

Command	Purpose
`Switch(config)# ip igmp snooping vlan` *vlan_ID* `immediate-leave`	Enables immediate-leave processing in the VLAN. **Note** This command applies only to IGMPv2 hosts.

This example shows how to enable IGMP immediate-leave processing on interface VLAN 200 and to verify the configuration:

```
Switch(config)# ip igmp snooping vlan 200 immediate-leave
Configuring immediate leave on vlan 200
Switch(config)# end
Switch# show ip igmp interface vlan 200 | include immediate leave
Immediate leave               : Disabled
Switch(config)#
```

Configuring Explicit Host Tracking

For IGMPv3, EHT is enabled by default and can be disabled on a per-VLAN basis.

To disable EHT processing on a VLAN, perform this task:

Command	Purpose
`Switch(config)#[no] ip igmp snooping vlan` *vlan_ID* **explicit-tracking**	Enables EHT on a VLAN. The **no** keyword disables EHT.

This example shows how to disable IGMP EHT on VLAN 200 and to verify the configuration:

```
Switch(config)# no ip igmp snooping vlan 200 explicit-tracking
Switch(config)#
Switch(config)# end
Switch# show ip igmp snooping vlan 200 | include Explicit host tracking
Explicit host tracking         : Disabled
```

Configuring a Host Statically

Hosts normally join multicast groups dynamically, but you can also configure a host statically on an interface.

To configure a host statically on an interface, perform this task:

Command	Purpose
`Switch(config-if)# ip igmp snooping vlan` *vlan_ID* **static** *mac_address* **interface** *interface_num*	Configures a host statically in the VLAN. **Note** This command cannot be configured to receive traffic for specific source IP addresses.

This example shows how to configure a host statically in VLAN 200 on interface FastEthernet 2/11:

```
Switch(config)# ip igmp snooping vlan 200 static 0100.5e02.0203 interface fastethernet
2/11
Configuring port FastEthernet2/11 on group 0100.5e02.0203 vlan 200
Switch(config)#
```

Suppressing Multicast Flooding

An IGMP snooping-enabled switch will flood multicast traffic to all ports in a VLAN when a spanning-tree Topology Change Notification (TCN) is received. Multicast flooding suppression enables a switch to stop sending such traffic. To support flooding suppression, a new interface command and two new global commands are introduced in release 12.1(11b)EW.

The new interface command is as follows:

[**no | default**] **ip igmp snooping tcn flood**

These are the new global commands:

[**no | default**] **ip igmp snooping tcn flood query count** [**1 - 10**]

[**no | default**] **ip igmp snooping tcn query solicit**

Prior to release 12.1(11b)EW, when a spanning tree topology change notification (TCN) was received by a switch, the multicast traffic was flooded to all the ports in a VLAN for a period of three IGMP query intervals. This was necessary for redundant configurations. In release 12.1(11b)EW, the default time period the switch will wait before multicast flooding will stop was changed to two IGMP query intervals.

This flooding behavior is undesirable if the switch that does the flooding has many ports that are subscribed to different groups. The traffic could exceed the capacity of the link between the switch and the end host, resulting in packet loss.

With the **no ip igmp snooping tcn flood** command, you can disable multicast flooding on a switch interface following a topology change. Only the multicast groups that have been joined by a port are sent to that port, even during a topology change.

With the **ip igmp snooping tcn flood query count** command, you can enable multicast flooding on a switch interface for a short period of time following a topology change by configuring an IGMP query threshold.

Typically, if a topology change occurs, the spanning tree root switch issues a global IGMP leave message (referred to as a “query solicitation”) with the group multicast address 0.0.0.0. When a switch receives this solicitation, it floods this solicitation on all ports in the VLAN where the spanning tree change occurred. When the upstream router receives this solicitation, it immediately issues an IGMP general query.

With the **ip igmp snooping tcn query solicit** command, you can now direct a non-spanning tree root switch to issue the same query solicitation.

The following sections provide additional details on the new commands and illustrate how you can use them.

IGMP Snooping Interface Configuration

A topology change in a VLAN may invalidate previously learned IGMP snooping information. A host that was on one port before the topology change may move to another port after the topology change. When the topology changes, the Catalyst 4500 series switch takes special actions to ensure that multicast traffic is delivered to all multicast receivers in that VLAN.

When the spanning tree protocol is running in a VLAN, a spanning tree topology change notification (TCN) is issued by the root switch in the VLAN. A Catalyst 4500 series switch that receives a TCN in a VLAN for which IGMP snooping has been enabled immediately enters into “multicast flooding mode” for a period of time until the topology restabilizes and the new locations of all multicast receivers are learned.

While in "multicast flooding mode," IP multicast traffic is delivered to all ports in the VLAN, and not restricted to those ports on which multicast group members have been detected.

Starting with 12.1(11b)EW, you can manually prevent IP multicast traffic from being flooded to a switchport by using the **no ip igmp snooping tcn flood** command on that port.

For trunk ports, the configuration will apply to all VLANs.

By default, multicast flooding is enabled. Use the **no** keyword to disable flooding, and use **default** to restore the default behavior (flooding is enabled).

To disable multicast flooding on an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects the interface to configure.
Step 2	`Switch(config-if)# no ip igmp snooping tcn flood`	Disables multicast flooding on the interface when TCNs are received by the switch. To enable multicast flooding on the interface, enter this command: **default ip igmp snooping tcn flood**
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show running interface {fastethernet | gigabitethernet} slot/port`	Verifies the configuration.

This example shows how to disable multicast flooding on interface FastEthernet 2/11:

```
Switch(config)# interface fastethernet 2/11
Switch(config-if)# no ip igmp snooping tcn flood
Switch(config-if)# end
Switch#
```

IGMP Snooping Switch Configuration

By default, "flooding mode" persists until the switch receives two IGMP general queries. You can change this period of time by using the
ip igmp snooping tcn flood query count *n* command, where *n* is a number between 1 and 10.

This command operates at the global configuration level.

The default number of queries is 2. The **no** and **default** keywords restore the default.

To establish an IGMP query threshold, perform this task:

	Command	Purpose
Step 1	`Switch(config)#` **ip igmp snooping tcn flood query count <n>**	Modifies the number of IGMP queries the switch will wait for before it stops flooding multicast traffic. To return the switch to the default number of IGMP queries, enter this command**:** **default ip igmp snooping tcn flood query count** .
Step 2	`Switch(config)# end`	Exits configuration mode.

This example shows how to modify the switch to stop flooding multicast traffic after four queries:

```
Switch(config)# ip igmp snooping tcn flood query count 4
Switch(config)# end
Switch#
```

When a spanning tree root switch receives a topology change in an IGMP snooping-enabled VLAN, the switch issues a query solicitation that causes an IOS router to send out one or more general queries. The new command **ip igmp snooping tcn query solicit** causes the switch to send the query solicitation whenever it notices a topology change, even if that switch is not the spanning tree root.

This command operates at the global configuration level.

By default, query solicitation is disabled unless the switch is the spanning tree root. The **default** keyword restores the default behavior.

To direct a switch to send a query solicitation, perform this task:

	Command	Purpose
Step 1	`Switch(config)#` **`ip igmp snooping tcn query solicit`**	Configures the switch to send a query solicitation when a TCN is detected. To stop the switch from sending a query solicitation (if it's not a spanning tree root switch), enter this command: **no ip igmp snooping tcn query solicit**
Step 2	`Switch(config)#` **`end`**	Exits configuration mode.

This example shows how to configure the switch to send a query solicitation upon detecting a TCN:

```
Switch(config)# ip igmp snooping tcn query solicit
Switch(config)# end
Switch#
```

Displaying IGMP Snooping Information

The following sections show how to display IGMP snooping information:

Displaying Querier Information

To display querier information, perform this task:

Command	Purpose
Switch# **show ip igmp snooping querier** [**vlan** *vlan_ID*]	Displays multicast router interfaces.

This example shows how to display the IGMP snooping querier information for all VLANs on the switch:

```
Switch# show ip igmp snooping querier
Vlan      IP Address     IGMP Version        Port
---------------------------------------------------
2         10.10.10.1     v2                  Router
3         172.20.50.22   v3                  Fa3/15
```

This example shows how to display the IGMP snooping querier information for VLAN 3:

```
Switch# show ip igmp snooping querier vlan 3
Vlan      IP Address     IGMP Version        Port
---------------------------------------------------
3         172.20.50.22   v3                  Fa3/15
```

Displaying IGMP Host Membership Information

Note By default, EHT maintains a maximum of 1000 entries in the EHT database. Once this limit is reached, no additional entries are created. To create additional entries, clear the database with the **clear ip igmp snooping membership vlan** command.

To display host membership information, perform this task:

Command	Purpose
Switch# **show ip igmp snooping membership** [**interface** *interface_num*][**vlan** *vlan_ID*] [**reporter** *a.b.c.d*] [**source** *a.b.c.d* **group** *a.b.c.d*]	Displays Explicit Host Tracking information. **Note** This command is valid only if EHT is enabled on the switch.

This example shows how to display host membership information for VLAN 20 and to delete the EHT database:

```
Switch# show ip igmp snooping membership vlan 20
#channels: 5
#hosts : 1
Source/Group Interface Reporter Uptime Last-Join Last-Leave

40.40.40.2/224.10.10.10 Gi4/1 20.20.20.20 00:23:37 00:06:50 00:20:30
40.40.40.3/224.10.10.10 Gi4/2 20.20.2020 00:23:37 00:06:50 00:20:30
40.40.40.4/224.10.10.10Gi4/1 20.20.20.20 00:39:42 00:09:17 -
```

```
40.40.40.5/224.10.10.10Fa2/1 20.20.20.20 00:39:42 00:09:17 -
40.40.40.6/224.10.10.10 Fa2/1 20.20.20.20 00:09:47 00:09:17 -

Switch# clear ip igmp snooping membership vlan 20
```

This example shows how to display host membership for interface gi4/1:

```
Switch# show ip igmp snooping membership interface gi4/1
#channels: 5
#hosts : 1
Source/Group Interface Reporter Uptime Last-Join Last-Leave

40.40.40.2/224.10.10.10 Gi4/1 20.20.20.20 00:23:37 00:06:50 00:20:30
40.40.40.4/224.10.10.10Gi4/1 20.20.20.20 00:39:42 00:09:17 -
```

This example shows how to display host membership for VLAN 20 and group 224.10.10.10:

```
Switch# show ip igmp snooping membership vlan 20 source 40.40.40.2 group 224.10.10.10
#channels: 5
#hosts : 1
Source/Group Interface Reporter Uptime Last-Join Last-Leave

40.40.40.2/224.10.10.10 Gi4/1 20.20.20.20 00:23:37 00:06:50 00:20:30
```

Displaying Group Information

To display detailed IGMPv3 information associated with a group, perform one of the following tasks:

Command	Purpose
`Switch# show ip igmp snooping groups [vlan vlan_ID]`	Displays groups, the type of reports that were received for the group (Host Type), and the list of ports on which reports were received. The report list includes neither the multicast router ports nor the complete forwarding port set for the group. Rather, it lists the ports on which the reports have been received. To display the complete forwarding port set for the group, display the CLI output for the MAC address that maps to this group by using the **show mac-address-table multicast** command.
`Switch# show ip igmp snooping groups [vlan vlan_ID a.b.c.d] [summary|sources|hosts]`	Displays information specific to a group address, providing details about the current state of the group with respect to sources and hosts. **Note** This command applies only to full IGMPv3 snooping support and can be used for IGMPv1, IGMPv2, or IGMPv3 groups.
`Switch# show ip igmp snooping groups [vlan vlan_ID] [count]`	Displays the total number of group addresses learned by the system on a global or per-VLAN basis.

This example shows how to display the host types and ports of a group in VLAN 1:

```
Switch# show ip igmp snooping groups vlan 10 226.6.6.7
Vlan      Group           Version     Ports
------------------------------------------------------
10        226.6.6.7       v3          Fa7/13, Fa7/14
Switch>
```

This example shows how to display the current state of a group with respect to a source IP address:

```
Switch# show ip igmp snooping groups vlan 10 226.6.6.7 sources
Source information for group 226.6.6.7:
Timers: Expired sources are deleted on next IGMP General Query

SourceIP       Expires   Uptime    Inc Hosts Exc Hosts
------------------------------------------------------
2.0.0.1        00:03:04  00:03:48  2         0
2.0.0.2        00:03:04  00:02:07  2         0
Switch>
```

This example shows how to display the current state of a group with respect to a host MAC address:

```
Switch# show ip igmp snooping groups vlan 10 226.6.6.7 hosts
IGMPv3 host information for group 226.6.6.7
Timers: Expired hosts are deleted on next IGMP General Query

Host (MAC/IP)  Filter mode    Expires   Uptime    # Sources
------------------------------------------------------------
175.1.0.29     INCLUDE        stopped   00:00:51       2
175.2.0.30     INCLUDE        stopped   00:04:14       2
```

This example shows how to display summary information for an IGMPv3 group:

```
Switch# show ip igmp snooping groups vlan 10 226.6.6.7 summary
Group Address (Vlan 10)        : 226.6.6.7
Host type                      : v3
Member Ports                   : Fa7/13, Fa7/14
Filter mode                    : INCLUDE
Expires                        : stopped
Sources                        : 2
Reporters (Include/Exclude)    : 2/0
```

This example shows how to display the total number of group addresses learned by the system globally:

```
Switch# show ip igmp snooping groups count
    Total number of groups:   54
```

This example shows how to display the total number of group addresses learned on VLAN 5:

```
Switch# show ip igmp snooping groups vlan 5 count
    Total number of groups:   30
```

Displaying Multicast Router Interfaces

When you enable IGMP snooping, the switch automatically learns to which interface the multicast routers are connected.

To display multicast router interfaces, perform this task:

Command	Purpose
Switch# **show ip igmp snooping mrouter vlan** *vlan_ID*	Displays multicast router interfaces.

This example shows how to display the multicast router interfaces in VLAN 1:

```
Switch# show ip igmp snooping mrouter vlan 1
vlan            ports
-----+---------------------------------------
  1          Gi1/1,Gi2/1,Fa3/48,Router
Switch#
```

Displaying MAC Address Multicast Entries

To display MAC address multicast entries for a VLAN, perform this task:

Command	Purpose
Switch# **show mac-address-table multicast vlan** *vlan_ID* [**count**]	Displays MAC address multicast entries for a VLAN.

This example shows how to display MAC address multicast entries for VLAN 1:

```
Switch# show mac-address-table multicast vlan 1
Multicast Entries
 vlan    mac address     type    ports
-------+---------------+-------+---------------------------------------
   1    0100.5e01.0101     igmp Switch,Gi6/1
   1    0100.5e01.0102     igmp Switch,Gi6/1
   1    0100.5e01.0103     igmp Switch,Gi6/1
   1    0100.5e01.0104     igmp Switch,Gi6/1
   1    0100.5e01.0105     igmp Switch,Gi6/1
   1    0100.5e01.0106     igmp Switch,Gi6/1
Switch#
```

This example shows how to display a total count of MAC address entries for VLAN 1:

```
Switch# show mac-address-table multicast vlan 1 count
Multicast MAC Entries for vlan 1:    4
Switch#
```

Displaying IGMP Snooping Information on a VLAN Interface

To display IGMP snooping information on a VLAN, perform this task:

Command	Purpose
Switch# **show ip igmp snooping vlan** *vlan_ID*	Displays IGMP snooping information on a VLAN interface.

This example shows how to display IGMP snooping information on VLAN 5:

```
Switch#show ip igmp snooping vlan 5
Global IGMP Snooping configuration:
-----------------------------------
IGMP snooping             :Enabled
IGMPv3 snooping support   :Full
Report suppression        :Enabled
TCN solicit query         :Disabled
TCN flood query count     :2

Vlan 5:
--------
IGMP snooping                  :Enabled
Immediate leave                :Disabled
Explicit Host Tracking         :Disabled
Multicast router learning mode :pim-dvmrp
CGMP interoperability mode     :IGMP_ONLY
```

Configuring IGMP Filtering

This section includes the following subsections:

Note The IGMP filtering feature works for IGMPv1 and IGMPv2 only.

In some environments, for example metropolitan or multiple-dwelling unit (MDU) installations, an administrator might want to control the multicast groups to which a user on a switch port can belong. This allows the administrator to control the distribution of multicast services, such as IP/TV, based on some type of subscription or service plan.

With the IGMP filtering feature, an administrator can exert this type of control. With this 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.

IGMP filtering controls only IGMP membership join reports and has no relationship to the function that directs the forwarding of IP multicast traffic.

You can also set the maximum number of IGMP groups that a Layer 2 interface can join with the **ip igmp max-groups** *<n>* command.

Default IGMP Filtering Configuration

Table 15-2 shows the default IGMP filtering configuration.

Table 15-2 Default IGMP Filtering Settings

Feature	Default Setting
IGMP filters	No filtering
IGMP maximum number of IGMP groups	No limit
IGMP profiles	None defined

Configuring IGMP Profiles

To configure an IGMP profile and to enter IGMP profile configuration mode, use the **ip igmp profile** global configuration command. From the IGMP profile configuration 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 using these commands:

- **deny**: Specifies that matching addresses are denied; this is the default condition.
- **exit**: Exits from igmp-profile configuration mode.
- **no**: Negates a command or sets 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 starting and ending addresses.

By default, no IGMP profiles are configured. When a profile is configured with neither the **permit** nor the **deny** keyword, the default is to deny access to the range of IP addresses.

To create an IGMP profile for a port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# ip igmp profile` *profile number*	Enters IGMP profile configuration mode, and assigns a number to the profile you are configuring. The range is from 1 to 4,294,967,295.
Step 3	`Switch(config-igmp-profile)# permit | deny`	(Optional) Sets the action to permit or deny access to the IP multicast address. If no action is configured, the default for the profile is to deny access.
Step 4	`Switch(config-igmp-profile)# range` *ip multicast address*	Enters 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 **range** command multiple times to enter multiple addresses or ranges of addresses.
Step 5	`Switch(config-igmp-profile)# end`	Returns to privileged EXEC mode.

	Command	Purpose
Step 6	`Switch# show ip igmp profile profile number`	Verifies the profile configuration.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

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 were to deny (the default), it would not appear in the **show ip igmp profile** command output.

```
Switch# config t
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 a profile to multiple interfaces, but each interface can only have one profile applied to it.

Note You can apply IGMP profiles to Layer 2 ports only. You cannot apply IGMP profiles to routed ports (or SVIs) or to ports that belong to an EtherChannel port group.

To apply an IGMP profile to a switch port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode, and enter the physical interface to configure, for example **fastethernet2/3**. The interface must be a Layer 2 port that does not belong to an EtherChannel port group.
Step 3	`Switch(config-if)# ip igmp filter profile number`	Applies the specified IGMP profile to the interface. The profile number can be from 1 to 4,294,967,295.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show running configuration interface interface-id`	Verifies the configuration.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To remove a profile from an interface, use the **no ip igmp filter** command.

This example shows how to apply IGMP profile 4 to an interface and to verify the configuration:

```
Switch# config t
Switch(config)# interface fastethernet2/12
Switch(config-if)# ip igmp filter 4
Switch(config-if)# end
Switch# show running-config interface fastethernet2/12
Building configuration...

Current configuration : 123 bytes
!
interface FastEthernet2/12
 no ip address
 shutdown
 snmp trap link-status
 ip igmp max-groups 25
 ip igmp filter 4
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** interface configuration command. Use the **no** form of this command to set the maximum back to the default, which is no limit.

Note This restriction can be applied to Layer 2 ports only. You cannot set a maximum number of IGMP groups on routed ports (or SVIs) or on ports that belong to an EtherChannel port group.

To apply an IGMP profile on a switch port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode, and enter the physical interface to configure, for example **gigabitethernet1/1**. The interface must be a Layer 2 port that does not belong to an EtherChannel group.
Step 3	`Switch(config-if)# ip igmp max-groups` *number*	Sets the maximum number of IGMP groups that the interface can join. The range is from 0 to 4,294,967,294. By default, no maximum is set.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show running-configuration interface` *interface-id*	Verifies the configuration.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To remove the maximum group limitation and return to the default of no maximum, use the **no ip igmp max-groups** command.

This example shows how to limit the number of IGMP groups that an interface can join to 25.

```
Switch# config t
Switch(config)# interface fastethernet2/12
Switch(config-if)# ip igmp max-groups 25
Switch(config-if)# end
Switch# show running-config interface fastethernet2/12
Building configuration...

Current configuration : 123 bytes
!
interface FastEthernet2/12
 no ip address
 shutdown
 snmp trap link-status
 ip igmp max-groups 25
 ip igmp filter 4
end
```

Displaying IGMP Filtering Configuration

You can display IGMP profile and maximum group configuration for all interfaces on the switch or for a specified interface.

To display IGMP profiles, perform this task:

Command	Purpose
Switch# **show ip igmp profile** [*profile number*]	Displays the specified IGMP profile or all IGMP profiles defined on the switch.

To display interface configuration, perform this task:

Command	Purpose
Switch# **show running-configuration** [**interface** *interface-id*]	Displays the configuration of the specified interface or 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.

This is an example of the **show ip igmp profile** privileged EXEC command when no profile number is entered. All profiles defined on the switch are displayed.

```
Switch# show ip igmp profile
IGMP Profile 3
    range 230.9.9.0 230.9.9.0
IGMP Profile 4
    permit
    range 229.9.9.0 229.255.255.255
```

This is an example of the **show running-config** privileged EXEC command when an interface is specified with IGMP maximum groups configured and IGMP profile 4 has been applied to the interface.

```
Switch# show running-config interface fastethernet2/12
Building configuration...
Current configuration : 123 bytes
!
interface FastEthernet2/12
 no ip address
 shutdown
 snmp trap link-status
 ip igmp max-groups 25
 ip igmp filter 4
end
```

CHAPTER 16

Configuring 802.1Q and Layer 2 Protocol Tunneling

Virtual private networks (VPNs) provide enterprise-scale connectivity on a shared infrastructure, often Ethernet-based, with the same security, prioritization, reliability, and manageability requirements of private networks. Tunneling is a feature designed for service providers who carry traffic of multiple customers across their networks and who are required to maintain the VLAN and Layer 2 protocol configurations of each customer without impacting the traffic of other customers. The Catalyst 4500 series switch supports IEEE 802.1Q tunneling and Layer 2 protocol tunneling.

Note 802.1Q requires Supervisor Engine V; Layer 2 protocol tunneling is supported on all supervisor engines.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

This chapter contains these sections:

Understanding 802.1Q Tunneling

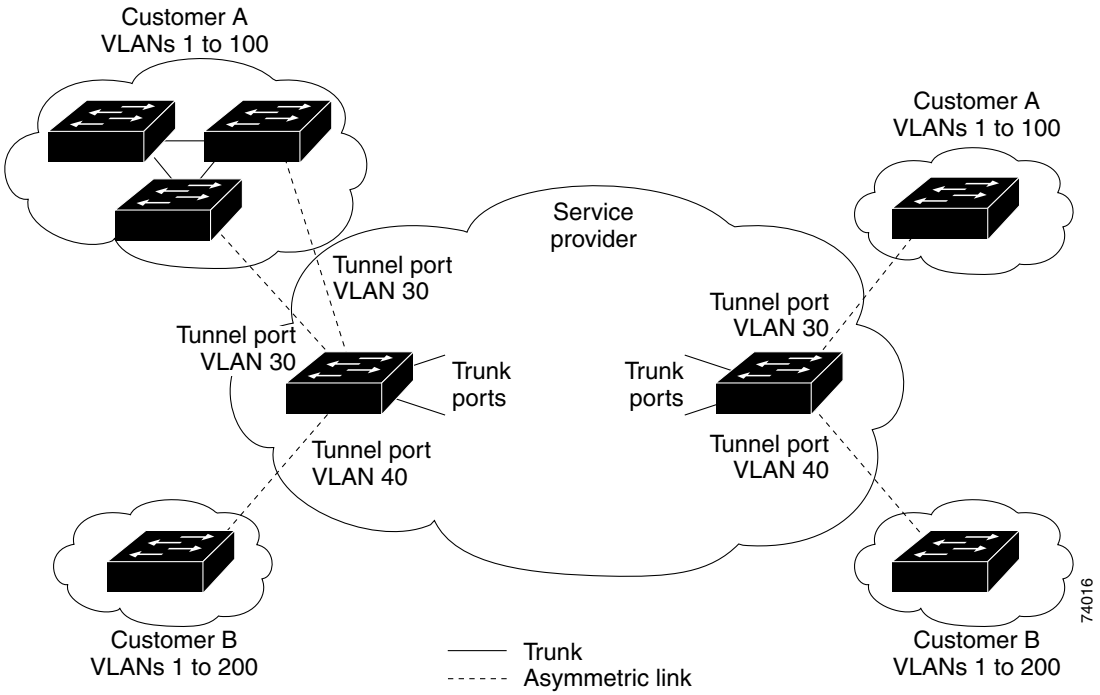
The VLAN ranges required by different customers in the same Service Provider network might overlap, and customer traffic through the infrastructure might be mixed. Assigning a unique range of VLAN IDs to each customer would restrict customer configurations and could easily exceed the VLAN limit (4096) of the 802.1Q specification.

802.1Q tunneling enables Service Providers to use a single VLAN to support customers who have multiple VLANs, while preserving customer VLAN IDs and keeping traffic in different customer VLANs segregated.

A port configured to support 802.1Q tunneling is called a tunnel port. When you configure tunneling, you assign a tunnel port to a VLAN ID that is dedicated to tunneling. Each customer requires a separate Service Provider VLAN ID, but that Service Provider VLAN ID supports VLANs of all the customers.

Customer traffic tagged in the normal way with appropriate VLAN IDs comes from an 802.1Q trunk port on the customer device and into a tunnel port on the Service Provider edge switch. The link between the customer device and the edge switch is asymmetric because one end is configured as an 802.1Q trunk port, and the other end is configured as a tunnel port. You assign the tunnel port interface to an access VLAN ID that is unique to each customer. See Figure 16-1.

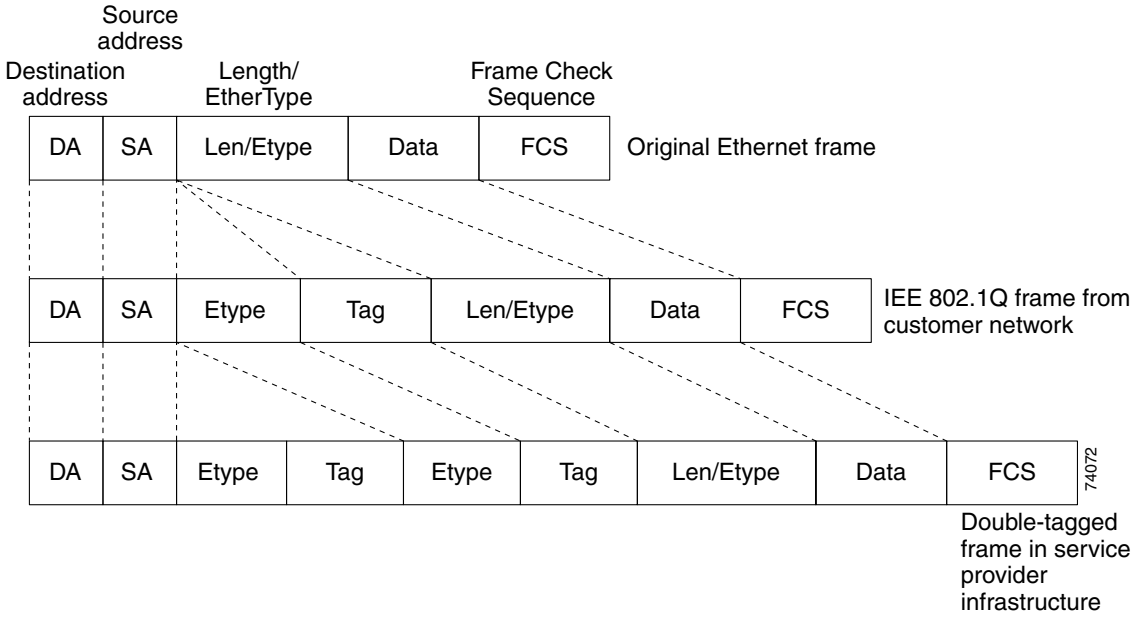
Figure 16-1 802.1Q Tunnel Ports in a Service Provider Network



Packets coming from the customer trunk port into the tunnel port on the Service Provider edge switch are normally 802.1Q-tagged with the appropriate VLAN ID. When the tagged packets exit the trunk port into the Service Provider network, they are encapsulated with another layer of an 802.1Q tag (called the *metro tag*) that contains the VLAN ID that is unique to the customer. The original customer 802.1Q tag is preserved in the encapsulated packet. Therefore, packets entering the Service Provider network are double-tagged, with the metro tag containing the customer's access VLAN ID, and the inner VLAN ID being that of the incoming traffic.

When the double-tagged packet enters another trunk port in a Service Provider core switch, the metro tag is stripped as the switch processes the packet. When the packet exits another trunk port on the same core switch, the same metro tag is again added to the packet. Figure 16-2 shows the tag structures of the Ethernet packets starting with the original, or normal, frame.

Figure 16-2 Original (Normal), 802.1Q, and Double-Tagged Ethernet Packet Formats



When the packet enters the trunk port of the Service Provider egress switch, the metro tag is again stripped as the switch processes the packet. However, the metro tag is not added when the packet is sent out the tunnel port on the edge switch into the customer network. The packet is sent as a normal 802.1Q-tagged frame to preserve the original VLAN numbers in the customer network.

All packets entering the Service Provider network through a tunnel port on an edge switch are treated as untagged packets, whether they are untagged or already tagged with 802.1Q headers. The packets are encapsulated with the metro tag VLAN ID (set to the access VLAN of the tunnel port) when they are sent through the Service Provider network on an 802.1Q trunk port. The priority field on the metro tag is set to the interface class of service (CoS) priority configured on the tunnel port. (The default is zero if none is configured.)

In Figure 16-1, Customer A was assigned VLAN 30, and Customer B was assigned VLAN 40. Packets entering the edge-switch tunnel ports with 802.1Q tags are double-tagged when they enter the Service Provider network, with the metro tag containing VLAN ID 30 or 40, appropriately, and the inner tag containing the original customer VLAN number, for example, VLAN 100. Even if Customers A and B both have VLAN 100 in their networks, the traffic remains segregated within the Service Provider network because the metro tag is different. Each customer controls its own VLAN numbering space, which is independent of the VLAN numbering space used by other customers and the VLAN numbering space used by the Service Provider network.

Configuring 802.1Q Tunneling

These sections describe 802.1Q tunneling configuration:

Note By default, 802.1Q tunneling is disabled because the default switch port mode is dynamic auto. Tagging of 802.1Q native VLAN packets on all 802.1Q trunk ports is also disabled.

802.1Q Tunneling Configuration Guidelines

When you configure 802.1Q tunneling, you should always use asymmetrical links for traffic going through a tunnel and should dedicate one VLAN for each tunnel. You should also be aware of configuration requirements for native VLANs and maximum transmission units (MTUs). For more information about MTUs, see the "System MTU" section on page 16-5.

Native VLANs

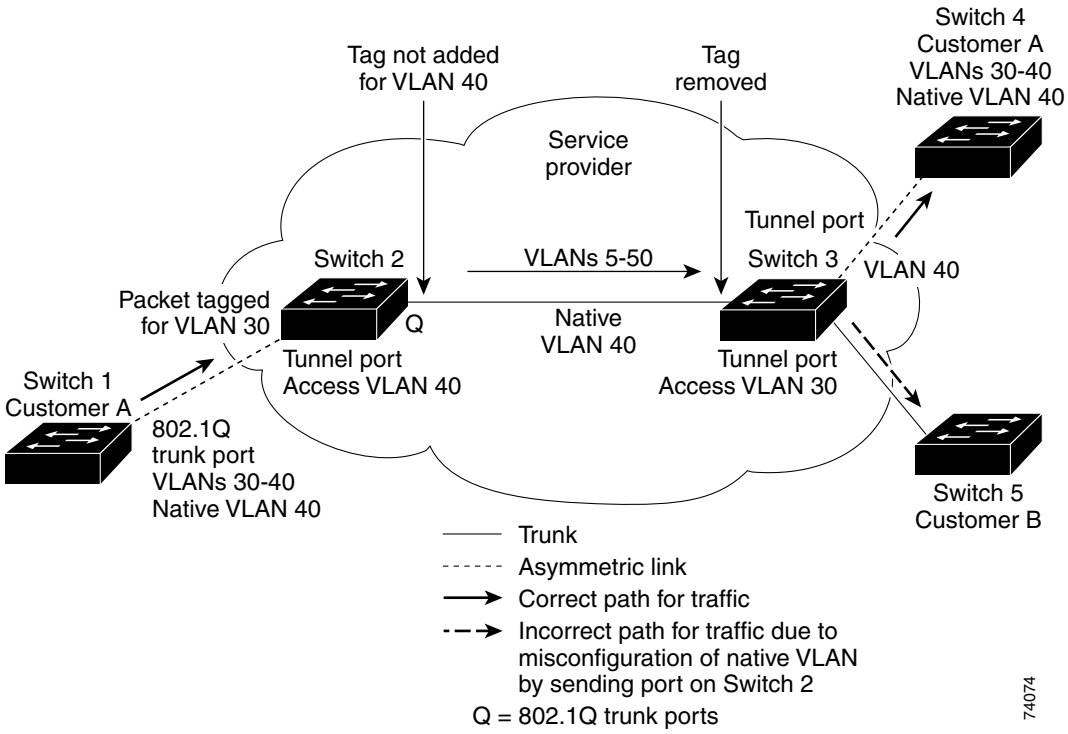
When configuring 802.1Q tunneling on an edge switch, you must use 802.1Q trunk ports for sending packets into the Service Provider network. However, packets going through the core of the Service Provider network can be carried through 802.1Q trunks, ISL trunks, or nontrunking links. When 802.1Q trunks are used in these core switches, the native VLANs of the 802.1Q trunks must not match any native VLAN of the nontrunking (tunneling) port on the same switch because traffic on the native VLAN would not be tagged on the 802.1Q sending trunk port.

See Figure 16-3. VLAN 40 is configured as the native VLAN for the 802.1Q trunk port from Customer A at the ingress edge switch in the Service Provider network (Switch 2). Switch 1 of Customer A sends a tagged packet on VLAN 30 to the ingress tunnel port of Switch 2 in the Service Provider network, which belongs to access VLAN 40. Because the access VLAN of the tunnel port (VLAN 40) is the same as the native VLAN of the edge-switch trunk port (VLAN 40), the metro tag is not added to tagged packets received from the tunnel port. The packet carries only the VLAN 30 tag through the Service Provider network to the trunk port of the egress-edge switch (Switch 3) and is misdirected through the egress switch tunnel port to Customer B.

These are some ways to solve this problem:

- Use ISL trunks between core switches in the Service Provider network. Although customer interfaces connected to edge switches must be 802.1Q trunks, we recommend using ISL trunks for connecting switches in the core layer.
- Use the **switchport trunk native vlan tag** per-port command and the **vlan dot1q tag native** global configuration command to configure the edge switch so that all packets going out an 802.1Q trunk, including the native VLAN, are tagged. If the switch is configured to tag native VLAN packets on all 802.1Q trunks, the switch accepts untagged packets, but sends only tagged packets.
- Ensure that the native VLAN ID on the edge-switch trunk port is not within the customer VLAN range. For example, if the trunk port carries traffic of VLANs 100 to 200, assign the native VLAN a number outside that range.

Figure 16-3 Potential Problem with 802.1Q Tunneling and Native VLANs



System MTU

The default system MTU for traffic on the Catalyst 4500 series switch is 1500 bytes. You can configure the switch to support larger frames by using the **system mtu** global configuration command. Because the 802.1Q tunneling feature increases the frame size by 4 bytes when the metro tag is added, you must configure all switches in the Service Provider network to be able to process larger frames by increasing the switch system MTU size to at least 1504 bytes. The maximum allowable system MTU for Catalyst 4500 Gigabit Ethernet switches is 9198 bytes; the maximum system MTU for Fast Ethernet switches is 1552 bytes.

802.1Q Tunneling and Other Features

Although 802.1Q tunneling works well for Layer 2 packet switching, there are incompatibilities between some Layer 2 features and Layer 3 switching.

- A tunnel port cannot be a routed port.
- IP routing is not supported on a VLAN that includes 802.1Q ports. Packets received from a tunnel port are forwarded based only on Layer 2 information. If routing is enabled on a switch virtual interface (SVI) that includes tunnel ports, untagged IP packets received from the tunnel port are recognized and routed by the switch. Customers can access the Internet through the native VLAN. If this access is not needed, you should not configure SVIs on VLANs that include tunnel ports.
- Tunnel ports do not support IP access control lists (ACLs).
- Layer 3 quality of service (QoS) ACLs and other QoS features related to Layer 3 information are not supported on tunnel ports. MAC-based QoS is supported on tunnel ports.

- EtherChannel port groups are compatible with tunnel ports as long as the 802.1Q configuration is consistent within an EtherChannel port group.
- Port Aggregation Protocol (PAgP), Link Aggregation Control Protocol (LACP), and UniDirectional Link Detection (UDLD) are supported on 802.1Q tunnel ports.
- Dynamic Trunking Protocol (DTP) is not compatible with 802.1Q tunneling because you must manually configure asymmetric links with tunnel ports and trunk ports.
- Loopback detection is supported on 802.1Q tunnel ports.
- When a port is configured as an 802.1Q tunnel port, spanning-tree bridge protocol data unit (BPDU) filtering is automatically enabled on the interface. Cisco Discovery Protocol (CDP) is automatically disabled on the interface.

Configuring an 802.1Q Tunneling Port

To configure a port as an 802.1Q tunnel port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode and the interface to be configured as a tunnel port. This should be the edge port in the Service Provider network that connects to the customer switch. Valid interfaces include physical interfaces and port-channel logical interfaces (port channels 1 to 64).
Step 3	`Switch(config-if)# switchport access vlan` *vlan-id*	Specifies the default VLAN, which is used if the interface stops trunking. This VLAN ID is specific to the particular customer.
Step 4	`Switch(config-if)# switchport mode dot1q-tunnel`	Sets the interface as an 802.1Q tunnel port.
Step 5	`Switch(config-if)# exit`	Returns to global configuration mode.
Step 6	`Switch(config)# vlan dot1q tag native`	(Optional) Sets the switch to enable tagging of native VLAN packets on all 802.1Q trunk ports. When not set, and a customer VLAN ID is the same as the native VLAN, the trunk port does not apply a metro tag, and packets could be sent to the wrong destination.
Step 7	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 8	`Switch# show dot1q-tunnel`	Displays the tunnel ports on the switch.
Step 9	`Switch# show vlan dot1q tag native`	Displays 802.1Q native-VLAN tagging status.
Step 10	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Use the **no vlan dot1q tag native** global command and the **no switchport mode dot1q-tunnel** interface configuration command to return the port to the default state of dynamic auto. Use the **no vlan dot1q tag native** global configuration command to disable tagging of native VLAN packets.

This example shows how to configure an interface as a tunnel port, enable tagging of native VLAN packets, and verify the configuration. In this configuration, the VLAN ID for the customer connected to Gigabit Ethernet interface 2/7 is VLAN 22.

```
Switch(config)# interface gigabitethernet2/7
Switch(config-if)# switchport access vlan 22
% Access VLAN does not exist. Creating vlan 22
Switch(config-if)# switchport mode dot1q-tunnel
Switch(config-if)# exit
Switch(config)# vlan dot1q tag native
Switch(config)# end
Switch# show dot1q-tunnel interface gigabitethernet2/7
Port
-----
LAN Port(s)
-----
Gi2/7
Switch# show vlan dot1q tag native
dot1q native vlan tagging is enabled globally
```

Understanding Layer 2 Protocol Tunneling

Customers at different sites connected across a Service Provider network need to use various Layer 2 protocols to scale their topologies to include all remote and local sites. STP must run properly, and every VLAN should build a proper spanning tree that includes the local site and all remote sites across the Service Provider network. Cisco Discovery Protocol (CDP) must discover neighboring Cisco devices from local and remote sites. VLAN Trunking Protocol (VTP) must provide consistent VLAN configuration throughout all sites in the customer network.

When protocol tunneling is enabled, edge switches on the inbound side of the Service Provider network encapsulate Layer 2 protocol packets with a special MAC address and send them across the Service Provider network. Core switches in the network do not process these packets but forward them as normal packets. Layer 2 protocol data units (PDUs) for CDP, STP, or VTP cross the Service Provider network and are delivered to customer switches on the outbound side of the Service Provider network. Identical packets are received by all customer ports on the same VLANs with these results:

- Users on each of a customer's sites can properly run STP, and every VLAN can build a correct spanning tree, based on parameters from all sites and not just from the local site.
- CDP discovers and shows information about the other Cisco devices connected through the Service Provider network.
- VTP provides consistent VLAN configuration throughout the customer network, propagating to all switches through the Service Provider.

Layer 2 protocol tunneling can be used independently or can enhance 802.1Q tunneling. If protocol tunneling is not enabled on 802.1Q tunneling ports, remote switches at the receiving end of the Service Provider network do not receive the PDUs and cannot properly run STP, CDP, and VTP. When protocol tunneling *is* enabled, Layer 2 protocols within each customer's network are totally separate from those running within the Service Provider network. Customer switches on different sites that send traffic through the Service Provider network with 802.1Q tunneling achieve complete knowledge of the customer's VLAN. If 802.1Q tunneling is not used, you can still enable Layer 2 protocol tunneling by connecting to the customer switch through access ports and by enabling tunneling on the Service Provider access port.

As an example, Customer A in Figure 16-4 has four switches in the same VLAN that are connected through the Service Provider network. If the network does not tunnel PDUs, switches on the far ends of the network cannot properly run STP, CDP, and VTP. For example, STP for a VLAN on a switch in

Customer A's Site 1 will build a spanning tree on the switches at that site without considering convergence parameters based on Customer A's switch in Site 2. Figure 16-5 shows one possible spanning tree topology.

Figure 16-4 Layer 2 Protocol Tunneling

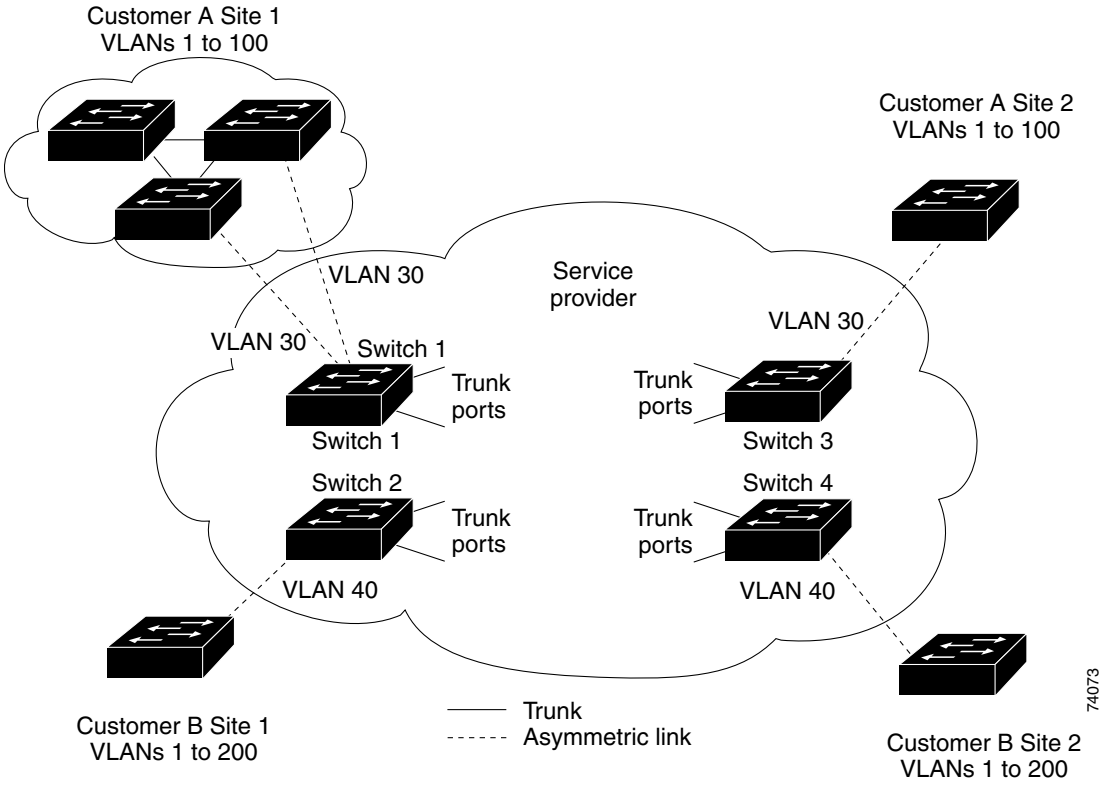
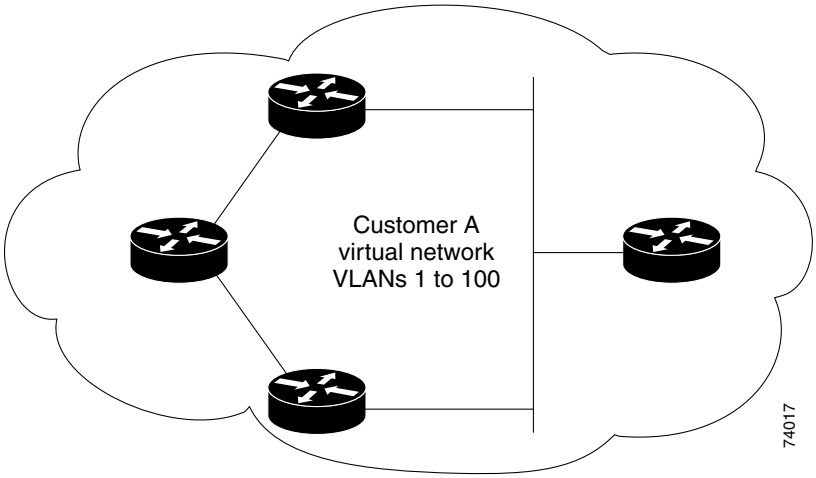


Figure 16-5 Layer 2 Network Topology without Proper Convergence



Configuring Layer 2 Protocol Tunneling

You can enable Layer 2 protocol tunneling (by protocol) on the access ports or tunnel ports that are connected to the customer in the edge switches of the Service Provider network. The Service Provider edge switches connected to the customer switch perform the tunneling process. Edge-switch tunnel ports are connected to customer 802.1Q trunk ports. Edge-switch access ports are connected to customer access ports.

When the Layer 2 PDUs that entered the Service Provider inbound edge switch through the tunnel port or the access port exit through its the trunk port into the Service Provider network, the switch overwrites the customer PDU-destination MAC address with a well-known Cisco proprietary multicast address (01-00-0c-cd-cd-d0). If 802.1Q tunneling is enabled, packets are also double-tagged; the outer tag is the customer metro tag, and the inner tag is the customer's VLAN tag. The core switches ignore the inner tags and forward the packet to all trunk ports in the same metro VLAN. The edge switches on the outbound side restore the proper Layer 2 protocol and MAC address information and forward the packets to all tunnel or access ports in the same metro VLAN. Therefore, the Layer 2 PDUs remain intact and are delivered across the Service Provider network to the other side of the customer network.

See Figure 16-4, with Customer A and Customer B in access VLANs 30 and 40, respectively. Asymmetric links connect the Customers in Site 1 to edge switches in the Service Provider network. The Layer 2 PDUs (for example, BPDUs) coming into Switch 2 from Customer B in Site 1 are forwarded to the infrastructure as double-tagged packets with the well-known MAC address as the destination MAC address. These double-tagged packets have the metro VLAN tag of 40, as well as an inner VLAN tag (for example, VLAN 100). When the double-tagged packets enter Switch 4, the metro VLAN tag 40 is removed. The well-known MAC address is replaced with the respective Layer 2 protocol MAC address, and the packet is sent to Customer B on Site 2 as a single-tagged frame in VLAN 100.

You can also enable Layer 2 protocol tunneling on access ports on the edge switch connected to access ports on the customer switch. In this case, the encapsulation and de-encapsulation process is the same as described in the previous paragraph, except that the packets are not double-tagged in the Service Provider network. The single tag is the customer-specific access VLAN tag.

This section contains the following subsections:

Default Layer 2 Protocol Tunneling Configuration

Table 16-1 shows the default configuration for Layer 2 protocol tunneling.

Table 16-1 Default Layer 2 Ethernet Interface VLAN Configuration

Feature	Default Setting
Layer 2 protocol tunneling	Disabled.
Shutdown threshold	None set.
Drop threshold	None set.
CoS value	If a CoS value is configured on the interface for data packets, that value is the default used for Layer 2 PDUs. If none is configured, the default is 5.

Layer 2 Protocol Tunneling Configuration Guidelines

These are some configuration guidelines and operating characteristics of Layer 2 protocol tunneling:

- The switch supports tunneling of CDP, STP, including multiple STP (MSTP), and VTP. Protocol tunneling is disabled by default but can be enabled for the individual protocols on 802.1Q tunnel ports or on access ports.
- Dynamic Trunking Protocol (DTP) is not compatible with Layer 2 protocol tunneling because you must manually configure asymmetric links with tunnel ports and trunk ports.
- Tunneling is not supported on trunk ports. If you enter the **l2protocol-tunnel** interface configuration command on a trunk port, the command is accepted, but Layer 2 tunneling does not take affect unless you change the port to a tunnel port or an access port.
- EtherChannel port groups are compatible with tunnel ports when the 802.1Q configuration is consistent within an EtherChannel port group.
- If an encapsulated PDU (with the proprietary destination MAC address) is received from a tunnel port or an access port with Layer 2 tunneling enabled, the tunnel port is shut down to prevent loops. The port also shuts down when a configured shutdown threshold for the protocol is reached. You can manually re-enable the port (by entering a **shutdown** and a **no shutdown** command sequence). If errdisable recovery is enabled, the operation is retried after a specified time interval.
- Only decapsulated PDUs are forwarded to the customer network. The spanning-tree instance running on the Service Provider network does not forward BPDUs to tunnel ports. CDP packets are not forwarded from tunnel ports.
- When protocol tunneling is enabled on an interface, you can set a per-protocol, per-port, shutdown threshold for the PDUs generated by the customer network. If the limit is exceeded, the port shuts down. You can also limit the BPDU rate by using QoS ACLs and policy maps on a tunnel port.
- When protocol tunneling is enabled on an interface, you can set a per-protocol, per-port, drop threshold for the PDUs generated by the customer network. If the limit is exceeded, the port drops PDUs until the rate at which it receives them is below the drop threshold.
- Because tunneled PDUs (especially STP BPDUs) must be delivered to all remote sites so that the customer virtual network operates properly, you can give PDUs higher priority within the Service Provider network than data packets received from the same tunnel port. By default, the PDUs use the same CoS value as data packets.

Configuring Layer 2 Tunneling

To configure a port for Layer 2 protocol tunneling, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode, and enter the interface to be configured as a tunnel port. This should be the edge port in the Service Provider network that connects to the customer switch. Valid interfaces can be physical interfaces and port-channel logical interfaces (port channels 1 to 64).

	Command	Purpose

Step 3	`Switch(config-if)# switchport mode access`
	or
	`switchport mode dot1q-tunnel`
		Configures the interface as an access port or as an 802.1Q tunnel port.

Step 4	`Switch(config-if)# l2protocol-tunnel [cdp | stp | vtp]`	Enables protocol tunneling for the desired protocol. If no keyword is entered, tunneling is enabled for all three Layer 2 protocols.
Step 5	`Switch(config-if)# l2protocol-tunnel shutdown-threshold [cdp | stp | vtp] value`	(Optional) Configures the threshold for packets-per-second accepted for encapsulation. The interface is disabled if the configured threshold is exceeded. If no protocol option is specified, the threshold applies to each of the tunneled Layer 2 protocol types. The range is 1 to 4096. The default is to have no threshold configured. **Note** If you also set a drop threshold on this interface, the shutdown-threshold value must be greater than or equal to the drop-threshold value.
Step 6	`Switch(config-if)# l2protocol-tunnel drop-threshold [cdp | stp | vtp] value`	(Optional) Configures the threshold for packets-per-second accepted for encapsulation. The interface drops packets if the configured threshold is exceeded. If no protocol option is specified, the threshold applies to each of the tunneled Layer 2 protocol types. The range is 1 to 4096. The default is to have no threshold configured. **Note** If you also set a shutdown threshold on this interface, the drop-threshold value must be less than or equal to the shutdown-threshold value.
Step 7	`Switch(config-if)# exit`	Returns to global configuration mode.
Step 8	`Switch(config)# errdisable recovery cause l2ptguard`	(Optional) Configures the recovery mechanism from a Layer 2 maximum-rate error so that the interface is re-enabled and can try again. Errdisable recovery is disabled by default; when enabled, the default time interval is 300 seconds.
Step 9	`Switch(config)# l2protocol-tunnel cos value`	(Optional) Configures the CoS value for all tunneled Layer 2 PDUs. The range is 0 to 7; the default is the default CoS value for the interface. If none is configured, the default is 5.
Step 10	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 11	`Switch# show l2protocol`	Displays the Layer 2 tunnel ports on the switch, including the protocols configured, the thresholds, and the counters.
Step 12	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Use the **no l2protocol-tunnel** [**cdp** | **stp** | **vtp**] interface configuration command to disable protocol tunneling for one of the Layer 2 protocols or for all three. Use the **no l2protocol-tunnel shutdown-threshold** [**cdp** | **stp** | **vtp**] and the **no l2protocol-tunnel drop-threshold** [**cdp** | **stp** | **vtp**] commands to return the shutdown and drop thresholds to the default settings.

This example shows how to configure Layer 2 protocol tunneling for CDP, STP, and VTP and how to verify the configuration.

```
Switch(config)# interface FastEthernet2/1
Switch(config-if)# l2protocol-tunnel cdp
Switch(config-if)# l2protocol-tunnel stp
Switch(config-if)# l2protocol-tunnel vtp
```

```
Switch(config-if)# l2protocol-tunnel shutdown-threshold 1500
Switch(config-if)# l2protocol-tunnel drop-threshold 1000
Switch(config-if)# exit
Switch(config)# l2protocol-tunnel cos 7
Switch(config)# end
Switch# show l2protocol
COS for Encapsulated Packets: 7
Port    Protocol Shutdown  Drop      Encapsulation Decapsulation Drop
                 Threshold Threshold Counter       Counter       Counter
------- -------- --------- --------- ------------- ------------- -------------
Fa2/11  cdp           1500      1000 2288          2282          0
        stp           1500      1000 116           13            0
        vtp           1500      1000 3             67            0
```

Monitoring and Maintaining Tunneling Status

Table 16-2 shows the commands for monitoring and maintaining 802.1Q and Layer 2 protocol tunneling.

Table 16-2 Commands for Monitoring and Maintaining Tunneling

Command	Purpose
`Switch# clear l2protocol-tunnel counters`	Clears the protocol counters on Layer 2 protocol tunneling ports.
`Switch# show dot1q-tunnel`	Displays 802.1Q tunnel ports on the switch.
`Switch# show dot1q-tunnel interface` *interface-id*	Verifies if a specific interface is a tunnel port.
`Switch# show l2protocol-tunnel`	Displays information about Layer 2 protocol tunneling ports.
`Switch# show errdisable recovery`	Verifies if the recovery timer from a Layer 2 protocol-tunnel error disable state is enabled.
`Switch# show l2protocol-tunnel interface` *interface-id*	Displays information about a specific Layer 2 protocol tunneling port.
`Switch# show l2protocol-tunnel summary`	Displays only Layer 2 protocol summary information.
`Switch# show vlan dot1q native`	Displays the status of native VLAN tagging on the switch.

Note With Release 12.2(20)EW, the BPDU filtering configuration for both dot1q and Layer 2 protocol tunneling is no longer visible in the running configuration as "spanning-tree bpdufilter enable." Instead, it is visible in the output of the **show spanning tree int detail** command as shown below.

```
Switch# show spann int f6/1 detail
 Port 321 (FastEthernet6/1) of VLAN0001 is listening
   Port path cost 19, Port priority 128, Port Identifier 128.321.
   Designated root has priority 32768, address 0008.e341.4600
   Designated bridge has priority 32768, address 0008.e341.4600
   Designated port id is 128.321, designated path cost 0
   Timers: message age 0, forward delay 2, hold 0
   Number of transitions to forwarding state: 0
   Link type is point-to-point by default
   ** Bpdu filter is enabled internally **
   BPDU: sent 0, received 0
```

Understanding and Configuring CDP

This chapter describes how to configure Cisco Discovery Protocol (CDP) on the Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the commands used in this chapter, refer to the *Cisco IOS Configuration Fundamentals Configuration Guide*, Release 12.2; *Cisco IOS System Management*; *Configuring Cisco Discovery Protocol (CDP)* at this URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ffun_c/fcfprt3/fcf015.htm and to the *Cisco IOS Configuration Fundamentals Command Reference*, Release 12.1; *Cisco IOS System Management Commands*; and *CDP Commands* publication at this URL: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ffun_r/ffrprt3/frf015.htm

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of CDP

CDP is a protocol that runs over Layer 2 (the data link layer) on all Cisco routers, bridges, access servers, and switches. CDP allows network management applications to discover Cisco devices that are neighbors of already known devices, in particular, neighbors running lower-layer, transparent protocols.With CDP, network management applications can learn the device type and the SNMP agent address of neighboring devices. CDP enables applications to send SNMP queries to neighboring devices.

CDP runs on all LAN and WAN media that support Subnetwork Access Protocol (SNAP).

Each CDP-configured device sends periodic messages to a multicast address. Each device advertises at least one address at which it can receive SNMP messages. The advertisements also contain the time-to-live, or holdtime information, which indicates the length of time a receiving device should hold CDP information before discarding it.

Configuring CDP

The following sections describe how to configure CDP:

Enabling CDP Globally

To enable CDP globally, perform this task:

Command	Purpose
`Switch(config)# [no] cdp run`	Enables CDP globally. Use the **no** keyword to disable CDP globally.

This example shows how to enable CDP globally:

```
Switch(config)# cdp run
```

Displaying the CDP Global Configuration

To display the CDP configuration, perform this task:

Command	Purpose
`Switch# show cdp`	Displays global CDP information.

This example shows how to display the CDP configuration:

```
Switch# show cdp
Global CDP information:
        Sending CDP packets every 120 seconds
        Sending a holdtime value of 180 seconds
        Sending CDPv2 advertisements is enabled
Switch#
```

For additional CDP **show** commands, see the "Monitoring and Maintaining CDP" section on page 17-3.

Enabling CDP on an Interface

To enable CDP on an interface, perform this task:

Command	Purpose
`Switch(config-if)# [no] cdp enable`	Enables CDP on an interface. Use the **no** keyword to disable CDP on an interface.

This example shows how to enable CDP on Fast Ethernet interface 5/1:

```
Switch(config)# interface fastethernet 5/1
Switch(config-if)# cdp enable
```

This example shows how to disable CDP on Fast Ethernet interface 5/1:

```
Switch(config)# interface fastethernet 5/1
Switch(config-if)# no cdp enable
```

Displaying the CDP Interface Configuration

To display the CDP configuration for an interface, perform this task:

Command	Purpose
`Switch# show cdp interface [type/number]`	Displays information about interfaces where CDP is enabled.

This example shows how to display the CDP configuration of Fast Ethernet interface 5/1:

```
Switch# show cdp interface fastethernet 5/1
FastEthernet5/1 is up, line protocol is up
  Encapsulation ARPA
  Sending CDP packets every 120 seconds
  Holdtime is 180 seconds
Switch#
```

Monitoring and Maintaining CDP

To monitor and maintain CDP on your device, perform one or more of these tasks:

Command	Purpose
`Switch# clear cdp counters`	Resets the traffic counters to zero.
`Switch# clear cdp table`	Deletes the CDP table of information about neighbors.
`Switch# show cdp`	Displays global information such as frequency of transmissions and the holdtime for packets being transmitted.

Command	Purpose
Switch# **show cdp entry** *entry_name* [**protocol** | **version**]	Displays information about a specific neighbor. The display can be limited to protocol or version information.
Switch# **show cdp interface** [*type/number*]	Displays information about interfaces on which CDP is enabled.
Switch# **show cdp neighbors** [*type/number*] [**detail**]	Displays information about neighboring equipment. The display can be limited to neighbors on a specific interface and expanded to provide more detailed information.
Switch# **show cdp traffic**	Displays CDP counters, including the number of packets sent and received and checksum errors.
Switch# **show debugging**	Displays information about the types of debugging that are enabled for your switch.

This example shows how to clear the CDP counter configuration on your switch:

```
Switch# clear cdp counters
```

This example shows how to display information about the neighboring equipment:

```
Switch# show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
JAB023807H1      Fas 5/3            127         T S       WS-C2948  2/46
JAB023807H1      Fas 5/2            127         T S       WS-C2948  2/45
JAB023807H1      Fas 5/1            127         T S       WS-C2948  2/44
JAB023807H1      Gig 1/2            122         T S       WS-C2948  2/50
JAB023807H1      Gig 1/1            122         T S       WS-C2948  2/49
JAB03130104      Fas 5/8            167         T S       WS-C4003  2/47
JAB03130104      Fas 5/9            152         T S       WS-C4003  2/48
```

Configuring UDLD

This chapter describes how to configure the UniDirectional Link Detection (UDLD) and Unidirectional Ethernet on the Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of UDLD

UDLD allows devices connected through fiber-optic or copper Ethernet cables (for example, Category 5 cabling) to monitor the physical configuration of the cables and detect when a unidirectional link exists. A unidirectional link occurs whenever traffic transmitted by the local device over a link is received by the neighbor but traffic transmitted from the neighbor is not received by the local device. When a unidirectional link is detected, UDLD shuts down the affected interface and alerts the user. Unidirectional links can cause a variety of problems, including spanning tree topology loops.

UDLD is a Layer 2 protocol that works with the Layer 1 mechanisms to determine 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 interfaces. When you enable both autonegotiation and UDLD, Layer 1 and Layer 2 detections work together to prevent physical and logical unidirectional connections and the malfunctioning of other protocols.

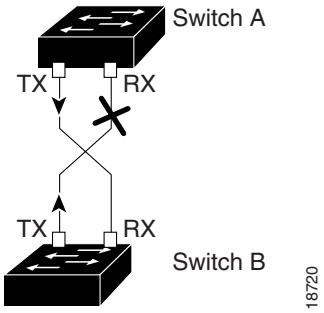
If one of the fiber strands in a pair is disconnected, as long as autonegotiation is active, the link does not stay up. In this case, the logical link is undetermined, and UDLD does not take any action. If both fibers are working normally from a Layer 1 perspective, then UDLD at Layer 2 determines whether or not those fibers are connected correctly and whether or not traffic is flowing bidirectionally between the right neighbors. This check cannot be performed by autonegotiation because autonegotiation operates at Layer 1.

The switch periodically transmits UDLD packets to neighbor devices on interfaces with UDLD enabled. If the packets are echoed back within a specific time frame and they are lacking a specific acknowledgment (echo), the link is flagged as unidirectional and the interface is shut down. Devices on both ends of the link must support UDLD in order for the protocol to successfully identify and disable unidirectional links.

Note By default, UDLD is locally disabled on copper interfaces to avoid sending unnecessary control traffic on this type of media, since it is often used for access interfaces.

Figure 18-1 shows an example of a unidirectional link condition. Switch B successfully receives traffic from Switch A on the interface. However, Switch A does not receive traffic from Switch B on the same interface. UDLD detects the problem and disables the interface.

Figure 18-1 Unidirectional Link



Default UDLD Configuration

Table 18-1 shows the UDLD default configuration.

Table 18-1 UDLD Default Configuration

Feature	Default Status
UDLD global enable state	Globally disabled
UDLD per-interface enable state for fiber-optic media	Enabled on all Ethernet fiber-optic interfaces
UDLD per-interface enable state for twisted-pair (copper) media	Disabled on all Ethernet 10/100 and 1000BaseTX interfaces

Configuring UDLD on the Switch

The following sections describe how to configure UDLD:

- Enabling UDLD Globally, page 18-3
- Enabling UDLD on Individual Interfaces, page 18-3
- Disabling UDLD on Nonfiber-Optic Interfaces, page 18-3
- Disabling UDLD on Fiber-Optic Interfaces, page 18-4
- Resetting Disabled Interfaces, page 18-4

Enabling UDLD Globally

To enable UDLD globally on all fiber-optic interfaces on the switch, perform this task:

Command	Purpose
`Switch(config)# [no] udld enable`	Enables UDLD globally on fiber-optic interfaces on the switch. Use the **no** keyword to globally disable UDLD on fiber-optic interfaces. **Note** This command configures only fiber-optic interfaces. An individual interface configuration overrides the setting of this command.

Enabling UDLD on Individual Interfaces

To enable UDLD on individual interfaces, perform this task:

	Command	Purpose
Step 1	`Switch(config-if)# udld enable`	Enables UDLD on a specific interface. On a fiber-optic interface, this command overrides the **udld enable** global configuration command setting.
Step 2	`Switch# show udld interface`	Verifies the configuration.

Disabling UDLD on Nonfiber-Optic Interfaces

To disable UDLD on individual nonfiber-optic interfaces, perform this task:

	Command	Purpose
Step 1	`Switch(config-if)# no udld enable`	Disables UDLD on a nonfiber-optic interface. **Note** On fiber-optic interfaces, the **no udld enable** command reverts the interface configuration to the **udld enable** global configuration command setting.
Step 2	`Switch# show udld interface`	Verifies the configuration.

Disabling UDLD on Fiber-Optic Interfaces

To disable UDLD on individual fiber-optic interfaces, perform this task:

	Command	Purpose
Step 1	`Switch(config-if)# udld disable`	Disables UDLD on a fiber-optic interface. **Note** This command is not supported on nonfiber-optic interfaces. Use the **no** keyword to revert to the **udld enable** global configuration command setting.
Step 2	`Switch# show udld interface`	Verifies the configuration.

Resetting Disabled Interfaces

To reset all interfaces that have been shut down by UDLD, perform this task:

Command	Purpose
`Switch# udld reset`	Resets all interfaces that have been shut down by UDLD.

Configuring Unidirectional Ethernet

This chapter describes how to configure Unidirectional Ethernet on the Catalyst 4500 series switch and contains these sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Unidirectional Ethernet

You can set non-blocking GigaPorts to unidirectionally transmit or receive traffic. Unidirectional Ethernet uses only one strand of fiber for either transmitting or receiving one-way traffic for the GigaPort, instead of two strands of fiber for a full-duplex GigaPort Ethernet. Configuring your GigaPorts either to transmit or receive traffic effectively doubles the amount of traffic capabilities for applications, such as video streaming, where most traffic is sent as unacknowledged unidirectional video broadcast streams.

Configuring Unidirectional Ethernet

Note You must configure Unidirectional Ethernet on the non-blocking GigaPort, which will automatically disable UDLD on the port.

To enable Unidirectional Ethernet, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] unidirectional {send-only | receive-only}`	Enables Unidirectional Ethernet. Use the **no** keyword to disable Unidirectional Ethernet.

	Command	Purpose
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface} unidirectional`	Verifies the configuration.

This example shows how to set Gigabit Ethernet interface 1/1 to unidirectionally send traffic:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if)# unidirectional send-only
Switch(config-if)# end

Warning!

Enable l2 port unidirectional mode will automatically disable port udld.
You must manually ensure that the unidirectional link does not create
a spanning tree loop in the network.

Enable l3 port unidirectional mode will automatically disable ip routing
on the port. You must manually configure static ip route and arp entry
in order to route ip traffic.
```

This example shows how to set Gigabit Ethernet interface 1/1 to receive traffic unidirectionally:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if)# unidirectional receive-only
Switch(config-if)# end

Warning!

Enable l2 port unidirectional mode will automatically disable port udld.
You must manually ensure that the unidirectional link does not create
a spanning tree loop in the network.

Enable l3 port unidirectional mode will automatically disable ip routing
on the port. You must manually configure static ip route and arp entry
in order to route ip traffic.
```

This example shows how to verify the configuration

```
Switch>show interface gigabitethernet 1/1 unidirectional
  show interface gigabitethernet 1/1 unidirectional
  Unidirectional configuration mode: send only
  CDP neighbour unidirectional configuration mode: receive only
```

This example shows how to disable Unidirectional Ethernet on Gigabit Ethernet interface 1/1:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if)# no unidirectional
Switch(config-if)# end
```

This example shows the result of issuing the **show interface** command for a port that does not support Unidirectional Ethernet:

```
Switch#show interface f6/1 unidirectional
Unidirectional Ethernet is not supported on FastEthernet6/1
```

Configuring Layer 3 Interfaces

This chapter describes the Layer 3 interfaces on a Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Layer 3 Interfaces

This section contains the following subsections:

The Catalyst 4500 series switch supports Layer 3 interfaces with the Cisco IOS IP and IP routing protocols. Layer 3, the *network* layer, is primarily responsible for the routing of data in packets across logical internetwork paths.

Layer 2, the *data link* layer, contains the protocols that control the *physical* layer (Layer 1) and how data is framed before being transmitted on the medium. The Layer 2 function of filtering and forwarding data in frames between two segments on a LAN is known as *bridging*.

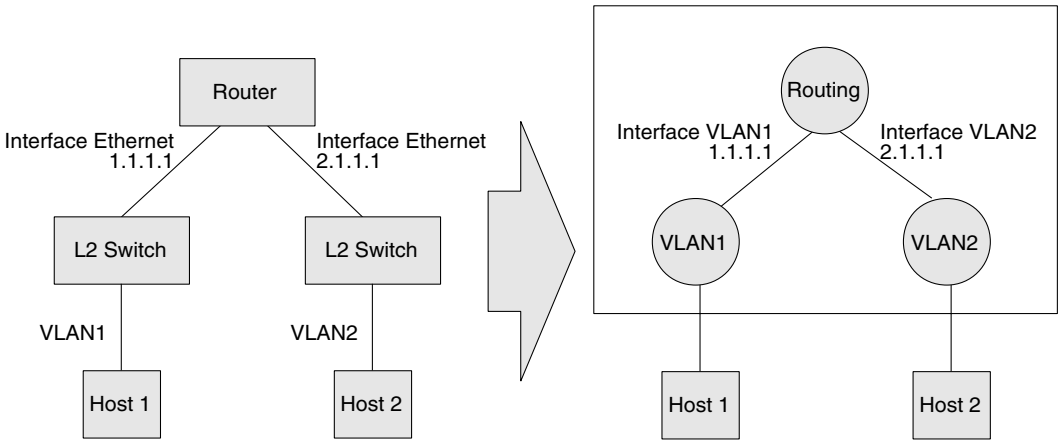
The Catalyst 4500 series switch supports two types of Layer 3 interfaces. The logical Layer 3 VLAN interfaces integrate the functions of routing and bridging. The physical Layer 3 interfaces allow the Catalyst 4500 series switch to be configured like a traditional router.

Logical Layer 3 VLAN Interfaces

The logical Layer 3 VLAN interfaces provide logical routing interfaces to VLANs on Layer 2 switches. A traditional network requires a physical interface from a router to a switch to perform inter-VLAN routing. The Catalyst 4500 series switch supports inter-VLAN routing by integrating the routing and bridging functions on a single Catalyst 4500 series switch.

Figure 20-1 shows how the routing and bridging functions in the three physical devices of the traditional network are performed logically on one Catalyst 4500 series switch.

Figure 20-1 Logical Layer 3 VLAN Interfaces for the Catalyst 4500 Series Switch

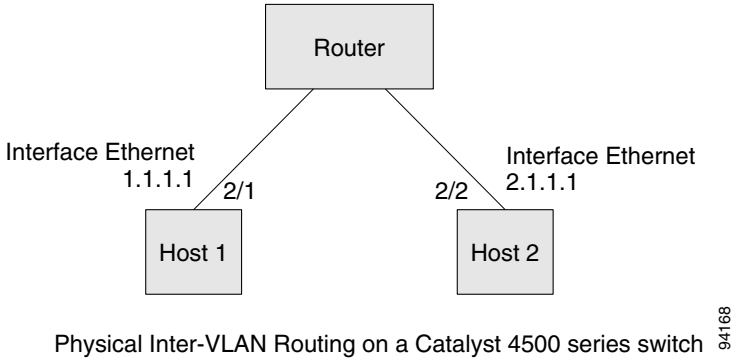


Physical Layer 3 Interfaces

The physical Layer 3 interfaces support capabilities equivalent to a traditional router. These Layer 3 interfaces provide hosts with physical routing interfaces to a Catalyst 4500 series switch.

Figure 20-2 shows how the Catalyst 4500 series switch functions as a traditional router.

Figure 20-2 Physical Layer 3 Interfaces for the Catalyst 4500 Series Switch



Configuration Guidelines

A Catalyst 4500 series switch supports AppleTalk routing and IPX routing. For AppleTalk routing and IPX routing information, refer to "Configuring AppleTalk" and "Configuring Novell IPX" in the Cisco IOS AppleTalk and Novell IPX Configuration Guide at the following URL:

http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/atipx_c/index.htm

A Catalyst 4500 series switch does not support subinterfaces or the **encapsulation** keyword on Layer 3 Fast Ethernet or Gigabit Ethernet interfaces.

Configuring Logical Layer 3 VLAN Interfaces

Note Before you can configure logical Layer 3 VLAN interfaces, you must create and configure the VLANs on the switch, assign VLAN membership to the Layer 2 interfaces, enable IP routing if IP routing is disabled, and specify an IP routing protocol.

To configure logical Layer 3 VLAN interfaces, perform this task:

	Command	Purpose
Step 1	`Switch(config)# vlan vlan_ID`	Creates the VLAN.
Step 2	`Switch(config)# interface vlan vlan_ID`	Selects an interface to configure.
Step 3	`Switch(config-if)# ip address ip_address subnet_mask`	Configures the IP address and IP subnet.
Step 4	`Switch(config-if)# no shutdown`	Enables the interface.
Step 5	`Switch(config-if)# end`	Exits configuration mode.
Step 6	`Switch# copy running-config startup-config`	Saves your configuration changes to NVRAM.

Step 7	`Switch# show interfaces [type slot/interface]`
	`Switch# show ip interfaces [type slot/interface]`
	`Switch# show running-config interfaces [type slot/interface]`
	`Switch# show running-config interfaces vlan vlan_ID`
		Verifies the configuration.

This example shows how to configure the logical Layer 3 VLAN interface vlan 2 and assign an IP address:

```
Switch> enable
Switch# config term
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# vlan 2
Switch(config)# interface vlan 2
Switch(config-if)# ip address 10.1.1.1 255.255.255.248
Switch(config-if)# no shutdown
Switch(config-if)# end
```

This example uses the **show interfaces** command to display the interface IP address configuration and status of Layer 3 VLAN interface vlan 2:

```
Switch# show interfaces vlan 2
Vlan2 is up, line protocol is down
  Hardware is Ethernet SVI, address is 00D.588F.B604 (bia 00D.588F.B604)
  Internet address is 172.20.52.106/29
  MTU 1500 bytes, BW 1000000 Kbit, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 interface resets
     0 output buffer failures, 0 output buffers swapped out
Switch#
```

This example uses the **show running-config** command to display the interface IP address configuration of Layer 3 VLAN interface vlan 2:

```
Switch# show running-config
Building configuration...

Current configuration : !
interface Vlan2
 ip address 10.1.1.1 255.255.255.248
!
ip classless
no ip http server
!
!
line con 0
line aux 0
line vty 0 4
!
end
```

Configuring Physical Layer 3 Interfaces

Note Before you can configure physical Layer 3 interfaces, you must enable IP routing if IP routing is disabled, and specify an IP routing protocol.

To configure physical Layer 3 interfaces, perform this task:

	Command	Purpose
Step 1	`Switch(config)#ip routing`	Enables IP routing (Required only if disabled.)
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port} | {port-channel port_channel_number}`	Selects an interface to configure.
Step 3	`Switch(config-if)#no switchport`	Converts this port from physical Layer 2 port to physical Layer 3 port.
Step 4	`Switch(config-if)# ip address ip_address subnet_mask`	Configures the IP address and IP subnet.
Step 5	`Switch(config-if)# no shutdown`	Enables the interface.
Step 6	`Switch(config-if)# end`	Exits configuration mode.
Step 7	`Switch# copy running-config startup-config`	Saves your configuration changes to NVRAM.

Step 8	`Switch# show interfaces [type slot/interface]`
	`Switch# show ip interfaces [type slot/interface]`
	`Switch# show running-config interfaces [type slot/interface]`
		Verifies the configuration.

This example shows how to configure an IP address on Fast Ethernet interface 2/1:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip routing
Switch(config)# interface fastethernet 2/1
Switch(config-if)# no switchport
Switch(config-if)# ip address 10.1.1.1 255.255.255.248
Switch(config-if)# no shutdown
Switch(config-if)# end
Switch#
```

This example uses the **show running-config** command to display the interface IP address configuration of Fast Ethernet interface 2/1:

```
Switch# show running-config
Building configuration...
!
interface FastEthernet2/1
 no switchport
 ip address 10.1.1.1 255.255.255.248
!
…
ip classless
no ip http server
!
!
line con 0
line aux 0
line vty 0 4
!
end
```

Configuring Cisco Express Forwarding

This chapter describes Cisco Express Forwarding (CEF) on the Catalyst 4500 series switch. It also provides guidelines, procedures, and examples to configure this feature.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of CEF

This section contains information on the two primary components that comprise the CEF operation:

Benefits of CEF

CEF is advanced Layer 3 IP switching technology that optimizes performance and scalability for large networks with dynamic traffic patterns or networks with intensive web-based applications and interactive sessions.

CEF provides the following benefits:

- Improves performance over the caching schemes of multilayer switches, which often flush the entire cache when information changes in the routing tables.
- Provides load balancing that distributes packets across multiple links based on Layer 3 routing information. If a network device discovers multiple paths to a destination, the routing table is updated with multiple entries for that destination. Traffic to that destination is then distributed among the various paths.

CEF stores information in several data structures rather than the route cache of multilayer switches. The data structures optimize lookup for efficient packet forwarding.

Forwarding Information Base

The Forwarding Information Base (FIB) is a table that contains a copy of the forwarding information in the IP routing table. When routing or topology changes occur in the network, the route processor updates the IP routing table and CEF updates the FIB. Because there is a one-to-one correlation between FIB entries and routing table entries, the FIB contains all known routes and eliminates the need for route cache maintenance that is associated with switching paths, such as fast switching and optimum switching. CEF uses the FIB to make IP destination-based switching decisions and maintain next-hop address information based on the information in the IP routing table.

On the Catalyst 4500 series switches, CEF loads the FIB in to the Integrated Switching Engine hardware to increase the performance of forwarding. The Integrated Switching Engine has a finite number of forwarding slots for storing routing information. If this limit is exceeded, CEF is automatically disabled and all packets are forwarded in software. In this situation, you should reduce the number of routes on the switch and then reenable hardware switching with the **ip cef** command.

Adjacency Tables

In addition to the FIB, CEF uses adjacency tables to prepend Layer 2 addressing information. Nodes in the network are said to be *adjacent* if they are within a single hop from each other. The adjacency table maintains Layer 2 next-hop addresses for all FIB entries.

Adjacency Discovery

The adjacency table is populated as new adjacent nodes are discovered. Each time an adjacency entry is created (such as through the Address Resolution Protocol (ARP), a link-layer header for that adjacent node is stored in the adjacency table. Once a route is determined, the link-layer header points to a next hop and corresponding adjacency entry. The link-layer header is subsequently used for encapsulation during CEF switching of packets.

Adjacency Resolution

A route might have several paths to a destination prefix, such as when a router is configured for simultaneous load balancing and redundancy. For each resolved path, a pointer is added for the adjacency corresponding to the next-hop interface for that path. This mechanism is used for load balancing across several paths.

Adjacency Types That Require Special Handling

In addition to adjacencies for next-hop interfaces (host-route adjacencies), other types of adjacencies are used to expedite switching when certain exception conditions exist. When the prefix is defined, prefixes requiring exception processing are cached with one of the special adjacencies listed in Table 21-1.

Table 21-1 Adjacency Types for Exception Processing

This adjacency type...	Receives this processing...
Null adjacency	Packets destined for a Null0 interface are dropped. A Null0 interface can be used as an effective form of access filtering.
Glean adjacency	When a router is connected directly to several hosts, the FIB table on the router maintains a prefix for the subnet rather than for each individual host. The subnet prefix points to a glean adjacency. When packets need to be forwarded to a specific host, the adjacency database is gleaned for the specific prefix.
Punt adjacency	Features that require special handling or features that are not yet supported by CEF switching are sent (punted) to the next higher switching level.
Discard adjacency	Packets are discarded.
Drop adjacency	Packets are dropped.

Unresolved Adjacency

When a link-layer header is prepended to packets, FIB requires the prepend to point to an adjacency corresponding to the next hop. If an adjacency was created by FIB and was not discovered through a mechanism such as ARP, the Layer 2 addressing information is not known and the adjacency is considered incomplete. When the Layer 2 information is known, the packet is forwarded to the route processor, and the adjacency is determined through ARP.

Catalyst 4500 Series Switch Implementation of CEF

This section contains the following subsections:

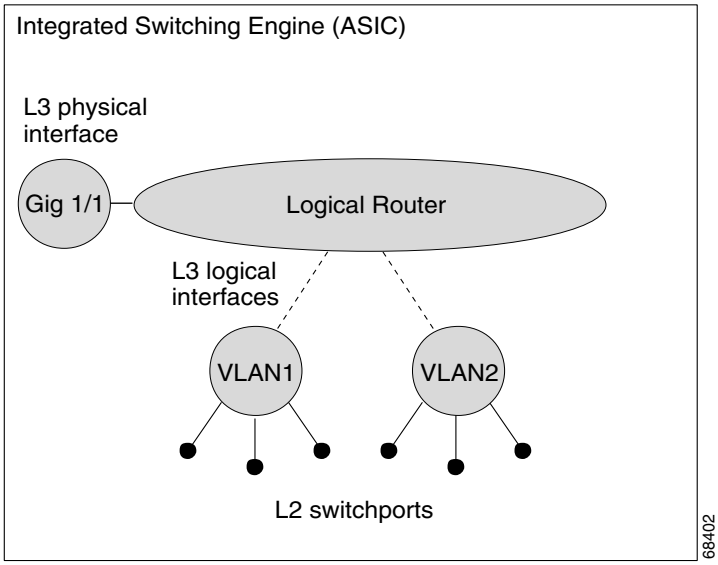
Catalyst 4500 series switches support an ASIC-based Integrated Switching Engine that provides these features:

- Ethernet bridging at Layer 2
- IP routing at Layer 3

Because the ASIC is specifically designed to forward packets, the Integrated Switching Engine hardware can run this process much faster than CPU subsystem software.

Figure 21-1 shows a high-level view of the ASIC-based Layer 2 and Layer 3 switching process on the Integrated Switching Engine.

Figure 21-1 Logical L2/L3 Switch Components



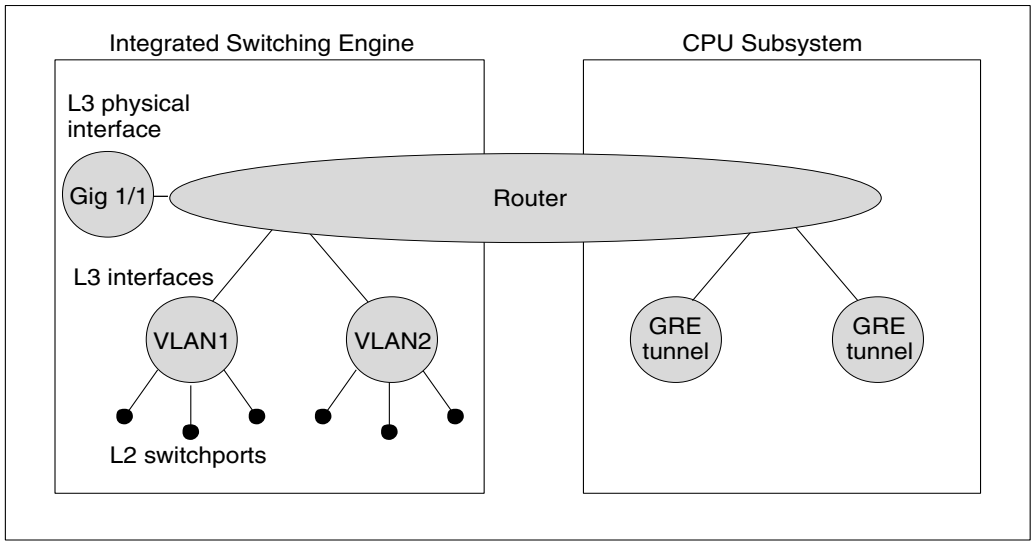
The Integrated Switching Engine performs inter-VLAN routing on logical Layer 3 interfaces with the ASIC hardware. The ASIC hardware also supports a physical Layer 3 interface that can be configured to connect with a host, a switch, or a router.

Hardware and Software Switching

For the majority of packets, the Integrated Switching Engine performs the packet forwarding function in hardware. These packets are hardware-switched at very high rates. Exception packets are forwarded by the CPU subsystem software. Statistic reports should show that the Integrated Switching Engine is forwarding the vast majority of packets in hardware. Software forwarding is significantly slower than hardware forwarding, but packets forwarded by the CPU subsystem do not reduce hardware forwarding speed.

Figure 21-2 shows a logical view of the Integrated Switching Engine and the CPU subsystem switching components.

Figure 21-2 Hardware and Software Switching Components



The Integrated Switching Engine performs inter-VLAN routing in hardware. The CPU subsystem software supports Layer 3 interfaces to VLANs that use Subnetwork Access Protocol (SNAP) encapsulation. The CPU subsystem software also supports generic routing encapsulation (GRE) tunnel.

Hardware Switching

Hardware switching is the normal operation for the Supervisor Engine III and Supervisor Engine IV.

Software Switching

Software switching occurs when traffic cannot be processed in hardware. The following types of exception packets are processed in software at a much slower rate:

- Packets that use IP header options

Note Packets that use TCP header options are switched in hardware because they do not affect the forwarding decision.

- Packets that have an expiring IP time-to-live (TTL) counter
- Packets that are forwarded to a tunnel interface
- Packets that arrive with non-supported encapsulation types
- Packets that are routed to an interface with non-supported encapsulation types
- Packets that exceed the MTU of an output interface and must be fragmented
- Packets that require an IGMP redirect to be routed
- 802.3 Ethernet packets

Load Balancing

The Catalyst 4500 series switch supports load balancing for routing packets in the Integrated Switching Engine hardware. Load balancing is always enabled. It works when multiple routes for the same network with different next-hop addresses are configured. These routes can be configured either statically or through a routing protocol such as OSPF or EIGRP.

The hardware makes a forwarding decision by using a hardware load sharing hash function to compute a value, based on the source and destination IP addresses and the source and destination TCP port numbers (if available). This load sharing hash value is then used to select which route to use to forward the packet. All hardware switching within a particular flow (such as a TCP connection) will be routed to the same next hop, thereby reducing the chance that packet reordering will occur. Up to eight different routes for a particular network are supported.

Software Interfaces

Cisco IOS for the Catalyst 4500 series switch supports GRE and IP tunnel interfaces that are not part of the hardware forwarding engine. All packets that flow to or from these interfaces must be processed in software and will have a significantly lower forwarding rate than that of hardware-switched interfaces. Also, Layer 2 features are not supported on these interfaces.

CEF Configuration Restrictions

The Integrated Switching Engine supports only ARPA and ISL/802.1q encapsulation types for Layer 3 switching in hardware. The CPU subsystem supports a number of encapsulations such as SNAP for Layer 2 switching that you can use for Layer 3 switching in software.

Configuring CEF

These sections describe how to configure CEF:

Enabling CEF

By default, CEF is enabled globally on the Catalyst 4500 series switch. No configuration is required.

To reenable CEF, perform this task:

Command	Purpose
`Switch(config)# ip cef`	Enables standard CEF operation.

Configuring Load Balancing for CEF

CEF load balancing is based on a combination of source and destination packet information; it allows you to optimize resources by distributing traffic over multiple paths for transferring data to a destination. You can configure load balancing on a per-destination basis. Load-balancing decisions are made on the outbound interface. You can configure per-destination load balancing for CEF on outbound interfaces.

The following topics are discussed:

Configuring Per-Destination Load Balancing

Per-destination load balancing is enabled by default when you enable CEF. To use per-destination load balancing, you do not perform any additional tasks once you enable CEF.

Per-destination load balancing allows the router to use multiple paths to achieve load sharing. Packets for a given source-destination host pair are guaranteed to take the same path, even if multiple paths are available. Traffic destined for different pairs tend to take different paths. Per-destination load balancing is enabled by default when you enable CEF; it is the load balancing method of choice in most situations.

Because per-destination load balancing depends on the statistical distribution of traffic, load sharing becomes more effective as the number of source-destination pairs increases.

You can use per-destination load balancing to ensure that packets for a given host pair arrive in order. All packets for a certain host pair are routed over the same link or links.

Configuring Load Sharing Hash Function

When multiple unicast routes exist to a particular destination IP prefix, the hardware will send packets matching that prefix across all possible routes, thereby sharing the load across all next hop routers. By default, the route used is chosen by computing a hash of the source and destination IP addresses and using the resulting value to select the route. This preserves packet ordering for packets within a flow by ensuring that all packets within a single IP source/destination flow are sent on the same route, but it provides a near-random distribution of flows to routes.

The load-sharing hash function can be changed, so that in addition to the source and destination IP addresses, the source TCP/UDP port, the destination TCP/UDP port, or both can also be included in the hash.

To the configure load sharing hash function to use the source and/or destination ports, perform this task:

Command	Purpose
`Switch (config)# [no] ip cef load-sharing algorithm include-ports source destination]`	Enables load sharing hash function to use source and destination ports. Use the **no** keyword to set the switch to use the default Cisco IOS load-sharing algorithm.

For more information on load sharing, refer to the *Configuring Cisco Express Forwarding* module of the Cisco IOS documentation at this URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fwitch_c/swprt1/xcfcefc.htm

Note The **include-ports** option does not apply to software-switched traffic on the Catalyst 4500 series switches.

Viewing CEF Information

You can view the collected CEF information. To view CEF information, perform this task:

Command	Purpose
`Switch# show ip cef`	Displays the collected CEF information.

Monitoring and Maintaining CEF

To display information about IP traffic, perform this task:

Command	Purpose
`Switch# show interface` *type slot/interface* `| begin L3`	Displays a summary of IP unicast traffic.

This example shows how to display information about IP unicast traffic on interface Fast Ethernet 3/3:

```
Switch# show interface fastethernet 3/3 | begin L3
  L3 in Switched: ucast: 0 pkt, 0 bytes - mcast: 12 pkt, 778 bytes mcast
  L3 out Switched: ucast: 0 pkt, 0 bytes - mcast: 0 pkt, 0 bytes
     4046399 packets input, 349370039 bytes, 0 no buffer
     Received 3795255 broadcasts, 2 runts, 0 giants, 0 throttles
<...output truncated...>
Switch#
```

Note The IP unicast packet count is updated approximately every five seconds.

Displaying IP Statistics

IP unicast statistics are gathered on a per-interface basis. To display IP statistics, perform this task:

Command	Purpose
`Switch# show interface` *type number* `counters detail`	Displays IP statistics.

This example shows how to display IP unicast statistics for Part 3/1:

```
Switch# show interface fastethernet 3/1 counters detail

Port               InBytes       InUcastPkts      InMcastPkts       InBcastPkts
Fa3/1           7263539133           5998222          6412307               156

Port              OutBytes      OutUcastPkts     OutMcastPkts      OutBcastPkts
Fa3/1           7560137031           5079852         12140475                38

Port             InPkts 64        OutPkts 64    InPkts 65-127    OutPkts 65-127
Fa3/1                11274            168536          7650482          12395769

Port         InPkts 128-255   OutPkts 128-255   InPkts 256-511   OutPkts 256-511
Fa3/1                31191             55269            26923             65017

Port        InPkts 512-1023  OutPkts 512-1023
Fa3/1               133807            151582

Port       InPkts 1024-1518 OutPkts 1024-1518 InPkts 1519-1548 OutPkts 1519-1548
Fa3/1                 N/A               N/A              N/A               N/A

Port       InPkts 1024-1522 OutPkts 1024-1522 InPkts 1523-1548 OutPkts 1523-1548
Fa3/1              4557008           4384192                0                 0

Port       Tx-Bytes-Queue-1  Tx-Bytes-Queue-2 Tx-Bytes-Queue-3  Tx-Bytes-Queue-4
Fa3/1                    64                 0            91007        7666686162

Port       Tx-Drops-Queue-1  Tx-Drops-Queue-2 Tx-Drops-Queue-3  Tx-Drops-Queue-4
Fa3/1                    0                 0                0                 0

Port         Rx-No-Pkt-Buff     RxPauseFrames    TxPauseFrames   PauseFramesDrop
Fa3/1                    0                 0                0               N/A

Port       UnsupOpcodePause
Fa3/1                    0
Switch#
```

To display CEF (software switched) and hardware IP unicast adjacency table information, perform this task:

Command	Purpose
`Switch# show adjacency [interface] [detail | internal | summary]`	Displays detailed adjacency information, including Layer 2 information, when the optional **detail** keyword is used.

This example shows how to display adjacency statistics:

```
Switch# show adjacency gigabitethernet 3/5 detail
Protocol Interface                 Address
IP       GigabitEthernet9/5        172.20.53.206(11)
                                   504 packets, 6110 bytes
                                   00605C865B82
                                   000164F83FA50800
                                   ARP        03:49:31
```

Note Adjacency statistics are updated approximately every 10 seconds.

CHAPTER 22

Understanding and Configuring IP Multicast

This chapter describes IP multicast routing on the Catalyst 4500 series switch. It also provides procedures and examples to configure IP multicast routing.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Note For more detailed information on IP multicast, refer to the discussion at: http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fipr_c/ipcpt3/

This chapter includes the following major sections:

Overview of IP Multicast

This section includes these subsections:

At one end of the IP communication spectrum is IP unicast, where a source IP host sends packets to a specific destination IP host. In IP unicast, the destination address in the IP packet is the address of a single, unique host in the IP network. These IP packets are forwarded across the network from the source to the destination host by routers. At each point on the path between source and destination, a router uses a unicast routing table to make unicast forwarding decisions, based on the IP destination address in the packet.

At the other end of the IP communication spectrum is an IP broadcast, where a source host sends packets to all hosts on a network segment. The destination address of an IP broadcast packet has the host portion of the destination IP address set to all ones and the network portion set to the address of the subnet. IP hosts, including routers, understand that packets, which contain an IP broadcast address as the destination address, are addressed to all IP hosts on the subnet. Unless specifically configured otherwise, routers do not forward IP broadcast packets, so IP broadcast communication is normally limited to a local subnet.

IP multicasting falls between IP unicast and IP broadcast communication. IP multicast communication enables a host to send IP packets to a *group* of hosts anywhere within the IP network. To send information to a specific group, IP multicast communication uses a special form of IP destination address called an IP *multicast group address*. The IP multicast group address is specified in the IP destination address field of the packet.

To multicast IP information, Layer 3 switches and routers must forward an incoming IP packet to all output interfaces that lead to *members* of the IP multicast group. In the multicasting process on the Catalyst 4500 series switch, a packet is replicated in the Integrated Switching Engine, forwarded to the appropriate output interfaces, and sent to each member of the multicast group.

It is not uncommon for people to think of IP multicasting and video conferencing as almost the same thing. Although the first application in a network to use IP multicast is often video conferencing, video is only one of many IP multicast applications that can add value to a company's business model. Other IP multicast applications that have potential for improving productivity include multimedia conferencing, data replication, real-time data multicasts, and simulation applications.

This section contains the following subsections:

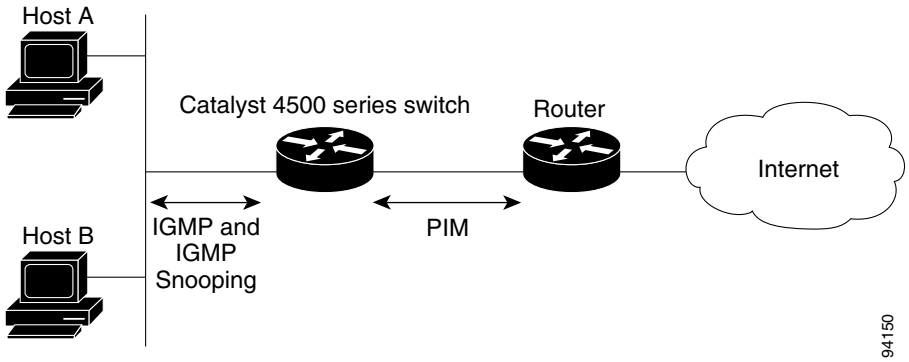
IP Multicast Protocols

The Catalyst 4500 series switch primarily uses these protocols to implement IP multicast routing:

- Internet Group Management Protocol (IGMP)
- Protocol Independent Multicast (PIM)
- IGMP snooping and Cisco Group Management Protocol

Figure 22-1 shows where these protocols operate within the IP multicast environment.

Figure 22-1 IP Multicast Routing Protocols



Internet Group Management Protocol

IGMP messages are used by IP multicast hosts to send their local Layer 3 switch or router a request to join a specific multicast group and begin receiving multicast traffic. With some extensions in IGMPv2, IP hosts can also send a request to a Layer 3 switch or router to leave an IP multicast group and not receive the multicast group traffic.

Using the information obtained via IGMP, a Layer 3 switch or router maintains a list of multicast group memberships on a per-interface basis. A multicast group membership is active on an interface if at least one host on the interface sends an IGMP request to receive multicast group traffic.

Protocol-Independent Multicast

PIM is *protocol independent* because it can leverage whichever unicast routing protocol is used to populate the unicast routing table, including EIGRP, OSPF, BGP, or static route, to support IP multicast. PIM also uses a unicast routing table to perform the reverse path forwarding (RPF) check function instead of building a completely independent multicast routing table. PIM does not send and receive multicast routing updates between routers like other routing protocols do.

PIM Dense Mode

PIM Dense Mode (PIM-DM) uses a *push* model to flood multicast traffic to every corner of the network. PIM-DM is intended for networks in which most LANs need to receive the multicast, such as LAN TV and corporate or financial information broadcasts. It can be an efficient delivery mechanism if there are active receivers on every subnet in the network.

PIM Sparse Mode

PIM Sparse Mode (PIM-SM) uses a *pull* model to deliver multicast traffic. Only networks with active receivers that have explicitly requested the data will be forwarded the traffic. PIM-SM is intended for networks with several different multicasts, such as desktop video conferencing and collaborative computing, that go to a small number of receivers and are typically in progress simultaneously.

For more detailed information on PIM Dense and Spare Mode, refer to this URL:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fipr_c/ipcpt3.

IGMP Snooping and CGMP

IGMP snooping is used for multicasting in a Layer 2 switching environment. With IGMP snooping, a Layer 3 switch or router examines Layer 3 information in the IGMP packets in transit between hosts and a router. When the switch receives the IGMP Host Report from a host for a particular multicast group, the switch adds the host's port number to the associated multicast table entry. When the switch receives the IGMP Leave Group message from a host, it removes the host's port from the table entry.

Because IGMP control messages are transmitted as multicast packets, they are indistinguishable from multicast data if only the Layer 2 header is examined. A switch running IGMP snooping examines every multicast data packet to determine whether it contains any pertinent IGMP control information. If IGMP snooping is implemented on a low end switch with a slow CPU, performance could be severely impacted when data is transmitted at high rates. On the Catalyst 4500 series switches, IGMP snooping is implemented in the forwarding ASIC, so it does not impact the forwarding rate.

Note A Catalyst 4500 series switch can act as a CGMP server for switches that do not support IGMP snooping, such as Catalyst 4500 family switches with Supervisor Engine I and Supervisor Engine II. You cannot configure the switch as a CGMP client. To configure a Catalyst 4500 series switch as a client, use IGMP snooping.

CGMP is a Cisco protocol that allows Catalyst switches to leverage IGMP information on Cisco routers to make Layer 2 forwarding decisions. CGMP is configured on the multicast routers and the Layer 2 switches. As a result, IP multicast traffic is delivered only to those Catalyst switchports with hosts that have requested the traffic. Switchports that have not explicitly requested the traffic will not receive it.

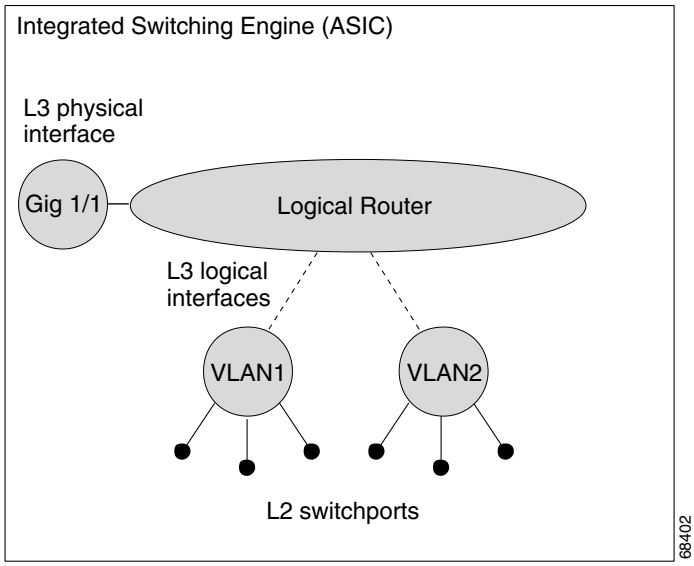
IP Multicast on the Catalyst 4500 Series Switch

The Catalyst 4500 series switch supports an ASIC-based Integrated Switching Engine that provides Ethernet bridging at Layer 2 and IP routing at Layer 3. Because the ASIC is specifically designed to forward packets, the Integrated Switching Engine hardware provides very high performance with ACLs and QoS enabled. At wire-speed, forwarding in hardware is significantly faster than the CPU subsystem software, which is designed to handle exception packets.

The Integrated Switching Engine hardware supports interfaces for inter-VLAN routing and switchports for Layer 2 bridging. It also provides a physical Layer 3 interface that can be configured to connect with a host, a switch, or a router.

Figure 22-2 shows a logical view of Layer 2 and Layer 3 forwarding in the Integrated Switching Engine hardware.

Figure 22-2 Logical View of Layer 2 and Layer 3 Forwarding in Hardware



This section contains the following subsections:

CEF, MFIB, and Layer 2 Forwarding

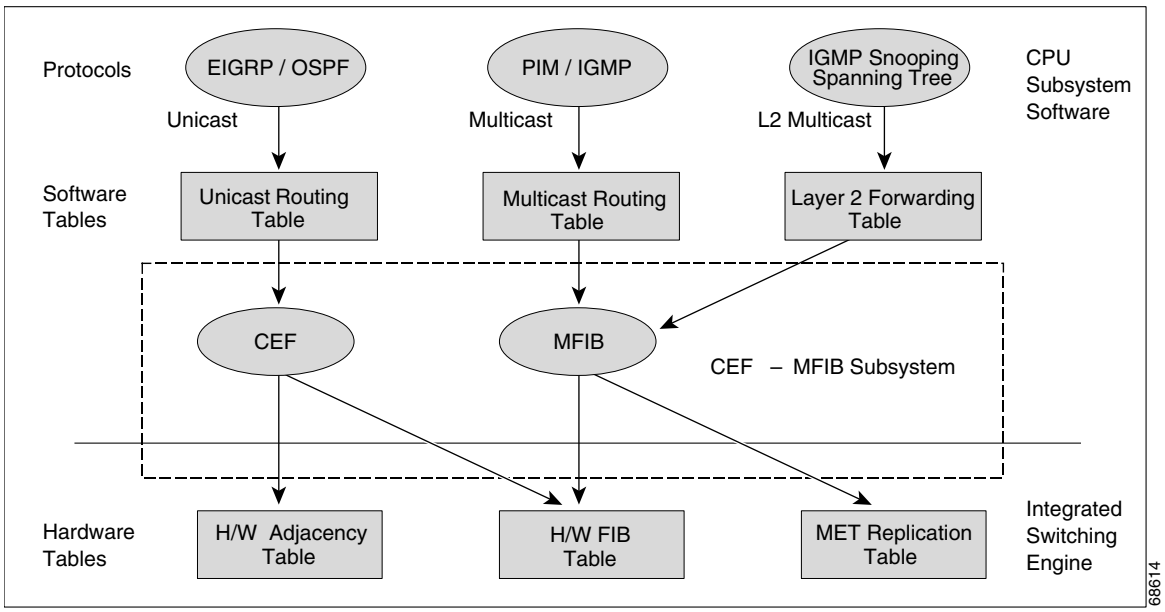
The implementation of IP multicast on the Catalyst 4500 series switch is an extension of centralized Cisco Express Forwarding (CEF). CEF extracts information from the unicast routing table, which is created by unicast routing protocols, such as BGP, OSPF, and EIGR and loads it into the hardware Forwarding Information Base (FIB). With the unicast routes in the FIB, when a route is changed in the upper-layer routing table, only one route needs to be changed in the hardware routing state. To forward unicast packets in hardware, the Integrated Switching Engine looks up source and destination routes in ternary content addressable memory (TCAM), takes the adjacency index from the hardware FIB, and gets the Layer 2 rewrite information and next-hop address from the hardware adjacency table.

The new Multicast Forwarding Information Base (MFIB) subsystem is the multicast analog of the unicast CEF. The MFIB subsystem extracts the multicast routes that PIM and IGMP create and refines them into a protocol-independent format for forwarding in hardware. The MFIB subsystem removes the protocol-specific information and leaves only the essential forwarding information. Each entry in the MFIB table consists of an (S,G) or (*,G) route, an input RPF VLAN, and a list of Layer 3 output interfaces. The MFIB subsystem, together with platform-dependent management software, loads this multicast routing information into the hardware FIB and hardware multicast expansion table (MET).

The Catalyst 4500 series switch performs Layer 3 routing and Layer 2 bridging at the same time. There can be multiple Layer 2 switchports on any VLAN interface. To determine the set of output switchports on which to forward a multicast packet, the Supervisor Engine III combines Layer 3 MFIB information with Layer 2 forwarding information and stores it in the hardware MET for packet replication.

Figure 22-3 shows a functional overview of how the Catalyst 4500 series switch combines unicast routing, multicast routing, and Layer 2 bridging information to forward in hardware.

Figure 22-3 Combining CEF, MFIB, and Layer 2 Forwarding Information in Hardware



Like the CEF unicast routes, the MFIB routes are Layer 3 and must be merged with the appropriate Layer 2 information. The following example shows an MFIB route:

```
(*,224.1.2.3)
RPF interface is Vlan3
Output Interfaces are:
Vlan 1
Vlan 2
```

The route (*,224.1.2.3) is loaded in the hardware FIB table and the list of output interfaces is loaded into the MET. A pointer to the list of output interfaces, the MET index, and the RPF interface are also loaded in the hardware FIB with the (*,224.1.2.3) route. With this information loaded in hardware, merging of the Layer 2 information can begin. For the output interfaces on VLAN1, the Integrated Switching Engine must send the packet to all switchports in VLAN1 that are in the spanning tree forwarding state. The same process applies to VLAN 2. To determine the set of switchports in VLAN 2, the Layer 2 Forwarding Table is used.

When the hardware routes a packet, in addition to sending it to all of the switchports on all output interfaces, the hardware also sends the packet to all switchports (other than the one it arrived on) in the input VLAN. For example, assume that VLAN 3 has two switchports in it, Gig 3/1 and Gig 3/2. If a host on Gig 3/1 sends a multicast packet, the host on Gig 3/2 might also need to receive the packet. To send a multicast packet to the host on Gig 3/2, all of the switchports in the ingress VLAN must be added to the portset that is loaded in the MET.

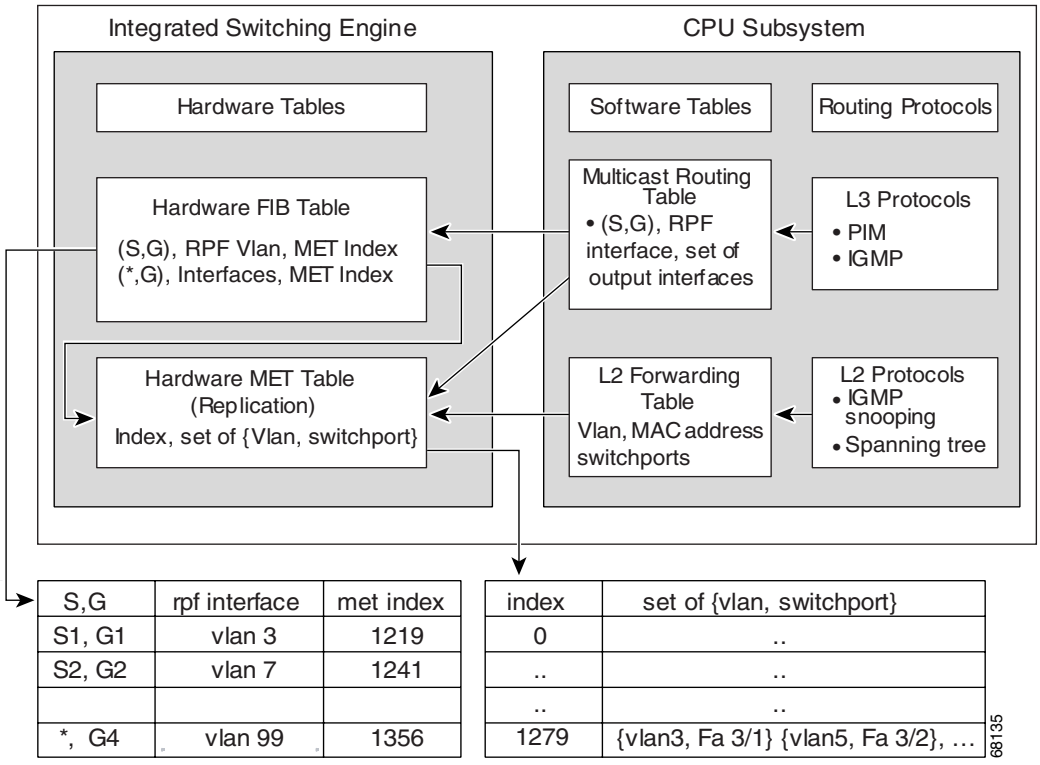
If VLAN 1 contains 1/1 and 1/2, VLAN 2 contains 2/1 and 2/2, and VLAN 3 contains 3/1 and 3/2, the MET chain for this route would contain these switchports: (1/1,1/2,2/1,2/2,3/1, and 3/2).

If IGMP snooping is on, the packet should not be forwarded to all output switchports on VLAN 2. The packet should be forwarded only to switchports where IGMP snooping has determined that there is either a group member or router. For example, if VLAN 1 had IGMP snooping enabled, and IGMP snooping determined that only port 1/2 had a group member on it, then the MET chain would contain these switchports: (1/1,1/2, 2/1, 2/2, 3/1, and 3/2).

IP Multicast Tables

Figure 22-4 shows some key data structures that the Catalyst 4500 series switch uses to forward IP multicast packets in hardware.

Figure 22-4 IP Multicast Tables and Protocols



The Integrated Switching Engine maintains the hardware FIB table to identify individual IP multicast routes. Each entry consists of a destination group IP address and an optional source IP address. Multicast traffic flows on primarily two types of routes: (S,G) and (*,G). The (S,G) routes flow from a source to a group based on the IP address of the multicast source and the IP address of the multicast group destination. Traffic on a (*,G) route flows from the PIM RP to all receivers of group G. Only sparse-mode groups use (*,G) routes. The Integrated Switching Engine hardware contains space for a total of 128,000 routes, which are shared by unicast routes, multicast routes, and multicast fast-drop entries.

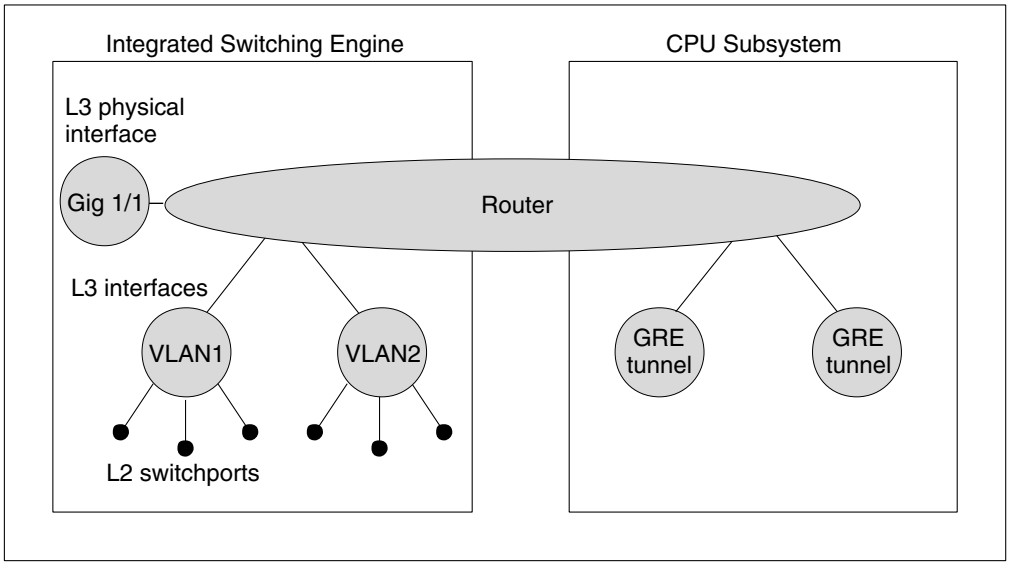
Output interface lists are stored in the multicast expansion table (MET). The MET has room for up to 32,000 output interface lists. The MET resources are shared by both Layer 3 multicast routes and by Layer 2 multicast entries. The actual number of output interface lists available in hardware depends on the specific configuration. If the total number of multicast routes exceed 32,000, multicast packets might not be switched by the Integrated Switching Engine. They would be forwarded by the CPU subsystem at much slower speeds.

Hardware and Software Forwarding

The Integrated Switching Engine forwards the majority of packets in hardware at very high rates of speed. The CPU subsystem forwards exception packets in software. Statistical reports should show that the Integrated Switching Engine is forwarding the vast majority of packets in hardware.

Figure 22-5 shows a logical view of the hardware and software forwarding components.

Figure 22-5 Hardware and Software Forwarding Components



In the normal mode of operation, the Integrated Switching Engine performs inter-VLAN routing in hardware. The CPU subsystem supports generic routing encapsulation (GRE) tunnels for forwarding in software.

Replication is a particular type of forwarding where, instead of sending out one copy of the packet, the packet is replicated and multiple copies of the packet are sent out. At Layer 3, replication occurs only for multicast packets; unicast packets are never replicated to multiple Layer 3 interfaces. In IP multicasting, for each incoming IP multicast packet that is received, many replicas of the packet are sent out.

IP multicast packets can be transmitted on the following types of routes:

- Hardware routes
- Software routes
- Partial routes

Hardware routes occur when the Integrated Switching Engine hardware forwards all replicas of a packet. Software routes occur when the CPU subsystem software forwards all replicas of a packet. Partial routes occur when the Integrated Switching Engine forwards some of the replicas in hardware and the CPU subsystem forwards some of the replicas in software.

Partial Routes

Note The conditions listed below cause the replicas to be forwarded by the CPU subsystem software, but the performance of the replicas that are forwarded in hardware is not affected.

The following conditions cause some replicas of a packet for a route to be forwarded by the CPU subsystem:

- The switch is configured with the **ip igmp join-group** command as a member of the IP multicast group on the RPF interface of the multicast source.
- The switch is the first-hop to the source in PIM sparse mode. In this case, the switch must send PIM-register messages to the RP.

Software Routes

Note If any one of the following conditions is configured on the RPF interface or the output interface, all replication of the output is performed in software.

The following conditions cause all replicas of a packet for a route to be forwarded by the CPU subsystem software:

- The interface is configured with multicast helper.
- The interface is a generic routing encapsulation (GRE) or Distance Vector Multicast Routing Protocol (DVMRP) tunnel.
- The interface uses non-Advanced Research Products Agency (ARPA) encapsulation.

The following packets are always forwarded in software:

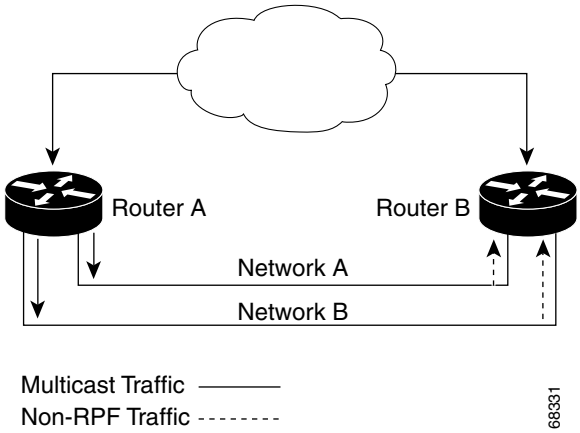
- Packets sent to multicast groups that fall into the range 224.0.0.* (where * is in the range from 0 to 255). This range is used by routing protocols. Layer 3 switching supports all other multicast group addresses.
- Packets with IP options.

Non-Reverse Path Forwarding Traffic

Traffic that fails an Reverse Path Forwarding (RPF) check is called non-RPF traffic. Non-RPF traffic is forwarded by the Integrated Switching Engine by filtering (persistently dropping) or rate limiting the non-RPF traffic.

In a redundant configuration where multiple Layer 3 switches or routers connect to the same LAN segment, only one device forwards the multicast traffic from the source to the receivers on the outgoing interfaces. Figure 22-6 shows how Non-RPF traffic can occur in a common network configuration.

Figure 22-6 Redundant Multicast Router Configuration in a Stub Network



In this kind of topology, only Router A, the PIM designated router (PIM DR), forwards data to the common VLAN. Router B receives the forwarded multicast traffic, but must drop this traffic because it has arrived on the wrong interface and fails the RPF check. Traffic that fails the RPF check is called non-RPF traffic.

Multicast Fast Drop

In IP multicast protocols, such as PIM-SM and PIM-DM, every (S,G) or (*,G) route has an incoming interface associated with it. This interface is referred to as the reverse path forwarding interface. In some cases, when a packet arrives on an interface other than the expected RPF interface, the packet must be forwarded to the CPU subsystem software to allow PIM to perform special protocol processing on the packet. One example of this special protocol processing that PIM performs is the PIM Assert protocol.

By default, the Integrated Switching Engine hardware sends all packets that arrive on a non-RPF interface to the CPU subsystem software. However, processing in software is not necessary in many cases, because these non-RPF packets are often not needed by the multicast routing protocols. The problem is that if no action is taken, the non-RPF packets that are sent to the software can overwhelm the CPU.

Use the **ip mfib fastdrop** command to enable or disable MFIB fast drops.

To prevent this from happening, the CPU subsystem software loads fast-drop entries in the hardware when it receives an RPF failed packet that is not needed by the PIM protocols running on the switch. A fast-drop entry is keyed by (S,G, incoming interface). Any packet matching a fast-drop entry is bridged in the ingress VLAN, but is not sent to the software, so the CPU subsystem software is not overloaded by processing these RPF failures unnecessarily.

Protocol events, such as a link going down or a change in the unicast routing table, can impact the set of packets that can safely be fast dropped. A packet that was correctly fast dropped before might, after a topology change, need to be forwarded to the CPU subsystem software so that PIM can process it. The CPU subsystem software handles flushing fast-drop entries in response to protocol events so that the PIM code in IOS can process all the necessary RPF failures.

The use of fast-drop entries in the hardware is critical in some common topologies because it is possible to have persistent RPF failures. Without the fast-drop entries, the CPU would be exhausted by RPF failed packets that it did not need to process.

Multicast Forwarding Information Base

The Multicast Forwarding Information Base (MFIB) subsystem supports IP multicast routing in the Integrated Switching Engine hardware on the Catalyst 4500 series switch. The MFIB logically resides between the IP multicast routing protocols in the CPU subsystem software (PIM, IGMP, MSDP, MBGP, and DVMRP) and the platform-specific code that manages IP multicast routing in hardware. The MFIB translates the routing table information created by the multicast routing protocols into a simplified format that can be efficiently processed and used for forwarding by the Integrated Switching Engine hardware.

To display the information in the multicast routing table, use the **show ip mroute** command. To display the MFIB table information, use the **show ip mfib** command. To display the information in the hardware tables, use the **show platform hardware** command.

The MFIB table contains a set of IP multicast routes. There are several types of IP multicast routes, including (S,G) and (*,G) routes. Each route in the MFIB table can have one or more optional flags associated with it. The route flags indicate how a packet that matches a route should be forwarded. For example, the Internal Copy (IC) flag on an MFIB route indicates that a process on the switch needs to receive a copy of the packet. The following flags can be associated with MFIB routes:

- Internal Copy (IC) flag—set on a route when a process on the router needs to receive a copy of all packets matching the specified route
- Signalling (S) flag—set on a route when a process needs to be notified when a packet matching the route is received; the expected behavior is that the protocol code updates the MFIB state in response to receiving a packet on a signalling interface
- Connected (C) flag——when set on an MFIB route, has the same meaning as the Signalling (S) flag, except that the C flag indicates that only packets sent by directly connected hosts to the route should be signalled to a protocol process

A route can also have a set of optional flags associated with one or more interfaces. For example, an (S,G) route with the flags on VLAN 1 indicates how packets arriving on VLAN 1 should be treated, and they also indicate whether packets matching the route should be forwarded onto VLAN 1. The per-interface flags supported in the MFIB include the following:

- Accepting (A)—set on the interface that is known in multicast routing as the RPF interface. A packet that arrives on an interface that is marked as Accepting (A) is forwarded to all Forwarding (F) interfaces.
- Forwarding (F)—used in conjunction with the Accepting (A) flag as described above. The set of Forwarding interfaces that form what is often referred to as the multicast *"olist"* or output interface list.
- Signalling (S)—set on an interface when some multicast routing protocol process in IOS needs to be notified of packets arriving on that interface.
- Not platform fast-switched (NP)—used in conjunction with the Forwarding (F) flag. A Forwarding interface is also marked as not platform fast-switched whenever that output interface cannot be fast switched by the platform. The NP flag is typically used when the Forwarding interface cannot be routed in hardware and requires software forwarding. For example, Catalyst 4500 series switch tunnel interfaces are not hardware switched, so they are marked with the NP flag. If there are any NP interfaces associated with a route, then for every packet arriving on an Accepting interface, one copy of that packet is sent to the software forwarding path for software replication to those interfaces that were not switched in hardware.

Note When PIM-SM routing is in use, the MFIB route might include an interface like in this example: PimTunnel [1.2.3.4]. This is a virtual interface that the MFIB subsystem creates to indicate that packets are being tunnelled to the specified destination address. A PimTunnel interface cannot be displayed with the normal **show interface** command.

S/M, 224/4

An (S/M, 224/4) entry is created in the MFIB for every multicast-enabled interface. This entry ensures that all packets sent by directly connected neighbors can be Register-encapsulated to the PIM-SM RP. Typically, only a small number of packets would be forwarded using the (S/M,224/4) route, until the (S,G) route is established by PIM-SM.

For example, on an interface with IP address 10.0.0.1 and netmask 255.0.0.0, a route would be created matching all IP multicast packets in which the source address is anything in the class A network 10. This route can be written in conventional subnet/masklength notation as (10/8,224/4). If an interface has multiple assigned IP addresses, then one route is created for each such IP address.

Unsupported Features

The following IP multicast features are not supported in this release:

- Controlling the transmission rate to a multicast group
- Load splitting IP multicast traffic across equal-cost paths

Configuring IP Multicast Routing

The following sections describe IP multicast routing configuration tasks:

- Default Configuration in IP MUlticast Routing, page 22-13
- Enabling IP Multicast Routing, page 22-13
- Enabling PIM on an Interface, page 22-13

For more detailed information on IP multicast routing, such as Auto-RP, PIM Version 2, and IP multicast static routes, refer to the *Cisco IOS IP and IP Routing Configuration Guide, Release 12.2.*

Default Configuration in IP MUlticast Routing

Table 22-1 shows the IP multicast default configuration.

Table 22-1 Default IP Multicast Configuration

Feature	Default Value
Rate limiting of RPF	Enabled globally
IP multicast routing	Disabled globally **Note** When IP multicast routing is disabled, IP multicast traffic data packets are not forwarded by the Catalyst 4500 series switch. However, IP multicast control traffic will continue to be processed and forwarded. Therefore, IP multicast routes can remain in the routing table even if IP multicast routing is disabled.
PIM	Disabled on all interfaces
IGMP snooping	Enabled on all VLAN interfaces **Note** If you disable IGMP snooping on an interface, all output ports are forwarded by the Integrated Switching Engine. When IGMP snooping is disabled on an input VLAN interface, multicast packets related to that interface are sent to all forwarding switchports in the VLAN.

Note Source-specific multicast and IGMP v3 are supported.

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/ios122/122cgcr/fipr_c/ipcpt3/1cfssm.htm

Enabling IP Multicast Routing

Enabling IP multicast routing allows the Catalyst 4500 series switch to forward multicast packets. To enable IP multicast routing on the router, perform this task in global configuration mode:

Command	Purpose
`Switch(config)# ip multicast-routing`	Enables IP multicast routing.

Enabling PIM on an Interface

Enabling PIM on an interface also enables IGMP operation on that interface. An interface can be configured to be in dense mode, sparse mode, or sparse-dense mode. The mode determines how the Layer 3 switch or router populates its multicast routing table and how the Layer 3 switch or router forwards multicast packets it receives from its directly connected LANs. You must enable PIM in one of these modes for an interface to perform IP multicast routing.

When the switch populates the multicast routing table, dense-mode interfaces are always added to the table. Sparse-mode interfaces are added to the table only when periodic join messages are received from downstream routers, or when there is a directly connected member on the interface. When forwarding from a LAN, sparse-mode operation occurs if there is an RP known for the group. If so, the packets are encapsulated and sent toward the RP. When no RP is known, the packet is flooded in a dense-mode fashion. If the multicast traffic from a specific source is sufficient, the receiver's first-hop router can send join messages toward the source to build a source-based distribution tree.

There is no default mode setting. By default, multicast routing is disabled on an interface.

Enabling Dense Mode

To configure PIM on an interface to be in dense mode, perform this task:

Command	Purpose
`Switch(config-if)# ip pim dense-mode`	Enables dense-mode PIM on the interface.

See the "PIM Dense Mode Example" section at the end of this chapter for an example of how to configure a PIM interface in dense mode.

Enabling Sparse Mode

To configure PIM on an interface to be in sparse mode, perform this task:

Command	Purpose
`Switch(config-if)# ip pim sparse-mode`	Enables sparse-mode PIM on the interface.

See the "PIM Sparse Mode Example" section at the end of this chapter for an example of how to configure a PIM interface in sparse mode.

Enabling Sparse-Dense Mode

When you enter either the **ip pim sparse-mode** or **ip pim dense-mode** command, sparseness or denseness is applied to the interface as a whole. However, some environments might require PIM to run in a single region in sparse mode for some groups and in dense mode for other groups.

An alternative to enabling only dense mode or only sparse mode is to enable sparse-dense mode. In this case, the interface is treated as dense mode if the group is in dense mode; the interface is treated in sparse mode if the group is in sparse mode. If you want to treat the group as a sparse group, and the interface is in sparse-dense mode, you must have an RP.

If you configure sparse-dense mode, the idea of sparseness or denseness is applied to the group on the switch, and the network manager should apply the same concept throughout the network.

Another benefit of sparse-dense mode is that Auto-RP information can be distributed in a dense-mode manner; yet, multicast groups for user groups can be used in a sparse-mode manner. Thus, there is no need to configure a default RP at the leaf routers.

When an interface is treated in dense mode, it is populated in a multicast routing table's outgoing interface list when either of the following is true:

- When there are members or DVMRP neighbors on the interface
- When there are PIM neighbors and the group has not been pruned

When an interface is treated in sparse mode, it is populated in a multicast routing table's outgoing interface list when either of the following is true:

- When there are members or DVMRP neighbors on the interface
- When an explicit join has been received by a PIM neighbor on the interface

To enable PIM to operate in the same mode as the group, perform this task:

Command	Purpose
`Switch(config-if)# ip pim sparse-dense-mode`	Enables PIM to operate in sparse or dense mode, depending on the group.

Monitoring and Maintaining IP Multicast Routing

You can remove all contents of a particular cache, table, or database. You also can display specific statistics. The following sections describe how to monitor and maintain IP multicast:

Displaying System and Network Statistics

You can display specific statistics, such as the contents of IP routing tables and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path your device's packets are taking through the network.

To display various routing statistics, you can perform any of these tasks:

Command	Purpose
`Switch# ping [group-name | group-address]`	Sends an ICMP Echo Request to a multicast group address.
`Switch# show ip mroute [hostname | group_number]`	Displays the contents of the IP multicast routing table.
`Switch# show ip pim interface [type number] [count]`	Displays information about interfaces configured for PIM.
`Switch# show ip interface`	Displays PIM information for all interfaces.

Displaying the Multicast Routing Table

The following is sample output from the **show ip mroute** command for a router operating in dense mode. This command displays the contents of the IP multicast FIB table for the multicast group named cbone-audio.

```
Switch# show ip mroute cbone-audio

IP Multicast Routing Table
Flags: D - Dense, S - Sparse, C - Connected, L - Local, P - Pruned
R - RP-bit set, F - Register flag, T - SPT-bit set
Timers: Uptime/Expires
Interface state: Interface, Next-Hop, State/Mode

(*, 224.0.255.1), uptime 0:57:31, expires 0:02:59, RP is 0.0.0.0, flags: DC
    Incoming interface: Null, RPF neighbor 0.0.0.0, Dvmrp
    Outgoing interface list:
     Ethernet0, Forward/Dense, 0:57:31/0:02:52
     Tunnel0, Forward/Dense, 0:56:55/0:01:28

(198.92.37.100/32, 224.0.255.1), uptime 20:20:00, expires 0:02:55, flags: C
    Incoming interface: Tunnel0, RPF neighbor 10.20.37.33, Dvmrp
    Outgoing interface list:
     Ethernet0, Forward/Dense, 20:20:00/0:02:52
```

The following is sample output from the **show ip mroute** command for a router operating in sparse mode:

```
Switch# show ip mroute

IP Multicast Routing Table
Flags: D - Dense, S - Sparse, C - Connected, L - Local, P - Pruned
R - RP-bit set, F - Register flag, T - SPT-bit set
Timers: Uptime/Expires
Interface state: Interface, Next-Hop, State/Mode

(*, 224.0.255.3), uptime 5:29:15, RP is 198.92.37.2, flags: SC
  Incoming interface: Tunnel0, RPF neighbor 10.3.35.1, Dvmrp
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 5:29:15/0:02:57

(198.92.46.0/24, 224.0.255.3), uptime 5:29:15, expires 0:02:59, flags: C
  Incoming interface: Tunnel0, RPF neighbor 10.3.35.1
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 5:29:15/0:02:57
```

Note Interface timers are not updated for hardware-forwarded packets. Entry timers are updated approximately every five seconds.

The following is sample output from the **show ip mroute** command with the **summary** keyword:

```
Switch# show ip mroute summary

IP Multicast Routing Table
Flags: D - Dense, S - Sparse, C - Connected, L - Local, P - Pruned
       R - RP-bit set, F - Register flag, T - SPT-bit set, J - Join SPT
Timers: Uptime/Expires
Interface state: Interface, Next-Hop, State/Mode

(*, 224.255.255.255), 2d16h/00:02:30, RP 171.69.10.13, flags: SJPC
```

```
(*, 224.2.127.253), 00:58:18/00:02:00, RP 171.69.10.13, flags: SJC

(*, 224.1.127.255), 00:58:21/00:02:03, RP 171.69.10.13, flags: SJC

(*, 224.2.127.254), 2d16h/00:00:00, RP 171.69.10.13, flags: SJCL
  (128.9.160.67/32, 224.2.127.254), 00:02:46/00:00:12, flags: CLJT
  (129.48.244.217/32, 224.2.127.254), 00:02:15/00:00:40, flags: CLJT
  (130.207.8.33/32, 224.2.127.254), 00:00:25/00:02:32, flags: CLJT
  (131.243.2.62/32, 224.2.127.254), 00:00:51/00:02:03, flags: CLJT
  (140.173.8.3/32, 224.2.127.254), 00:00:26/00:02:33, flags: CLJT
  (171.69.60.189/32, 224.2.127.254), 00:03:47/00:00:46, flags: CLJT
```

The following is sample output from the **show ip mroute** command with the **active** keyword:

```
Switch# show ip mroute active

Active IP Multicast Sources - sending >= 4 kbps

Group: 224.2.127.254, (sdr.cisco.com)
   Source: 146.137.28.69 (mbone.ipd.anl.gov)
     Rate: 1 pps/4 kbps(1sec), 4 kbps(last 1 secs), 4 kbps(life avg)

Group: 224.2.201.241, ACM 97
   Source: 130.129.52.160 (webcast3-e1.acm97.interop.net)
     Rate: 9 pps/93 kbps(1sec), 145 kbps(last 20 secs), 85 kbps(life avg)

Group: 224.2.207.215, ACM 97
   Source: 130.129.52.160 (webcast3-e1.acm97.interop.net)
     Rate: 3 pps/31 kbps(1sec), 63 kbps(last 19 secs), 65 kbps(life avg)
```

The following is sample output from the **show ip mroute** command with the **count** keyword:

```
Switch# show ip mroute count

IP Multicast Statistics - Group count: 8, Average sources per group: 9.87
Counts: Pkt Count/Pkts per second/Avg Pkt Size/Kilobits per second

Group: 224.255.255.255, Source count: 0, Group pkt count: 0
  RP-tree: 0/0/0/0

Group: 224.2.127.253, Source count: 0, Group pkt count: 0
  RP-tree: 0/0/0/0

Group: 224.1.127.255, Source count: 0, Group pkt count: 0
  RP-tree: 0/0/0/0

Group: 224.2.127.254, Source count: 9, Group pkt count: 14
  RP-tree: 0/0/0/0
  Source: 128.2.6.9/32, 2/0/796/0
  Source: 128.32.131.87/32, 1/0/616/0
  Source: 128.125.51.58/32, 1/0/412/0
  Source: 130.207.8.33/32, 1/0/936/0
  Source: 131.243.2.62/32, 1/0/750/0
  Source: 140.173.8.3/32, 1/0/660/0
  Source: 146.137.28.69/32, 1/0/584/0
  Source: 171.69.60.189/32, 4/0/447/0
  Source: 204.162.119.8/32, 2/0/834/0

Group: 224.0.1.40, Source count: 1, Group pkt count: 3606
  RP-tree: 0/0/0/0
  Source: 171.69.214.50/32, 3606/0/48/0, RPF Failed: 1203
```

```
Group: 224.2.201.241, Source count: 36, Group pkt count: 54152
  RP-tree: 7/0/108/0
  Source: 13.242.36.83/32, 99/0/123/0
  Source: 36.29.1.3/32, 71/0/110/0
  Source: 128.9.160.96/32, 505/1/106/0
  Source: 128.32.163.170/32, 661/1/88/0
  Source: 128.115.31.26/32, 192/0/118/0
  Source: 128.146.111.45/32, 500/0/87/0
  Source: 128.183.33.134/32, 248/0/119/0
  Source: 128.195.7.62/32, 527/0/118/0
  Source: 128.223.32.25/32, 554/0/105/0
  Source: 128.223.32.151/32, 551/1/125/0
  Source: 128.223.156.117/32, 535/1/114/0
  Source: 128.223.225.21/32, 582/0/114/0
  Source: 129.89.142.50/32, 78/0/127/0
  Source: 129.99.50.14/32, 526/0/118/0
  Source: 130.129.0.13/32, 522/0/95/0
  Source: 130.129.52.160/32, 40839/16/920/161
  Source: 130.129.52.161/32, 476/0/97/0
  Source: 130.221.224.10/32, 456/0/113/0
  Source: 132.146.32.108/32, 9/1/112/0
```

Note Multicast route byte and packet statistics are supported only for the first 1024 multicast routes. Output interface statistics are not maintained.

Displaying IP MFIB

You can display all routes in the MFIB, including routes that might not exist directly in the upper-layer routing protocol database but that are used to accelerate fast switching. These routes appear in the MFIB, even if dense-mode forwarding is in use.

To display various MFIB routing routes, perform one of these tasks:

Command	Purpose
`Switch# show ip mfib`	Displays the (S,G) and (*,G) routes that are used for packet forwarding. Displays counts for fast, slow, and partially-switched packets for every multicast route.
`Switch# show ip mfib all`	Displays all routes in the MFIB, including routes that may not exist directly in the upper-layer routing protocol database, but that are used to accelerate fast switching.These routes include the (S/M,224/4) routes.
`Switch# show ip mfib log [n]`	Displays a log of the most recent n MFIB related events, most recent first.
`Switch# show ip mfib counters`	Displays counts of MFIB related events. Only non-zero counters are shown.

The following is sample output from the **show ip mfib** command.

```
IP Multicast Forwarding Information Base
Entry Flags: C - Directly Connected, S - Signal,
             IC - Internal Copy
Interface Flags: A - Accept, F - Forward, S - Signal,
             NP - Not platform switched
Packets: Fast/Partial/Slow Bytes: Fast/Partial/Slow:
(171.69.10.13, 224.0.1.40), flags (IC)
   Packets: 2292/2292/0, Bytes: 518803/0/518803
   Vlan7 (A)
   Vlan100 (F NS)
   Vlan105 (F NS)
(*, 224.0.1.60), flags ()
   Packets: 2292/0/0, Bytes: 518803/0/0
   Vlan7 (A NS)
(*, 224.0.1.75), flags ()
   Vlan7 (A NS)
(10.34.2.92, 239.192.128.80), flags ()
   Packets: 24579/100/0, 2113788/15000/0 bytes
   Vlan7 (F NS)
   Vlan100 (A)
(*, 239.193.100.70), flags ()
   Packets: 1/0/0, 1500/0/0 bytes
   Vlan7 (A)
..
```

The fast-switched packet count represents the number of packets that were switched in hardware on the corresponding route.

The partially switched packet counter represents the number of times that a fast-switched packet was also copied to the CPU for software processing or for forwarding to one or more non-platform switched interfaces (such as a PimTunnel interface).

The slow-switched packet count represents the number of packets that were switched completely in software on the corresponding route.

Displaying IP MFIB Fast Drop

To display fast-drop entries, perform this task:

Command	Purpose
`Switch# show ip mfib fastdrop`	Displays all currently active fast-drop entries and indicates whether **fastdrop** is enabled.

The following is sample output from the **show ip mfib fastdrop** command.

```
Switch> show ip mfib fastdrop
MFIB fastdrop is enabled.
MFIB fast-dropped flows:
(10.0.0.1, 224.1.2.3, Vlan9 ) 00:01:32
(10.1.0.2, 224.1.2.3, Vlan9 ) 00:02:30
(1.2.3.4, 225.6.7.8, Vlan3) 00:01:50
```

The full (S,G) flow and the ingress interface on which incoming packets are dropped is shown. The timestamp indicates the age of the entry.

Displaying PIM Statistics

The following is sample output from the **show ip pim interface** command:

```
Switch# show ip pim interface

Address          Interface          Mode    Neighbor  Query     DR
                                            Count     Interval
198.92.37.6      Ethernet0          Dense   2         30        198.92.37.33
198.92.36.129    Ethernet1          Dense   2         30        198.92.36.131
10.1.37.2        Tunnel0            Dense   1         30        0.0.0.0
```

The following is sample output from the **show ip pim interface** command with a **count**:

```
Switch# show ip pim interface count

Address          Interface          FS  Mpackets In/Out
171.69.121.35    Ethernet0          *   548305239/13744856
171.69.121.35    Serial0.33         *   8256/67052912
198.92.12.73     Serial0.1719       *   219444/862191
```

The following is sample output from the **show ip pim interface** command with a **count** when IP multicast is enabled. The example lists the PIM interfaces that are fast-switched and process-switched, and the packet counts for these. The H is added to interfaces where IP multicast is enabled.

```
Switch# show ip pim interface count

States: FS - Fast Switched, H - Hardware Switched
Address          Interface          FS  Mpackets In/Out
192.1.10.2       Vlan10             * H 40886/0
192.1.11.2       Vlan11             * H 0/40554
192.1.12.2       Vlan12             * H 0/40554
192.1.23.2       Vlan23             *   0/0
192.1.24.2       Vlan24             *   0/0
```

Clearing Tables and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database might be necessary when the contents of the particular structure have become, or are suspected to be, invalid.

To clear IP multicast caches, tables, and databases, perform one of these tasks:

Command	Purpose
`Switch# clear ip mroute`	Deletes entries from the IP routing table.
`Switch# clear ip mfib counters`	Deletes all per-route and global MFIB counters.
`Switch# clear ip mfib fastdrop`	Deletes all fast-drop entries.

Note IP multicast routes can be regenerated in response to protocol events and as data packets arrive.

Configuration Examples

The following sections provide IP multicast routing configuration examples:

PIM Dense Mode Example

This example is a configuration of dense-mode PIM on an Ethernet interface:

```
ip multicast-routing
interface ethernet 0
 ip pim dense-mode
```

PIM Sparse Mode Example

This example is a configuration of sparse-mode PIM. The RP router is the router with the address 10.8.0.20.

```
ip multicast-routing
 ip pim rp-address 10.8.0.20 1
interface ethernet 1
 ip pim sparse-mode
```

BSR Configuration Example

This example is a configuration of a candidate BSR, which also happens to be a candidate RP:

```
version 11.3
!
ip multicast-routing
!
interface Ethernet0
 ip address 171.69.62.35 255.255.255.240
!
interface Ethernet1
 ip address 172.21.24.18 255.255.255.248
 ip pim sparse-dense-mode
!
interface Ethernet2
 ip address 172.21.24.12 255.255.255.248
 ip pim sparse-dense-mode
!
router ospf 1
 network 172.21.24.8 0.0.0.7 area 1
 network 172.21.24.16 0.0.0.7 area 1
!
ip pim bsr-candidate Ethernet2 30 10
ip pim rp-candidate Ethernet2 group-list 5
access-list 5 permit 239.255.2.0 0.0.0.255
```

Configuring Policy-Based Routing

This chapter describes the tasks for configuring policy-based routing (PBR) on a router and includes these major sections:

Note For a complete description of the PBR commands in this chapter, refer to the *Cisco IOS Quality of Service Solutions Command Reference* at: http://www.cisco.com/univercd/cc/td/doc/product/software/ios123/123tcr/123tqr/

Note To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release.

Overview of Policy-Based Routing

This section contains the following subsections:

PBR gives you a flexible means of routing packets by allowing you to configure a defined policy for traffic flows, lessening reliance on routes derived from routing protocols. To this end, PBR gives you more control over routing by extending and complementing the existing mechanisms provided by routing protocols. PBR allows you to specify a path for certain traffic, such as priority traffic over a high-cost link.

You can set up PBR as a way to route packets based on configured policies. For example, you can implement routing policies to allow or deny paths based on the identity of a particular end system, an application protocol, or the size of packets.

PBR allows you to perform the following tasks:

- Classify traffic based on extended access list criteria. Access lists, then establish the match criteria.
- Route packets to specific traffic-engineered paths.

Policies can be based on IP address, port numbers, or protocols. For a simple policy, you can use any one of these descriptors; for a complicated policy, you can use all of them.

Understanding PBR

All packets received on an interface with PBR enabled are passed through enhanced packet filters known as route maps. The route maps used by PBR dictate the policy, determining to where the packets are forwarded.

Route maps are composed of statements. The route map statements can be marked as permit or deny, and they are interpreted in the following ways:

- If a statement is marked as deny, the packets meeting the match criteria are sent back through the normal forwarding channels and destination-based routing is performed.
- If the statement is marked as permit and a packet matches the access-lists, then the first valid set clause is applied to that packet.

You specify PBR on the incoming interface (the interface on which packets are received), not outgoing interface.

Understanding PBR Flow Switching

The Catalyst 4500 switching engine supports matching a “set next-hop” route-map action with a packet on a permit ACL. All other route-map actions, as well as matches of deny ACLs, are supported by a flow switching model. In this model, the first packet on a flow that matches a route-map will be delivered to the software for forwarding. Software determines the correct destination for the packet and installs an entry into the TCAM so that future packets on that flow are switched in hardware. The Catalyst 4500 switching engine supports a maximum of 4096 flows.

Using Policy-Based Routing

You can enable PBR to change the routing path of certain packets from the obvious shortest path. For example, PBR can be used to provide the following functionality:

- equal access
- protocol-sensitive routing
- source-sensitive routing
- routing based on interactive versus batch traffic
- routing based on dedicated links

Some applications or traffic can benefit from source-specific routing; for example, you can transfer stock records to a corporate office on a higher-bandwidth, higher-cost link for a short time while sending routine application data, such as e-mail, over a lower-bandwidth, lower-cost link.

Policy-Based Routing Configuration Task List

To configure PBR, perform the tasks described in the following sections. The task in the first section is required; the tasks in the remaining sections are optional. See the end of this chapter for the section "Policy-Based Routing Configuration Examples."

- Enabling PBR (Required)
- Enabling Local PBR (Optional)

Enabling PBR

To enable PBR, you must create a route map that specifies the match criteria and the resulting action if all of the match clauses are met. Then you must enable PBR for that route map on a particular interface. All packets arriving on the specified interface matching the match clauses will be subject to PBR.

To enable PBR on an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# route-map map-tag [permit | deny] [sequence-number]`	Defines a route map to control where packets are output. This command puts the router into route-map configuration mode.
Step 2	`Switch(config-route-map)# match ip address {access-list-number | name} [...access-list-number | name]`	Specifies the match criteria. Matches the source and destination IP address that is permitted by one or more standard or extended access lists.

	Command	Purpose
Step 3		Specifies the action or actions to take on the packets that match the criteria. You can specify any or all of the following:
	`Switch(config-route-map)# set ip next-hop ip-address [... ip-address]`	• Specifies the next hop for which to route the packet (the next hop must be adjacent). This behavior is identical to a next hop specified in the normal routing table.
	`Switch(config-route-map)# set interface interface-type interface-number [... type number]`	• Sets output interface for the packet. This action specifies that the packet is forwarded out of the local interface. The interface must be a Layer 3 interface (no switchports), and the destination address in the packet must lie within the IP network assigned to that interface. If the destination address for the packet does not lie within that network, the packet is dropped.
	`Switch(config-route-map)# set ip default next-hop ip-address [... ip-address]`	• Sets next hop to which to route the packet if there is no explicit route for this destination. Before forwarding the packet to the next hop, the switch looks up the packet's destination address in the unicast routing table. If a match is found, the packet is forwarded by way of the routing table. If no match is found, the packet is forwarded to the specified next hop.
	`Switch(config-route-map)# set default interface interface-type interface-number [... type ...number]`	• Sets output interface for the packet if there is no explicit route for this destination. Before forwarding the packet to the next hop, the switch looks up the packet's destination address in the unicast routing table. If a match is found, the packet is forwarded via the routing table. If no match is found, the packet is forwarded to the specified output interface. If the destination address for the packet does not lie within that network, the packet is dropped.
Step 4	`Switch(config-route-map)# interface interface-type interface-number`	Specifies the interface. This command puts the router into interface configuration mode.
Step 5	`Switch(config-if)# ip policy route-map map-tag`	Identifies the route map to use for PBR. One interface can only have one route map tag, but you can have multiple route map entries with different sequence numbers. These entries are evaluated in sequence number order until the first match. If there is no match, packets will be routed as usual.

The **set** commands can be used in conjunction with each other. These commands are evaluated in the order shown in Step 3 in the previous task table. A usable next hop implies an interface. Once the local router finds a next hop and a usable interface, it routes the packet.

Enabling Local PBR

Packets that are generated by the router are not normally policy-routed. To enable local PBR for such packets, indicate which route map the router should use by performing this task:

Command	Purpose
`Switch(config)# ip local policy route-map map-tag`	Identifies the route map to use for local PBR.

All packets originating on the router will then be subject to local PBR.

Use the **show ip local policy** command to display the route map used for local PBR, if one exists.

Unsupported Commands

The following PBR commands in config-route-map mode are in the CLI but not supported in Cisco IOS for the Catalyst 4500 series switches. If you attempt to use these commands, an error message displays.

- **match-length**
- **set ip qos**
- **set ip tos**
- **set ip precedence**

Policy-Based Routing Configuration Examples

The following sections provide PBR configuration examples:

- Equal Access Example, page 23-5
- Differing Next Hops Example, page 23-6
- Deny ACE Example, page 23-6

For information on how to configure policy-based routing, see the section "Policy-Based Routing Configuration Task List" in this chapter.

Equal Access Example

The following example provides two sources with equal access to two different service providers. Packets arriving on interface fastethernet 3/1 from the source 1.1.1.1 are sent to the router at 6.6.6.6 if the router has no explicit route for the destination of the packet. Packets arriving from the source 2.2.2.2 are sent to the router at 7.7.7.7 if the router has no explicit route for the destination of the packet. All other packets for which the router has no explicit route to the destination are discarded.

```
Switch (config)# access-list 1 permit ip 1.1.1.1
access-list 1 permit ip 1.1.1.1
!
interface fastethernet 3/1
 ip policy route-map equal-access
```

```
!

route-map equal-access permit 10
 match ip address 1
 set ip default next-hop 6.6.6.6
route-map equal-access permit 20
 match ip address 2
 set ip default next-hop 7.7.7.7
route-map equal-access permit 30
 set default interface null0
```

Note If the packets you want to drop do not match either of the first two route-map clauses, then change **set default interface null0** to **set interface null0**.

Differing Next Hops Example

The following example illustrates how to route traffic from different sources to different places (next hops). Packets arriving from source 1.1.1.1 are sent to the next hop at 3.3.3.3; packets arriving from source 2.2.2.2 are sent to the next hop at 3.3.3.5.

```
access-list 1 permit ip 1.1.1.1
access-list 2 permit ip 2.2.2.2
!
interface fastethernet 3/1
 ip policy route-map Texas
!
route-map Texas permit 10
 match ip address 1
 set ip next-hop 3.3.3.3
!
route-map Texas permit 20
 match ip address 2
 set ip next-hop 3.3.3.5
```

Deny ACE Example

The following example illustrates how to stop processing a given route map sequence, and to jump to the next sequence. Packets arriving from source 1.1.1.1 will skip sequence 10 and jump to sequence 20. All other packets from subnet 1.1.1.0 will follow the set statement in sequence 10.

```
access-list 1 deny ip 1.1.1.1
access-list 1 permit ip 1.1.1.0 0.0.0.255
access-list 2 permit ip 1.1.1.1
access-list 2 permit ip 2.2.2.2
!
interface fastethernet 3/1
ip policy route-map Texas
!
route-map Texas permit 10
match ip address 1
set ip next-hop 3.3.3.3
!
route-map Texas permit 20
match ip address 2
set ip next-hop 3.3.3.5
```

Understanding and Configuring VTP

This chapter describes the VLAN Trunking Protocol (VTP) on the Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of VTP

VTP is a Layer 2 messaging protocol that maintains VLAN configuration consistency by managing the addition, deletion, and renaming of VLANs within a VTP domain. A VTP domain (also called a VLAN management domain) is made up of one or more network devices that share the same VTP domain name and that are interconnected with trunks. VTP minimizes misconfigurations and configuration inconsistencies that can result in a number of problems, such as duplicate VLAN names, incorrect VLAN-type specifications, and security violations.

Before you create VLANs, you must decide whether you want to use VTP in your network. With VTP, you can make configuration changes centrally on one or more network devices and have those changes automatically communicated to all the other network devices in the network.

Note For complete information on configuring VLANs, see Chapter 7, "Understanding and Configuring VLANs."

These sections describe how VTP works:

Understanding the VTP Domain

A VTP domain is made up of one or more interconnected network devices that share the same VTP domain name. A network device can be configured to be in only one VTP domain. You make global VLAN configuration changes for the domain using either the command-line interface (CLI) or Simple Network Management Protocol (SNMP).

By default, the Catalyst 4500 series switch is in VTP server mode and is in the no-management domain state until the switch receives an advertisement for a domain over a trunk link or you configure a management domain. You cannot create or modify VLANs on a VTP server until the management domain name is specified or learned.

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 ignores advertisements with a different management domain name or an earlier configuration revision number.

If you configure the switch as VTP transparent, you can create and modify VLANs, but the changes affect only the individual switch.

When you make a change to the VLAN configuration on a VTP server, the change is propagated to all network devices in the VTP domain. VTP advertisements are transmitted out all Inter-Switch Link (ISL) and IEEE 802.1Q trunk connections.

VTP maps VLANs dynamically across multiple LAN types with unique names and internal index associations. Mapping eliminates unnecessary device administration for network administrators.

Understanding VTP Modes

You can configure a Catalyst 4500 series switch to operate in any one of these VTP modes:

- Server—In VTP server mode, you can create, modify, and delete VLANs and specify other configuration parameters (such as VTP version and VTP pruning) for the entire VTP domain. VTP servers advertise their VLAN configuration to other network devices in the same VTP domain and synchronize their VLAN configuration with other network devices based on advertisements received over trunk links. VTP server is the default mode.
- Client—VTP clients behave the same way as VTP servers, but you cannot create, change, or delete VLANs on a VTP client.
- Transparent—VTP transparent network devices do not participate in VTP. A VTP transparent network device does not advertise its VLAN configuration and does not synchronize its VLAN configuration based on received advertisements. However, in VTP version 2, transparent network devices do forward VTP advertisements that they receive on their trunking LAN interfaces.

Note Catalyst 4500 series switch automatically change from VTP server mode to VTP client mode if the switch detects a failure while writing configuration to NVRAM. If this happens, the switch cannot be returned to VTP server mode until the NVRAM is functioning.

Understanding VTP Advertisements

Each network device in the VTP domain sends periodic advertisements out each trunking LAN interface to a reserved multicast address. VTP advertisements are received by neighboring network devices, which update their VTP and VLAN configurations as necessary.

The following global configuration information is distributed in VTP advertisements:

- VLAN IDs (ISL and 802.1Q)
- Emulated LAN names (for ATM LANE)
- 802.10 SAID values (FDDI)
- VTP domain name
- VTP configuration revision number
- VLAN configuration, including maximum transmission unit (MTU) size for each VLAN
- Frame format

Understanding VTP Version 2

If you use VTP in your network, you must decide whether to use VTP version 1 or version 2.

Note Catalyst 4500 series switch do not support Token Ring or FDDI media. The switch does not forward FDDI, FDDI-Net, Token Ring Concentrator Relay Function [TrCRF], or Token Ring Bridge Relay Function [TrBRF] traffic, but it does propagate the VLAN configuration via VTP.

VTP version 2 supports the following features, which are not supported in version 1:

- Token Ring support—VTP version 2 supports Token Ring LAN switching and VLANs (TrBRF and TrCRF).
- 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.
- Version-Dependent Transparent Mode—In VTP version 1, a VTP transparent network device inspects VTP messages for the domain name and version, and forwards a message only if the version and domain name match. Because only one domain is supported in the supervisor engine software, VTP version 2 forwards VTP messages in transparent mode, without checking the version.
- 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 digest on a received VTP message is correct, its information is accepted without consistency checks.

Understanding VTP Pruning

VTP pruning enhances network bandwidth use by reducing unnecessary flooded traffic, such as broadcast, multicast, and unicast packets. VTP pruning increases available bandwidth by restricting flooded traffic to those trunk links that the traffic must use to access the appropriate network devices. By default, VTP pruning is disabled.

For VTP pruning to be effective, all devices in the management domain must either support VTP pruning or, on devices that do not support VTP pruning, you must manually configure the VLANs allowed on trunks.

Figure 24-1 shows a switched network without VTP pruning enabled. Interface 1 on Switch 1 and Interface 2 on Switch 4 are assigned to the Red VLAN. A broadcast is sent from the host connected to Switch 1. Switch 1 floods the broadcast and every network device in the network receives it, even though Switches 3, 5, and 6 have no interfaces in the Red VLAN.

You can enable pruning globally on the Catalyst 4500 series switch (see the "Enabling VTP Pruning" section on page 24-6).

Figure 24-1 Flooding Traffic without VTP Pruning

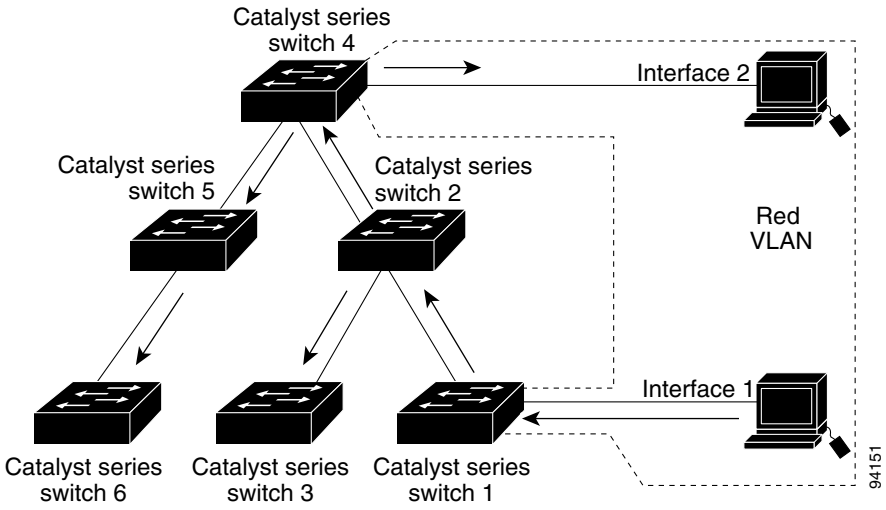
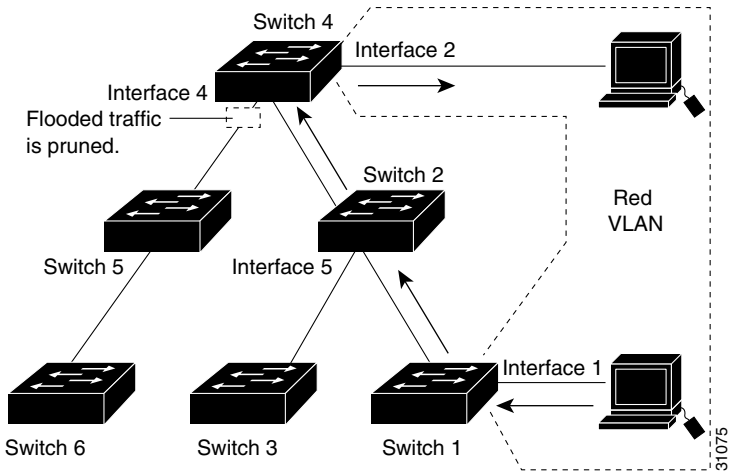


Figure 24-2 shows the same switched network with VTP pruning enabled. The broadcast traffic from Switch 1 is not forwarded to Switches 3, 5, and 6 because traffic for the Red VLAN has been pruned on the links indicated (Interface 5 on Switch 2 and Interface 4 on Switch 4).

Figure 24-2 Flooding Traffic with VTP Pruning



Enabling VTP pruning on a VTP server enables pruning for the entire management domain. VTP pruning takes effect several seconds after you enable it. By default, VLANs 2 through 1000 are eligible for pruning. VTP pruning does not prune traffic from pruning-ineligible VLANs. VLAN 1 is always ineligible for pruning; traffic from VLAN 1 cannot be pruned.

To configure VTP pruning on a trunking LAN interface, use the **switchport trunk pruning vlan** command. VTP pruning operates when a LAN interface is trunking. You can set VLAN pruning eligibility regardless of whether VTP pruning is enabled or disabled for the VTP domain, whether any given VLAN exists, and regardless of whether the LAN interface is currently trunking.

VTP Configuration Guidelines and Restrictions

Follow these guidelines and restrictions when implementing VTP in your network:

- All network devices in a VTP domain must run the same VTP version.
- You must configure a password on each network device in the management domain when VTP is in secure mode.

Caution If you configure VTP in secure mode, the management domain will not function properly if you do not assign a management domain password to each network device in the domain.

- A VTP version 2-capable network device can operate in the same VTP domain as a network device running VTP version 1 if VTP version 2 is disabled on the VTP version 2-capable network device (VTP version 2 is disabled by default).
- Do not enable VTP version 2 on a network device unless all of the network devices in the same VTP domain are version 2-capable. When you enable VTP version 2 on a server, all of the version 2-capable network devices in the domain enable VTP version 2.
- Enabling or disabling VTP pruning on a VTP server enables or disables VTP pruning for the entire management domain.
- Configuring VLANs as eligible for pruning on a Catalyst 4500 series switch affects pruning eligibility for those VLANs on that switch only, not on all network devices in the VTP domain.

VTP Default Configuration

Table 24-1 shows the default VTP configuration.

Table 24-1 VTP Default Configuration

Feature	Default Value
VTP domain name	Null
VTP mode	Server
VTP version 2 enable state	Version 2 is disabled
VTP password	None
VTP pruning	Disabled

Configuring VTP

The following sections describe how to configure VTP:

Configuring VTP Global Parameters

The following sections describe configuring the VTP global parameters:

Configuring a VTP Password

To configure the VTP password, perform this task:

Command	Purpose
`Switch# [no] vtp password` *password_string*	Sets a password for the VTP domain. The password can be from 8 to 64 characters. Uses the **no** keyword to remove the password.

This example shows how to configure a VTP password:

```
Switch#vtp password WATER
Setting device VLAN database password to WATER.
Switch#show vtp password
VTP Password:WATER
Switch#
```

Enabling VTP Pruning

To enable VTP pruning in the management domain, perform this task:

	Command	Purpose
Step 1	`Switch# [no] vtp pruning`	Enables VTP pruning in the management domain. Use the **no** keyword to disable VTP pruning in the management domain.
Step 2	`Switch# show vtp status`	Verifies the configuration.

This example shows how to enable VTP pruning in the management domain:

```
Switch# vtp pruning
Pruning switched ON
```

This example shows how to verify the configuration:

```
Switch# show vtp status | include Pruning
VTP Pruning Mode                : Enabled
Switch#
```

Enabling VTP Version 2

By default, VTP version 2 is disabled on VTP version 2-capable network devices. When you enable VTP version 2 on a server, every VTP version 2-capable network device in the VTP domain enables version 2.

Caution VTP version 1 and VTP version 2 are not interoperable on network devices in the same VTP domain. Every network device in the VTP domain must use the same VTP version. Do not enable VTP version 2 unless every network device in the VTP domain supports version 2.

To enable VTP version 2, perform this task:

	Command	Purpose
Step 1	`Switch# [no] vtp version {1 | 2}`	Enables VTP version 2. Use the **no** keyword to revert to the default.
Step 2	`Switch# show vtp status`	Verifies the configuration.

This example shows how to enable VTP version 2:

```
Switch# vtp version 2
V2 mode enabled.
Switch#
```

This example shows how to verify the configuration:

```
Switch# show vtp status | include V2
VTP V2 Mode                     : Enabled
Switch#
```

Configuring the Switch as a VTP Server

To configure the Catalyst 4500 series switch as a VTP server, perform this task:

	Command	Purpose
Step 1	`Switch# configuration terminal`	Enters configuration mode.
Step 2	`Switch(config)# vtp mode server`	Configures the switch as a VTP server.
Step 3	`Switch(config)# vtp domain` *domain_name*	Defines the VTP domain name, which can be up to 32 characters long.

	Command	Purpose
Step 4	`Switch(config)# end`	Exits VLAN configuration mode.
Step 5	`Switch# show vtp status`	Verifies the configuration.

This example shows how to configure the switch as a VTP server:

```
Switch# configuration terminal
Switch(config)# vtp mode server
Setting device to VTP SERVER mode.
Switch(config)# vtp domain Lab_Network
Setting VTP domain name to Lab_Network
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show vtp status
VTP Version                     : 2
Configuration Revision          : 247
Maximum VLANs supported locally : 1005
Number of existing VLANs        : 33
VTP Operating Mode              : Server
VTP Domain Name                 : Lab_Network
VTP Pruning Mode                : Enabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x45 0x52 0xB6 0xFD 0x63 0xC8 0x49 0x80
Configuration last modified by 0.0.0.0 at 8-12-99 15:04:49
Local updater ID is 172.20.52.34 on interface Gi1/1 (first interface found)
Switch#
```

Configuring the Switch as a VTP Client

To configure the Catalyst 4500 series switch as a VTP client, perform this task:

	Command	Purpose
Step 1	`Switch# configuration terminal`	Enters configuration mode.
Step 2	`Switch(config)# [no] vtp mode client`	Configure the switch as a VTP client. Use the **no** keyword to return to the default setting (server mode).
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show vtp status`	Verifies the configuration.

This example shows how to configure the switch as a VTP client:

```
Switch# configuration terminal
Switch(config)# vtp mode client
Setting device to VTP CLIENT mode.
Switch(config)# exit
Switch#
```

This example shows how to verify the configuration:

```
Switch# show vtp status
VTP Version                     : 2
Configuration Revision          : 247
Maximum VLANs supported locally : 1005
Number of existing VLANs        : 33
VTP Operating Mode              : Client
VTP Domain Name                 : Lab_Network
VTP Pruning Mode                : Enabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x45 0x52 0xB6 0xFD 0x63 0xC8 0x49 0x80
Configuration last modified by 0.0.0.0 at 8-12-99 15:04:49
Switch#
```

Disabling VTP (VTP Transparent Mode)

To disable VTP on the Catalyst 4500 series switch, perform this task:

	Command	Purpose
Step 1	`Switch# configuration terminal`	Enters configuration mode.
Step 2	`Switch(config)# [no] vtp mode transparent`	Disables VTP on the switch.Use the **no** keyword to return to the default setting (server mode).
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show vtp status`	Verifies the configuration.

This example shows how to disable VTP on the switch:

```
Switch# configuration terminal
Switch(config)# vtp transparent
Setting device to VTP mode.
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show vtp status
VTP Version                     : 2
Configuration Revision          : 247
Maximum VLANs supported locally : 1005
Number of existing VLANs        : 33
VTP Operating Mode              : Transparent
VTP Domain Name                 : Lab_Network
VTP Pruning Mode                : Enabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x45 0x52 0xB6 0xFD 0x63 0xC8 0x49 0x80
Configuration last modified by 0.0.0.0 at 8-12-99 15:04:49
Switch#
```

Displaying VTP Statistics

To display VTP statistics, including VTP advertisements sent and received and VTP errors, perform this task:

Command	Purpose
`Switch# show vtp counters`	Displays VTP statistics.

This example shows how to display VTP statistics:

```
Switch# show vtp counters
VTP statistics:
Summary advertisements received    : 7
Subset advertisements received     : 5
Request advertisements received    : 0
Summary advertisements transmitted : 997
Subset advertisements transmitted  : 13
Request advertisements transmitted : 3
Number of config revision errors   : 0
Number of config digest errors     : 0
Number of V1 summary errors        : 0

VTP pruning statistics:

Trunk            Join Transmitted Join Received    Summary advts received from
                                                   non-pruning-capable device
---------------- ---------------- ---------------- ---------------------------
Fa5/8               43071            42766            5
```

CHAPTER 25

Configuring VRF-lite

Virtual Private Networks (VPNs) provide a secure way for customers to share bandwidth over an ISP backbone network. A VPN is a collection of sites sharing a common routing table. A customer site is connected to the service provider network by one or more interfaces, and the service provider associates each interface with a VPN routing table. A VPN routing table is called a VPN routing/forwarding (VRF) table.

With the VRF-lite feature, the Catalyst 4500 series switch supports multiple VPN routing/forwarding instances in customer edge devices. (VRF-lite is also termed multi-VRF CE, or multi-VRF Customer Edge Device). VRF-lite allows a service provider to support two or more VPNs with overlapping IP addresses using one interface.

Note The switch does not use Multiprotocol Label Switching (MPLS) to support VPNs. For information about MPLS VRF, refer to the *Cisco IOS Switching Services Configuration Guide for Release 12.3* at: http://www.cisco.com/univerd/cc/td/doc/product/software/ios123/123cgcr/swit_vcg.htm

This chapter includes these topics:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Understanding VRF-lite

VRF-lite is a feature that enables a service provider to support two or more VPNs, where IP addresses can be overlapped among the VPNs. VRF-lite uses input interfaces to distinguish routes for different VPNs and forms virtual packet-forwarding tables by associating one or more Layer 3 interfaces with each VRF. Interfaces in a VRF can be either physical, such as Ethernet ports, or logical, such as VLAN SVIs, but a Layer 3 interface cannot belong to more than one VRF at any time.

Note VRF-lite interfaces must be Layer 3 interfaces.

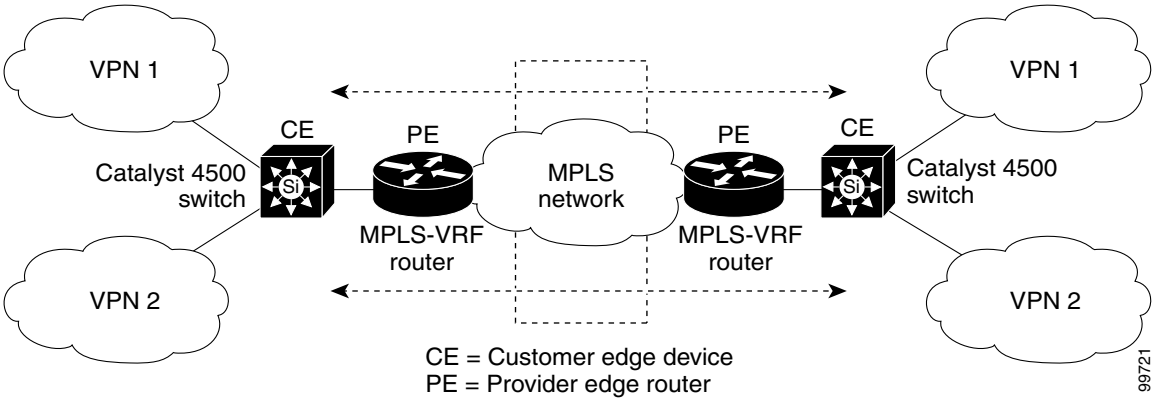
VRF-lite includes these devices:

- Customer edge (CE) devices provide customer access to the service provider network over a data link to one or more provider edge routers. The CE device advertises the site's local routes to the provider edge router and learns the remote VPN routes from it. A Catalyst 4500 switch can be a CE.
- Provider edge (PE) routers exchange routing information with CE devices by using static routing or a routing protocol such as BGP, RIPv1, or RIPv2.
- The PE is only required to maintain VPN routes for those VPNs to which it is directly attached, eliminating the need for the PE to maintain all of the service provider VPN routes. Each PE router maintains a VRF for each of its directly connected sites. Multiple interfaces on a PE router can be associated with a single VRF if all of these sites participate in the same VPN. Each VPN is mapped to a specified VRF. After learning local VPN routes from CEs, a PE router exchanges VPN routing information with other PE routers by using internal BGP (IBPG).
- Provider routers (or core routers) are any routers in the service provider network that do not attach to CE devices.

With VRF-lite, multiple customers can share one CE, and only one physical link is used between the CE and the PE. The shared CE maintains separate VRF tables for each customer and switches or routes packets for each customer based on its own routing table. VRF-lite extends limited PE functionality to a CE device, giving it the ability to maintain separate VRF tables to extend the privacy and security of a VPN to the branch office.

Figure 25-1 shows a configuration where each Catalyst 4500 switch acts as multiple virtual CEs. Because VRF-lite is a Layer 3 feature, each interface in a VRF must be a Layer 3 interface.

Figure 25-1 Catalyst 4500 Switches Acting as Multiple Virtual CEs



This is the packet-forwarding process in a VRF-lite CE-enabled network as shown in Figure 25-1:

- When the CE receives a packet from a VPN, it looks up the routing table based on the input interface. When a route is found, the CE forwards the packet to the PE.
- When the ingress PE receives a packet from the CE, it performs a VRF lookup. When a route is found, the router adds a corresponding MPLS label to the packet and sends it to the MPLS network.
- When an egress PE receives a packet from the network, it strips the label and uses the label to identify the correct VPN routing table. Then the egress PE performs the normal route lookup. When a route is found, it forwards the packet to the correct adjacency.
- When a CE receives a packet from an egress PE, it uses the input interface to look up the correct VPN routing table. If a route is found, the CE forwards the packet within the VPN.

To configure VRF, create a VRF table and specify the Layer 3 interface associated with the VRF. Then configure the routing protocols in the VPN and between the CE and the PE. BGP is the preferred routing protocol used to distribute VPN routing information across the provider's backbone. The VRF-lite network has three major components:

- VPN route target communities—Lists of all other members of a VPN community. You need to configure VPN route targets for each VPN community member.
- Multiprotocol BGP peering of VPN community PE routers—Propagates VRF reachability information to all members of a VPN community. You need to configure BGP peering in all PE routers within a VPN community.
- VPN forwarding—Transports all traffic between all VPN community members across a VPN service-provider network.

Default VRF-lite Configuration

Table 25-1 shows the default VRF configuration.

Table 25-1 Default VRF Configuration

Feature	Default Setting
VRF	Disabled. No VRFs are defined.
Maps	No import maps, export maps, or route maps are defined.
VRF maximum routes	None.
Forwarding table	The default for an interface is the global routing table.

VRF-lite Configuration Guidelines

Consider these points when configuring VRF in your network:

- A switch with VRF-lite is shared by multiple customers, and all customers have their own routing tables.
- Because customers use different VRF tables, the same IP addresses can be reused. Overlapped IP addresses are allowed in different VPNs.
- VRF-lite lets multiple customers share the same physical link between the PE and the CE. Trunk ports with multiple VLANs separate packets among customers. All customers have their own VLANs.
- VRF-lite does not support all MPLS-VRF functionality: label exchange, LDP adjacency, or labeled packets.
- For the PE router, there is no difference between using VRF-lite or using multiple CEs. In Figure 25-1, multiple virtual Layer 3 interfaces are connected to the VRF-lite device.
- The Catalyst 4500 series switch supports configuring VRF by using physical ports, VLAN SVIs, or a combination of both. The SVIs can be connected through an access port or a trunk port.
- A customer can use multiple VLANs as long as they do not overlap with those of other customers. A customer's VLANs are mapped to a specific routing table ID that is used to identify the appropriate routing tables stored on the switch.
- The Layer 3 TCAM resource is shared between all VRFs. To ensure that any one VRF has sufficient CAM space, use the **maximum routes** command.
- A Catalyst 4500 series switch using VRF can support one global network and up to 64 VRFs. The total number of routes supported is limited by the size of the TCAM.
- Most routing protocols (BGP, OSPF, EIGRP, RIP and static routing) can be used between the CE and the PE. However, we recommend using external BGP (EBGP) for these reasons:
  - BGP does not require multiple algorithms to communicate with multiple CEs.
  - BGP is designed for passing routing information between systems run by different administrations.
  - BGP makes it easy to pass attributes of the routes to the CE.
- VRF-lite does not support IGRP and ISIS.
- VRF-lite does not affect the packet switching rate.
- Multicast cannot be configured on the same Layer 3 interface at the same time.
- The **capability vrf-lite** subcommand under **router ospf** should be used when configuring OSPF as the routing protocol between the PE and the CE.

Configuring VRFs

To configure one or more VRFs, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# ip routing`	Enables IP routing.
Step 3	`Switch(config)# ip vrf vrf-name`	Names the VRF, and enter VRF configuration mode.
Step 4	`Switch(config-vrf)# rd route-distinguisher`	Creates a VRF table by specifying a route distinguisher. Enter either an AS number and an arbitrary number (xxx:y) or an IP address and arbitrary number (A.B.C.D:y).
Step 5	`Switch(config-vrf)# route-target {export | import | both} route-target-ext-community`	Creates a list of import, export, or import and export route target communities for the specified VRF. Enter either an AS system number and an arbitrary number (xxx:y) or an IP address and an arbitrary number (A.B.C.D:y). **Note** This command is effective only if BGP is running.
Step 6	`Switch(config-vrf)# import map route-map`	(Optional) Associates a route map with the VRF.
Step 7	`Switch(config-vrf)# interface interface-id`	Enters interface configuration mode and specify the Layer 3 interface to be associated with the VRF. The interface can be a routed port or SVI.
Step 8	`Switch(config-if)# ip vrf forwarding vrf-name`	Associates the VRF with the Layer 3 interface.
Step 9	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 10	`Switch# show ip vrf [brief | detail | interfaces] [vrf-name]`	Verifies the configuration. Display information about the configured VRFs.
Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Note For complete syntax and usage information for the commands, refer to the switch command reference for this release and the *Cisco IOS Switching Services Command Reference for Release 12.2*.

Use the **no ip vrf** *vrf-name* global configuration command to delete a VRF and to remove all interfaces from it. Use the **no ip vrf forwarding** interface configuration command to remove an interface from the VRF.

Configuring a VPN Routing Session

Routing within the VPN can be configured with any supported routing protocol (RIP, OSPF, or BGP) or with static routing. The configuration shown here is for OSPF, but the process is the same for other protocols.

To configure OSPF in the VPN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# router ospf process-id vrf vrf-name`	Enables OSPF routing, specifies a VPN forwarding table, and enters router configuration mode.
Step 3	`Switch(config-router)# log-adjacency-changes`	(Optional) Logs changes in the adjacency state. This is the default state.
Step 4	`Switch(config-router)# redistribute bgp autonomous-system-number subnets`	Sets the switch to redistribute information from the BGP network to the OSPF network.
Step 5	`Switch(config-router)# network network-number area area-id`	Defines a network address and mask on which OSPF runs and the area ID for that network address.
Step 6	`Switch(config-router)# end`	Returns to privileged EXEC mode.
Step 7	`Switch# show ip ospf process-id`	Verifies the configuration of the OSPF network.
Step 8	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Use the **no router ospf** *process-id* **vrf** *vrf-name* global configuration command to disassociate the VPN forwarding table from the OSPF routing process.

Configuring BGP PE to CE Routing Sessions

To configure a BGP PE to CE routing session, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# router bgp autonomous-system-number`	Configures the BGP routing process with the AS number passed to other BGP routers and enters router configuration mode.
Step 3	`Switch(config-router)# network network-number mask network-mask`	Specifies a network and mask to announce using BGP.
Step 4	`Switch(config-router)# redistribute ospf process-id match internal`	Sets the switch to redistribute OSPF internal routes.
Step 5	`Switch(config-router)# network network-number area area-id`	Defines a network address and mask on which OSPF runs and the area ID for that network address.
Step 6	`Switch(config-router-af)# address-family ipv4 vrf vrf-name`	Defines BGP parameters for PE to CE routing sessions and enters VRF address-family mode.
Step 7	`Switch(config-router-af)# neighbor address remote-as as-number`	Defines a BGP session between PE and CE routers.
Step 8	`Switch(config-router-af)# neighbor address activate`	Activates the advertisement of the IPv4 address family.
Step 9	`Switch(config-router-af)# end`	Returns to privileged EXEC mode.

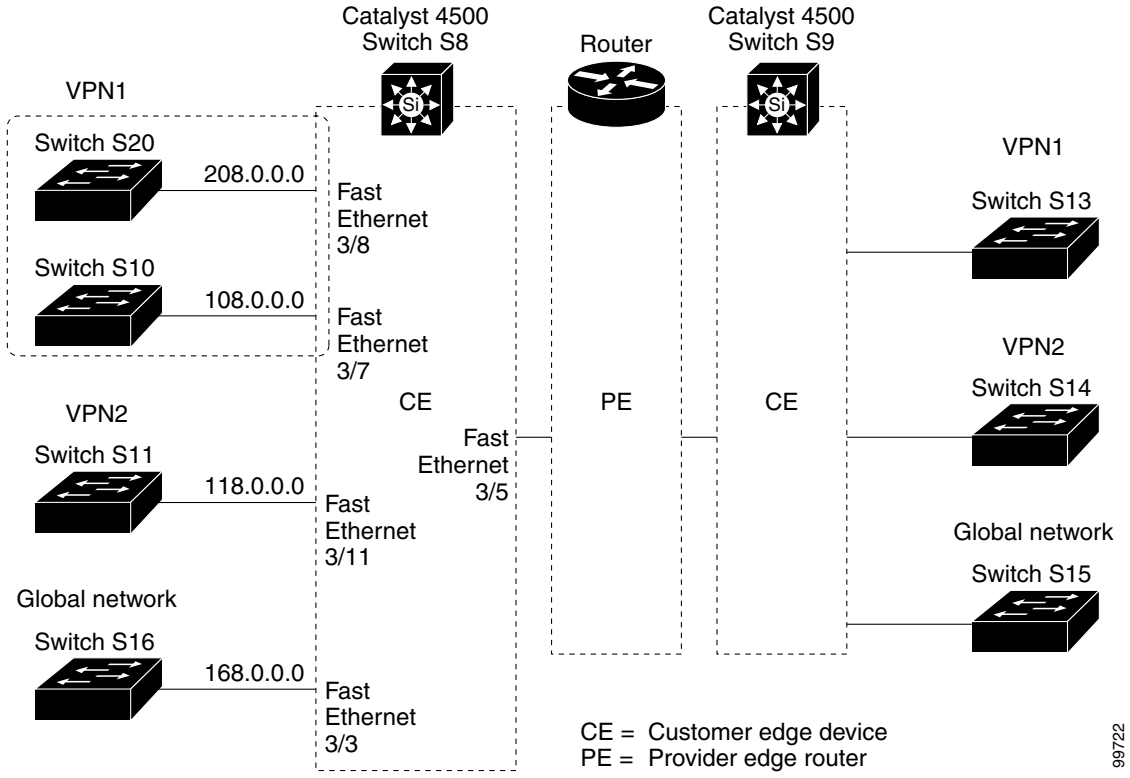
	Command	Purpose
Step 10	`Switch# show ip bgp [ipv4] [neighbors]`	Verifies BGP configuration.
Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Use the **no router bgp** *autonomous-system-number* global configuration command to delete the BGP routing process. Use the command with keywords to delete routing characteristics.

VRF-lite Configuration Example

Figure 25-2 is a simplified example of the physical connections in a network similar to that in Figure 25-1. OSPF is the protocol used in VPN1, VPN2, and the global network. BGP is used in the CE to PE connections. The example commands show how to configure the CE switch S8 and include the VRF configuration for switches S20 and S11 and the PE router commands related to traffic with switch S8. Commands for configuring the other switches are not included but would be similar.

Figure 25-2 VRF-lite Configuration Example



Configuring Switch S8

On switch S8, enable routing and configure VRF.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip routing
Switch(config)# ip vrf v11
Switch(config-vrf)# rd 800:1
Switch(config-vrf)# route-target export 800:1
Switch(config-vrf)# route-target import 800:1
Switch(config-vrf)# exit
Switch(config)# ip vrf v12
Switch(config-vrf)# rd 800:2
Switch(config-vrf)# route-target export 800:2
Switch(config-vrf)# route-target import 800:2
Switch(config-vrf)# exit
```

Configure the loopback and physical interfaces on switch S8. Fast Ethernet interface 3/5 is a trunk connection to the PE. Interfaces 3/7 and 3/11 connect to VPNs:

```
Switch(config)# interface loopback1
Switch(config-if)# ip vrf forwarding v11
Switch(config-if)# ip address 8.8.1.8 255.255.255.0
Switch(config-if)# exit

Switch(config)# interface loopback2
Switch(config-if)# ip vrf forwarding v12
Switch(config-if)# ip address 8.8.2.8 255.255.255.0
Switch(config-if)# exit

Switch(config)# interface FastEthernet3/5
Switch(config-if)# switchport trunk encapsulation dot1q
Switch(config-if)# switchport mode trunk
Switch(config-if)# no ip address
Switch(config-if)# exit

Switch(config)# interface FastEthernet3/8
Switch(config-if)# switchport access vlan 208
Switch(config-if)# no ip address
Switch(config-if)# exit

Switch(config)# interface FastEthernet3/11
Switch(config-if)# switchport trunk encapsulation dot1q
Switch(config-if)# switchport mode trunk
Switch(config-if)# no ip address
Switch(config-if)# exit
```

Configure the VLANs used on switch S8. VLAN 10 is used by VRF 11 between the CE and the PE. VLAN 20 is used by VRF 12 between the CE and the PE. VLANs 118 and 208 are used for VRF for the VPNs that include switch S11 and switch S20, respectively:

```
Switch(config)# interface Vlan10
Switch(config-if)# ip vrf forwarding v11
Switch(config-if)# ip address 38.0.0.8 255.255.255.0
Switch(config-if)# exit

Switch(config)# interface Vlan20
Switch(config-if)# ip vrf forwarding v12
Switch(config-if)# ip address 83.0.0.8 255.255.255.0
Switch(config-if)# exit
```

```
Switch(config)# interface Vlan118
Switch(config-if)# ip vrf forwarding v12
Switch(config-if)# ip address 118.0.0.8 255.255.255.0
Switch(config-if)# exit

Switch(config)# interface Vlan208
Switch(config-if)# ip vrf forwarding v11
Switch(config-if)# ip address 208.0.0.8 255.255.255.0
Switch(config-if)# exit
```

Configure OSPF routing in VPN1 and VPN2:

```
Switch(config)# router ospf 1 vrf vl1
Switch(config-router)# redistribute bgp 800 subnets
Switch(config-router)# network 208.0.0.0 0.0.0.255 area 0
Switch(config-router)# exit
Switch(config)# router ospf 2 vrf vl2
Switch(config-router)# redistribute bgp 800 subnets
Switch(config-router)# network 118.0.0.0 0.0.0.255 area 0
Switch(config-router)# exit
```

Configure BGP for CE to PE routing:

```
Switch(config)# router bgp 800
Switch(config-router)# address-family ipv4 vrf vl2
Switch(config-router-af)# redistribute ospf 2 match internal
Switch(config-router-af)# neighbor 83.0.0.3 remote-as 100
Switch(config-router-af)# neighbor 83.0.0.3 activate
Switch(config-router-af)# network 8.8.2.0 mask 255.255.255.0
Switch(config-router-af)# exit

Switch(config-router)# address-family ipv4 vrf vl1
Switch(config-router-af)# redistribute ospf 1 match internal
Switch(config-router-af)# neighbor 38.0.0.3 remote-as 100
Switch(config-router-af)# neighbor 38.0.0.3 activate
Switch(config-router-af)# network 8.8.1.0 mask 255.255.255.0
Switch(config-router-af)# end
```

Configuring Switch S20

Configure S20 to connect to CE:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip routing
Switch(config)# interface Fast Ethernet 0/7
Switch(config-if)# no switchport
Switch(config-if)# ip address 208.0.0.20 255.255.255.0
Switch(config-if)# exit

Switch(config)# router ospf 101
Switch(config-router)# network 208.0.0.0 0.0.0.255 area 0
Switch(config-router)# end
```

Configuring Switch S11

Configure S11 to connect to CE:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip routing
Switch(config)# interface Gigabit Ethernet 0/3
Switch(config-if)# switchport trunk encapsulation dot1q
Switch(config-if)# switchport mode trunk
Switch(config-if)# no ip address
Switch(config-if)# exit

Switch(config)# interface Vlan118
Switch(config-if)# ip address 118.0.0.11 255.255.255.0
Switch(config-if)# exit

Switch(config)# router ospf 101
Switch(config-router)# network 118.0.0.0 0.0.0.255 area 0
Switch(config-router)# end
```

Configuring the PE Switch S3

On switch S3 (the router), these commands configure only the connections to switch S8:

```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)# ip vrf v1
Router(config-vrf)# rd 100:1
Router(config-vrf)# route-target export 100:1
Router(config-vrf)# route-target import 100:1
Router(config-vrf)# exit

Router(config)# ip vrf v2
Router(config-vrf)# rd 100:2
Router(config-vrf)# route-target export 100:2
Router(config-vrf)# route-target import 100:2
Router(config-vrf)# exit

Router(config)# ip cef
Router(config)# interface Loopback1
Router(config-if)# ip vrf forwarding v1
Router(config-if)# ip address 3.3.1.3 255.255.255.0
Router(config-if)# exit

Router(config)# interface Loopback2
Router(config-if)# ip vrf forwarding v2
Router(config-if)# ip address 3.3.2.3 255.255.255.0
Router(config-if)# exit

Router(config)# interface Fast Ethernet3/0.10
Router(config-if)# encapsulation dot1q 10
Router(config-if)# ip vrf forwarding v1
Router(config-if)# ip address 38.0.0.3 255.255.255.0
Router(config-if)# exit

Router(config)# interface Fast Ethernet3/0.20
Router(config-if)# encapsulation dot1q 20
Router(config-if)# ip vrf forwarding v2
Router(config-if)# ip address 83.0.0.3 255.255.255.0
Router(config-if)# exit
```

```
Router(config)# router bgp 100
Router(config-router)# address-family ipv4 vrf v2
Router(config-router-af)# neighbor 83.0.0.8 remote-as 800
Router(config-router-af)# neighbor 83.0.0.8 activate
Router(config-router-af)# network 3.3.2.0 mask 255.255.255.0
Router(config-router-af)# exit
Router(config-router)# address-family ipv4 vrf v1
Router(config-router-af)# neighbor 83.0.0.8 remote-as 800
Router(config-router-af)# neighbor 83.0.0.8 activate
Router(config-router-af)# network 3.3.1.0 mask 255.255.255.0
Router(config-router-af)# end
```

Displaying VRF-lite Status

To display information about VRF-lite configuration and status, perform one of the following tasks:

Command	Purpose
`Switch# show ip protocols vrf` *vrf-name*	Displays routing protocol information associated with a VRF.
`Switch# show ip route vrf` *vrf-name* [**connected**] [*protocol* [*as-number*]] [**list**] [**mobile**] [**odr**] [**profile**] [**static**] [**summary**] [**supernets-only**]	Displays IP routing table information associated with a VRF.
`Switch# show ip vrf` [**brief** | **detail** | **interfaces**] [*vrf-name*]	Displays information about the defined VRF instances.

Note For more information about the information in the displays, refer to the *Cisco IOS Switching Services Command Reference for Release 12.2* at:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fswtch_r

CHAPTER 26

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 a Catalyst 4500 series switch. It also provides guidelines, procedures, and configuration examples.

This chapter consists of these sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of 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.

QoS selects network traffic (both unicast and multicast), prioritizes it according to its relative importance, and uses congestion avoidance to provide priority-indexed treatment; QoS can also limit the bandwidth used by network traffic. QoS can make network performance more predictable and bandwidth utilization more effective.

This section contains the following subsections:

Prioritization

The QoS implementation for this release is based on the DiffServ 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 (*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 26-1:

- Prioritization values 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 interfaces 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 interfaces 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.

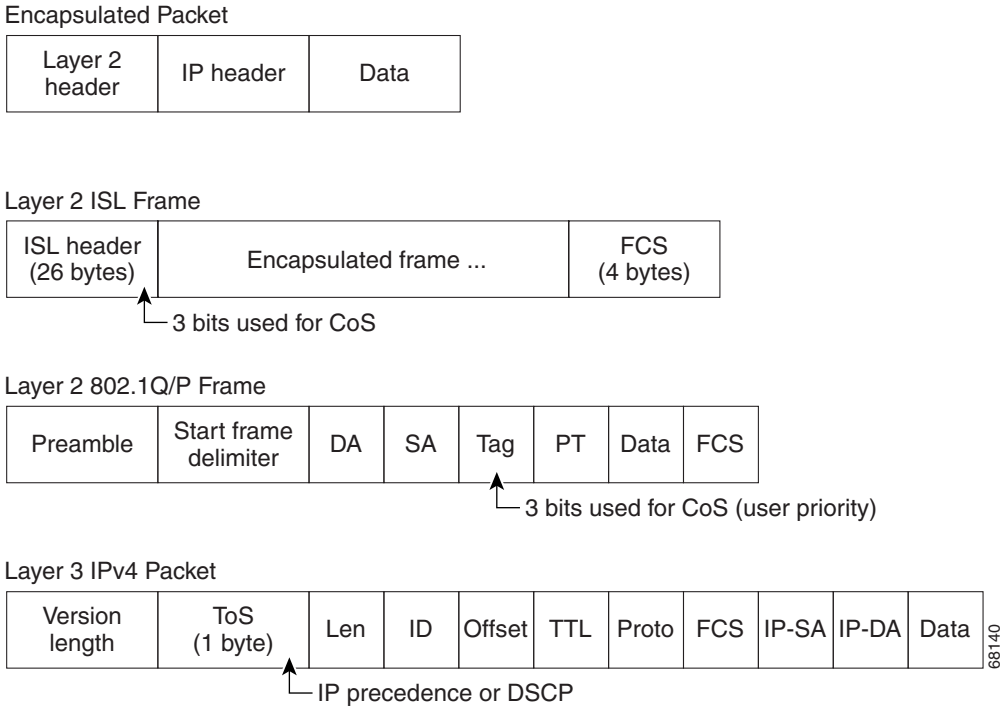
- Prioritization bits in Layer 3 packets:

  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.

Figure 26-1 QoS Classification Layers in Frames and Packets



All switches and routers across 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.

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 you need over incoming and outgoing traffic.

QoS Terminology

The following terms are used when discussing QoS features:

- *Packets* carry traffic at Layer 3.
- *Frames* carry traffic at Layer 2. Layer 2 frames carry Layer 3 packets.
- *Labels* are prioritization values carried in Layer 3 packets and Layer 2 frames:
  - Layer 2 class of service (CoS) values, which range between zero for low priority and seven for high priority:

    Layer 2 Inter-Switch Link (ISL) frame headers have a 1-byte User field that carries an IEEE 802.1p CoS value in the three least significant bits.

    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.

    Other frame types cannot carry Layer 2 CoS values.

Note On interfaces configured as Layer 2 ISL trunks, all traffic is in ISL frames. On interfaces configured as Layer 2 802.1Q trunks, all traffic is in 802.1Q frames except for traffic in the native VLAN.

  - Layer 3 IP precedence values—The IP version 4 specification defines the three most significant bits of the 1-byte ToS field as IP precedence. IP precedence values range between zero for low priority and seven for high priority.
  - Layer 3 differentiated services code point (DSCP) values—The Internet Engineering Task Force (IETF) has defined the six most significant bits of the 1-byte IP ToS field as the DSCP. The per-hop behavior represented by a particular DSCP value is configurable. DSCP values range between 0 and 63. See the "Configuring DSCP Maps" section on page 26-40.

Note Layer 3 IP packets can carry either an IP precedence value or a DSCP value. QoS supports the use of either value, since DSCP values are backwards compatible with IP precedence values. See Table 26-1.

Table 26-1 IP Precedence and DSCP Values

3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP		3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP
	8	7	6	5	4	3				8	7	6	5	4	3	
0	0	0	0	0	0	0	0		4	1	0	0	0	0	0	32
	0	0	0	0	0	1	1			1	0	0	0	0	1	33
	0	0	0	0	1	0	2			1	0	0	0	1	0	34
	0	0	0	0	1	1	3			1	0	0	0	1	1	35
	0	0	0	1	0	0	4			1	0	0	1	0	0	36
	0	0	0	1	0	1	5			1	0	0	1	0	1	37
	0	0	0	1	1	0	6			1	0	0	1	1	0	38
	0	0	0	1	1	1	7			1	0	0	1	1	1	39
1	0	0	1	0	0	0	8		5	1	0	1	0	0	0	40
	0	0	1	0	0	1	9			1	0	1	0	0	1	41
	0	0	1	0	1	0	10			1	0	1	0	1	0	42
	0	0	1	0	1	1	11			1	0	1	0	1	1	43
	0	0	1	1	0	0	12			1	0	1	1	0	0	44
	0	0	1	1	0	1	13			1	0	1	1	0	1	45
	0	0	1	1	1	0	14			1	0	1	1	1	0	46
	0	0	1	1	1	1	15			1	0	1	1	1	1	47
2	0	1	0	0	0	0	16		6	1	1	0	0	0	0	48
	0	1	0	0	0	1	17			1	1	0	0	0	1	49
	0	1	0	0	1	0	18			1	1	0	0	1	0	50
	0	1	0	0	1	1	19			1	1	0	0	1	1	51
	0	1	0	1	0	0	20			1	1	0	1	0	0	52
	0	1	0	1	0	1	21			1	1	0	1	0	1	53
	0	1	0	1	1	0	22			1	1	0	1	1	0	54
	0	1	0	1	1	1	23			1	1	0	1	1	1	55
3	0	1	1	0	0	0	24		7	1	1	1	0	0	0	56
	0	1	1	0	0	1	25			1	1	1	0	0	1	57
	0	1	1	0	1	0	26			1	1	1	0	1	0	58
	0	1	1	0	1	1	27			1	1	1	0	1	1	59
	0	1	1	1	0	0	28			1	1	1	1	0	0	60
	0	1	1	1	0	1	29			1	1	1	1	0	1	61
	0	1	1	1	1	0	30			1	1	1	1	1	0	62
	0	1	1	1	1	1	31			1	1	1	1	1	1	63

1. MSb = most significant bit

- *Classification* is the selection of traffic to be marked.
- *Marking*, according to RFC 2475, is the process of setting a Layer 3 DSCP value in a packet; in this publication, the definition of marking is extended to include setting Layer 2 CoS values.
- *Scheduling* is the assignment of Layer 2 frames to a queue. QoS assigns frames to a queue based on internal DSCP values as shown in Internal DSCP Values, page 26-12.
- *Policing* is limiting bandwidth used by a flow of traffic. Policing can mark or drop traffic.

Basic QoS Model

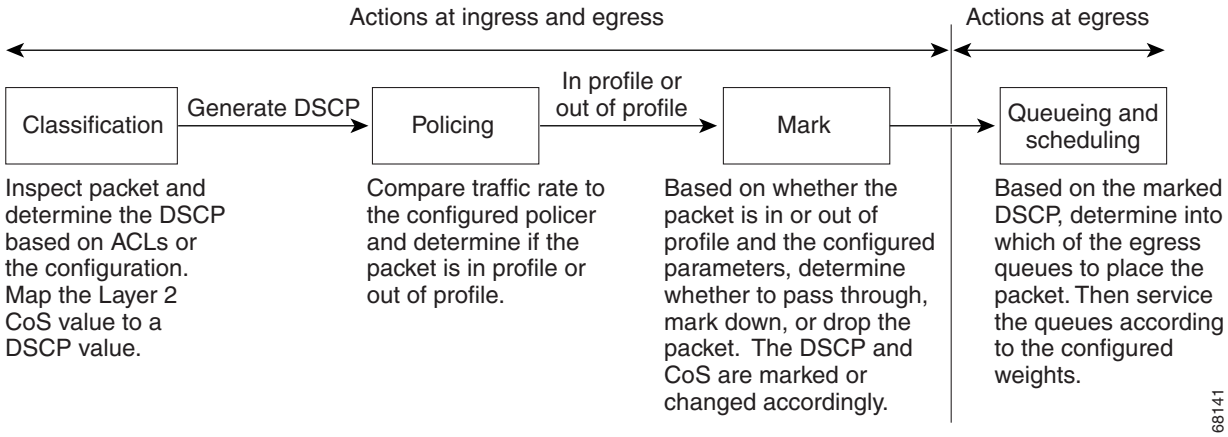
Figure 26-2 shows the basic QoS model. Actions at the ingress and egress interfaces include classifying traffic, policing, and marking:

- Classifying distinguishes one kind of traffic from another. The process generates an internal DSCP for a packet, which identifies all the future QoS actions to be performed on this packet. For more information, see the "Classification" section on page 26-5.
- Policing determines whether a packet is in or out of profile by comparing the traffic rate to the configured policer, which limits the bandwidth consumed by a flow of traffic. The result of this determination is passed to the marker. For more information, see the "Policing and Marking" section on page 26-9.
- Marking evaluates the policer configuration information regarding the action to be taken when a packet is out of profile and decides what to do with the packet (pass through a packet without modification, mark down the DSCP value in the packet, or drop the packet). For more information, see the "Policing and Marking" section on page 26-9.

Actions at the egress interface include queueing and scheduling:

- Queueing evaluates the internal DSCP and determines which of the four egress queues in which to place the packet.
- Scheduling services the four egress (transmit) queues based on the sharing and shaping configuration of the egress (transmit) port. Sharing and shaping configurations are described in the "Queueing and Scheduling" section on page 26-13.

Figure 26-2 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.

You specify which fields in the frame or packet that you want to use to classify incoming traffic.

Classification options are shown in Figure 26-3.

For non-IP traffic, you have the following classification options:

- Use the port default. If the packet is a non-IP packet, assign the default port DSCP value to the incoming packet.
- Trust the CoS value in the incoming frame (configure the port to trust CoS). Then use the configurable CoS-to-DSCP map to generate the internal DSCP value. Layer 2 ISL frame headers carry the CoS value in the three least-significant bits of the 1-byte User field. Layer 2 802.1Q frame headers carry the CoS value in the three most-significant bits of the Tag Control Information field. CoS values range from 0 for low priority to 7 for high priority. If the frame does not contain a CoS value, assign the default port CoS to the incoming frame.

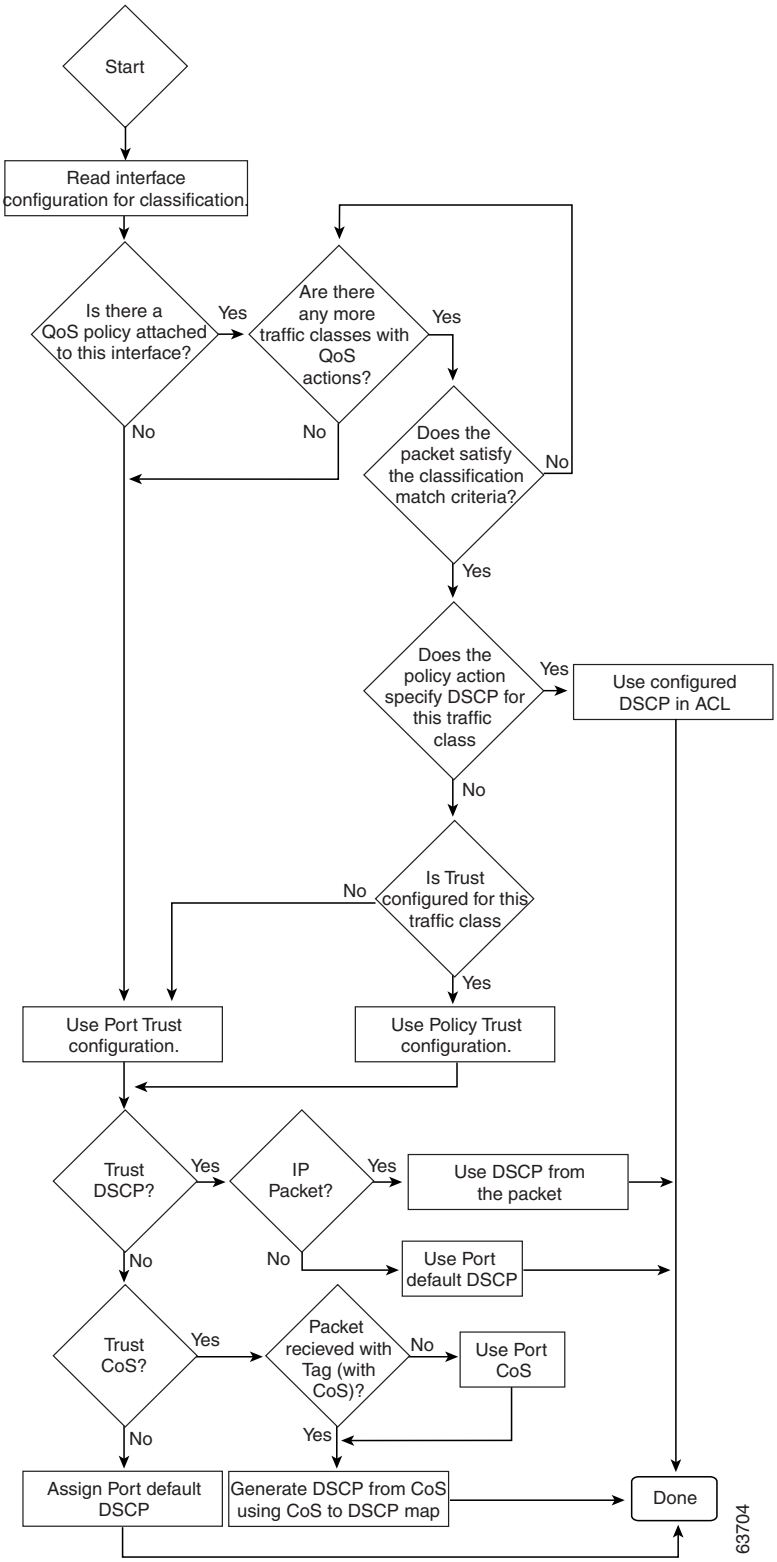
  The trust DSCP configuration is meaningless for non-IP traffic. If you configure a port with trust DSCP and non-IP traffic is received, the switch assigns the default port DSCP.

For IP traffic, you have the following classification options:

- Trust the IP DSCP in the incoming packet (configure the port to trust DSCP), and assign the same DSCP to the packet for internal use. The IETF defines the six most-significant bits of the 1-byte Type of Service (ToS) field as the DSCP. The priority represented by a particular DSCP value is configurable. DSCP values range from 0 to 63.
- Trust the CoS value (if present) in the incoming packet, and generate the DSCP by using the CoS-to-DSCP map.
- Perform the classification based on a configured IP standard or extended ACL, which examines various fields in the IP header. If no ACL is configured, the packet is assigned the default DSCP based on the trust state of the ingress port; otherwise, the policy map specifies the DSCP to assign to the incoming frame.

For information on the maps described in this section, see the "Mapping Tables" section on page 26-13. For configuration information on port trust states, see the "Configuring the Trust State of Interfaces" section on page 26-35.

Figure 26-3 Classification Flowchart



Classification Based on QoS ACLs

A packet can be classified for QoS using multiple match criteria, and the classification can specify whether the packet should match all of the specified match criteria or at least one of the match criteria. To define a QoS classifier, you can provide the match criteria using the 'match' statements in a class-map. In the 'match' statements, you can specify the fields in the packet to match on, or you can use IP standard or IP extended ACLs. For more information, see the "Classification Based on Class Maps and Policy Maps" section on page 26-8.

If the class-map is configured to match all the match criteria, then a packet must satisfy all the match statements in the class-map before the QoS action is taken. The QoS action for the packet is not taken if the packet does not match even one match criterion in the class-map.

If the class-map is configured to match at least one match criterion, then a packet must satisfy at least one of the match statements in the class-map before the QoS action is taken. The QoS action for the packet is not taken if the packet does not match any match criteria in the class-map.

Note When you use the IP standard and IP extended ACLs, the permit and deny ACEs in the ACL have a slightly different meaning in the QoS context.

- If a packet encounters (and satisfies) an ACE with a "permit," then the packet "matches" the match criterion in the QoS classification.
- If a packet encounters (and satisfies) an ACE with a "deny," then the packet "does not match" the match criterion in the QoS classification.
- If no match with a permit action is encountered and all the ACEs have been examined, then the packet "does not match" the criterion in the QoS classification.

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 class map, you can create a policy that defines the QoS actions for a traffic class. 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. For configuration information, see the "Configuring a QoS Policy" section on page 26-27.

Classification Based on Class Maps and Policy Maps

A class map is a mechanism that you use to isolate and name a specific traffic flow (or class) from all other traffic. The class map defines the criterion 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 can specify the QoS actions via a policy map.

A policy map specifies the QoS actions for the traffic classes. Actions can include trusting the CoS or DSCP 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 an interface.

You create a class map by using the **class-map** global configuration command. When you enter the **class-map** command, the switch enters the class-map configuration mode. In this mode, you define the match criteria 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 **trust** or **set** policy-map configuration and policy-map class configuration commands. To make the policy map effective, you attach it to an interface by using the **service-policy** interface configuration command.

The policy map can also contain commands that define the policer, (the bandwidth limitations of the traffic) and the action to take if the limits are exceeded. For more information, see the "Policing and Marking" section on page 26-9.

A policy map also has these characteristics:

- A policy map can contain up to 255 class statements.
- You can have different classes within a policy-map.
- A policy-map trust state supersedes an interface trust state.

For configuration information, see the "Configuring a QoS Policy" section on page 26-27.

Policing and Marking

After a packet is classified and has an internal DSCP value assigned to it, the policing and marking process can begin as shown in Figure 26-4.

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 specifies the action to take for packets that are in or out of profile. These actions, carried out by the marker, include passing through the packet without modification, dropping the packet, or marking down the packet with a new DSCP value that is obtained from the configurable policed-DSCP map. For information on the policed-DSCP map, see the "Mapping Tables" section on page 26-13.

You can create these types of policers:

- Individual

  QoS applies the bandwidth limits specified in the policer separately to each matched traffic class for each port/VLAN to which the policy-map is attached to. You configure this type of policer within a policy map by using the **police** command under policy-map class configuration mode.

- 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 configuration command. You specify the bandwidth limits of the policer by using the **qos aggregate-policer** global configuration command. In this way, the aggregate policer is shared by multiple classes of traffic within a policy map.

When configuring policing and policers, keep these items in mind:

- For IP packets, only the length of the IP payload (the total length field in the IP header) is used by the policer for policing computation. The Layer 2 header and trailer length are not taken into account. For example, for a 64-byte Ethernet II IP packet, only 46 bytes are taken into account for policing (64 bytes - 14 byte Ethernet Header - 4 bytes Ethernet CRC).

  For non-IP packets, the Layer 2 length as specified in the Layer 2 Header is used by the policer for policing computation. To specify additional Layer 2 encapsulation length when policing IP packets, use the **qos account layer2 encapsulation** command.

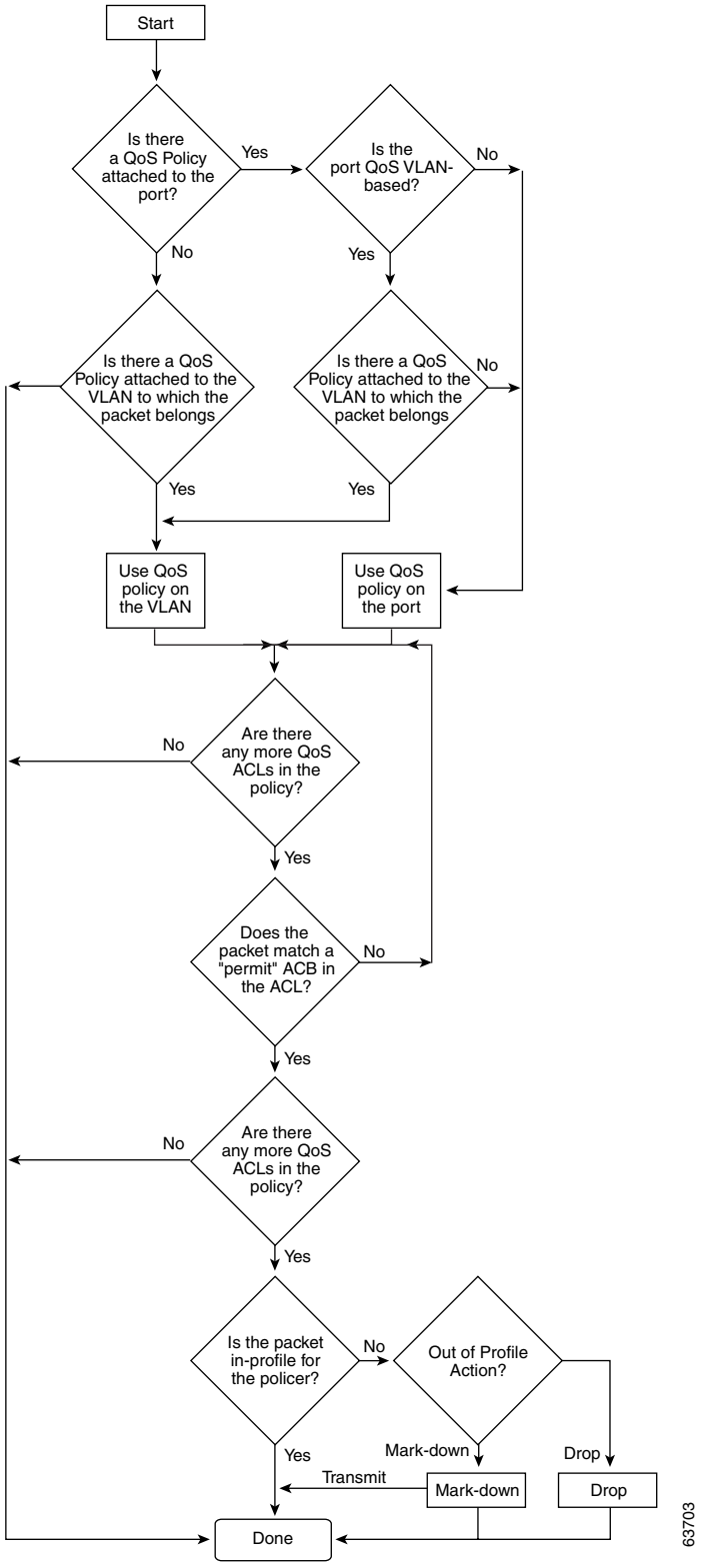
- By default, no policers are configured.
- Only the average rate and committed burst parameters are configurable.
- Policing can occur on ingress and egress interfaces:
  - 1020 policers are supported on ingress
  - 1020 policers are supported on egress

  Note Policers 0 through 3 are reserved.

  - All policers can be individual or aggregate.
  - Two input and two output policers are reserved and used for "no policing" policers.
- On an interface configured for QoS, all traffic received or sent through the interface is classified, policed, and marked according to the policy-map attached to the interface. However, if the interface is configured to use VLAN-based QoS (using the **qos vlan-based** command), the traffic received or sent through the interface is classified, policed, and marked according to the policy-map attached to the VLAN (configured on the VLAN interface) to which the packet belongs. If there is no policy-map attached to the VLAN to which the packet belongs, the policy-map attached to the interface is used.

After you configure the policy map and policing actions, attach the policy to an ingress or egress interface by using the **service-policy** interface configuration command. For configuration information, see the "Configuring a QoS Policy" section on page 26-27 and the "Creating Named Aggregate Policers" section on page 26-25.

Figure 26-4 Policing and Marking Flowchart



Internal DSCP Values

The following sections describe the internal DSCP values:

Internal DSCP Sources

During processing, QoS represents the priority of all traffic (including non-IP traffic) with an internal DSCP value. QoS derives the internal DSCP value from the following:

- For trust-CoS traffic, from received or ingress interface Layer 2 CoS values
- For trust-DSCP traffic, from received or ingress interface DSCP values
- For untrusted traffic, from ingress interface DSCP value

The trust state of traffic is the trust state of the ingress interface unless set otherwise by a policy action for this traffic class.

QoS uses configurable mapping tables to derive the internal 6-bit DSCP value from CoS, which are 3-bit values (see the"Configuring DSCP Maps" section on page 26-40).

Egress ToS and CoS Sources

For egress IP traffic, QoS creates a ToS byte from the internal DSCP value and sends it to the egress interface to be written into IP packets. For **trust-dscp** and **untrusted** IP traffic, the ToS byte includes the original 2 least-significant bits from the received ToS byte.

Note The internal ToS value can mimic an IP precedence value (see Table 26-1 on page 26-4).

For all egress traffic, QoS uses a configurable mapping table to derive a CoS value from the internal ToS value associated with traffic (see the "Configuring the DSCP-to-CoS Map" section on page 26-42). QoS sends the CoS value to be written into ISL and 802.1Q frames.

For traffic received on an ingress interface configured to *trust CoS* using the **qos trust cos** command, the transmit CoS is always the incoming packet CoS (or the ingress interface default CoS if the packet is received untagged).

When the interface trust state is not configured to *trust dscp* using the **qos trust dscp** command, the security and QoS ACL classification will always use the interface DSCP and not the incoming packet DSCP.

Mapping Tables

During QoS processing, the switch represents the priority of all traffic (including non-IP traffic) with an internal DSCP value:

- During classification, QoS uses configurable mapping tables to derive the internal DSCP (a 6-bit value) from received CoS. These maps include the CoS-to-DSCP map.
- During policing, QoS can assign another DSCP value to an IP or non-IP packet (if the packet is out of profile and the policer specifies a marked down DSCP value). This configurable map is called the policed-DSCP map.
- Before the traffic reaches the scheduling stage, QoS uses the internal DSCP to select one of the four egress queues for output processing. The DSCP-to-egress queue mapping can be configured using the **qos map dscp to tx-queue** command.

The CoS-to-DSCP and DSCP-to-CoS map have default values that might or might not be appropriate for your network.

For configuration information, see the "Configuring DSCP Maps" section on page 26-40.

Queueing and Scheduling

Each physical port has four transmit queues (egress queues). Each packet that needs to be transmitted is enqueued to one of the transmit queues. The transmit queues are then serviced based on the transmit queue scheduling algorithm.

Once the final transmit DSCP is computed (including any markdown of DSCP), the transmit DSCP to transmit queue mapping configuration determines the transmit queue. The packet is placed in the transmit queue of the transmit port, determined from the transmit DSCP. Use the **qos map dscp to tx-queue** command to configure the transmit DSCP to transmit queue mapping. The transmit DSCP is the internal DSCP value if the packet is a non-IP packet as determined by the QoS policies and trust configuration on the ingress and egress ports.

For configuration information, see the "Configuring Transmit Queues" section on page 26-38.

Active Queue Management

Active queue management (AQM) is the pro-active approach of informing you about congestion before a buffer overflow occurs. AQM is done using Dynamic buffer limiting (DBL). DBL tracks the queue length for each traffic flow in the switch. When the queue length of a flow exceeds its limit, DBL will drop packets or set the Explicit Congestion Notification (ECN) bits in the packet headers.

DBL classifies flows in two categories, adaptive and aggressive. Adaptive flows reduce the rate of packet transmission once it receives congestion notification. Aggressive flows do not take any corrective action in response to congestion notification. For every active flow the switch maintains two parameters, "buffersUsed" and "credits". All flows start with "max-credits", a global parameter. When a flow with credits less than "aggressive-credits" (another global parameter) it is considered an aggressive flow and is given a small buffer limit called "aggressiveBufferLimit".

Queue length is measured by the number of packets. The number of packets in the queue determines the amount of buffer space that a flow is given. When a flow has a high queue length the computed value is lowered. This allows new incoming flows to receive buffer space in the queue. This allows all flows to get a proportional share of packets through the queue.

Sharing Link Bandwidth Among Transmit Queues

The four transmit queues for a transmit port share the available link bandwidth of that transmit port. You can set the link bandwidth to be shared differently among the transmit queues using **bandwidth** command in interface transmit queue configuration mode. With this command, you assign the minimum guaranteed bandwidth for each transmit queue.

By default, all queues are scheduled in a round robin manner.

Bandwidth can only be configured on these ports:

- Uplink ports on supervisor engines
- Ports on the WS-X4306-GB module
- The 2 1000BASE-X ports on the WS-X4232-GB-RJ module
- The first 2 ports on the WS-X4418-GB module
- The two 1000BASE-X ports on the WS-X4412-2GB-TX module

Strict Priority / Low Latency Queueing

You can configure transmit queue 3 on each port with higher priority using the **priority high** tx-queue configuration command in the interface configuration mode. When transmit queue 3 is configured with higher priority, packets in transmit queue 3 are scheduled ahead of packets in other queues.

When transmit queue 3 is configured at a higher priority, the packets are scheduled for transmission before the other transmit queues only if it has not met the allocated bandwidth sharing configuration. Any traffic that exceeds the configured shape rate will be queued and transmitted at the configured rate. If the burst of traffic, exceeds the size of the queue, packets will be dropped to maintain transmission at the configured shape rate.

Traffic Shaping

Traffic Shaping provides the ability to control the rate of outgoing traffic in order to make sure that the traffic conforms to the maximum rate of transmission contracted for it. Traffic that meets certain profile can be shaped to meet the downstream traffic rate requirements to handle any data rate mismatches.

Each transmit queue can be configured to transmit a maximum rate using the **shape** command. The configuration allows you to specify the maximum rate of traffic. Any traffic that exceeds the configured shape rate will be queued and transmitted at the configured rate. If the burst of traffic exceeds the size of the queue, packets will be dropped to maintain transmission at the configured shape rate.

Packet Modification

A packet is classified, policed, and queued to provide QoS. Packet modifications can occur during this process:

- For IP packets, classification involves assigning a DSCP to the packet. However, the packet is not modified at this stage; only an indication of the assigned DSCP is carried along. The reason for this is that QoS classification and ACL lookup occur in parallel, and it is possible that the ACL specifies that the packet should be denied and logged. In this situation, the packet is forwarded with its original DSCP to the CPU, where it is again processed through ACL software.

- For non-IP packets, classification involves assigning an internal DSCP to the packet, but because there is no DSCP in the non-IP packet, no overwrite occurs. Instead, the internal DSCP is used both for queueing and scheduling decisions and for writing the CoS priority value in the tag if the packet is being transmitted on either an ISL or 802.1Q trunk port.
- 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.

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 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 content or size, and sends it from a single queue.)

When you enable auto-QoS, it automatically classifies traffic based on 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 identify ports that receive trusted voice over IP (VoIP) traffic through an uplink. Auto-QoS then performs these functions:

- Detects the presence or absence of IP phones
- Configures QoS classification
- Configures egress queues

These sections describe how to configure auto-QoS on your switch:

- Generated Auto-QoS Configuration, page 26-15
- Effects of Auto-QoS on the Configuration, page 26-16
- Configuration Guidelines, page 26-17
- Enabling Auto-QoS for VoIP, page 26-17

Generated Auto-QoS Configuration

By default, auto-QoS is disabled on all interfaces.

When you enable the auto-QoS feature on the first interface, these automatic actions occur:

- QoS is globally enabled (**qos** global configuration command).
- DBL is enabled globally (**qos dbl** global configuration command)
- When you enter the **auto qos voip trust** interface configuration command, the ingress classification on the specified interface is set to trust the CoS label received in the packet if the specified interface is configured as Layer 2 (and is set to trust DSCP if the interface is configured as Layer 3). (See Table 26-2.)

- When you enter the **auto qos voip cisco-phone** interface configuration command, the trusted boundary feature is enabled. It 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 interface is set to trust the cos label received in the packet, because some old phones do not mark dscp. When a Cisco IP phone is absent, the ingress classification is set to not trust the cos label in the packet.

  For information about the trusted boundary feature, see the "Configuring a Trusted Boundary to Ensure Port Security" section on page 26-24.

When you enable auto-QoS by using the **auto qos voip cisco-phone** or the **auto qos voip trust** interface configuration commands, the switch automatically generates a QoS configuration based on the traffic type and ingress packet label and applies the commands listed in Table 26-2 to the interface.

Table 26-2 Generated Auto-QoS Configuration

Description	Automatically Generated Command

The switch automatically enables standard QoS and DBL configures the cos-to-DSCP map (maps CoS values in incoming packets to a DSCP value).	`Switch(config)# qos`
	`Switch(config)# qos map cos 3 to 26`
	`Switch(config)# qos dbl`
	`Switch(config)# qos map cos 5 to 46`

The switch automatically configures the DSCP-to-Tx-queue mapping.	`Switch(config)# qos map dscp 24 25 26 27 b28 29 30 31 to tx-queue 4` `Switch(config)# qos map dscp 32 33 34 35 36 37 38 39 to tx-queue 4`

The switch automatically sets the ingress classification on the interface to trust the CoS/DSCP value received in the packet.	`Switch(config-if)# qos trust cos`
	`or`
	`Switch(config-if)# qos trust dscp`

The switch automatically creates a QoS service policy, enables DBL on the policy, and attaches it to the interface.	`Switch(config)# policy-map autoqos-voip-policy`
	`Switch(config-pmap)# class class-default`
	`Switch(config-pmap-c)# dbl`

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)# qos trust device cisco-phone`

The switch assigns a higher priority for queue 3. Limit for shaping on queue 3 is selected so that it is 33 percent of the link speed. Configure shaping as 33 percent on those ports where sharing is supported.
This procedure ensures that the higher-priority queue does not starve other queues.
	`Switch(config-if)# tx-queue 3`
	`Switch(config-if-tx-queue)# priority high`
	`Switch(config-if-tx-queue)# shape percent 33`
	`Switch(config-if-tx-queue)# bandwidth percent 33`

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.

Configuration Guidelines

Before configuring auto-QoS, you should be aware of this information:

- In this release, auto-QoS configures the switch only for VoIP with Cisco IP phones.
- To take advantage of the auto-QoS defaults, do not configure any standard-QoS commands before entering the auto-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.
- You can enable auto-QoS on static, dynamic-access, voice VLAN access, and trunk ports.
- By default, the CDP is enabled on all interfaces. For auto-QoS to function properly, do not disable the CDP.
- To enable **auto qos voip trust** on Layer 3 interfaces, change the port to Layer 3, then apply auto-QoS to make it trust DSCP.

Enabling Auto-QoS for VoIP

To enable auto-QoS for VoIP within a QoS domain, perform this task:

	Command	Purpose
Step 1	`Switch# debug auto qos`	(Optional) Enables debugging for auto-QoS. When debugging is enabled, the switch displays the QoS commands that are automatically generated and applied when auto-QoS is enabled or disabled.
Step 2	`Switch# configure terminal`	Enters global configuration mode.
Step 3	`Switch(config)# interface` *interface-id*	Enters interface configuration mode, and specify the interface that is connected to a Cisco IP phone or the uplink interface that is connected to another switch or router in the interior of the network.
Step 4	`Switch(config-if)# auto qos voip {cisco-phone | trust}`	Enables auto-QoS. The keywords have these meanings: • **cisco-phone**—If the interface is connected to a Cisco IP phone, the cos labels of incoming packets are trusted only when the telephone is detected. • **trust**—The uplink interface is connected to a trusted switch or router, and the VoIP traffic classification in the ingress packet is trusted.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show auto qos interface` *interface-id*	Verifies your entries. This command displays the auto-QoS configuration that was initially applied; it does not display any user changes to the configuration that might be in effect.

To disable auto-QoS on an interface, use the **no auto qos voip** interface configuration command. When you enter this command, the switch changes the auto-QoS settings to the standard-QoS default settings for that interface. It will not change any global configuration performed by auto-QoS. Global configuration remains the same.

This example shows how to enable auto-QoS and to trust the CoS labels in incoming packets when the device connected to Fast Ethernet interface 1/1 is detected as a Cisco IP phone:

```
Switch(config)# interface fastethernet1/1
Switch(config-if)# auto qos voip cisco-phone
```

This example shows how to enable auto-QoS and to trust the cos/dscp labels in incoming packets when the switch or router connected to Gigabit Ethernet interface 1/1 is a trusted device:

```
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# auto qos voip trust
```

This example shows how to display the QoS commands that are automatically generated when auto-QoS is enabled:

```
Switch# debug auto qos
AutoQoS debugging is on
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# auto qos voip cisco-phone
```

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:

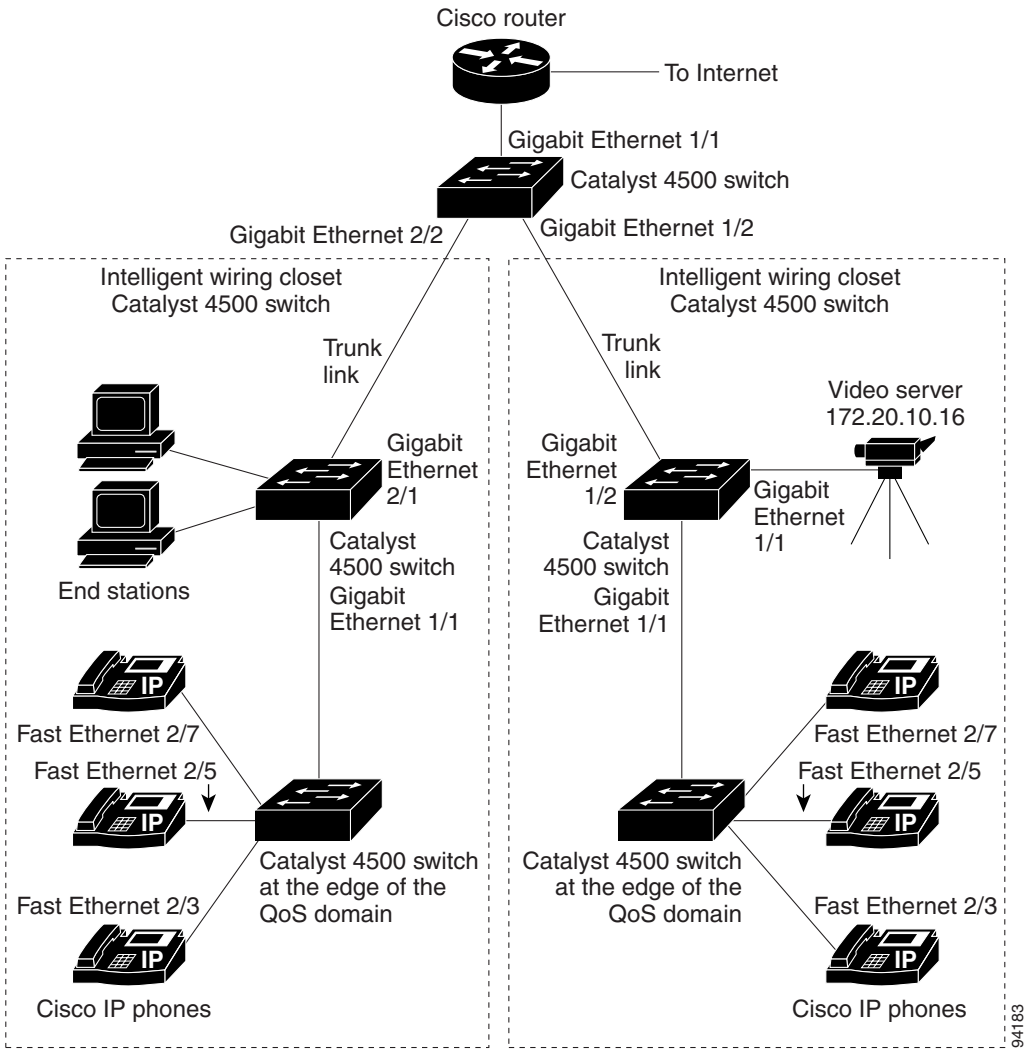
- **show qos**
- **show qos map**
- **show qos interface** [*interface-id*]

For more information about these commands, refer to the command reference for this release.

Auto-QoS Configuration Example

This section describes how you could implement auto-QoS in a network, as shown in Figure 26-5.

Figure 26-5 Auto-QoS Configuration Example Network



The intelligent wiring closets in Figure 26-5 are composed of Catalyst 4500 switches. The object of this example is to prioritize the VoIP traffic over all other traffic. To do so, enable auto-QoS on the switches at the edge of the QoS domains in the wiring closets.

Note 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.

To configure the switch at the edge of the QoS domain to prioritize the VoIP traffic over all other traffic, perform this task:

	Command	Purpose
Step 1	`Switch# debug auto qos`	Enables debugging for auto-QoS. When debugging is enabled, the switch displays the QoS configuration that is automatically generated when auto-QoS is enabled.
Step 2	`Switch# configure terminal`	Enters global configuration mode.
Step 3	`Switch(config)# cdp enable`	Enables CDP globally. By default, CDP is enabled.
Step 4	`Switch(config)# interface fastethernet2/3`	Enters interface configuration mode.
Step 5	`Switch(config-if)# auto qos voip cisco-phone`	Enables auto-QoS on the interface, and specifies that the interface is connected to a Cisco IP phone. The CoS labels of incoming packets are trusted only when the IP phone is detected.
Step 6	`Switch(config)# interface fastethernet2/5`	Enters interface configuration mode.
Step 7	`Switch(config)# auto qos voip cisco-phone`	Enables auto-QoS on the interface, and specifies that the interface is connected to a Cisco IP phone.
Step 8	`Switch(config)# interface fastethernet2/7`	Enters interface configuration mode.
Step 9	`Switch(config)# auto qos voip cisco-phone`	Enables auto-QoS on the interface, and specifies that the interface is connected to a Cisco IP phone.
Step 10	`Switch(config)# interface gigabit1/1`	Enters interface configuration mode.
Step 11	`Switch(config)# auto qos voip trust`	Enables auto-QoS on the interface, and specifies that the interface is connected to a trusted router or switch.
Step 12	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 13	`Switch# show auto qos`	Verifies your entries. This command displays the auto-QoS configuration that is initially applied; it does not display any user changes to the configuration that might be in effect. For information about the QoS configuration that might be affected by auto-QoS, see the "Displaying Auto-QoS Information" section on page 26-18.
Step 14	`Switch# show auto qos interface` *interface-id*	Verifies your entries. This command displays the auto-QoS configuration that was initially applied; it does not display any user changes to the configuration that might be in effect.
Step 15	`Switch# copy running-config startup-config`	Saves the **auto qos voip** interface configuration commands and the generated auto-QoS configuration in the configuration file.

Configuring QoS

Before configuring 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 describe how to configure QoS on the Catalyst 4000 family switch:

Default QoS Configuration

Table 26-3 shows the QoS default configuration.

Table 26-3 QoS Default Configuration

Feature	Default Value
Global QoS configuration	Disabled
Interface QoS configuration (port based)	Enabled when QoS is globally enabled
Interface CoS value	0
Interface DSCP value	0

Table 26-3 QoS Default Configuration (continued)

Feature	Default Value
CoS to DSCP map (DSCP set from CoS values)	CoS 0 = DSCP 0 CoS 1 = DSCP 8 CoS 2 = DSCP 16 CoS 3 = DSCP 24 CoS 4 = DSCP 32 CoS 5 = DSCP 40 CoS 6 = DSCP 48 CoS 7 = DSCP 56
DSCP to CoS map (CoS set from DSCP values)	DSCP 0–7 = CoS 0 DSCP 8–15 = CoS 1 DSCP 16–23 = CoS 2 DSCP 24–31 = CoS 3 DSCP 32–39 = CoS 4 DSCP 40–47 = CoS 5 DSCP 48–55 = CoS 6 DSCP 56–63 = CoS 7
Marked-down DSCP from DSCP map (Policed-DSCP)	Marked-down DSCP value equals original DSCP value (no markdown)
Policers	None
Policy maps	None
Transmit queue sharing	1/4 of the link bandwidth
Transmit queue size	1/4 of the transmit queue entries for the port. The transmit queue size of a port depends on the type of port, ranging from 240 packets per transmit queue to 1920 packets per transmit queue.
Transmit queue shaping	None
DCSP-to-Transmit queue map	DSCP 0–15 Queue 1 DSCP 16–31 Queue 2 DSCP 32–47 Queue 3 DSCP 48–63 Queue 4
High priority transmit queue	Disabled
With QoS disabled	
Interface trust state	Trust DSCP
With QoS enabled	With QoS enabled and all other QoS parameters at default values, QoS sets IP DSCP to zero and Layer 2 CoS to zero in all traffic transmitted.
Interface trust state	Untrusted

Configuration Guidelines

Before beginning the QoS configuration, you should be aware of this information:

- If you have EtherChannel ports configured on your switch, you must configure QoS classification and policing on the EtherChannel. The transmit queue configuration must be configured on the individual physical ports that comprise the EtherChannel.
- It is not possible to match IP fragments against configured IP extended ACLs to enforce QoS. IP fragments are transmitted as best effort. IP fragments are denoted by fields in the IP header.
- It is not possible to match IP options against configured IP extended ACLs to enforce QoS. These packets are sent to the CPU and processed by software. IP options are denoted by fields in the IP header.
- Control traffic (such as spanning-tree BPDUs and routing update packets) received by the switch are subject to all ingress QoS processing.
- If you want to use the set command in the policy map, you must enable IP routing (disabled by default) and configure an IP default route to send traffic to the next-hop device that is capable of forwarding.

Note QoS processes both unicast and multicast traffic.

Enabling QoS Globally

To enable QoS globally, perform this task:

	Command	Purpose
Step 1	`Switch(config)# qos`	Enables QoS on the switch. Use the **no qos** command to globally disable QoS.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show qos`	Verifies the configuration.

This example shows how to enable QoS globally:

```
Switch(config)# qos
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos
  QoS is enabled globally

Switch#
```

Configuring a Trusted Boundary to Ensure Port Security

In a typical network, you connect a Cisco IP phone to a switch port as discussed in Chapter 27, "Configuring Voice Interfaces." 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 determines the priority of the packet. For most Cisco IP phone configurations, the traffic sent from the telephone to the switch is trusted to ensure that voice traffic is properly prioritized over other types of traffic in the network. By using the **qos trust cos** interface configuration command, you can configure the switch port to which the telephone is connected to trust the CoS labels of all traffic received on that port.

In some situations, you also might connect a PC or workstation to the IP phone. In this case, 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. With this command, you can prevent a PC from taking advantage of a high-priority data queue.

However, if a user bypasses the telephone and connects the PC directly to the switch, the CoS labels generated by the PC are trusted by the switch (because of the trusted CoS setting) and can allow misuse of high-priority queues. The trusted boundary feature solves this problem by using the 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.

Note If CDP is not running on the switch globally or on the port in question, trusted boundary will not work.

When you configure trusted boundary on a port, trust is disabled. Then, when a phone is plugged in and detected, trust is enabled. (It may take a few minutes to detect the phone.) Now, when a phone is unplugged (and not detected), the trusted boundary feature disables the trusted setting on the switch port and prevents misuse of a high-priority queue.

To enable trusted boundary on a port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode, and specifies the interface connected to the IP phone. Valid interfaces include physical interfaces.
Step 3	`Switch(config)# qos trust [cos | dscp]`	Configures the interface to trust the CoS value in received traffic. By default, the port is not trusted.
Step 4	`Switch(config)# qos trust device cisco-phone`	Specifies that the Cisco IP phone is a trusted device. You cannot enable both trusted boundary and auto-QoS (**auto qos voip** interface configuration command) at the same time; they are mutually exclusive.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show qos interface interface-id`	Verifies your entries.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To disable the trusted boundary feature, use the **no qos trust device cisco-phone** interface configuration command.

Enabling Dynamic Buffer Limiting

To enable DBL globally on the switch, perform this task:

	Command	Purpose
Step 1	`Switch(config)# qos dbl`	Enables DBL on the switch. Use the **no qos dbl** command to disable AQM.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show qos dbl`	Verifies the configuration.

This example shows how to enable DBL globally:

```
Switch(config)# qos dbl
Global DBL enabled
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos dbl
DBL is enabled globally
DBL flow includes vlan
DBL flow includes l4-ports
DBL does not use ecn to indicate congestion
DBL exceed-action mark probability:15%
DBL max credits:15
DBL aggressive credit limit:10
DBL aggressive buffer limit:2 packets
Switch#
```

Creating Named Aggregate Policers

To create a named aggregate policer, perform this task:

Command	Purpose
`Switch(config)# qos aggregate-policer` *policer_name rate burst* `[[conform-action {transmit | drop}] [exceed-action {transmit | drop | policed-dscp-transmit}]]`	Creates a named aggregate policer.

An aggregate policer can be applied to one or more interfaces. However, if you apply the same policer to the input direction on one interface and to the output direction on a different interface, then you have created the equivalent of two different aggregate policers in the switching engine. Each policer has the same policing parameters, with one policing the ingress traffic on one interface and the other policing the egress traffic on another interface. If an aggregate policer is applied to multiple interfaces in the same direction, then only one instance of the policer is created in the switching engine.

Similarly, an aggregate policer can be applied to a port or to a VLAN. If you apply the same aggregate policer to a port and to a VLAN, then you have created the equivalent of two different aggregate policers in the switching engine. Each policer has the same policing parameters, with one policing the traffic on the configured port and the other policing the traffic on the configured VLAN. If an aggregate policer is applied to only ports or only VLANs, then only one instance of the policer is created in the switching engine.

In effect, if you apply a single aggregate policer to ports and VLANs in different directions, then you have created the equivalent of four aggregate policers; one for all ports sharing the policer in input direction, one for all ports sharing the policer in output direction, one for all VLANs sharing the policer in input direction and one for all VLANs sharing the policer in output direction.

When creating a named aggregate policer, note the following:

- The valid range of values for the *rate* parameter is as follows:
  - Minimum—32 kilobits per second
  - Maximum—32 gigabits per second

  See the "Configuration Guidelines" section on page 26-23.
- Rates can be entered in bits-per-second, or you can use the following abbreviations:
  - k to denote 1000 bps
  - m to denote 1000000 bps
  - g to denote 1000000000 bps

  Note You can also use a decimal point. For example, a rate of 1,100,000 bps can be entered as 1.1m.
- The valid range of values for the *burst* parameter is as follows:
  - Minimum—1 kilobyte
  - Maximum—512 megabytes
- Bursts can be entered in bytes, or you can use the following abbreviation:
  - k to denote 1000 bytes
  - m to denote 1000000 bytes
  - g to denote 1000000000 bytes

  Note You can also use a decimal point. For example, a burst of 1,100,000 bytes can be entered as 1.1m.
- Optionally, you can specify a conform action for matched in-profile traffic as follows:
  - The default conform action is **transmit**.
  - Enter the **drop** keyword to drop all matched traffic.

  Note When you configure **drop** as the conform action, QoS configures **drop** as the exceed action.
- Optionally, for traffic that exceeds the CIR, you can specify an exceed action as follows:
  - The default exceed action is **drop**.
  - Enter the **policed-dscp-transmit** keyword to cause all matched out-of-profile traffic to be marked down as specified in the markdown map.
  - For no policing, enter the **transmit** keyword to transmit all matched out-of-profile traffic.
- You can enter the **no qos aggregate-policer** *policer_name* command to delete a named aggregate policer.

This example shows how to create a named aggregate policer with a 10 Mbps rate limit and a 1-MB burst size that transmits conforming traffic and marks down out-of-profile traffic.

```
Switch(config)# qos aggregate-policer aggr-1 10000000 1000000 conform-action transmit
exceed-action policed-dscp-transmit
Switch(config)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos aggregate-policer aggr-1
Policer aggr-1
  Rate(bps):10000000 Normal-Burst(bytes):1000000
  conform-action:transmit exceed-action:policed-dscp-transmit
  Policymaps using this policer:
Switch#
```

Configuring a QoS Policy

The following subsections describe QoS policy configuration:

Note QoS policies process both unicast and multicast traffic.

Overview of QoS Policy Configuration

Configuring a QoS policy requires you to configure traffic classes and the policies that will be applied to those traffic classes, and to attach the policies to interfaces using these commands:

- **access-list** (optional for IP traffic—you can filter IP traffic with **class-map** commands):
  - QoS supports these access list types:

Protocol	Numbered Access Lists?	Extended Access Lists?	Named Access Lists?
IP	Yes: 1 to 99 1300 to 1999	Yes: 100 to 199 2000 to 2699	Yes

  - See Chapter 32, “Configuring Network Security with ACLs,” for information about ACLs on the Catalyst 4500 series switches.
- **class-map** (optional)—Enter the **class-map** command to define one or more traffic classes by specifying the criteria by which traffic is classified (see the “Configuring a Class Map (Optional)” section on page 26-28).

- **policy-map**—Enter the **policy-map** command to define the following for each class of traffic:
  - Internal DSCP source
  - Aggregate or individual policing and marking
- **service-policy**—Enter the **service-policy** command to attach a policy map to an interface.

Configuring a Class Map (Optional)

The following subsections describe class map configuration:

- Creating a Class Map, page 26-28
- Configuring Filtering in a Class Map, page 26-28

Enter the **class-map** configuration command to define a traffic class and the match criteria that will be used to identify traffic as belonging to that class. Match statements can include criteria such as an ACL, an IP precedence value, or a DSCP value. The match criteria are defined with one match statement entered within the class-map configuration mode.

Creating a Class Map

To create a class map, perform this task:

Command	Purpose
`Switch(config)# [no] class-map [match-all | match-any] class_name`	Creates a named class map. Use the **no** keyword to delete a class map.

Configuring Filtering in a Class Map

To configure filtering in a class map, perform one of these tasks:

Command	Purpose
`Switch(config-cmap)# [no] match access-group {acl_index | name acl_name}`	(Optional) Specifies the name of the ACL used to filter traffic. Use the **no** keyword to remove the statement from a class map. **Note** Access lists are not documented in this publication. See the reference under **access-list** in the "Configuring a QoS Policy" section on page 26-27.
`Switch (config-cmap)# [no] match ip precedence ipp_value1 [ipp_value2 [ipp_valueN]]`	(Optional—for IP traffic only) Specifies up to eight IP precedence values used as match criteria. Use the **no** keyword to remove the statement from a class map.
`Switch (config-cmap)# [no] match ip dscp dscp_value1 [dscp_value2 [dscp_valueN]]`	(Optional—for IP traffic only) Specifies up to eight DSCP values used as match criteria. Use the **no** keyword to remove the statement from a class map.
`Switch (config-cmap)# [no] match any`	(Optional) Matches any IP traffic or non-IP traffic.

Note Any Input or Output policy that uses a class-map with the **match ip precedence** or **match ip dscp** class-map commands, requires that the port on which the packet is received, be configured to **trust dscp**. If the incoming port trust state is not set to **trust dscp**, the IP packet DSCP/IP-precedence is not used for matching the traffic; instead the receiving port's default DSCP is used.

Note The interfaces on the Catalyst 4000 family switch do not support the **match classmap**, **match destination-address**, **match input-interface**, **match mpls**, **match not**, **match protocol**, **match qos-group**, and **match source-address** keywords.

Verifying Class-Map Configuration

To verify class-map configuration, perform this task:

	Command	Purpose
Step 1	`Switch (config-cmap)# end`	Exits configuration mode.
Step 2	`Switch# show class-map class_name`	Verifies the configuration.

This example shows how to create a class map named **ipp5** and how to configure filtering to match traffic with IP precedence 5:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# class-map ipp5
Switch(config-cmap)# match ip precedence 5
Switch(config-cmap)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show class-map ipp5
 Class Map match-all ipp5 (id 1)
   Match ip precedence 5

Switch#
```

Configuring a Policy Map

You can attach only one policy map to an interface. Policy maps can contain one or more policy-map classes, each with different match criteria and policers.

Configure a separate policy-map class in the policy map for each type of traffic that an interface receives. Put all commands for each type of traffic in the same policy-map class. QoS does not attempt to apply commands from more than one policy-map class to matched traffic.

The following sections describe policy-map configuration:

- Creating a Policy Map, page 26-30
- Configuring Policy-Map Class Actions, page 26-30

Creating a Policy Map

To create a policy map, perform this task:

Command	Purpose
`Switch(config)# [no] policy-map policy_name`	Creates a policy map with a user-specified name. Use the **no** keyword to delete the policy map.

Configuring Policy-Map Class Actions

These sections describe policy-map class action configuration:

- Configuring the Policy-Map Class Trust State, page 26-30
- Configuring the Policy Map Class DBL State, page 26-30
- Configuring Policy-Map Class Policing, page 26-31
- Using a Named Aggregate Policer, page 26-31
- Configuring a Per-Interface Policer, page 26-31

Configuring the Policy-Map Class Trust State

To configure the policy-map class trust state, perform this task:

Command	Purpose
`Switch(config-pmap-c)# [no] trust {cos | dscp}`	Configures the policy-map class trust state, which selects the value that QoS uses as the source of the internal DSCP value (see the "Internal DSCP Values" section on page 26-12). Use the **no** keyword to clear a configured value and return to the default.

When configuring the policy-map class trust state, note the following:

- You can enter the **no trust** command to use the trust state configured on the ingress interface (this is the default).
- With the **cos** keyword, QoS sets the internal DSCP value from received or interface CoS.
- With the **dscp** keyword, QoS uses received DSCP.

Configuring the Policy Map Class DBL State

To configure the policy map class DBL state, perform this task:

Command	Purpose
`Switch(config-pmap-c)# [no] dbl`	Configures the policy-map class DBL state, which tracks the queue length of traffic flows (see the "Active Queue Management" section on page 26-13). Use the **no** keyword to clear an DBL value and return to the default.

When configuring the policy-map class DBL state, note the following:

- Any class that uses a named aggregate policer must have the same DBL configuration to work.

Configuring Policy-Map Class Policing

These sections describe configuration of policy-map class policing:

- Using a Named Aggregate Policer, page 26-31
- Configuring a Per-Interface Policer, page 26-31

Using a Named Aggregate Policer

To use a named aggregate policer (see the "Creating Named Aggregate Policers" section on page 26-25), perform this task:

Command	Purpose
`Switch(config-pmap-c)# [no] police aggregate` *aggregate_name*	Uses a previously defined aggregate policer. Use the **no** keyword to delete the policer from the policy map class.

Configuring a Per-Interface Policer

To configure a per-interface policer (see the "Policing and Marking" section on page 26-9), perform this task:

Command	Purpose
`Switch(config-pmap-c)# [no] police` *rate burst* `[[conform-action {transmit | drop}] [exceed-action {transmit | drop | policed-dscp-transmit}]]`	Configures a per-interface policer. Use the **no** keyword to delete a policer from the policy map class.

When configuring a per-interface policer, note the following:

- The valid range of values for the *rate* parameter is as follows:
  - Minimum—32 kilobits per second, entered as 32000
  - Maximum—32 gigabits per second, entered as 32000000000

Note See the "Configuration Guidelines" section on page 26-23.

- Rates can be entered in bits-per-second, or you can use the following abbreviations:
  - k to denote 1000 bps
  - m to denote 1000000 bps
  - g to denote 1000000000 bps

Note You can also use a decimal point. For example, a rate of 1,100,000 bps can be entered as 1.1m.

- The valid range of values for the *burst* parameter is as follows:
  - Minimum—1 kilobyte
  - Maximum—512 megabytes
- Bursts can be entered in bytes, or you can use the following abbreviation:
  - k to denote 1000 bytes
  - m to denote 1000000 bytes
  - g to denote 1000000000 bytes

Note You can also use a decimal point. For example, a burst of 1,100,000 bytes can be entered as 1.1m.

- Optionally, you can specify a conform action for matched in-profile traffic as follows:
  - The default conform action is **transmit**.
  - You can enter the **drop** keyword to drop all matched traffic.
- Optionally, for traffic that exceeds the CIR, you can enter the **policed-dscp-transmit** keyword to cause all matched out-of-profile traffic to be marked down as specified in the markdown map. See "Configuring the Policed-DSCP Map" section on page 26-41.
  - For no policing, you can enter the **transmit** keyword to transmit all matched out-of-profile traffic.

This example shows how to create a policy map named **ipp5-policy** that uses the class-map named **ipp5**, is configured to rewrite the packet precedence to 6 and to aggregate police the traffic that matches IP precedence value of 5:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# policy-map ipp5-policy
Switch(config-pmap)# class ipp5
Switch(config-pmap-c)# set ip precedence 6
Switch(config-pmap-c)# dbl
Switch(config-pmap-c)# police 2000000000 2000000 conform-action transmit exceed-action
policed-dscp-transmit
Switch(config-pmap-c)# end
```

Verifying Policy-Map Configuration

To verify policy-map configuration, perform this task:

	Command	Purpose
Step 1	`Switch(config-pmap-c)# end`	Exits policy-map class configuration mode. **Note** Enter additional **class** commands to create additional classes in the policy map.
Step 2	`Switch# show policy-map policy_name`	Verifies the configuration.

This example shows how to verify the configuration:

```
Switch# show policy-map ipp5-policy
show policy ipp5-policy
 Policy Map ipp5-policy
  class  ipp5
   set ip precedence 6
   dbl
police 2000000000 2000000 conform-action transmit exceed-action
policed-dscp-transmit
Switch#
```

Attaching a Policy Map to an Interface

To attach a policy map to an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] service-policy input policy_map_name`	Attaches a policy map to the input direction of the interface. Use the **no** keyword to detach a policy map from an interface.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show policy-map interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface}`	Verifies the configuration.

This example shows how to attach the policy map named **pmap1** to Fast Ethernet interface 5/36:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/36
Switch(config-if)# service-policy input pmap1
Switch(config-if)# end
```

This example shows how to verify the configuration:

```
Switch# show policy-map interface fastethernet 5/36
FastEthernet6/1

   service-policy input:p1

     class-map:c1 (match-any)
       238474 packets
       match:access-group 100
        38437 packets
       police:aggr-1
        Conform:383934 bytes Exceed:949888 bytes

    class-map:class-default (match-any)
      0 packets
      match:any
        0 packets
Switch#
```

Enabling or Disabling QoS on an Interface

The **qos** interface command reenables any previously configured QoS features. The **qos** interface command does not affect the interface queueing configuration.

To enable or disable QoS features for traffic from an interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] qos`	Enables QoS on the interface. Use the **no** keyword to disable QoS on an interface.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show qos interface`	Verifies the configuration.

This example shows how to disable QoS on interface VLAN 5:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface vlan 5
Switch(config-if)# no qos
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos | begin QoS is disabled
  QoS is disabled on the following interfaces:
    Vl5
<...Output Truncated...>
Switch#
```

Configuring VLAN-Based QoS on Layer 2 Interfaces

By default, QoS uses policy maps attached to physical interfaces. For Layer 2 interfaces, you can configure QoS to use policy maps attached to a VLAN. See the "Attaching a Policy Map to an Interface" section on page 26-33.

To configure VLAN-based QoS on a Layer 2 interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/interface | Port-channel number`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] qos vlan-based`	Configures VLAN-based QoS on a Layer 2 interface. Use the **no** keyword to disable VLAN-based QoS on an interface.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show qos`	Verifies the configuration.

Note If no input QoS policy is attached to a Layer 2 interface, then the input QoS policy attached to the VLAN (on which the packet is received), if any, is used even if the port is not configured as VLAN-based. If you do not want this default, attach a placeholder input QoS policy to the Layer 2 interface. Similarly, if no output QoS policy is attached to a Layer 2 interface, then the output QoS policy attached to the VLAN (on which the packet is transmitted), if any, is used even if the port is not configured as VLAN-based. If you do not want this default, attach a placeholder output QoS policy to the layer 2 interface.

This example shows how to configure VLAN-based QoS on Fast Ethernet interface 5/42:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/42
Switch(config-if)# qos vlan-based
Switch(config-if)# end
```

This example shows how to verify the configuration:

```
Switch# show qos | begin QoS is vlan-based
QoS is vlan-based on the following interfaces:
    Fa5/42
Switch#
```

Note When a layer 2 interface is configured with VLAN-based QoS, and if a packet is received on the port for a VLAN on which there is no QoS policy, then the QoS policy attached to the port, if any is used. This applies for both Input and Output QoS policies.

Configuring the Trust State of Interfaces

This command configures the trust state of interfaces. By default, all interfaces are untrusted.

To configure the trust state of an interface, perform this task;

	Command	Purpose
Step 1	`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] qos trust [dscp | cos]`	Configures the trust state of an interface. Use the **no** keyword to clear a configured value and return to the default.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show qos`	Verifies the configuration.

When configuring the trust state of an interface, note the following:

- You can use the **no qos trust** command to set the interface state to untrusted.
- For traffic received on an ingress interface configured to *trust CoS* using the **qos trust cos** command, the transmit CoS is always the incoming packet CoS (or the ingress interface default CoS if the packet is received untagged).
- When the interface trust state is not configured to *trust dscp* using the **qos trust dscp** command, the security and QoS ACL classification will always use the interface DSCP and not the incoming packet DSCP.

This example shows how to configure Gigabit Ethernet interface 1/1 with the **trust cos** keywords:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if)# qos trust cos
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos interface gigabitethernet 1/1 | include trust
  Trust state: trust COS
Switch#
```

Configuring the CoS Value for an Interface

QoS assigns the CoS value specified with this command to untagged frames from ingress interfaces configured as trusted and to all frames from ingress interfaces configured as untrusted.

To configure the CoS value for an ingress interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] qos cos default_cos`	Configures the ingress interface CoS value. Use the **no** keyword to clear a configured value and return to the default.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show qos interface {fastethernet | gigabitethernet} slot/interface`	Verifies the configuration.

This example shows how to configure the CoS 5 as the default on Fast Ethernet interface 5/24:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/24
Switch(config-if)# qos cos 5
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos interface fastethernet 5/24 | include Default COS
  Default COS is 5
Switch#
```

Configuring DSCP Values for an Interface

QoS assigns the DSCP value specified with this command to non IPv4 frames received on interfaces configured to trust DSCP and to all frames received on interfaces configured as untrusted.

To configure the DSCP value for an ingress interface, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/interface | Port-channel number`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] qos dscp default_dscp`	Configures the ingress interface DSCP value. Use the **no** keyword to clear a configured value and return to the default.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show qos interface {fastethernet | gigabitethernet} slot/interface`	Verifies the configuration.

This example shows how to configure the DSCP 5 as the default on Fast Ethernet interface 5/24:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/24
Switch(config-if)# qos dscp 5
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show qos interface fastethernet 6/1
QoS is enabled globally
Port QoS is enabled
  Port Trust State:CoS
  Default DSCP:0 Default CoS:0

  Tx-Queue   Bandwidth   ShapeRate   Priority   QueueSize
               (bps)       (bps)                (packets)
    1        31250000    disabled    N/A        240
    2        31250000    disabled    N/A        240
    3        31250000    disabled    normal     240
    4        31250000    disabled    N/A        240
Switch#
```

Configuring Transmit Queues

The following sections describes how to configure the transmit queues:

Depending on the complexity of your network and your QoS solution, you might need to perform all of the procedures in the next sections, but first you will need to make decisions about these characteristics:

- Which packets are assigned (by DSCP value) to each queue?
- What is the size of a transmit queue relative to other queues for a given port?
- How much of the available bandwidth is allotted to each queue?
- What is the maximum rate and burst of traffic that can be transmitted out of each transmit queue?

Mapping DSCP Values to Specific Transmit Queues

To map the DSCP values to a transmit queue, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] qos map dscp dscp-values to tx-queue queue-id`	Maps the DSCP values to the transit queue. *dscp-list* can contain up 8 DSCP values. The *queue-id* can range from 1 to 4. Use the **no qos map dscp to tx-queue** command to clear the DSCP values from the transit queue.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show qos maps dscp tx-queues`	Verifies the configuration.

This example shows how to map DSCP values to transit queue 2.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# qos map dscp 50 to tx-queue 2
Switch(config)# end
Switch#
```

This example shows how to verify the configuration.

```
Switch# show qos maps dscp tx-queue
DSCP-TxQueue Mapping Table (dscp = d1d2)
d1 :d2  0  1  2  3  4  5  6  7  8  9
---------------------------------------
0 :   02 02 02 01 01 01 01 01 01 01
1 :   01 01 01 01 01 01 02 02 02 02
2 :   02 02 02 02 02 02 02 02 02 02
3 :   02 02 03 03 03 03 03 03 03 03
4 :   03 03 03 03 03 03 03 03 04 04
5 :   04 04 04 04 04 04 04 04 04 04
6 :   04 04 04 04
Switch#
```

Allocating Bandwidth Among Transmit Queues

To configure the transmit queue bandwidth, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface gigabitethernet slot/interface`	Selects the interface to configure.
Step 2	`Switch(config-if)# tx-queue queue_id`	Selects the transmit queue to configure.
Step 3	`Switch(config-if-tx-queue)# [no] [bandwidth rate | percent percent]`	Sets the bandwidth rate for the transmit queue. Use the **no** keyword to reset the transmit queue bandwidth ratios to the default values.
Step 4	`Switch(config-if-tx-queue)# end`	Exits configuration mode.
Step 5	`Switch# show qos interface`	Verifies the configuration.

The bandwidth rate varies with the interface.

Bandwidth can only be configured on these interfaces:

- Uplink ports on Supervisor Engine III (WS-X4014)
- Ports on the WS-X4306-GB module
- The 2 1000BASE-X ports on the WS-X4232-GB-RJ module
- The first 2 ports on the WS-X4418-GB module
- The two 1000BASE-X ports on the WS-X4412-2GB-TX module

This example shows how to configure the bandwidth of 1 Mbps on transmit queue 2.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if)# tx-queue 2
Switch(config-if-tx-queue)#bandwidth 1000000
Switch(config-if-tx-queue)# end
Switch#
```

Configuring Traffic Shaping of Transmit Queues

To guarantee that packets transmitted from a transmit queue do not exceed a specified maximum rate, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/interface`	Selects the interface to configure.
Step 2	`Switch(config-if)# tx-queue queue_id`	Selects the transmit queue to configure.
Step 3	`Switch(config-if-tx-queue)# [no] [shape rate | percent percent]`	Sets the transmit rate for the transmit queue. Use the **no** keyword to clear the transmit queue maximum rate.
Step 4	`Switch(config-if-tx-queue)# end`	Exits configuration mode.
Step 5	`Switch# show qos interface`	Verifies the configuration.

This example shows how to configure the shape rate to 1 Mbps on transmit queue 2.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if-tx-queue)# tx-queue 2
Switch(config-if-tx-queue)# shape 1000000
Switch(config-if-tx-queue)# end
Switch#
```

Configuring a High Priority Transmit Queue

To configure transmit queue 3 at a higher priority, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/interface`	Selects the interface to configure.
Step 2	`Switch(config-if)# tx-queue 3`	Selects transmit queue 3 to configure.
Step 3	`Switch(config-if)# [no] priority high`	Sets the transmit queue to high priority. Use the **no** keyword to clear the transmit queue priority.
Step 4	`Switch(config-if)# end`	Exits configuration mode.
Step 5	`Switch# show qos interface`	Verifies the configuration.

This example shows how to configure transmit queue 3 to high priority.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface gigabitethernet 1/1
Switch(config-if-tx-queue)# tx-queue 3
Switch(config-if-tx-queue)# priority high
Switch(config-if)# end
Switch#
```

Configuring DSCP Maps

The following sections describes how to configure the DSCP maps. It contains this configuration information:

- Configuring the CoS-to-DSCP Map, page 26-40
- Configuring the Policed-DSCP Map, page 26-41
- Configuring the DSCP-to-CoS Map, page 26-42

All the maps 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 26-4 shows the default CoS-to-DSCP map.

Table 26-4 Default CoS-to-DSCP Map

CoS value	0	1	2	3	4	5	6	7
DSCP value	0	8	16	24	32	40	48	56

If these values are not appropriate for your network, you need to modify them.

To modify the CoS-to-DSCP map, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# qos map cos` *cos1 ... cos8* `to dscp` *dscp*	Modifies the CoS-to-DSCP map. For *cos1...cos8*, you can enter up to 8 CoS; valid values range from 0 to 7. Separate each CoS value with a space. The *dscp* range is 0 to 63.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show qos maps cos-dscp`	Verifies your entries.
Step 5	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default map, use the **no qos cos to dscp** global configuration command.

This example shows how to modify and display the CoS-to-DSCP map:

```
Switch# configure terminal
Switch(config)# qos map cos 0 to dscp 20
Switch(config)# end
Switch# show qos maps cos dscp

CoS-DSCP Mapping Table:
CoS:  0   1  2  3  4  5  6  7
---------------------------------
DSCP: 20  8 16 24 32 40 48 56
Switch(config)#
```

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.

To modify the CoS-to-DSCP map, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# qos map dscp policed` *dscp-list* `to dscp` *mark-down-dscp*	Modifies the policed-DSCP map. • For *dscp-list*, enter up to 8 DSCP values separated by spaces. Then enter the **to** keyword. • For *mark-down-dscp*, enter the corresponding policed (marked down) DSCP value.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show qos maps dscp policed`	Verifies your entries.
Step 5	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default map, use the **no qos dscp policed** global configuration command.

This example shows how to map DSCP 50 to 57 to a marked-down DSCP value of 0:

```
Switch# configure terminal
Switch(config)# qos map dscp policed 50 51 52 53 54 55 56 57 to dscp 0
Switch(config)# end
Switch# show qos maps dscp policed
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 00 58 59
      6 :    60 61 62 63
```

Note In the above 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.

Table 26-5 shows the default DSCP-to-CoS map.

Table 26-5 Default DSCP-to-CoS Map

DSCP value	0–7	8–15	16–23	24–31	32–39	40–47	48–55	56–63
CoS value	0	1	2	3	4	5	6	7

If the values above are not appropriate for your network, you need to modify them.

To modify the DSCP-to-CoS map, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# qos map dscp` *dscp-list* `to cos` *cos*	Modifies the DSCP-to-CoS map. • For *dscp-list*, enter up to 8 DSCP values separated by spaces. Then enter the **to** keyword. • For *cos*, enter only one CoS value to which the DSCP values correspond. The DSCP range is 0 to 63; the CoS range is 0 to 7.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show qos maps dscp to cos`	Verifies your entries.
Step 5	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default map, use the **no qos dscp to 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# configure terminal
Switch(config)# qos map dscp 0 8 16 24 32 40 48 50 to cos 0
Switch(config)# end
Switch# show 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 01
      1 :    01 01 01 01 01 01 00 02 02 02
      2 :    02 02 02 02 00 03 03 03 03 03
      3 :    03 03 00 04 04 04 04 04 04 04
      4 :    00 05 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 Voice Interfaces

This chapter describes how to configure voice interfaces for the Catalyst 4500 series switches.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Voice Interfaces

Catalyst 4500 series switches can connect to a Cisco 7960 IP phone and carry IP voice traffic. If necessary, the switch can supply electrical power to the circuit connecting it to the Cisco 7960 IP phone.

Because the sound quality of an IP telephone call can deteriorate if the data is unevenly sent, the switch uses quality of service (QoS) based on IEEE 802.1p class of service (CoS). QoS uses classification and scheduling to transmit network traffic from the switch in a predictable manner. See Chapter 26, "Configuring QoS" for more information on QoS.

You can configure the Cisco 7960 IP phone to forward traffic with an 802.1p priority. You can use the CLI to configure a Catalyst 4500 series switch to honor or ignore a traffic priority assigned by a Cisco 7960 IP phone.

The Cisco 7960 IP phone contains an integrated three-port 10/100 switch. The ports are dedicated connections as described below:

- Port 1 connects to the Catalyst 4500 series switch or other device that supports voice-over-IP.
- Port 2 is an internal 10/100 interface that carries the phone traffic.
- Port 3 connects to a PC or other device.

Figure 27-1 shows one way to configure a Cisco 7960 IP phone.

Figure 27-1 Cisco 7960 IP Phone Connected to a Catalyst 4500 Series Switch

Configuring a Port to Connect to a Cisco 7960 IP Phone

Because a Cisco 7960 IP phone also supports connection to a PC or another device, an interface connecting a Catalyst 4500 series switch to a Cisco 7960 IP phone can carry a mix of voice and data traffic.

There are three configurations for a port connected to a Cisco 7960 IP phone:

- All traffic is transmitted according to the default CoS priority of the port. This is the default.
- Voice traffic is given a higher priority by the phone (CoS priority is always 5), and all traffic is in the same VLAN.
- Voice and data traffic are carried on separate VLANs.

To configure a port to instruct the phone to give voice traffic a higher priority and to forward all traffic through the 802.1Q native VLAN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to configure.
Step 3	`Switch(config-if)# switchport voice vlan dot1p`	Instructs the switch to use 802.1p priority tagging for voice traffic and to use VLAN 1 (default native VLAN) to carry all traffic.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show interface {fastethernet | gigabitethernet} slot/port switchport`	Verifies the port configuration.

Configuring Voice Ports for Voice and Data Traffic

Because voice and data traffic can travel through the same voice port, you should specify a different VLAN for each type of traffic. You can configure a switch port to forward voice and data traffic on different VLANs.

To configure a port to receive voice and data from a Cisco IP Phone on different VLANs, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to configure.
Step 3	`Switch(config-if)# switchport voice vlan vlan_num`	Instructs the Cisco IP phone to forward all voice traffic through a specified VLAN. The Cisco IP phone forwards the traffic with an 802.1p priority of 5.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show interface {fastethernet | gigabitethernet} slot/port switchport`	Verifies the configuration.

In the following example, VLAN 1 carries data traffic, and VLAN 2 carries voice traffic. In this configuration, you must connect all Cisco IP phones and other voice-related devices to switch ports that belong to VLAN 2.

```
Switch# configure terminal
Switch(config)# interface fastethernet 2/5
SSwitch(config-if)# switchport voice vlan 2
switchport voice vlan 2
Switch(config-if)# end
Switch# show interface fastethernet 2/5 switchport
show interface fastethernet 2/5 switchport
Name:Fa2/5
Switchport:Enabled
Administrative Mode:dynamic auto
Operational Mode:down
Administrative Trunking Encapsulation:negotiate
Negotiation of Trunking:On
Access Mode VLAN:1 (default)
Trunking Native Mode VLAN:1 (default)
Voice VLAN:2 ((Inactive))
Appliance trust:none
Administrative private-vlan host-association:none
Administrative private-vlan mapping:none
Operational private-vlan:none
Trunking VLANs Enabled:ALL
Pruning VLANs Enabled:2-1001
Switch#
```

Overriding the CoS Priority of Incoming Frames

A PC or another data device can connect to a Cisco 7960 IP phone port. The PC can generate packets with an assigned CoS value. You can also use the switch CLI to override the priority of frames arriving on the phone port from connected devices, and you can set the phone port to accept (trust) the priority of frames arriving on the port.

To override the CoS priority setting received from the non-voice port on the Cisco 7960 IP phone, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the interface to configure.
Step 3	`Switch(config-if)# [no] qos trust extend cos 3`	Sets the phone port to override the priority received from the PC or the attached device and forward the received data with a priority of 3. Use the **no** keyword to return the port to its default setting.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show interface {fastethernet | gigabitethernet} slot/port switchport`	Verifies the change.

Configuring Inline Power

The Catalyst 4500 series switch senses if it is connected to a Cisco 7960 IP phone. The Catalyst 4500 series switch can supply inline power to the Cisco 7960 IP phone if there is no power on the circuit. The Cisco 7960 IP phone can also be connected to an AC power source and supply its own power to the voice circuit. If there is power on the circuit, the switch does not supply it.

You can configure the switch not to supply power to the Cisco 7960 IP phone and to disable the detection mechanism. See the "Configuring Power Over Ethernet" section on page 36-16 for the CLI commands that you can use to supply inline power to a Cisco 7960 IP phone.

CHAPTER 28

Understanding and Configuring 802.1X Port-Based Authentication

This chapter describes how to configure IEEE 802.1X port-based authentication to prevent unauthorized client devices from gaining access to the network.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Understanding 802.1X Port-Based Authentication

To configure 802.1X port-based authentication, you need to understand the concepts in these sections:

Note 802.1X support requires an authentication server that is configured for Remote Authentication Dial-In User Service (RADIUS). 802.1X authentication does not work unless the network access switch can route packets to the configured authentication RADIUS server. To verify that the switch can route packets, you must ping the server from the switch.

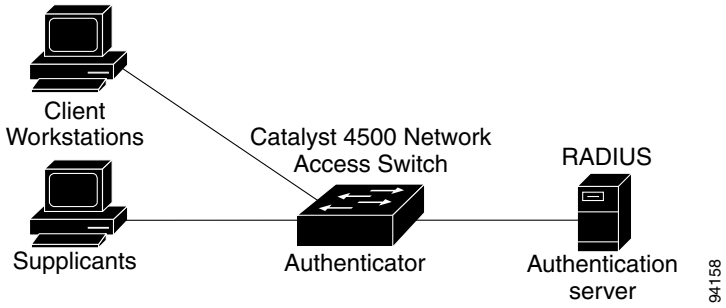
802.1X defines 802.1X port-based authentication as a client-server based access control and authentication protocol that restricts unauthorized clients from connecting to a LAN through publicly accessible ports. An authentication server validates each supplicant (client) connected to an authenticator (network access switch) port before making available any services offered by the switch or the LAN.

Until a client is authenticated, only Extensible Authentication Protocol over LAN (EAPOL) traffic is allowed through the port to which the client is connected. Once authentication succeeds, normal traffic can pass through the port.

Device Roles

With 802.1X port-based authentication, network devices have specific roles. Figure 28-1 shows the roles of each device.

Figure 28-1 802.1X Device Roles



- Client—The workstation that requests access to the LAN, and responds to requests from the switch. The workstation must be running 802.1X-compliant client software.

  Note For more information on 802.1X-compliant client application software such as Microsoft Windows 2000 Professional or Windows XP, refer to the Microsoft Knowledge Base article at this URL: http://support.microsoft.com

- Authenticator—Controls physical access to the network based on the authentication status of the client. The switch acts as an intermediary 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 encapsulates and decapsulates the Extensible Authentication Protocol (EAP) frames and interacts with the RADIUS authentication server.

  When the switch receives EAPOL frames and relays them to the authentication server, the Ethernet header is stripped and the remaining EAP frame is reencapsulated in the RADIUS format. The EAP frames are not modified or examined during encapsulation, and the authentication server must support EAP within the native frame format. When the switch receives frames from the authentication server, the frame header is removed from the server, leaving the EAP frame, which is then encapsulated for Ethernet and sent to the client.

  Cisco devices that are capable of functioning as an 802.1X network access point include Catalyst 4500 series switches, the Catalyst 3550 multilayer switch, the Catalyst 2950 switch, and a Cisco Airnet series wireless access point. These devices must be running software that supports the RADIUS client and 802.1X.

- Authentication server—Performs the actual authentication of the client. The authentication server validates the identity of the client and notifies the switch that the client is authorized to access the LAN and switch services. (The only supported authentication server is the RADIUS authentication server with EAP extensions; it is available in Cisco Secure Access Control Server version 3.2 and later.)

Authentication Initiation and Message Exchange

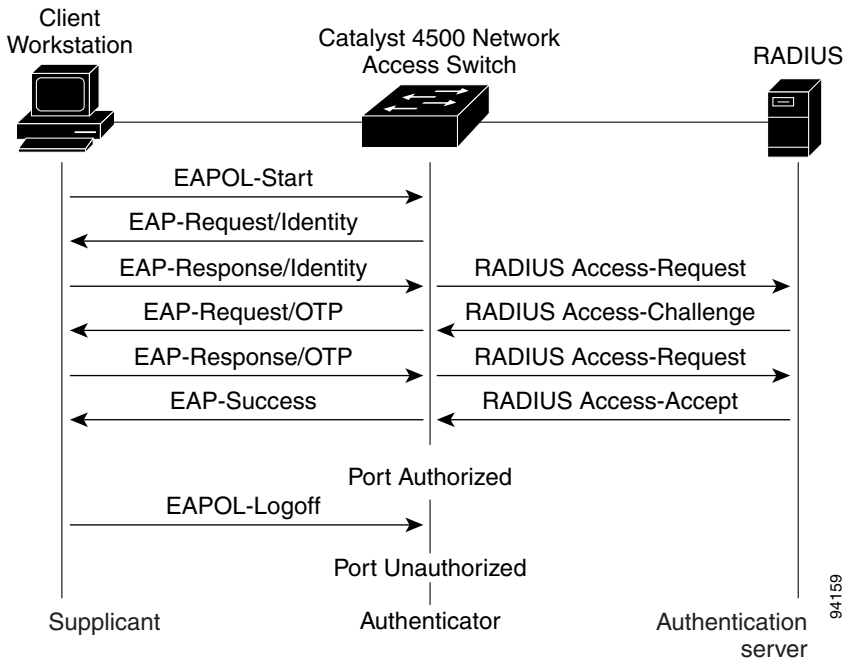
The switch or the client can initiate authentication. If you enable authentication on a port by using the **dot1x port-control auto** interface configuration command, the switch must initiate authentication when it determines that the port link state has changed. It then sends an EAP-request/identity frame to the client to request its identity (typically, the switch sends an initial identity/request frame followed by one or more requests for authentication information). 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.

If 802.1X 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 transmits frames as if the port is in the authorized state. A port in the authorized state means that the client has been successfully authenticated.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.

The specific exchange of EAP frames depends on the authentication method being used. Figure 28-2 shows a message exchange that is initiated by the client using the One-Time Password (OTP) authentication method with an authentication server.

Figure 28-2 Message Exchange



Ports in Authorized and Unauthorized States

The switch port state determines whether or not the client is granted access to the network. The port starts in the unauthorized state. While in this state, the port disallows all ingress and egress traffic except for 802.1X protocol packets. When a client is successfully authenticated, the port transitions to the authorized state, allowing all traffic for the client to flow normally.

If a client that does not support 802.1X is connected to an unauthorized 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. If the guest VLAN is configured for a port that connects to a client that does not support 802.1X, the port is placed in the configured guest VLAN and in the authorized state. For more information, see the "Using 802.1X Authentication for Guest VLANs" section on page 28-6.

In contrast, when an 802.1X-enabled client connects to a port that is not running the 802.1X protocol, the client initiates the authentication process by sending the EAPOL-start frame. When no response is received, the client sends the request 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 can control the port authorization state with the **dot1x port-control** interface configuration command and these keywords:

- **force-authorized**—Disables 802.1X authentication and causes the port to transition to the authorized state without any authentication exchange required. The port transmits and receives normal traffic without 802.1X-based authentication of the client. This setting is the default.
- **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 interface.

- **auto**—Enables 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 transitions 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. The switch can uniquely identify each client attempting to access the network by the client's MAC address.

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 authentication fails, the port remains in the unauthorized state, but authentication can be retried. If the authentication server cannot be reached, the switch can retransmit the request. If no response is received from the server after the specified number of attempts, authentication fails and network access is not granted.

If the link state of a port transitions from up to down, or if an EAPOL-logoff frame is received by the port, the port returns to the unauthorized state.

Using 802.1X with the VLAN Assignment

You can use the VLAN assignment to limit network access for certain users. With the VLAN assignment, 802.1X-authenticated ports are assigned to a VLAN based on the username of the client connected to that port. The RADIUS server database maintains the username-to-VLAN mappings. After successful 802.1X authentication of the port, the RADIUS server sends the VLAN assignment to the switch.

Note To enable the guest VLAN feature in Release 12.1(19)EW and later releases, the port must be statically configured as an access port.

When configured on the switch and the RADIUS server, 802.1X with VLAN assignment has these characteristics:

- If no VLAN is supplied by the RADIUS server, the port is configured in its access VLAN when authentication succeeds.
- If the authentication server provides invalid VLAN information, the port remains unauthorized. This situation prevents ports from appearing unexpectedly in an inappropriate VLAN due to a configuration error.

  Configuration errors might occur if you specify a VLAN for a routed port, a malformed VLAN ID, or a nonexistent or internal (routed port) VLAN ID. Similarly, an error might occur if you make an assignment to a voice VLAN ID.
- If the authentication server provides valid VLAN information, the port is authorized and placed in the specified VLAN when authentication succeeds.
- If the multiple-hosts mode is enabled, all hosts are in the same VLAN as the first authenticated user.
- If 802.1X is disabled on the port, the port is returned to the configured access VLAN.

To configure VLAN assignment you need to perform these tasks:

- Enable AAA authorization with the **network** keyword to allow interface configuration from the RADIUS server. For an illustration of how to apply the **aaa authorization network group radius** command, refer to the section "Enabling 802.1X Authentication" on page 12.
- Enable 802.1X. (The VLAN assignment feature is automatically enabled when you configure 802.1X on an access port.)

- Assign vendor-specific tunnel attributes in the RADIUS server. To ensure proper VLAN assignment, the RADIUS server must return these attributes to the switch:
  - Tunnel-Type = VLAN
  - Tunnel-Medium-Type = 802
  - Tunnel-Private-Group-ID = VLAN NAME

Using 802.1X Authentication for Guest VLANs

You can use guest VLANs to enable non-802.1X capable hosts to access networks that use 802.1X authentication. For example, you can use guest VLANs while you are upgrading your system to support 802.1X authentication.

Guest VLANs are supported on a per-port basis, and you can use any VLAN (except a private VLAN) as a guest VLAN. If a port is already forwarding on the guest VLAN and you enable 802.1X support on the network interface of the host, the port is immediately moved out of the guest VLAN and the authenticator waits for authentication to occur.

Enabling 802.1X authentication on a port starts the 802.1X protocol. If the host fails to respond to the packets from the authenticator within a certain amount of time, the authenticator puts the port in the guest VLAN.

Usage Guidelines for Using 802.1X Authentication with Guest VLANs on Windows-XP Hosts

The usage guidelines for using 802.1X authentication with guest VLANs on Windows-XP hosts are as follows:

- If the host fails to respond to the authenticator, the port attempts to connect three times (with a 30 second timeout between each attempt). After this time, the login/password window does not appear on the host, so you must unplug and reconnect the network interface cable.
- Hosts responding with an incorrect login/password fail authentication. Hosts failing authentication are not put in the guest VLAN. The first time that a host fails authentication, the quiet-period timer starts, and no activity occurs for the duration of the quiet-period timer. When the quiet-period timer expires, the host is presented with the login/password window. If the host fails authentication for the second time, the quiet-period timer starts again, and no activity will occur for the duration of the quiet-period timer. The host is presented with the login/password window a third time. If the host fails authentication the third time, the port is placed in the unauthorized state, and you must disconnect and reconnect the network interface cable.

Using 802.1X with Port Security

You can enable port security on an 802.1X port in either single- or multiple-host mode. (To do so, you must configure port security with the **switchport port-security** interface configuration command. Refer to the “Configuring Port Security” chapter in this guide.) When you enable port security and 802.1X on a port, 802.1X authenticates the port, and port security manages the number of MAC addresses allowed on that port, including that of the client. Hence an 802.1X port with port security enabled can be used to limit the number or group of clients that can access the network.

These examples describe the interaction between 802.1X and port security on the switch:

- When a client is authenticated, and the port security table is not full, the client's 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 an additional host is learned on the port. The action taken depends on which feature (802.1X or port security) detects the security violation:

  - If 802.1X detects the violation, the action is to err-disable the port.
  - If port security detects the violation, the action is to shutdown or restrict the port (the action is configurable).

  The following describes when port security and 802.1X security violations occur:

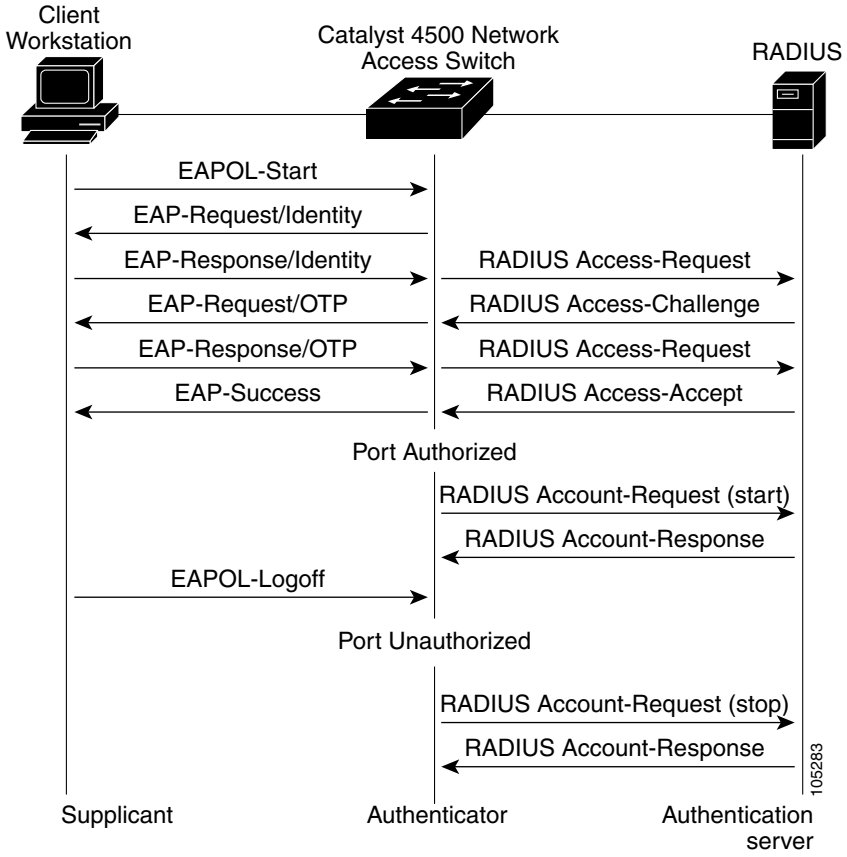
  - In single host mode, after the port is authorized, any MAC address received other than the client's will cause a 802.1X security violation.
  - In single host mode, if installation of an 802.1X client's MAC address fails because port security has already reached its limit (due to a configured secure MAC addresses), a port security violation is triggered.
  - In multi host mode, once the port is authorized, any additional MAC addresses that cannot be installed because the port security has reached its limit will trigger a port security violation.
- When an 802.1X client logs off, the port transitions back to an unauthenticated state, and all dynamic entries in the secure host table are cleared, including the entry for the client. Normal authentication then ensues.
- If you administratively shut down the port, the port becomes unauthenticated, and all dynamic entries are removed from the secure host table.
- Only 802.1X can remove the client's MAC address from the port security table. Note that in multi host mode, with the exception of the client's MAC address, all MAC addresses that are learned by port security can be deleted using port security CLIs.
- Whenever port security ages out a 802.1X client's MAC address, 802.1X attempts to reauthenticate the client. Only if the reauthentication succeeds will the client's MAC address be retained in the port security table.
- All of the 802.1X client's MAC addresses are tagged with (dot1x) when you display the port security table by using CLI.

802.1X RADIUS Accounting

802.1X RADIUS accounting relays important events to the RADIUS server (such as the client's connection session). This session is defined as the difference in time from when client is authorized to use the port and when the client stops using the port.

Figure 28-3 shows the 802.1X device roles.

Figure 28-3 Radius Accounting



Note You must configure the 802.1X client to send an EAP-logoff (Stop) message to the switch when the user logs off. If you do not configure the 802.1X client, an EAP-logoff message is not sent to the switch and the accompanying accounting Stop message will not be sent to the authentication server. Refer to the Microsoft Knowledge Base article at the URL: http://support.microsoft.com. Also refer to the Microsoft article at the URL: http://www.microsoft.com/technet/treeview/default.asp?url=/technet/columns/cableguy/cg0703.asp, and set the SupplicantMode registry to 3 and the AuthMode registry to 1.

The client uses EAP to authenticate itself with the RADIUS server. The switch relays EAP packets between the client and the RADIUS server.

After the client is authenticated, the switch sends accounting-request packets to the RADIUS server, which responds with accounting-response packets to acknowledge the receipt of the request.

A RADIUS accounting-request packet contains one or more Attribute-Value pairs to report various events and related information to the RADIUS server. The following events are tracked:

- User successfully authenticates
- User logs-off
- Link-down occurs on a 802.1X port
- Reauthentication succeeds
- Reauthentication fails

When the port state transitions between authorized and unauthorized, the RADIUS messages are transmitted to the RADIUS server.

The switch does not log any accounting information. Instead, it sends such information to the RADIUS server, which must be configured to log accounting messages.

The 802.1X authentication, authorization and accounting process is as follows:

Step 1 A user connects to a port on the switch.

Step 2 Authentication is performed, for example, using the username/password method.

Step 3 VLAN assignment is enabled, as appropriate, per RADIUS server configuration.

Step 4 The switch sends a start message to an accounting server.

Step 5 Reauthentication is performed, as necessary.

Step 6 The switch sends an interim accounting update to the accounting server that is based on the result of reauthentication.

Step 7 The user disconnects from the port.

Step 8 The switch sends a stop message to the accounting server.

To configure 802.1X accounting, you need to do the following tasks:

- Enable logging of "Update/Watchdog packets from this AAA client" in your RADIUS server's Network Configuration tab.
- Enable "Logging>CVS RADIUS Accounting" in your RADIUS server System Configuration tab.
- Enable 802.1X accounting on your switch.
- Enable AAA accounting by using the **aaa system accounting** command. Refer to the "Enabling 802.1X Accounting" section on page 28-15.

Enabling AAA system accounting along with 802.1X accounting allows system reload events to be sent to the accounting RADIUS server for logging. By doing this, the accounting RADIUS server can infer that all active 802.1X sessions are appropriately closed.

Because RADIUS uses the unreliable transport protocol UDP, accounting messages may 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, the following system message appears:

```
Accounting message %s for session %s failed to receive Accounting Response.
```

When the stop message is not transmitted successfully, the following message appears:

```
00:09:55: %RADIUS-3-NOACCOUNTINGRESPONSE: Accounting message Start for session
172.20.50.145 sam 11/06/03 07:01:16 11000002 failed to receive Accounting Response.
```

Use the **show radius statistics** command to display the number of RADIUS messages that do not receive the accounting response message.

Supported Topologies

The 802.1X port-based authentication supports two topologies:

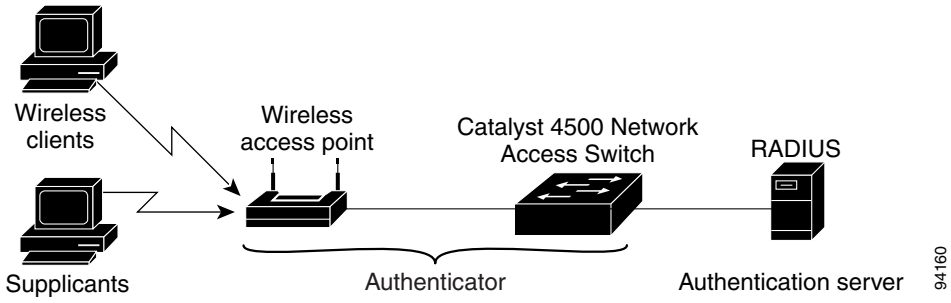
- Point to point

- Wireless LAN

In a point-to-point configuration (see Figure 28-1 on page 28-2), only one client can be connected to the 802.1X-enabled switch port when the multi-host mode is not enabled (the default). The switch detects the client 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.

Figure 28-4 illustrates 802.1X port-based authentication in a wireless LAN. You must configure the 802.1X port as a multiple-host port that is authorized as a wireless access point once the client is authenticated. (See the "Enabling Multiple Hosts" section on page 28-20.) When the port is authorized, all other hosts that are indirectly attached to the port are granted access to the network. If the port becomes unauthorized (reauthentication fails or an EAPOL-logoff message is received), the switch denies access to the network for all wireless access point-attached clients. In this topology, the wireless access point is responsible for authenticating clients attached to it, and the wireless access point acts as a client to the switch.

Figure 28-4 Wireless LAN Example



How to Configure 802.1X

These sections describe how to configure 802.1X:

- Default 802.1X Configuration, page 28-11
- 802.1X Configuration Guidelines, page 28-12
- Enabling 802.1X Authentication, page 28-12 (required)
- Configuring Switch-to-RADIUS-Server Communication, page 28-14 (required)
- Enabling 802.1X Accounting, page 28-15
- Configuring 802.1X with Guest VLANs, page 28-16
- Enabling Periodic Reauthentication, page 28-16 (optional)
- Manually Reauthenticating a Client Connected to a Port, page 28-17 (optional)
- Changing the Quiet Period, page 28-17 (optional)
- Changing the Switch-to-Client Retransmission Time, page 28-18 (optional)
- Setting the Switch-to-Client Frame-Retransmission Number, page 28-19 (optional)
- Enabling Multiple Hosts, page 28-20 (optional)
- Resetting the 802.1X Configuration to the Default Values, page 28-20 (optional)

Default 802.1X Configuration

Table 28-1 shows the default 802.1X configuration.

Table 28-1 Default 802.1X Configuration

Feature	Default Setting
Authentication, authorization, and accounting (AAA)	Disabled
RADIUS server • IP address • UDP authentication port • Key	 • None specified • 1812 • None specified
Per-interface 802.1X protocol enable state	Disabled (force-authorized) The port transmits and receives normal traffic without 802.1x-based authentication of the client.
Periodic reauthentication	Disabled
Time between reauthentication attempts	3600 sec
Quiet period	60 sec Number of seconds that the switch remains in the quiet state following a failed authentication exchange with the client.
Retransmission time	30 sec Number of seconds that the switch should wait for a response to an EAP request/identity frame from the client before retransmitting the request.
Maximum retransmission number	2 Number of times that the switch will send an EAP-request/identity frame before restarting the authentication process.
Multiple host support	Disabled
Client timeout period	30 sec When relaying a request from the authentication server to the client, the amount of time that the switch waits for a response before retransmitting the request to the client.
Authentication server timeout period	30 sec When relaying a response from the client to the authentication server, the amount of time that the switch waits for a reply before retransmitting the response to the server. This setting is not configurable.

802.1X Configuration Guidelines

This section describes the guidelines for configuring 802.1X authentication:

- The 802.1X protocol is supported on both Layer 2 static-access ports and Layer 3 routed ports, but it is not supported on the following port types:
  - Trunk port—If you try to enable 802.1X on a trunk port, an error message appears, and 802.1X is not enabled. If you try to change the mode of an 802.1X-enabled port to trunk, the port mode is not changed.
  - Default ports—All ports default as dynamic-access ports (auto). Use the **no switchport** command to access a router port.
  - Dynamic ports—A port in dynamic mode can negotiate with its neighbor to become a trunk port. If you try to enable 802.1X on a dynamic port, an error message appears, and 802.1X is not enabled. If you try to change the mode of an 802.1X-enabled port to dynamic, the port mode is not changed.
  - EtherChannel port—Before enabling 802.1X on the port, you must first remove it from the EtherChannel. If you try to enable 802.1X on an EtherChannel or on an active port in an EtherChannel, an error message appears, and 802.1X is not enabled. If you enable 802.1X on a not-yet active port of an EtherChannel, the port does not join the EtherChannel.
  - Switched Port Analyzer (SPAN) destination port—You can enable 802.1X on a port that is a SPAN destination port; however, 802.1X is disabled until the port is removed as a SPAN destination. You can enable 802.1X on a SPAN source port.

If you are planning to use either 802.1X accounting or VLAN assignment, be aware that both features utilize general AAA commands. For information how to configure AAA, refer to "Enabling 802.1X Authentication" on page 12 and "Enabling 802.1X Accounting" on page 15. Alternatively, you can refer to the Cisco IOS security documentation.

Refer to the following Cisco IOS security documentation for information on how to configure AAA system accounting:

- http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fsecur_c/index.htm
- http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fsecur_r/index.htm

Enabling 802.1X Authentication

To enable 802.1X port-based authentication, you first enable AAA, then specify the authentication method list. A method list describes the sequence and authentication methods that must be queried to authenticate a user.

The software uses the first method listed in the method list to authenticate users; if that method fails to respond, the software selects the next authentication method in the 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, the authentication process stops, and no other authentication methods are attempted.

To allow VLAN assignment, you must enable AAA authorization to configure the switch for all network-related service requests.

To configure 802.1X port-based authentication, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# aaa new-model`	Enables AAA.
Step 3	`Switch(config)# aaa authentication dot1x {default} method1 [method2...]`	Creates an 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 methods that are to be used in default situations. The default method list is automatically applied to all interfaces. Enter at least one of these keywords: • **group radius**—Use the list of all RADIUS servers for authentication. • **none**—Use no authentication. The client is automatically authenticated by the switch without using the information supplied by the client.
Step 4	`Switch(config)# aaa authorization network {default} group radius`	(Optional) Configure the switch for user RADIUS authorization for all network-related service requests, such as VLAN assignment.
Step 5	`Switch(config)# interface interface-id`	Enters interface configuration mode and specifies the interface to be enabled for 802.1X authentication.
Step 6	`Switch(config-if)# dot1x port-control auto`	Enables 802.1X authentication on the interface. For feature interaction information with trunk, dynamic, dynamic-access, EtherChannel, secure, and SPAN ports, see the "802.1X Configuration Guidelines" section on page 28-12.
Step 7	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 8	`Switch # show dot1x all`	Verifies your entries. Check the Status column in the 802.1X Port Summary section of the display. An enabled status means that the port-control value is set either to **auto** or to **force-unauthorized**.
Step 9	`Switch# show running-config`	Verifies your entries.
Step 10	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To disable AAA, use the **no aaa new-model** global configuration command.

To disable 802.1X AAA authentication, use the **no aaa authentication dot1x** {**default** | *list-name*} *method1* [*method2*...] global configuration command.

To disable 802.1X authentication, use the **dot1x port-control force-authorized** or the **no dot1x port-control** interface configuration command.

This example shows how to enable AAA and 802.1X on Fast Ethernet port 2/1:

```
Switch# configure terminal
Switch(config)# aaa new-model
Switch(config)# aaa authentication dot1x default group radius
Switch(config)# interface fastethernet2/1
Switch(config-if)# dot1x port-control auto
Switch(config-if)# end
```

Configuring Switch-to-RADIUS-Server Communication

A RADIUS security server is identified by its host name or IP address, host name and specific UDP port number, 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 they were configured.

To configure the RADIUS server parameters on the switch, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# radius-server host {hostname | ip-address} auth-port port-number [acct-port port-number] key string`	Configures the RADIUS server parameters on the switch. For *hostname* | *ip-address,* specify the hostname or IP address of the remote RADIUS server. For **auth-port** *port-number*, specify the UDP destination port for authentication requests. The default is 1812. For **acct-port** *port-number*, specify the UDP destination port for accounting requests. The default is 1813. 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. If you want to use multiple RADIUS servers, reenter this command.
Step 3	`Switch(config-if)# ip radius source-interface m/p`	Establishes the IP address to be used as the source address for all outgoing RADIUS packets.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show running-config`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

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. The first command specifies port 1612 as the authorization port, sets the encryption key to rad123. The second command dictates that key matches will be performed on the RADIUS server:

```
Switch(config)# radius-server host 172.120.39.46 auth-port 1612 key rad123
Switch(config)# ip radius source-interface m/p
```

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.

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.

Refer to the following Cisco IOS security documentation for information on how to configure AAA system accounting:

- http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fsecur_c/index.htm
- http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fsecur_r/index.htm

Enabling 802.1X Accounting

Note If you plan to implement system-wide accounting, you should also configure 802.1X accounting. Moreover, you need to inform the accounting server of the system reload event when the system is reloaded. Doing this, ensures that the accounting server knows that all outstanding 802.1X sessions on this system are closed.

Once you configure 802.1X authentication and switch-to-RADIUS server communication, perform this task to enable 802.1X accounting:

	Command	Purpose
Step 1	`Switch # configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# aaa accounting dot1x default start-stop group radius`	Enables 802.1X accounting, using the list of all RADIUS servers.
Step 3	`Switch(config)# clock timezone PST -8`	Sets the time zone for the accounting event-time stamp field.
Step 4	`Switch(config)# clock calendar-valid`	Enables the date for the accounting event-time stamp field.
Step 5	`Switch(config-if)# aaa accounting system default start-stop group radius`	(Optional) Enables system accounting (using the list of all RADIUS servers) and generates system accounting reload event messages when the switch reloads.
Step 6	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 7	`Switch # show running-config`	Verifies your entries.
Step 8	`Switch # copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to configure 802.1X accounting. The first command configures the RADIUS server, specifying 1813 as the UDP port for accounting:

```
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
```

Note 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.

Configuring 802.1X with Guest VLANs

Note When a port is put into a guest VLAN, it is automatically placed into multihost mode, and an unlimited number of hosts can connect through the port. Changing the multihost configuration does not effect a port in a guest VLAN.

To configure 802.1X with guest-VLAN, perform this task:

	Command	Purpose
Step 1	`Switch # configure terminal`	Enters global configuration mode.
Step 2	`Switch(config-if)# interface interface-id`	Enters interface configuration mode and specifies the interface to be enabled for 802.1X authentication.
Step 3	`Switch(config-if)# dot1x port-control auto]`	Enables 802.1X authentication on the interface. For feature interaction information with trunk, dynamic, dynamic-access, EtherChannel, secure, and SPAN ports, see the "802.1X Configuration Guidelines" section on page 28-12.
Step 4	`Switch(config-if)# dot1x guest-vlan vlan-id`	Enables a guest VLAN on a particular interface.
Step 5	`Switch(config-if)# end`	Returns to configuration mode.
Step 6	`Switch(config)# end`	Returns to privileged EXEC mode.

To disable the guest VLAN feature on a particular port, use the **no dot1x guest-vlan** interface configuration command.

This example shows how to enable a guest VLAN on Fast Ethernet interface 4/3:

```
Switch# configure terminal
Switch(config)# interface fastethernet4/3
Switch(config-if)# dot1x port-control auto
Switch(config-if)# dot1x guest-vlan 50
Switch(config-if)# end
Switch(config)# end
Switch#
```

Enabling Periodic Reauthentication

You can enable periodic 802.1X client reauthentication and specify how often it occurs. If you do not specify a time value before enabling reauthentication, the interval between reauthentication attempts is 3600 seconds.

Automatic 802.1X client reauthentication is a per-interface setting and can be set for clients connected to individual ports. To manually reauthenticate the client connected to a specific port, see the "Manually Reauthenticating a Client Connected to a Port" section on page 28-17.

To enable periodic reauthentication of the client and to configure the number of seconds between reauthentication attempts, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and specifies the interface to be enabled for periodic reauthentication.
Step 3	`Switch(config-if)# dot1x re-authentication`	Enables periodic reauthentication of the client, which is disabled by default.
Step 4	`Switch(config)# dot1x timeout reauth-period seconds`	Specifies the number of seconds between reauthentication attempts. The range is 1 to 65,535; the default is 3600 seconds. This command affects the behavior of the switch only if periodic reauthentication is enabled.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show dot1x all`	Verifies your entries.
Step 7	`Switch(config)# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To disable periodic reauthentication, use the **no dot1x re-authentication** interface configuration command. To return to the default number of seconds between reauthentication attempts, use the **no dot1x timeout reauth-period** global configuration command.

This example shows how to enable periodic reauthentication and set the number of seconds between reauthentication attempts to 4000:

```
Switch(config)# dot1x timeout reauth-period 4000
Switch(config)# dot1x re-authentication
```

Manually Reauthenticating a Client Connected to a Port

You can manually reauthenticate a client connected to a specific port at any time by entering the **dot1x re-authenticate interface** *interface-id* privileged EXEC command. If you want to enable or disable periodic reauthentication, see the "Enabling Periodic Reauthentication" section on page 28-16.

This example shows how to manually reauthenticate the client connected to Fast Ethernet port 1/1:

```
Switch# dot1x re-authenticate interface fastethernet1/1
Starting reauthentication on FastEthernet1/1
```

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 idle time is determined by the **quiet-period** value. 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.

To change the quiet period, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and specifies the interface to be enabled for timeout **quiet-period**.
Step 3	`Switch(config)# dot1x timeout quiet-period seconds`	Sets the number of seconds that the switch remains in the **quiet-period** following a failed authentication exchange with the client. The range is 0 to 65,535 seconds; the default is 60.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show dot1x all`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default quiet-period, use the **no dot1x timeout quiet-period** configuration command. This example shows how to set the **quiet-period** on the switch to 30 seconds:

```
Switch(config)# 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 retransmits 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.

To change the amount of time that the switch waits for client notification, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and specifies the interface to be enabled for timeout tx-period.
Step 3	`Switch(config-if)# dot1x timeout tx-period seconds`	Sets the number of seconds that the switch waits for a response to an EAP-request/identity frame from the client before retransmitting the request. The range is 1 to 65,535 seconds; the default is 30.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show dot1x all`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default retransmission time, use the **no dot1x timeout tx-period** interface configuration command.

This example shows how to set the retransmission time to 60 seconds:

```
Switch(config)# dot1x timeout tx-period 60
```

Setting the Switch-to-Client Frame-Retransmission Number

In addition to changing the switch-to-client retransmission times, you can change the number of times that the switch sends EAP-Request/Identity and other EAP-Request frames to the client before restarting the authentication process. The number of EAP-Request/Identity retransmissions is controlled by the **dot1x max-reauth-req** command; the number of retransmissions for other EAP-Request frames is controlled by the **dot1x max-req** command.

Note You should change the default values of these commands only to adjust for unusual circumstances such as unreliable links or specific behavioral problems with certain clients and authentication servers.

To set the switch-to-client frame-retransmission numbers, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode and specifies the interface to be enabled for **max-reauth-req** and/or **max-req**.
Step 3	`Switch(config-if)# dot1x max-req` *count* or `Switch(config-if)# dot1x max-req` *count*	Specifies the number of times that the switch retransmits an EAP-request frame of a type other than EAP-request/identity to the client before restarting the authentication process. Specifies the number of times that the switch retransmits an EAP-request/identity frame to the client before restarting the authentication process. The range for *count* is 1 to 10; the default is 2.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show dot1x all`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To return to the default retransmission number, use the **no dot1x max-req** and **no dot1x max-reauth-req** global configuration command.

This example shows how to set 5 as the number of times that the switch retransmits an EAP-request/identity request before restarting the authentication process:

```
Switch(config)# dot1x max-reauth-req 5
```

Enabling Multiple Hosts

You can attach multiple hosts to a single 802.1X-enabled port as shown in Figure 28-4 on page 28-10. In this mode, only one of the attached hosts must be successfully authorized for all hosts to be granted network access. If the port becomes unauthorized (reauthentication fails or an EAPOL-logoff message is received), all attached clients are denied access to the network.

To allow multiple hosts (clients) on an 802.1X-authorized port that has the **dot1x port-control** interface configuration command set to **auto**, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode and specifies the interface to which multiple hosts are indirectly attached.
Step 3	`Switch(config-if)# dot1x multiple-hosts`	Allows multiple hosts (clients) on an 802.1X-authorized port. Make sure that the **dot1x port-control** interface configuration command set is set to **auto** for the specified interface.
Step 4	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show dot1x all interface` *interface-id*	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To disable multiple hosts on the port, use the **no dot1x multiple-hosts** interface configuration command.

This example shows how to enable 802.1X on Fast Ethernet interface 0/1 and to allow multiple hosts:

```
Switch(config)# interface fastethernet0/1
Switch(config-if)# dot1x port-control auto
Switch(config-if)# dot1x multiple-hosts
```

Resetting the 802.1X Configuration to the Default Values

To reset the 802.1X configuration to the default values, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# dot1x default`	Resets the configurable 802.1X parameters to the default values.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show dot1x all`	Verifies your entries.
Step 5	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Displaying 802.1X Statistics and Status

To display 802.1X statistics for all interfaces, use the **show dot1x statistics** privileged EXEC command. To display 802.1X statistics for a specific interface, use the **show dot1x statistics interface** *interface-id* privileged EXEC command.

To display the 802.1X administrative and operational status for the switch, use the **show dot1x all** privileged EXEC command. To display the 802.1X administrative and operational status for a specific interface, use the **show dot1x interface** *interface-id* privileged EXEC command.

Configuring Port Security

This chapter describes how to configure port security on Catalyst 4500 series switches. It provides guidelines, procedures, and configuration examples.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

This chapter consists of these sections:

Overview of Port Security

You can use the port security feature to restrict input to an interface by limiting and identifying MAC addresses of the workstations that are 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 workstation attempting to access the port is different from any of the identified secure MAC addresses, a security violation occurs.

After you have set the maximum number of secure MAC addresses on a port, the secure addresses are included in an address table in one of these ways:

- You can configure all secure MAC addresses by using the **switchport port-security mac-address** *mac_address* interface configuration command.
- You can allow the port to dynamically configure secure MAC addresses with the MAC addresses of connected devices.
- You can configure a number of addresses and allow the rest to be dynamically configured.

Note If the port shuts down, all dynamically learned addresses are removed.

- You can configure MAC addresses to be sticky. 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, the interface does not need to dynamically relearn them when the switch restarts. Although sticky secure addresses can be manually configured, it is not recommended.

You can configure an interface to convert the dynamic MAC addresses to sticky secure MAC addresses and to add them to the running configuration by enabling *sticky learning*. To enable sticky learning, enter the **switchport port-security mac-address sticky** 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.

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 configuration, 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.

After the maximum number of secure MAC addresses is configured, they are stored in an address table. To ensure that an attached device has the full bandwidth of the port, configure the MAC address of the attached device and set the maximum number of addresses to one, which is the default.

Note When a Catalyst 4500 series switch port is configured to support voice as well as port security, the maximum number of allowable MAC addresses on this port should be changed to three.

A security violation occurs if the maximum number of secure MAC addresses has been added to the address table and a workstation whose MAC address is not in the address table attempts to access the interface.

You can configure the interface for one of these violation modes, based on the action to be taken if a violation occurs:

- Restrict—A port security violation restricts data, causes the SecurityViolation counter to increment, and causes an SNMP Notification to be generated. The rate at which SNMP traps are generated can be controlled by the **snmp-server enable traps port-security trap-rate** command. The default value (“0”) causes an SNMP trap to be generated for every security violation.
- Shutdown—A port security violation causes the interface to shut down immediately. 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 reenable it by entering the **shutdown** and **no shut down** interface configuration commands. This is the default mode.

  You can also customize the time to recover from the specified error disable cause (default is 300 seconds) by entering the **errdisable recovery interval** *interval* command.

Default Port Security Configuration

Table 29-1 shows the default port security configuration for an interface.

Table 29-1 Default Port Security Configuration

Feature	Default Setting
Port security	Disabled on a port
Maximum number of secure MAC addresses	1
Violation mode	Shutdown. The port shuts down when the maximum number of secure MAC addresses is exceeded, and an SNMP trap notification is sent.
Aging	Disabled
Aging type	Absolute
Static Aging	Disabled
Sticky	Disabled

Port Security Guidelines and Restrictions

Follow these guidelines when configuring port security:

- A secure port cannot be a trunk port.
- A secure port cannot be a destination port for Switch Port Analyzer (SPAN).
- A secure port cannot belong to an EtherChannel port-channel interface.
- A secure port and static MAC address configuration are mutually exclusive.

Configuring Port Security

These sections describe how to configure port security:

- Configuring Port Security on an Interface, page 29-4
- Configuring Port Security Aging, page 29-6

Configuring Port Security on an Interface

To restrict traffic through a port by limiting and identifying MAC addresses of the stations allowed to access the port, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface interface_id`	Enters interface configuration mode and enters the physical interface to configure, for example **gigabitethernet 3/1**.
Step 2	`Switch(config-if)# switchport mode access`	Sets the interface mode as access; an interface in the default mode (dynamic desirable) cannot be configured as a secure port.
Step 3	`Switch(config-if)# switchport port-security`	Enables port security on the interface.
Step 4	`Switch(config-if)# switchport port-security maximum value`	(Optional) Sets the maximum number of secure MAC addresses for the interface. The range is 1 to 3072; the default is 1.
Step 5	`Switch(config-if)# switchport port-security violation {restrict | shutdown}`	(Optional) Sets the violation mode, the action to be taken when a security violation is detected, as one of these: • **restrict**—A port security violation restricts data and causes the SecurityViolation counter to increment and send an SNMP trap notification. • **shutdown**—The interface is error-disabled when a security 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 or you can manually reenable it by entering the **shutdown** and **no shut down** interface configuration commands.
Step 6	`Switch(config-if)# switchport port-security limit rate invalid-source-mac`	Sets the rate limit for bad packets.
Step 7	`Switch(config-if)# switchport port-security mac-address mac_address`	(Optional) Enters 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.
Step 8	`Switch(config-if)# switchport port-security mac-address sticky`	(Optional) Enable sticky learning on the interface.
Step 9	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 10	`Switch# show port-security address interface interface_id` `Switch# show port-security address`	Verifies your entries.

- To return the interface to the default condition as not a secure port, use the **no switchport port-security** interface configuration command.
- To return the interface to the default number of secure MAC addresses, use the no **switchport port-security maximum** *value*.
- To delete a MAC address from the address table, use the **no switchport port-security mac-address** *mac_address* command.
- To return the violation mode to the default condition (shutdown mode), use the **no switchport port-security violation** {**restrict** | **shutdown**} command.
- To disable sticky learning on an interface, use the **no switchport port-security mac-address sticky** command. The interface converts the sticky secure MAC addresses to dynamic secure addresses.
- To delete a sticky secure MAC addresses from the address table, use the **no switchport port-security sticky mac-address** *mac_address* command. To delete all the sticky addresses on an interface or a VLAN, use the **no switchport port-security sticky interface** *interface-id* command.
- To clear dynamically learned port security MAC in the CAM table, use the **clear port-security dynamic** command. The **address** keyword enables you to clear a secure MAC addresses. The **interface** keyword enables you to clear all secure addresses on an interface.

This example shows how to enable port security on Fast Ethernet port 12 and how to set the maximum number of secure addresses to 5. The violation mode is the default, and no secure MAC addresses are configured.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 3/12
Switch(config-if)# switchport mode access
Switch(config-if)# switchport port-security
Switch(config-if)# switchport port-security maximum 5
Switch(config-if)# switchport port-security mac-address sticky
Switch(config-if)# end
Switch# show port-security interface fastethernet 3/12
Port Security              :Enabled
Port Status                :Secure-up
Violation Mode             :Shutdown
Aging Time                 :0
Aging Type                 :Absolute
SecureStatic Address Aging :Enabled
Maximum MAC Addresses      :5
Total MAC Addresses        :0
Configured MAC Addresses   :0
Sticky MAC Addresses       :11
Last Source Address        :0000.0000.0401
Security Violation Count   :0
```

This example shows how to configure a secure MAC address on Fast Ethernet port 5/1 and verify the configuration:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport port-security
Switch(config-if)# switchport port-security maximum 10
Switch(config-if)# switchport port-security mac-address 0000.0000.0003 (Static secure MAC)
Switch(config-if)# switchport port-security mac-address sticky
Switch(config-if)#
switchport port-security mac-address sticky 0000.0000.0001 (Sticky static MAC)
Switch(config-if)# switchport port-security mac-address sticky 0000.0000.0002
Switch(config-if)# end
```

```
Switch#show port address
Secure Mac Address Table
------------------------------------------------------------------------
Vlan    Mac Address       Type                      Ports   Remaining Age
                                                              (mins)
----    -----------       ----                      -----   -------------
   1    0000.0000.0001    SecureSticky              Fa5/1        -
   1    0000.0000.0002    SecureSticky              Fa5/1        -
   1    0000.0000.0003    SecureConfigured          Fa5/1        -

------------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     : 2
Max Addresses limit in System (excluding one mac per port) : 1024
```

Configuring Port Security Aging

You can use port security aging to set the aging time and aging type for all secure addresses on a port.

Use this feature to remove and add PCs on a secure port without manually deleting the existing secure MAC addresses while still limiting the number of secure addresses on a port.

To configure port security aging, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface interface_id`	Enters interface configuration mode for the port on which you want to enable port security aging.
Step 2	`Switch(config-if)# switchport port-security [ aging {static | time aging_time | type {absolute | inactivity} ]`	Sets the aging time for the secure port. The **static** keyword enables aging for statically configured secure addresses on this port. The **time** *aging_tim*e keyword specifies the aging time for this port. Valid range for *aging_time* is from 0 to 1440 minutes. If the time is equal to 0, aging is disabled for this port. The **type** keyword sets the aging type as **absolute** or **inactive**. For absolute aging, all the secure addresses on this port ago out exactly after the time (minutes) specified and are removed from the secure address list. For inactive aging, the secure addresses on this port ago out only if there is no data traffic from the secure source address for the specified time period.
Step 3	`Switch(config-if)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show port security [interface interface_id] [address]`	Verifies your entries.

To disable port security aging for all secure addresses on a port, use the **no switchport port-security aging time** interface configuration command.

This example shows how to set the aging time as 2 hours for the secure addresses on the Fast Ethernet interface 5/1:

```
Switch(config)# interface fastethernet 5/1
Switch(config-if)# switchport port-security aging time 120
```

This example shows how to set the aging time as 2 minutes:

```
Switch(config-if)# switchport port-security aging time 2
```

You can verify the previous commands by entering the **show port-security interface** *interface_id* command.

Displaying Port Security Settings

Use the **show port-security** command to display port-security settings for an interface or for the switch.

To display traffic control information, perform one or more of these tasks:

Command	Purpose
`Switch# show port-security [interface interface_id]`	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.
`Switch# show port-security [interface interface_id] address`	Displays all secure MAC addresses configured on all switch interfaces or on a specified interface with aging information for each address.

This example displays output from the **show port-security** command when you do not enter an interface:

```
Switch# show port-security
Secure Port  MaxSecureAddr  CurrentAddr  SecurityViolation  Security Action
                 (Count)       (Count)          (Count)
---------------------------------------------------------------------------
      Fa3/1              2            2                  0         Restrict
      Fa3/2              2            2                  0         Restrict
      Fa3/3              2            2                  0         Shutdown
      Fa3/4              2            2                  0         Shutdown
      Fa3/5              2            2                  0         Shutdown
      Fa3/6              2            2                  0         Shutdown
      Fa3/7              2            2                  0         Shutdown
      Fa3/8              2            2                  0         Shutdown
     Fa3/10              1            0                  0         Shutdown
     Fa3/11              1            0                  0         Shutdown
     Fa3/12              1            0                  0         Restrict
     Fa3/13              1            0                  0         Shutdown
     Fa3/14              1            0                  0         Shutdown
     Fa3/15              1            0                  0         Shutdown
     Fa3/16              1            0                  0         Shutdown
---------------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     :8
Max Addresses limit in System (excluding one mac per port) :1024
Global SNMP trap control for port-security                 :20 (traps per second)
```

This example displays output from the **show port-security** command for a specified interface:

```
Switch# show port-security interface fastethernet 5/1
Port Security              : Enabled
Port Status                : Secure-up
Violation Mode             : Shutdown
Aging Time                 : 0 mins
Aging Type                 : Absolute
SecureStatic Address Aging : Disabled
Maximum MAC Addresses      : 1
Total MAC Addresses        : 1
Configured MAC Addresses   : 0
Sticky MAC Addresses       : 1
Last Source Address        : 0000.0001.001a
Security Violation Count   : 0
```

This example displays output from the **show port-security address** command:

```
Switch#sh port-security address
          Secure Mac Address Table
------------------------------------------------------------------------
Vlan    Mac Address       Type                Ports   Remaining Age
                                                          (mins)
----    -----------       ----                -----   -------------
   1    0000.0001.0000    SecureConfigured    Fa3/1       15 (I)
   1    0000.0001.0001    SecureConfigured    Fa3/1       14 (I)
   1    0000.0001.0100    SecureConfigured    Fa3/2        -
   1    0000.0001.0101    SecureConfigured    Fa3/2        -
   1    0000.0001.0200    SecureConfigured    Fa3/3        -
   1    0000.0001.0201    SecureConfigured    Fa3/3        -
   1    0000.0001.0300    SecureConfigured    Fa3/4        -
   1    0000.0001.0301    SecureConfigured    Fa3/4        -
   1    0000.0001.1000    SecureDynamic    Fa3/5        -
   1    0000.0001.1001    SecureDynamic    Fa3/5        -
   1    0000.0001.1100    SecureDynamic    Fa3/6        -
   1    0000.0001.1101    SecureDynamic    Fa3/6        -
   1    0000.0001.1200    SecureSticky    Fa3/7        -
   1    0000.0001.1201    SecureSticky    Fa3/7        -
   1    0000.0001.1300    SecureSticky    Fa3/8        -
   1    0000.0001.1301    SecureSticky    Fa3/8        -
------------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     :8
Max Addresses limit in System (excluding one mac per port) :1024
```

CHAPTER 30

Configuring DHCP Snooping and IP Source Guard

This chapter describes how to configure Dynamic Host Configuration Protocol (DHCP) snooping and IP Source Guard on Catalyst 4500 series switches. It provides guidelines, procedures, and configuration examples.

This chapter consists of the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of DHCP Snooping

DHCP snooping is a DHCP security feature that provides security by filtering untrusted DHCP messages and by building and maintaining a DHCP snooping binding table. An untrusted message is a message that is received from outside the network or firewall and that can cause traffic attacks within your network.

The DHCP snooping binding table contains the MAC address, IP address, lease time, binding type, VLAN number, and interface information that corresponds to the local untrusted interfaces of a switch; it does not contain information regarding hosts interconnected with a trusted interface. An untrusted interface is an interface that is configured to receive messages from outside the network or firewall. A trusted interface is an interface that is configured to receive only messages from within the network.

DHCP snooping acts like a firewall between untrusted hosts and DHCP servers. It also gives you a way to differentiate between untrusted interfaces connected to the end-user and trusted interfaces connected to the DHCP server or another switch.

Note In order to enable DHCP snooping on a VLAN, you must enable DHCP snooping on the switch.

You can configure DHCP snooping for switches and VLANs. When you enable DHCP snooping on a switch, the interface acts as a Layer 2 bridge, intercepting and safeguarding DHCP messages going to a Layer 2 VLAN. When you enable DHCP snooping on a VLAN, the switch acts as a Layer 2 bridge within a VLAN domain.

Overview of the DHCP Snooping Database Agent

To retain the bindings across switch reloads, you must use the DHCP snooping database agent. Without this agent, the bindings established by DHCP snooping are lost upon switch reload. Connectivity is lost as well.

The mechanism for the database agent stores the bindings in a file at a configured location. Upon reload, the switch reads the file to build the database for the bindings. The switch keeps the file current by writing to the file as the database changes.

The format of the file that contains the bindings is as follows:

```
<initial-checksum>
TYPE DHCP-SNOOPING
VERSION 1
BEGIN
<entry-1> <checksum-1>
<entry-2> <checksum-1-2>
...
...
<entry-n> <checksum-1-2-..-n>
END
```

Each entry in the file is tagged with a checksum that is used to validate the entries whenever the file is read. The <initial-checksum> entry on the first line helps distinguish entries associated with the latest write from entries that are associated with a previous write.

This is a sample bindings file:

```
3ebe1518
TYPE DHCP-SNOOPING
VERSION 1
BEGIN
1.1.1.1 512 0001.0001.0005 3EBE2881 Gi1/1                                    e5e1e733
1.1.1.1 512 0001.0001.0002 3EBE2881 Gi1/1                                    4b3486ec
1.1.1.1 1536 0001.0001.0004 3EBE2881 Gi1/1                                   f0e02872
1.1.1.1 1024 0001.0001.0003 3EBE2881 Gi1/1                                   ac41adf9
1.1.1.1 1 0001.0001.0001 3EBE2881 Gi1/1                                      34b3273e
END
```

Each entry holds an IP address, VLAN, MAC address, lease time (in hex), and the interface associated with a binding. At the end of each entry is a checksum that accounts for all the bytes from the start of the file through all the bytes associated with the entry. Each entry consists of 72 bytes of data, followed by a space, followed by a checksum.

Upon bootup, when the calculated checksum equals the stored checksum, a switch reads entries from the file and adds the bindings to the DHCP snooping database. When the calculated checksum does not equal the stored checksum, the entry read from the file is ignored and so are all the entries following the failed entry. The switch also ignores all those entries from the file whose lease time has expired. (This situation

is possible because the lease time might indicate an expired time.) An entry from the file is also ignored if the interface referred to in the entry, no longer exists on the system or if it is a router port or a DHCP snooping-trusted interface.

When a switch learns of new bindings or when it loses some bindings, the switch writes the modified set of entries from the snooping database to the file. The writes are performed with a configurable delay to batch as many changes as possible before the actual write happens. Associated with each transfer is a timeout after which a transfer is aborted if it is not completed. These timers are referred to as the write delay and abort timeout.

Configuring DHCP Snooping on the Switch

When you configure DHCP snooping on your switch, you are enabling the switch to differentiate untrusted interfaces from trusted interfaces. You must enable DHCP snooping globally before you can use DHCP snooping on a VLAN. You can enable DHCP snooping independently from other DHCP features.

Once you have enabled DHCP snooping, all the DHCP relay information option configuration commands are disabled; this includes the following commands:

- **ip dhcp relay information check**
- **ip dhcp relay information policy**
- **ip dhcp relay information trusted**
- **ip dhcp relay information trust-all**

These sections describe how to configure DHCP snooping:

Note For DHCP server configuration information, refer to "Configuring DHCP" in the *Cisco IOS IP and IP Routing Configuration Guide* at:
http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/ip_c/ipcprt1/1cddhcp.htm

Default Configuration for DHCP Snooping

DHCP snooping is disabled by default. Table 30-1 shows all the default configuration values for each DHCP snooping option.

Table 30-1 Default Configuration Values for DHCP Snooping

Option	Default Value/State
DHCP snooping	Disabled
DHCP snooping information option	Enabled
DHCP snooping limit rate	Infinite (functions as if rate limiting were disabled)

Table 30-1 Default Configuration Values for DHCP Snooping (continued)

Option	Default Value/State
DHCP snooping trust	Untrusted
DHCP snooping vlan	Disabled

If you want to change the default configuration values, see the "Enabling DHCP Snooping" section.

Enabling DHCP Snooping

Note When DHCP snooping is enabled globally, DHCP requests are dropped until the ports are configured. Consequently, you should probably this feature during a maintenance window and not during production.

To enable DHCP snooping, perform this task:

	Command	Purpose
Step 1	`Switch(config)# ip dhcp snooping`	Enables DHCP snooping globally. You can use the **no** keyword to disable DHCP snooping.
Step 2	`Switch(config)# ip dhcp snooping vlan` *number* `[`*number*`] | vlan {`*vlan range*`}]`	Enables DHCP snooping on your VLAN or VLAN range
Step 3	`Switch(config-if)# ip dhcp snooping trust`	Configures the interface as trusted or untrusted. You can use the **no** keyword to configure an interface to receive messages from an untrusted client.
Step 4	`Switch(config-if)# ip dhcp snooping limit rate` *rate*	Configures the number of DHCP packets per second (pps) that an interface can receive.[1]
Step 5	`Switch(config)# end`	Exits configuration mode.
Step 6	`Switch# show ip dhcp snooping`	Verifies the configuration.

1. Cisco recommends not configuring the untrusted interface rate limit to more than 100 packets per second. The recommended rate limit for each untrusted client is 15 packets per second. Normally, the rate limit applies to untrusted interfaces. If you want to set up rate limiting for trusted interfaces, keep in mind that trusted interfaces aggregate all DHCP traffic in the switch, and you will need to adjust the rate limit to a higher value. You should fine tune this threshold depending on the network configuration. The CPU should not receive DHCP packets at a sustained rate of more than 1,000 packets per second

You can configure DHCP snooping for a single VLAN or a range of VLANs. To configure a single VLAN, enter a single VLAN number. To configure a range of VLANs, enter a beginning and an ending VLAN number or a dash and range of VLANs.

This example shows how to enable DHCP snooping on VLANs 10 through 100:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip dhcp snooping
Switch(config)# ip dhcp snooping vlan 10 100
Switch(config)# interface GigabitEthernet 5/1
Switch(config-if)# ip dhcp snooping trust
Switch(config-if)# interface FastEthernet 2/1
Switch(config-if)# ip dhcp snooping limit rate 100
```

```
Switch(config)# end
Switch# show ip dhcp snooping
Switch DHCP snooping is enabled.
DHCP Snooping is configured on the following VLANs:
    10-100
Insertion of option 82 information is enabled.
Interface           Trusted        Rate limit (pps)
---------           -------        ----------------
FastEthernet2/1     yes            100
FastEthernet2/2     yes            none
FastEthernet3/1     no             20
GigabitEthernet5/1     yes            none

Switch#
```

The following configuration describes the DHCP snooping configuration steps if routing is defined on another Catalyst switch (for example, a Catalyst 6500 series switch):

```
// Trust the uplink gigabit Ethernet trunk port

interface range GigabitEthernet 1/1 - 2
switchport mode trunk
switchport trunk encapsulation dot1q
ip dhcp snooping trust

!

interface VLAN 14
ip address 10.33.234.1 255.255.254.0
ip helper-address 10.5.1.2
```

Note If you are enabling trunking on uplink gigabit interfaces, and the above routing configuration is defined on a Catalyst 6500 series switch, you must configure the "trust" relationship with downstream DHCP Snooping (on a Catalyst 4500 series switch) which adds Option 82. On a Catalyst 6500 series switch, this task is accomplished with **ip dhcp relay information trusted** VLAN configuration command.

Enabling DHCP Snooping on Private VLAN

DHCP snooping can be enabled on private VLANs, which provide isolation between Layer 2 ports within the same VLAN. If DHCP snooping is enabled (or disabled), the configuration is propagated to both the primary VLAN and its associated secondary VLANs. You cannot enable (or disable) DHCP snooping on a primary VLAN without reflecting this configuration change on the secondary VLANs.

Configuring DHCP snooping on a secondary VLAN is still allowed, but it will not take effect if the associated primary VLAN is already configured. If the associated primary VLAN is configured, the effective DHCP snooping mode on the secondary VLAN is derived from the corresponding primary VLAN. Manually configuring DHCP snooping on a secondary VLAN will cause the switch to issue this warning message:

```
DHCP Snooping configuration may not take effect on secondary vlan XXX
```

The **show ip dhcp snooping** command will display all VLANs (both primary and secondary) that have DHCP snooping enabled.

Enabling the DHCP Snooping Database Agent

To configure the database agent, perform one or more of the following tasks:

Command	Purpose

`Switch(config)# ip dhcp snooping database { url | write-delay seconds | timeout seconds }`
 	
`Switch(config)# no ip dhcp snooping database [write-delay | timeout]`
	(Required) Configures a URL for the database agent (or file) and the related timeout values.

`Switch# show ip dhcp snooping database [detail]`	(Optional) Displays the current operating state of the database agent and statistics associated with the transfers.
`Switch# clear ip dhcp snooping database statistics`	(Optional) Clears the statistics associated with the database agent.
`Switch# renew ip dhcp snooping database [validation none] [url]`	(Optional) Requests the read entries from a file at the given URL.

`Switch# ip dhcp snooping binding mac-addr vlan vlan ipaddr interface ifname expiry lease-in-seconds`
 	
`Switch# no ip dhcp snooping binding mac-addr vlan vlan ipaddr interface ifname`
	(Optional) Adds/deletes bindings to the snooping database.

Note Because both NVRAM and bootflash have limited storage capacity, storing a file on an TFTP server is preferred. Moreover, when a file is stored in a remote location accessible through TFTP, an RPR standby supervisor engine can take over the binding list when a switchover occurs.

Note Network-based URLs (such as TFTP and FTP) require that you create an empty file at the configured URL before the switch can write the set of bindings for the first time.

Configuration Examples for the Database Agent

The following examples show how to use the above commands.

Example 1: Enabling the Database Agent

The following example shows how to configure the DHCP snooping database agent to store the bindings at a given location and to view the configuration and operating state:

```
Switch# configure terminal
Switch(config)# ip dhcp snooping database tftp://10.1.1.1/directory/file
Switch(config)# end
Switch# show ip dhcp snooping database detail
Agent URL : tftp://10.1.1.1/directory/file
Write delay Timer : 300 seconds
Abort Timer : 300 seconds
```

```
Agent Running : No
Delay Timer Expiry : 7 (00:00:07)
Abort Timer Expiry : Not Running

Last Succeded Time : None
Last Failed Time : 17:14:25 UTC Sat Jul 7 2001
Last Failed Reason : Unable to access URL.

Total Attempts       :       21   Startup Failures :        0
Successful Transfers :        0   Failed Transfers :       21
Successful Reads     :        0   Failed Reads     :        0
Successful Writes    :        0   Failed Writes    :       21
Media Failures       :        0

First successful access: Read

Last ignored bindings counters :
Binding Collisions    :        0   Expired leases    :        0
Invalid interfaces    :        0   Unsupported vlans :        0
Parse failures        :        0
Last Ignored Time : None

Total ignored bindings counters:
Binding Collisions    :        0   Expired leases    :        0
Invalid interfaces    :        0   Unsupported vlans :        0
Parse failures        :        0

Switch#
```

The first three lines of output show the configured URL and related timer configuration values. The next three lines show the operating state and the amount of time left for expiry of write delay and abort timers.

Among the statistics shown in the output, startup failures indicate the number of attempts the read or create of the file has failed upon bootup.

Note Because the location is based off in the network, you must create a temporary file on the TFTP server. You can create a temporary file on a typical UNIX workstation by creating a 0 byte file “file” in the directory “directory” that can be referenced by the TFTP server daemon. With some server implementations on UNIX workstations, the file should be provided with full (777) permissions for write access to the file.

DHCP snooping bindings are keyed on the MAC address and VLAN combination. Therefore, if an entry in the remote file has an entry for a given MAC address and VLAN set, for which the switch already has a binding, the entry from the remote file is ignored when the file is read. This condition is referred to as the binding collision.

An entry in a file may no longer be valid because the lease indicated by the entry may have expired by the time it is read. The expired leases counter indicates the number of bindings ignored because of this condition. The Invalid interfaces counter refers to the number of bindings that have been ignored when the interface referred by the entry either does not exist on the system or is a router or DHCP snooping trusted interface if it exists, when the read happened. Unsupported VLANs refers to the number of entries that have been ignored because the indicated VLAN is not supported on the system. The Parse failures counter provides the number of entries that have been ignored when the switch is unable to interpret the meaning of the entries from the file.

The switch maintains two sets of counters for these ignored bindings. One provides the counters for a read that has at least one binding ignored by at least one of these conditions. These counters are shown as the "Last ignored bindings counters." The total ignored bindings counters provides a sum of the number of bindings that have been ignored because of all the reads since the switch bootup. These two set of counters are cleared by the **clear** command. Therefore, the total counter set may indicate the number of bindings that have been ignored since the last clear.

Example 2: Reading Binding Entries from a TFTP File

To manually read the entries from a TFTP file, perform this task:

	Command	Purpose
Step 1	`Switch# sh ip dhcp snooping database`	Displays the DHCP snooping database agent statistics.
Step 2	`Switch# renew ip dhcp snoop data` *url*	Directs the switch to read the file from given URL.
Step 3	`Switch# sh ip dhcp snoop data`	Displays the read status.
Step 4	`Switch# sh ip dhcp snoop bind`	Verifies whether the bindings were read successfully.

This is an example of how to manually read entries from the tftp://10.1.1.1/directory/file:

```
Switch# sh ip dhcp snooping database
Agent URL :
Write delay Timer : 300 seconds
Abort Timer : 300 seconds

Agent Running : No
Delay Timer Expiry : Not Running
Abort Timer Expiry : Not Running

Last Succeded Time : None
Last Failed Time : None
Last Failed Reason : No failure recorded.

Total Attempts       :        0   Startup Failures :        0
Successful Transfers :        0   Failed Transfers :        0
Successful Reads     :        0   Failed Reads     :        0
Successful Writes    :        0   Failed Writes    :        0
Media Failures       :        0
Switch#
Switch# renew ip dhcp snoop data tftp://10.1.1.1/directory/file
Loading directory/file from 10.1.1.1 (via GigabitEthernet1/1): !
[OK - 457 bytes]
Database downloaded successfully.

Switch#
00:01:29: %DHCP_SNOOPING-6-AGENT_OPERATION_SUCCEEDED: DHCP snooping database Read
succeeded.
Switch#
Switch# sh ip dhcp snoop data
Agent URL :
Write delay Timer : 300 seconds
Abort Timer : 300 seconds

Agent Running : No
Delay Timer Expiry : Not Running
Abort Timer Expiry : Not Running
```

```
Last Succeded Time : 15:24:34 UTC Sun Jul 8 2001
Last Failed Time : None
Last Failed Reason : No failure recorded.

Total Attempts       :        1   Startup Failures :        0
Successful Transfers :        1   Failed Transfers :        0
Successful Reads     :        1   Failed Reads     :        0
Successful Writes    :        0   Failed Writes    :        0
Media Failures       :        0
Switch#
Switch# sh ip dhcp snoop bind
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:01:00:01:00:05   1.1.1.1          49810       dhcp-snooping  512   GigabitEthernet1/1
00:01:00:01:00:02   1.1.1.1          49810       dhcp-snooping  512   GigabitEthernet1/1
00:01:00:01:00:04   1.1.1.1          49810       dhcp-snooping  1536  GigabitEthernet1/1
00:01:00:01:00:03   1.1.1.1          49810       dhcp-snooping  1024  GigabitEthernet1/1
00:01:00:01:00:01   1.1.1.1          49810       dhcp-snooping  1     GigabitEthernet1/1
Switch#
Switch#clear ip dhcp snoop bind
Switch#sh ip dhcp snoop bind
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
Switch#
```

Example 3: Adding Information to the DHCP Snooping Database

To manually add a binding to the DHCP snooping database, perform the following task:

	Command	Purpose
Step 1	`Switch# show ip dhcp snooping binding`	Views the DHCP snooping database
Step 2	`Switch# ip dhcp snooping binding` *binding-id* `vlan` *vlan-id* `interface` *interface* `expiry` *lease-time*	Adds the binding using the 'ip dhcp snooping' exec command
Step 3	`Switch# show ip dhcp snooping binding`	Checks the DHCP snooping database

This example shows how to manually add a binding to the DHCP snooping database:

```
Switch# show ip dhcp snooping binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
Switch#
Switch# ip dhcp snooping binding 1.1.1 vlan 1 1.1.1.1 interface gi1/1 expiry 1000

Switch# show ip dhcp snooping binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:01:00:01:00:01   1.1.1.1          992         dhcp-snooping  1     GigabitEthernet1/1
Switch#
```

Displaying DHCP Snooping Information

You can display a DHCP snooping binding table and configuration information for all interfaces on a switch.

Displaying a Binding Table

The DHCP snooping binding table for each switch contains binding entries that correspond to untrusted ports. The table does not contain information about hosts interconnected with a trusted port because each interconnected switch will have its own DHCP snooping binding table.

This example shows how to display the DHCP snooping binding information for a switch:

```
Switch# sh ip dhcp snooping binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:02:B3:3F:3B:99   55.5.5.2         6943        dhcp-snooping  10    FastEthernet6/10
Switch#
```

Table 30-2 describes the fields in the **show ip dhcp snooping binding** command output.

Table 30-2 show ip dhcp snooping binding Command Output

Field	Description
MAC Address	Client hardware MAC address
IP Address	Client IP address assigned from the DHCP server
Lease (seconds)	IP address lease time
Type	Binding type; dynamic binding learned by dhcp-snooping or statically-configured binding.
VLAN	VLAN number of the client interface
Interface	Interface that connects to the DHCP client host

Displaying the DHCP Snooping Configuration

This example shows how to display the DHCP snooping configuration for a switch.

```
Switch# show ip dhcp snooping
Switch DHCP snooping is enabled.
DHCP Snooping is configured on the following VLANs:
    10 30-40 100 200-220
Insertion of option 82 information is enabled.
Interface           Trusted        Rate limit (pps)
---------           -------        ----------------
FastEthernet2/1     yes            10
FastEthernet3/1     yes            none
GigabitEthernet1/1  no             20
Switch#
```

Overview of IP Source Guard

Similar to DHCP snooping, this feature is enabled on a DHCP snooping untrusted Layer 2 port. Initially, all IP traffic on the port is blocked except for DHCP packets that are captured by the DHCP snooping process. When a client receives a valid IP address from the DHCP server, or when a static IP source binding is configured by the user, a per-port and VLAN Access Control List (PVACL) is installed on the port. This process restricts the client IP traffic to those source IP addresses configured in the binding; any IP traffic with a source IP address other than that in the IP source binding will be filtered out. This filtering limits a host's ability to attack the network by claiming a neighbor host's IP address.

Note If IP Source Guard is enabled on a trunk port with a large number of VLANs that have DHCP snooping enabled, you might run out of ACL hardware resources, and some packets might be switched in software instead.

Note When IP Source Guard is enabled, you might want to designate an alternative scheme for ACL hardware programming. For more information, see the “TCAM Programming and ACLs” section in the "Configuring Network Security with ACLs” chapter.

IP Source Guard supports the Layer 2 port only, including both access and trunk. For each untrusted Layer 2 port, there are two levels of IP traffic security filtering:

- Source IP address filter

  IP traffic is filtered based on its source IP address. Only IP traffic with a source IP address that matches the IP source binding entry is permitted.

  An IP source address filter is changed when a new IP source entry binding is created or deleted on the port. The port PVACL will be recalculated and reapplied in the hardware to reflect the IP source binding change. By default, if the IP filter is enabled without any IP source binding on the port, a default PVACL that denies all IP traffic is installed on the port. Similarly, when the IP filter is disabled, any IP source filter PVACL will be removed from the interface.

- Source IP and MAC address filter

  IP traffic is filtered based on its source IP address as well as its MAC address; only IP traffic with source IP and MAC addresses matching the IP source binding entry are permitted.

Note When IP source guard is enabled in IP and MAC filtering mode, the DHCP snooping option 82 must be enabled to ensure that the DHCP protocol works properly. Without option 82 data, the switch cannot locate the client host port to forward the DHCP server reply. Instead, the DHCP server reply is dropped, and the client cannot obtain an IP address.

Configuring IP Source Guard on the Switch

To enable IP Source Guard, perform this task:

	Command	Purpose
Step 1	`Switch(config)# ip dhcp snooping`	Enables DHCP snooping globally. You can use the **no** keyword to disable DHCP snooping.
Step 2	`Switch(config)# ip dhcp snooping vlan` *number* [*number*]	Enables DHCP snooping on your VLANs.
Step 3	`Switch(config-if)# no ip dhcp snooping trust`	Configures the interface as trusted or untrusted. You can use the **no** keyword of to configure an interface to receive only messages from within the network.
Step 4	`Switch(config-if)# ip verify source vlan dhcp-snooping port-security`	Enables IP source guard, source IP, and source MAC address filtering on the port.

	Command	Purpose
Step 5	`Switch(config-if)# switchport port-security limit rate invalid-source-mac N`	Enables security rate limiting for learned source MAC addresses on the port. **Note** This limit only applies to the port where IP Source Guard is enabled as filtering both IP and MAC addresses.
Step 6	`Switch(config)# ip source binding` *ip-addr ip* `vlan` *number* `interface` *interface*	Configures a static IP binding on the port.
Step 7	`Switch(config)# end`	Exits configuration mode.
Step 8	`Switch# show ip verify source interface` *interface-name*	Verifies the configuration.

Note The static IP source binding can only be configured on switch port. If you issue the **ip source binding vlan interface** command on a Layer 3 port, you will receive this error message:

```
Static IP source binding can only be configured on switch port.
```

This example shows how to enable per-Layer 2-port IP source guard on VLANs 10 through 20:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip dhcp snooping
Switch(config)# ip dhcp snooping vlan 10 20
Switch(config)# interface fa6/1
Switch(config-if)# switchport trunk encapsulation dot1q
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk native vlan 10
Switch(config-if)# switchport trunk allowed vlan 11-20
Switch(config-if)# no ip dhcp snooping trust
Switch(config-if)# ip verify source vlan dhcp-snooping
Switch(config)# end
Switch# sh ip verify source interface f6/1
Interface  Filter-type  Filter-mode  IP-address       Mac-address        Vlan
---------  -----------  -----------  ---------------  -----------------  ----------
Fa6/1      ip-mac       active       10.0.0.1                            10
Fa6/1      ip-mac       active       deny-all                            11-20
Switch#
```

The output shows that there is one valid DHCP binding to VLAN 10.

Configuring IP Source Guard on Private VLANs

For private VLAN ports, you must enable DHCP snooping on primary VLANs in order for IP source guard to be effective. IP source guard on a primary VLAN will automatically propagate to a secondary VLAN. Configuring a static IP source binding on a secondary VLAN is allowed, but it will not take effect. When manually configuring a static IP source binding on a secondary VLAN, you will receive the following warning:

Warning **IP source filter may not take effect on secondary vlan where IP source binding is configured. If private vlan feature is enabled, IP source filter on primary vlan will automatically propagate to all secondary vlans.**

Displaying IP Source Guard Information

You can display IP Source Guard PVACL information for all interfaces on a switch using the **show ip verify source** command.

- This example shows displayed PVACLs if DHCP snooping is enabled on VLAN 10 through 20, if interface fa6/1 is configured for IP filtering, and if there is an existing IP address binding 10.0.01 on VLAN 10:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/1      ip           active       10.0.0.1                         10
fa6/1      ip           active       deny-all                         11-20
```

Note The second entry shows that a default PVACL (deny all IP traffic) is installed on the port for those snooping-enabled VLANs that do not have a valid IP source binding.

- This example shows displayed PVACL for a trusted port:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/2      ip           inactive-trust-port
```

- This example shows displayed PVACL for a port in a VLAN not configured for DHCP snooping:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/3      ip           inactive-no-snooping-vlan
```

- This example shows displayed PVACLs for a port with multiple bindings configured for an IP/MAC filtering:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/4      ip-mac       active       10.0.0.2         aaaa.bbbb.cccc  10
fa6/4      ip-mac       active       11.0.0.1         aaaa.bbbb.cccd  11
fa6/4      ip-mac       active       deny-all         deny-all        12-20
```

- This example shows displayed PVACLs for a port configured for IP/MAC filtering but not for port security:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/5      ip-mac       active       10.0.0.3         permit-all      10
fa6/5      ip-mac       active       deny-all         permit-all      11-20
```

Note The MAC filter shows permit-all because port security is not enabled, so the MAC filter cannot apply to the port/VLAN and is effectively disabled. Always enable port security first.

- This example shows displayed error message when issuing the **show ip verify source** command on a port that does not have an IP source filter mode configured:

```
IP Source Guard is not configured on the interface fa6/6.
```

You can also use the **show ip verify source** command to display all interfaces on the switch that have IP source guard enabled:

```
Interface  Filter-type  Filter-mode  IP-address       Mac-address     Vlan
---------  -----------  -----------  ---------------  --------------  ---------
fa6/1      ip           active       10.0.0.1                         10
fa6/1      ip           active       deny-all                         11-20
fa6/2      ip           inactive-trust-port
fa6/3      ip           inactive-no-snooping-vlan
fa6/4      ip-mac       active       10.0.0.2         aaaa.bbbb.cccc  10
fa6/4      ip-mac       active       11.0.0.1         aaaa.bbbb.cccd  11
fa6/4      ip-mac       active       deny-all         deny-all        12-20
fa6/5      ip-mac       active       10.0.0.3         permit-all      10
fa6/5      ip-mac       active       deny-all         permit-all      11-20
```

Displaying IP Source Binding Information

You can display all IP source bindings configured on all interfaces on a switch using the **show ip source binding** command.

```
Switch# sh ip source binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:02:B3:3F:3B:99   55.5.5.2         6522        dhcp-snooping  10    FastEthernet6/10
00:00:00:0A:00:0B   11.0.0.1         infinite    static         10    FastEthernet6/10
Switch#
```

Table 30-3 describes the fields in the **show ip source binding** command output.

Table 30-3 show ip source binding Command Output

Field	Description
MAC Address	Client hardware MAC address
IP Address	Client IP address assigned from the DHCP server
Lease (seconds)	IP address lease time
Type	Binding type; static bindings configured from CLI to dynamic binding learned from DHCP Snooping
VLAN	VLAN number of the client interface
Interface	Interface that connects to the DHCP client host

CHAPTER 31

Understanding and Configuring Dynamic ARP Inspection

This chapter describes how to configure Dynamic ARP Inspection (DAI) on the Catalyst 4500 series switch.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Dynamic ARP Inspection

Dynamic ARP Inspection (DAI) is a security feature that validates Address Resolution Protocol (ARP) packets in a network. DAI allows a network administrator to intercept, log, and discard ARP packets with invalid MAC address to IP address bindings. This capability protects the network from certain "man-in-the-middle" attacks.

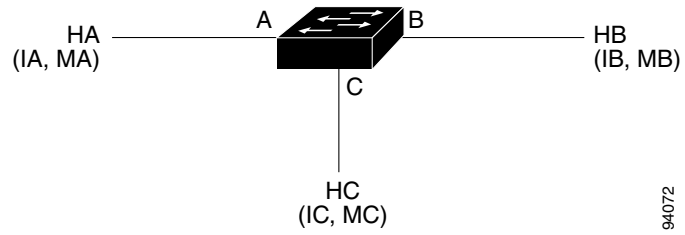
This section contains the following subsections:

ARP Cache Poisoning

You can attack hosts, switches, and routers connected to your Layer 2 network by "poisoning" their ARP caches. For example, a malicious user might intercept traffic intended for other hosts on the subnet by poisoning the ARP caches of systems connected to the subnet.

Consider the following configuration:

Figure 31-1 ARP Cache Poisoning



Hosts HA, HB, and HC are connected to the switch on interfaces A, B and C, all of which are on the same subnet. Their IP and MAC addresses are shown in parentheses; for example, Host HA uses IP address IA and MAC address MA. When HA needs to communicate to HB at the IP Layer, HA broadcasts an ARP request for the MAC address associated with IB. As soon as HB receives the ARP request, the ARP cache on HB is populated with an ARP binding for a host with the IP address IA and a MAC address MA; for example, IP address IA is bound to MAC address MA. When HB responds, the ARP cache on HA is populated with a binding for a host with the IP address IB and a MAC address MB.

Host HC can "poison" the ARP caches of HA and HB by broadcasting forged ARP responses with bindings for a host with an IP address of IA (or IB) and a MAC address of MC. Hosts with poisoned ARP caches use the MAC address MC as the destination MAC address for traffic intended for IA or IB. This means that HC intercepts that traffic. Because HC knows the true MAC addresses associated with IA and IB, HC can forward the intercepted traffic to those hosts using the correct MAC address as the destination. HC has inserted itself into the traffic stream from HA to HB, the classic "man in the middle" attack.

Dynamic ARP Inspection

To prevent ARP poisoning attacks such as the one described in the previous section, a switch must ensure that only valid ARP requests and responses are relayed. DAI prevents these attacks by intercepting all ARP requests and responses. Each of these intercepted packets is verified for valid MAC address to IP address bindings before the local ARP cache is updated or the packet is forwarded to the appropriate destination. Invalid ARP packets are dropped.

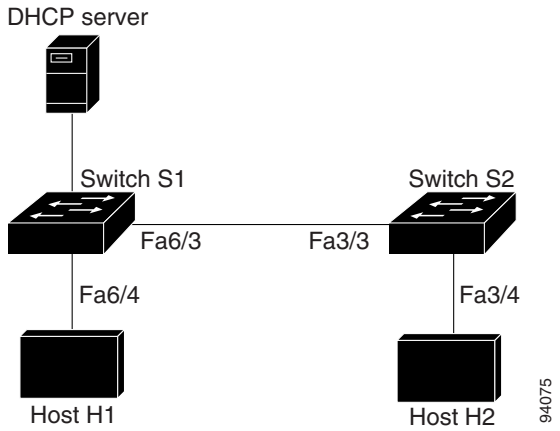
DAI determines the validity of an ARP packet based on valid MAC address to IP address bindings stored in a trusted database. This database is built at runtime by DHCP snooping, provided that it is enabled on the VLANs and on the switch in question. In addition, DAI can also validate ARP packets against user-configured ARP ACLs in order to handle hosts that use statically configured IP addresses.

DAI can also be configured to drop ARP packets when the IP addresses in the packet are invalid or when the MAC addresses in the body of the ARP packet do not match the addresses specified in the Ethernet header.

Interface Trust state, Security Coverage and Network Configuration

DAI associates a trust state with each interface on the system. Packets arriving on trusted interfaces bypass all DAI validation checks, while those arriving on untrusted interfaces go through the DAI validation process. In a typical network configuration for DAI, all ports connected to host ports are configured as untrusted, while all ports connected to switches are configured as trusted. With this configuration, all ARP packets entering the network from a given switch will have passed the security check; it is unnecessary to perform a validation at any other place in the VLAN / network:

Figure 31-2 Validation of ARP Packets on a DAI-enabled VLAN



Use the trust state configuration carefully.

Configuring interfaces as untrusted when they should be trusted can result in a loss of connectivity. If we assume that both S1 and S2 (in Figure 31-2) run DAI on the VLAN that holds H1 and H2, and if H1 and H2 were to acquire their IP addresses from S1, then only S2 binds the IP to MAC address of H1. Therefore, if the interface between S1 and S2 is untrusted, the ARP packets from H1 get dropped on S2. This condition would result in a loss of connectivity between H1 and H2.

Configuring interfaces to be trusted when they are actually untrusted leaves a security hole in the network. If S1 were not running DAI, then H1 can easily poison the ARP of S2 (and H2, if the inter-switch link is configured as trusted). This condition can occur even though S2 is running DAI.

DAI ensures that hosts (on untrusted interfaces) connected to a switch running DAI do not poison the ARP caches of other hosts in the network. It does not, however, ensure that hosts from other portions of the network do not poison the caches of the hosts connected to it.

To handle cases in which some switches in a VLAN run DAI and other switches do not, the interfaces connecting such switches should be configured as untrusted. To validate the bindings of packets from non-DAI switches, however, the switch running DAI should be configured with ARP ACLs. When it is not feasible to determine such bindings, switches running DAI should be isolated from non-DAI switches at Layer 3.

Note Depending on the setup of DHCP server and the network, it may not be possible to perform validation of a given ARP packet on all switches in the VLAN.

Relative Priority of Static Bindings and DHCP Snooping Entries

As mentioned previously, DAI populates its database of valid MAC address to IP address bindings through DHCP snooping. It also validates ARP packets against statically configured ARP ACLs. It is important to note that ARP ACLs have precedence over entries in the DHCP snooping database. ARP Packets are first compared to user-configured ARP ACLs. If the ARP ACL denies the ARP packet, then the packet will be denied even if a valid binding exists in the database populated by DHCP snooping.

Logging of Denied Packets

DAI maintains a log of denied IP ARP packets. Log messages are generated at a controlled rate, and log entries are cleared once messages are generated on their behalf.

Rate Limiting of ARP Packets

DAI performs validation checks in the CPU, so the number of incoming ARP packets is rate-limited to prevent a denial of service attack. By default, the rate for untrusted interfaces is set to 15 packets per second, whereas trusted interfaces have no rate limit. When the rate of incoming ARP packets exceeds the configured limit, the port is placed in the errdisable state. The port remains in that state until an administrator intervenes. You can enable errdisable recovery so that ports emerge from this state automatically after a specified timeout period.

Unless a rate limit is explicitly configured on an interface, changing the trust state of the interface will also change its rate limit to the default value for that trust state; that is, 15 packets per second for untrusted interfaces and unlimited for trusted interfaces. Once a rate limit is configured explicitly, the interface retains the rate limit even when its trust state is changed. At any time, the interface reverts to its default rate limit if the no form of the **rate limit** command is applied.

Port Channels and Their Behavior

A given physical port can join a channel only when the trust state of the physical port and of the channel match. Otherwise, the physical port remains suspended in the channel. A channel inherits its trust state from the first physical port that joined the channel. Consequently, the trust state of the first physical port need not match the trust state of the channel.

Conversely, when the trust state is changed on the channel, the new trust state is configured on all the physical ports that comprise the channel.

The rate limit check on port channels is unique. The rate of incoming packets on a physical port is checked against the port channel configuration rather than the physical ports configuration.

The rate limit configuration on a port channel is independent of the configuration on its physical ports.

The rate limit is cumulative across all physical port; that is, the rate of incoming packets on a port channel equals the sum of rates across all physical ports.

When you configure rate limits for ARP packets on trunks, you must account for VLAN aggregation because a high rate limit on one VLAN can cause a “denial of service” attack to other VLANs when the port is errdisabled by software. Similarly, when a port channel is errdisabled, a high rate limit on one physical port can cause other ports in the channel to go down.

Configuring Dynamic ARP Inspection

This section includes these scenarios:

Scenario One: Two Switches Support Dynamic ARP Inspection

Assume that there are two switches, S1 and S2 with hosts H1 and H2 attached, respectively. Both S1 and S2 are running DAI on VLAN 1 where the hosts are located. The S1 interface fa6/3 is connected to the S2 interface fa3/3, and a DHCP server is connected to S1. Both hosts acquire their IP addresses from the same DHCP server. Therefore, S1 has the binding for H1 and H2, and S2 has the binding for host H2.

To make the setup effective, you must configure the interface fa3/3 on S2 to be trusted. (You can leave interface fa6/3 on S1 as untrusted.) If the DHCP server is moved from S1 to a different location, however, the configuration will not work. To ensure that this setup works permanently, without compromising security, you must configure both interfaces fa6/3 on S1 and fa3/3 on S2 as trusted.

Configuring Switch S1

To enable DAI and configure fa6/3 on S1 as trusted, follow these steps:

Step 1 Verify the connection between switches S1 and S2:

```
S1# show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
S2               Fas 6/3            177         R S I     WS-C4006  Fas 3/3
S1#
```

Step 2 Enable DAI on VLAN 1 and verify the configuration:

```
S1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S1(config)# ip arp inspection vlan 1
S1(config)# end
S1# show ip arp inspection vlan 1

Source Mac Validation      : Disabled
Destination Mac Validation : Disabled
IP Address Validation      : Disabled

 Vlan     Configuration    Operation   ACL Match          Static ACL
 ----     -------------    ---------   ---------          ----------
    1     Enabled          Active

 Vlan     ACL Logging      DHCP Logging
 ----     -----------      ------------
    1     Deny             Deny
S1#
```

Step 3 Configure interface fa6/3 as trusted:

```
S1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S1(config)# in fa6/3
S1(config-if)# ip arp inspection trust
S1(config-if)# end
S1# show ip arp inspection interfaces fastEthernet 6/3

Interface        Trust State     Rate (pps)
 ---------------  -----------     ----------
 Fa6/3            Trusted              None
S1#
```

Step 4 Verify the bindings:

```
S1# show ip dhcp snooping binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:02:00:02:00:02   1.1.1.2          4993        dhcp-snooping  1     FastEthernet6/4
S1#
```

Step 5 Check the statistics before and after Dynamic ARP processes any packets:

```
S1# show ip arp inspection statistics vlan 1

Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              0              0              0              0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              0              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                       0
S1#
```

If H1 then sends out two ARP requests with an IP address of 1.1.1.2 and a MAC address of 0002.0002.0002, both requests are permitted, as reflected in the following statistics:

```
S1# show ip arp inspection statistics vlan 1

 Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              2              0              0              0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              2              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                       0
S1#
```

If H1 then tries to send an ARP request with an IP address of 1.1.1.3, the packet is dropped and an error message is logged:

```
00:12:08: %SW_DAI-4-DHCP_SNOOPING_DENY: 2 Invalid ARPs (Req) on Fa6/4, vlan
1.([0002.0002.0002/1.1.1.3/0000.0000.0000/0.0.0.0/02:42:35 UTC Tue Jul 10 2001])
S1# show ip arp inspection statistics vlan 1
S1#
```

The statistics will display as follows:

```
Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              2              2              2             0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              2              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                       0
S1#
```

Configuring Switch S2

To enable DAI and configure fa3/3 on S2 as trusted, follow these steps:

Step 1 Verify the connectivity:

```
S2# show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
S1               Fas 3/3            120         R S I     WS-C4006  Fas 6/3
S2#
```

Step 2 Enable DAI on VLAN 1, and verify the configuration:

```
S2# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S2(config)# ip arp inspection vlan 1
S2(config)# end
S2# show ip arp inspection vlan 1

Source Mac Validation      : Disabled
Destination Mac Validation : Disabled
IP Address Validation      : Disabled

 Vlan     Configuration    Operation   ACL Match          Static ACL
 ----     -------------    ---------   ---------          ----------
    1     Enabled          Active

 Vlan     ACL Logging      DHCP Logging
 ----     -----------      ------------
    1     Deny             Deny
S2#
```

Step 3 Configure interface fa3/3 as trusted:

```
S2# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S2(config)# interface fastEthernet 3/3
S2(config-if)# ip arp inspection trust
S2(config-if)# end
S2# show ip arp inspection interfaces
```

```
Interface        Trust State     Rate (pps)
 ---------------  -----------     ----------
 Gi1/1            Untrusted              15
 Gi1/2            Untrusted              15
 Gi3/1            Untrusted              15
 Gi3/2            Untrusted              15
 Fa3/3            Trusted               None
 Fa3/4            Untrusted              15
 Fa3/5            Untrusted              15
 Fa3/6            Untrusted              15
 Fa3/7            Untrusted              15

<output truncated>
S2#
```

Step 4 Verify the list of DHCP snooping bindings:

```
S2# show ip dhcp snooping binding
MacAddress          IpAddress        Lease(sec)  Type           VLAN  Interface
------------------  ---------------  ----------  -------------  ----  --------------------
00:01:00:01:00:01   1.1.1.1          4995        dhcp-snooping  1     FastEthernet3/4
S2#
```

Step 5 Check the statistics before and after Dynamic ARP processes any packets:

```
S2# show ip arp inspection statistics vlan 1

Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              0              0              0              0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              0              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                        0
S2#
```

If H2 then sends out an ARP request with the IP address 1.1.1.1 and the MAC address 0001.0001.0001, the packet is forwarded and the statistics are updated appropriately:

```
S2# show ip arp inspection statistics vlan 1

Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              1              0              0              0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              1              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                        0
S2#
```

Conversely, if H2 attempts to send an ARP request with the IP address 1.1.1.2, the request is dropped and an error message is logged:

```
00:18:08: %SW_DAI-4-DHCP_SNOOPING_DENY: 1 Invalid ARPs (Req) on Fa3/4, vlan
1.([0001.0001.0001/1.1.1.2/0000.0000.0000/0.0.0.0/01:53:21 UTC Fri May 23 2003])
S2#
```

The statistics will display as follows:

```
S2# show ip arp inspection statistics vlan 1

Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              1              1              1              0

 Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              1              0                     0

 Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                       0
S2#
```

Scenario Two: One Switch Supports Dynamic ARP Inspection

If switch S2 does not support DAI or DHCP snooping, configuring interface fa6/3 as trusted would leave a security hole because both S1 and H1 could be attacked by either S2 or H2. To prevent this possibility, you must configure interface fa6/3 as untrusted. To permit ARP packets from H2, you must set up an ARP ACL and apply it to VLAN 1. If the IP address of H2 is not static, such that it is impossible to apply the ACL configuration on S1, S1 and S2 must be separated at Layer 3, that is, have a router routing packets between S1 and S2.

To set up an ARP ACL on switch S1, follow these steps:

Step 1 Set up the access list to permit the IP address 1.1.1.1 and the MAC address 0001.0001.0001, and verify the configuration:

```
S1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S1(config)# arp access-list H2
S1(config-arp-nacl)# permit ip host 1.1.1.1 mac host 1.1.1
S1(config-arp-nacl)# end
S1# show arp access-list
ARP access list H2
    permit ip host 1.1.1.1 mac host 0001.0001.0001
```

Step 2 Apply the ACL to VLAN 1, and verify the configuration:

```
S1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S1(config)# ip arp inspection filter H2 vlan 1
S1(config)# end
S1#

S1# show ip arp inspection vlan 1

Source Mac Validation      : Disabled
Destination Mac Validation : Disabled
IP Address Validation      : Disabled

 Vlan     Configuration    Operation   ACL Match          Static ACL
 ----     -------------    ---------   ---------          ----------
    1     Enabled          Active      H2                No
```

```
 Vlan     ACL Logging      DHCP Logging
 ----     -----------      ------------
    1     Deny             Deny
S1#
```

Step 3 Establish the interface fa6/3 as untrusted, and verify the configuration:

```
S1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
S1(config)# in fa6/3
S1(config-if)# no ip arp inspection trust
S1(config-if)# end
Switch# show ip arp inspection interfaces fastEthernet 6/3

 Interface        Trust State     Rate (pps)
 ---------------  -----------     ----------
 Fa6/3            Untrusted               15

Switch#
```

When H2 sends 5 ARP requests through interface fa6/3 on S1 and a “get” is permitted by S1, the statistics are updated appropriately:

```
Switch# show ip arp inspection statistics vlan 1
Vlan      Forwarded        Dropped     DHCP Drops     ACL Drops
 ----      ---------        -------     ----------     ----------
    1              5              0              0              0
Vlan   DHCP Permits    ACL Permits   Source MAC Failures
 ----   ------------    -----------   -------------------
    1              0              5                    0
Vlan   Dest MAC Failures   IP Validation Failures
 ----   -----------------   ----------------------
    1                  0                       0
Switch#
```

Configuring Network Security with ACLs

This chapter describes how to use access control lists (ACLs) to configure network security on the Catalyst 4500 series switches.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

This chapter consists of the following major sections:

Understanding ACLs

This section contains the following subsections:

ACL Overview

An ACL is a collection of sequential permit and deny conditions that applies 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 permissions required to be forwarded, based on the conditions specified in the access lists. It tests the packets against the conditions in an access list one-by-one. The first match determines whether the switch accepts or rejects the packets. Because the switch stops testing conditions after the first match, the order of conditions in the list is critical. If no conditions match, the switch drops the packet. If there are no restrictions, the switch forwards the packet; otherwise, the switch drops the packet.

Switches traditionally operate at Layer 2, switching traffic within a VLAN, whereas routers route traffic between VLANs at Layer 3. The Catalyst 4500 series switch can accelerate packet routing between VLANs by using Layer 3 switching. The Layer 3 switch bridges the packet, and then routed the packet internally without going to an external router. The packet is then bridged again and sent to its destination. During this process, the switch can control all packets, including packets bridged within a VLAN.

You configure access lists on a router or switch to filter traffic and provide basic security for your network. If you do not configure ACLs, all packets passing through the switch could be allowed on 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 at router interfaces. For example, you can allow e-mail traffic to be forwarded but not Telnet traffic. ACLs can be configured to block inbound traffic, outbound traffic, or both. However, on Layer 2 interfaces, you can apply ACLs only in the inbound direction.

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 Catalyst 4500 series switch supports two types of ACLs:

- IP ACLs, which filter IP traffic, including TCP, the User Datagram Protocol (UDP), Internet Group Management Protocol (IGMP), and Internet Control Message Protocol (ICMP).
- MAC (Ethernet) ACLs, which filter non-IP traffic.

Supported Features That Use ACLs

The switch supports two applications of ACLs to filter traffic:

- Router ACLs are applied to Layer 3 interfaces. They control the access of routed traffic between VLANs. All Catalyst 4500 series switches can create router ACLs, but you must have a Cisco IOS software image on your switch to apply an ACL to a Layer 3 interface and filter packets routed between VLANs.
- Port ACLs perform access control on traffic entering a Layer 2 interface. If there are not enough hardware CAM entries, the output port ACL is not applied to the port and a warning message is given to user. (This restriction applies to all access group modes for output port ACLs.) When there are enough CAM entries, the output port ACL might be reapplied.

  If there is any output port ACL configured on a Layer 2 port, then no VACL or router ACL can be configured on the VLANs that the Layer 2 port belongs to. Also, the reverse is true: port ACLs and VLAN-based ACLs (VACLs and router ACLs) are mutually exclusive on a Layer 2 port. This restriction applies to all access group modes.

You can apply only one IP access list and one MAC access list to a Layer 2 interface.

- VLAN ACLs or VLAN maps control the access of all packets (bridged and routed). You can use VLAN maps to filter traffic between devices in the same VLAN. You do not need the enhanced image to create or apply VLAN maps. VLAN maps are configured to control access based on Layer 3 addresses for IP. MAC addresses using Ethernet ACEs control the access of unsupported protocols. After you apply a VLAN map to a VLAN, all packets (routed or bridged) entering the VLAN are checked against that map. Packets can either enter the VLAN through a switch port or through a routed port after being routed.

You can use both router ACLs and VLAN maps on the same switch.

Router ACLs

You can apply router ACLs on switch virtual interfaces (SVIs), which are Layer 3 interfaces to VLANs; on physical Layer 3 interfaces; and on Layer 3 EtherChannel interfaces. Router ACLs are applied on interfaces for specific directions (inbound or outbound). You can apply one IP access list in each direction.

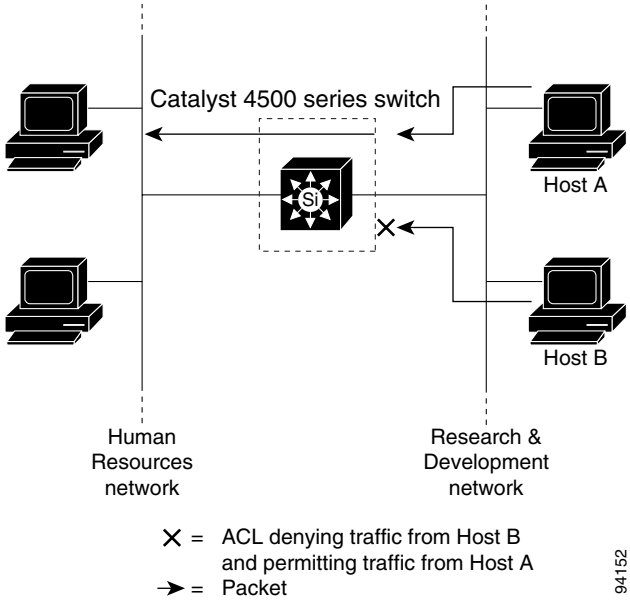
Multiple features can use one ACL for a given interface, and one feature can use multiple ACLs. When a single router ACL is used by multiple features, it is examined multiple times. The access list type determines the input to the matching operation:

- Standard IP access lists use source addresses for matching operations.
- Extended IP access lists use source and destination addresses and optional protocol type information for matching operations.

The switch examines ACLs associated with features configured on a given interface and a direction. As packets enter the switch on an interface, ACLs associated with all inbound features configured on that interface are examined. After packets are routed and before they are forwarded to the next hop, all ACLs associated with outbound features configured on the egress interface are examined.

ACLs permit or deny packet forwarding based on how the packet matches the entries in the ACL. For example, you can use access lists to allow one host to access a part of a network, but prevent another host from accessing the same part. In Figure 32-1, ACLs applied at the router input allow Host A to access the Human Resources network, but prevent Host B from accessing the same network.

Figure 32-1 Using ACLs to Control Traffic to a Network



Port ACLs

You can also apply ACLs to Layer 2 interfaces on a switch. Port ACLs are supported on physical interfaces and EtherChannel interfaces.

The following access lists are supported on Layer 2 interfaces:

- 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

As with router ACLs, the switch examines ACLs associated with features configured on a given interface and permits or denies packet forwarding based on how the packet matches the entries in the ACL. In the example in Figure 32-1, if all workstations were in the same VLAN, ACLs applied at the Layer 2 input would allow Host A to access the Human Resources network, but prevent Host B from accessing the same 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.

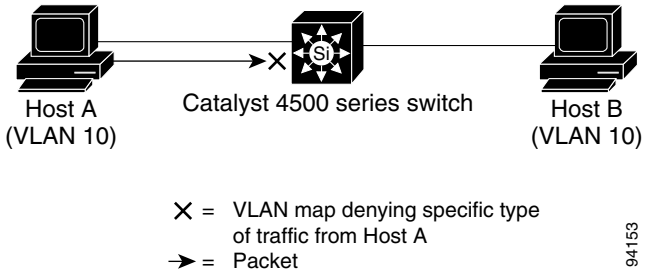
VLAN Maps

VLAN maps can control the access of all traffic in a VLAN. You can apply VLAN maps on the switch to all packets that are routed into or out of a VLAN or are bridged within a VLAN. Unlike router ACLs, VLAN maps are not defined by direction (input or output).

You can configure VLAN maps to match Layer 3 addresses for IP traffic. Access of all non-IP protocols is controlled with a MAC address and an Ethertype using MAC ACLs in VLAN maps. (IP traffic is not controlled by MAC ACLs in 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.

With VLAN maps, forwarding packets is permitted or denied, based on the action specified in the map. Figure 32-2 illustrates how a VLAN map is applied to deny a specific type of traffic from Host A in VLAN 10 from being forwarded.

Figure 32-2 Using VLAN Maps to Control Traffic



Hardware and Software ACL Support

This section describes how to determine whether ACLs are processed in hardware or in software:

- Flows that match a deny statement in standard and extended ACLs (input only) are dropped in hardware if ICMP unreachable messages are disabled.
- Flows that match a permit statement in standard and extended ACLs (input and output) are processed in hardware.
- The following ACL types are not supported in software:
  - Standard Xerox Network Systems (XNS) Protocol access list
  - Extended XNS access list
  - DECnet access list
  - Protocol type-code access list
  - Standard Internet Packet Exchange (IPX) access list
  - Extended IPX access list

Note Packets that require logging are processed in software. A copy of the packets is sent to the CPU for logging while the actual packets are forwarded in hardware so that non-logged packet processing is not impacted.

By default, the Catalyst 4500 series switch sends ICMP unreachable messages when a packet is denied by an access list; these packets are not dropped in hardware but are forwarded to the switch so that it can generate the ICMP unreachable message.

To drop access-list denied packets in hardware on the input interface, you must disable ICMP unreachable messages using the **no ip unreachables** interface configuration command. The **ip unreachables** command is enabled by default.

Packets denied by an output access list are always forwarded to the CPU.

TCAM Programming and ACLs

Two types of hardware resources are consumed when you program ACLs: entries and masks. If one of these resources is exhausted, no additional ACLs can be programmed into hardware. If the masks on a system are exhausted, but entries are available, changing the programming scheme from packed to scattered might free up masks, allowing additional ACLs to be programmed into hardware.

The goal is to use TCAM resources more efficiently by minimizing the number of masks per ACL entries. To compare TCAM utilization when employing the scattered or packed algorithms, use the **show platform hardware acl statistics utilization brief** command. To change the algorithm from packed to scattered, use the **access-list hardware entries** command. To disable an algorithm, use the **no acccess-list hardware entries** command.

Note To determine whether the packed algorithm is configured, use the **show running config** command. If packed is configured, the line **access-list hardware entries packed** will appear.

Note The default TCAM programming algorithm is packed.

The following output was collected from a switch running in packed mode. Observe that 89 percent of the masks are required to program only 49 percent of the ACL entries.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# access-list hardware entries packed
Switch(config)# end
Switch#
01:15:34: %SYS-5-CONFIG_I: Configured from console by console
Switch#
```

```
Switch# show platform hardware acl statistics utilization brief
                                        Entries/Total(%)  Masks/Total(%)
                                       -----------------  ---------------
            Input  Acl(PortAndVlan)  2016 / 4096 ( 49)   460 /  512 ( 89)
            Input  Acl(PortOrVlan)      6 / 4096 (  0)     4 /  512 (  0)
            Input  Qos(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Input  Qos(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)
            Output Acl(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Output Acl(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)
            Output Qos(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Output Qos(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)

            L4Ops: used 2 out of 64
```

The following output was collected after the algorithm was switched to scattered. Observe that the number of masks required to program 49 percent of the entries has decreased to 49 percent.

Note When you enable DHCP snooping and IP Source Guard on all ports on a chassis, you must use the scattered keyword.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# access-list hardware entries scattered
Switch(config)# end
Switch#
01:39:37: %SYS-5-CONFIG_I: Configured from console by console
Switch#
Switch# show platform hardware acl statistics utilization brief
Entries/Total(%)  Masks/Total(%)
                                       -----------------  ---------------
            Input  Acl(PortAndVlan)  2016 / 4096 ( 49)   252 /  512 ( 49)
            Input  Acl(PortOrVlan)      6 / 4096 (  0)     5 /  512 (  0)
            Input  Qos(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Input  Qos(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)
            Output Acl(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Output Acl(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)
            Output Qos(PortAndVlan)     0 / 4096 (  0)     0 /  512 (  0)
            Output Qos(PortOrVlan)      0 / 4096 (  0)     0 /  512 (  0)

            L4Ops: used 2 out of 64
Switch#
```

Layer 4 Operators in ACLs

The following sections describe guidelines and restrictions for configuring ACLs that include Layer 4 port operations:

- Restrictions for Layer 4 Operations, page 32-8
- Configuration Guidelines for Layer 4 Operations, page 32-8
- How ACL Processing Impacts CPU, page 32-9

Restrictions for Layer 4 Operations

You can specify these operator types, each of which uses one Layer 4 operation in the hardware:

- gt (greater than)
- lt (less than)
- neq (not equal)
- range (inclusive range)

We recommend that you not specify more than six different operations on the same ACL. If you exceed this number, each new operation might cause the affected ACE (access control entry) to be translated into multiple ACEs in hardware. If you exceed this number, the affected ACE might be processed in software.

Configuration Guidelines for Layer 4 Operations

Keep the following guidelines in mind when using Layer 4 operators:

- Layer 4 operations are considered different if the operator or operand differ. For example, the following ACL contains three different Layer 4 operations because gt 10 and gt 11 are considered two different Layer 4 operations:

```
... gt 10 permit
... lt 9 deny
... gt 11 deny
```

Note The eq operator can be used an unlimited number of times because eq does not use a Layer 4 operation in hardware.

- Layer 4 operations are considered different if the same operator/operand couple applies once to a source port and once to a destination port, as in the following example:

```
... Src gt 10....
... Dst gt 10
```

A more detailed example follows:

```
access-list 101
... (dst port) gt 10 permit
... (dst port) lt 9 deny
... (dst port) gt 11 deny
... (dst port) neq 6 permit
... (src port) neq 6 deny
... (dst port) gt 10 deny

access-list 102
... (dst port) gt 20 deny
... (src port) lt 9 deny
... (src port) range 11 13 deny
... (dst port) neq 6 permit
```

Access lists 101 and 102 use the following Layer 4 operations:

- Access list 101 Layer 4 operations: 5
  - gt 10 permit and gt 10 deny both use the same operation because they are identical and both operate on the destination port.
- Access list 102 Layer 4 operations: 4
- Total Layer 4 operations: 8 (due to sharing between the two access lists)
  - neg6 permit is shared between the two ACLs because they are identical and both operate on the same destination port.
- A description of the Layer 4 operations usage is as follows:
  - Layer 4 operation 1 stores gt 10 permit and gt 10 deny from ACL 101
  - Layer 4 operation 2 stores lt 9 deny from ACL 101
  - Layer 4 operation 3 stores gt 11 deny from ACL 101
  - Layer 4 operation 4 stores neg 6 permit from ACL 101 and 102
  - Layer 4 operation 5 stores neg 6 deny from ACL 101
  - Layer 4 operation 6 stores gt 20 deny from ACL 102
  - Layer 4 operation 7 stores lt 9 deny from ACL 102
  - Layer 4 operation 8 stores range 11 13 deny from ACL 102

How ACL Processing Impacts CPU

ACL processing can impact the CPU in two ways:

- For some packets, when the hardware runs out of resources, the software must perform the ACL matches:
  - TCP flag combinations other than rst ack and syn fin rst are processed in software. rst ack is equivalent to the keyword **established**.
  - You can specify up to six Layer 4 operations (lt, gt, neq, and range) in an ACL in order for all operations to be guaranteed to be processed in hardware. More than six Layer 4 operations will trigger an attempt to translate the excess operations into multiple ACEs in hardware. If this attempt fails, packets will be processed in software. The translation process is less likely to succeed on large ACLs with a great number of Layer 4 operations, and on switches with large numbers of ACLs configured. The precise limit depends on how many other ACLs are configured and which specific Layer 4 operations are used by the ACLs being translated. The eq operator does not require any Layer 4 operations and can be used any number of times.
  - If the total number of Layer 4 operations in an ACL is less than six, you can distribute the operations in any way you choose.

  Examples:

  The following access lists will be processed completely in hardware:

```
access-list 104 permit tcp any any established
access-list 105 permit tcp any any rst ack
access-list 107 permit tcp any synfin rst
```

Access lists 104 and 105 are identical; established is shorthand for rst and ack.

Access list 101, below, will be processed completely in software:

```
access-list 101 permit tcp any any urg
```

Because four source and two destination operations exist, access list 106, below, will be processed in hardware:

```
access-list 106 permit tcp any range 100 120 any range 120 140
access-list 106 permit tcp any range 140 160 any range 180 200
access-list 106 permit tcp any range 200 220
access-list 106 deny tcp any range 220 240
```

In the following code, the Layer 4 operations for the third ACE will trigger an attempt to translate dst lt 1023 into multiple ACEs in hardware, because three source and three destination operations exist. If the translation attempt fails, the third ACE will be processed in software.

```
access-list 102 permit tcp any lt 80 any gt 100
access-list 102 permit tcp any range 100 120 any range 120 1024
access-list 102 permit tcp any gt 1024 any lt 1023
```

Similarly, for access list 103, below, the third ACE will trigger an attempt to translate dst gt 1023 into multiple ACEs in hardware. If the attempt fails, the third ACE will be processed in software. Although the operations for source and destination ports look similar, they are considered different Layer 4 operations.)

```
access-list 103 permit tcp any lt 80 any lt 80
access-list 103 permit tcp any range 100 120 any range 100 120
access-list 103 permit tcp any gt 1024 any gt 1023
```

Note Remember that source port lt 80 and destination port lt 80 are considered different operations.

- Some packets must be sent to the CPU for accounting purposes, but the action is still performed by the hardware. For example, if a packet must be logged, a copy is sent to the CPU for logging, but the forwarding (or dropping) is performed in the hardware. Although logging slows the CPU, it does not affect the forwarding rate. This sequence of events would happen under the following conditions:
  - When a log keyword is used
  - When an output ACL denies a packet
  - When an input ACL denies a packet, and on the interface where the ACL is applied, **ip unreachable** is enabled (**ip unreachable** is enabled by default on all the interfaces)

Configuring Unicast MAC Address Filtering

To block all unicast traffic to or from a MAC address in a specified VLAN, perform this task:

Command	Purpose
`Switch(config)# mac-address-table static mac_address vlan vlan_ID drop`	Blocks all traffic to or from the configured unicast MAC address in the specified VLAN. To clear MAC address-based blocking, use the **no** form of this command without the **drop** keyword.

This example shows how to block all unicast traffic to or from MAC address 0050.3e8d.6400 in VLAN 12:

```
Router# configure terminal
Router(config)# mac-address-table static 0050.3e8d.6400 vlan 12 drop
```

Configuring Named MAC Extended ACLs

You can filter non-IP traffic on a VLAN and on a physical Layer 2 port by using MAC addresses and named MAC extended ACLs. The procedure is similar to that of configuring other extended named ACLs. You can use a number to name the access list, but MAC access list numbers from 700 to 799 are not supported.

Note Named MAC extended ACLs cannot be applied to Layer 3 interfaces.

For more information about the supported non-IP protocols in the **mac access-list extended** command, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

To create a named MAC extended ACL, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# mac access-list extended name`	Defines an extended MAC access list using a name.
Step 3	`Switch(config-ext-macl)# {deny | permit} {any | host source MAC address | source MAC address mask} {any | host destination MAC address | destination MAC address mask} [ protocol-family {appletalk | arp-non-ipv4 | decnet | ipx | ipv6 | rarp-ipv4 | rarp-non-ipv4 | vines | xns}]`	In extended MAC access-list configuration mode, specify to **permit** or **deny any** source MAC address, a source MAC address with a mask, or a specific **host** source MAC address and **any** destination MAC address, destination MAC address with a mask, or a specific destination MAC address. (Optional) • **[protocol-family {appletalk | arp-non-ipv4 | decnet | ipx | ipv6 | rarp-ipv4 | rarp-non-ipv4 | vines | xns }]**
Step 4	`Switch(config-ext-macl)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show access-lists [number | name]`	Shows the access list configuration.
Step 6	`Switch(config)# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

You can 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 (old) protocol-family decnet (new)
Switch(config-ext-macl)# permit any any
Switch(config-ext-macl)# end
Switch # show access-lists
Extended MAC access list mac1
    deny   any any decnet-iv (old) protocol-family decnet (new)
    permit any any
```

Configuring VLAN Maps

This section contains the following subsections:

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.

To create a VLAN map and apply it to one or more VLANs, perform this task

Step 1 Create the standard or extended IP ACLs or named MAC extended ACLs that you want to apply to the VLAN.

Step 2 Enter the **vlan access-map** global configuration command to create a VLAN ACL map entry.

Step 3 In access map configuration mode, you have the optional to enter an **action** (**forward** [the default] or **drop**) and enter the **match** command to specify an IP packet or a non-IP packet and to match the packet against one or more ACLs (standard or extended). If a match clause is not specified, the action is applied to all packets. The match clause can be used to match against multiple ACLs. If a packet matches any of the specified ACLs, the action is applied.

Note If the VLAN map has a match clause for the type of packet (IP or MAC) and the packet does not match the type, the default is to drop the packet. If there is no match clause in the VLAN map for that type of packet, and no action specified, the packet is forwarded.

Step 4 Use the **vlan filter** global configuration command to apply a VLAN map to one or more VLANs.

Note You cannot apply a VLAN map to a VLAN on a switch that has ACLs applied to Layer 2 interfaces (port ACLs).

VLAN Map Configuration Guidelines

Keep the following guidelines in mind when configuring VLAN maps:

- VLAN maps do not filter IPv4 ARP packets.
- If there is no router ACL configured to deny traffic on a routed VLAN interface (input or output), and no VLAN map configured, all traffic is permitted.
- Each VLAN map consists of a series of entries. The order of entries in a 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 if you have configured a very large number of ACLs.

Creating and Deleting VLAN Maps

Each VLAN map consists of an ordered series of entries. To create, add to, or delete a VLAN map entry, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# vlan access-map` *name* [*number*]	Creates a VLAN map, and give it a name and (optionally) a number. The number is the sequence number of the entry within the map. When you create VLAN maps with the same name, numbers are assigned sequentially in increments of 10. When modifying or deleting maps, you can enter the number of the map entry that you want to modify or delete. This command enables access-map configuration mode.
Step 3	`Switch(config-access-map)# action` {**drop** | **forward**}	(Optional) Sets the action for the map entry. The default is to forward.
Step 4	`Switch(config-access-map)# match` {**ip** | **mac**} **address** {*name* | *number*} [*name* | *number*]	Matches the packet (using either the IP or MAC address) against one or more standard or extended access lists. Note that packets are matched only against access lists of the correct protocol type. IP packets are compared with standard or extended IP access lists. Non-IP packets are only compared with named MAC extended access lists. If a match clause is not specified, the action is taken on all packets.
Step 5	`Switch(config-access-map)# end`	Returns to global configuration mode.

	Command	Purpose
Step 6	`Switch(config)# show running-config`	Displays the access list configuration.
Step 7	`Switch(config)# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

You can use the **no vlan access-map** *name* global configuration command to delete a map. You can use the **no vlan access-map** *name number* global configuration command to delete a single sequence entry from within the map. You can 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 then set the action to drop. A permit in the ACL is the same 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 ip1 ACL (TCP packets) would be dropped. You first create the ip1 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 ip1
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 ip1
Switch(config-access-map)# action drop
```

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.

```
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
```

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.

Example 2

In this example, the VLAN map is configured to drop IP packets and to forward MAC packets by default. By applying standard ACL 101 and the extended named access lists **igmp-match** and **tcp-match**, the VLAN map is configured to do the following:

- 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 is configured to drop MAC packets and forward IP packets by default. By applying MAC extended access lists, **good-hosts** and **good-protocols**, the VLAN map is configured to do the following:

- Forward MAC packets from hosts 0000.0c00.0111 and 0000.0c00.0211
- Forward MAC packets of DECnet or VINES (Virtual Integrated Network Service) protocol-family
- 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-nacl)# exit
Switch(config)# mac access-list extended good-protocols
Switch(config-ext-macl)# permit any any protocol-family decnet
Switch(config-ext-macl)# permit any any protocol-family vines
Switch(config-ext-nacl)# exit
Switch(config)# vlan access-map drop-mac-default 10
Switch(config-access-map)# match mac address good-hosts
Switch(config-access-map)# action forward
Switch(config-access-map)# exit
Switch(config)# vlan access-map drop-mac-default 20
Switch(config-access-map)# match mac address good-protocols
Switch(config-access-map)# action forward
```

Example 4

In this example, the VLAN map is configured to drop all packets (IP and non-IP). By applying access lists **tcp-match** and **good-hosts,** the VLAN map is configured to do the following:

- 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

To apply a VLAN map to one or more VLANs, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# vlan filter` *mapname* `vlan-list` *list*	Applies 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 comma, and dash, are optional.
Step 3	`Switch(config)# show running-config`	Displays the access list configuration.
Step 4	`cSwitch(config)# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

Note You cannot apply a VLAN map to a VLAN on a switch that has ACLs applied to Layer 2 interfaces (port ACLs).

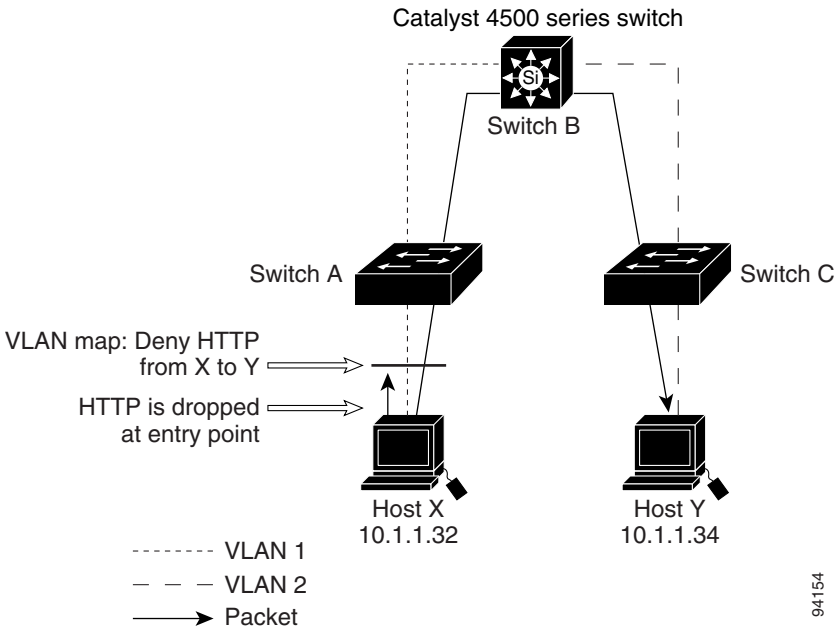
This example shows how to apply VLAN map 1 to VLANs 20 through 22:

```
Switch(config)# vlan filter map 1 vlan-list 20-22
```

Using VLAN Maps in Your Network

Figure 32-3 shows a typical wiring closet configuration. Host X and Host Y are in different VLANs, connected to wiring closet switches A and C. Traffic moving from Host X to Host Y is routed by Switch B. Access to traffic moving from Host X to Host Y can be controlled at the entry point of Switch A. In the following configuration, the switch can support a VLAN map and a QoS classification ACL.

Figure 32-3 Wiring Closet Configuration



For example, if you do not want HTTP traffic to be switched from Host X to Host Y, you could apply a VLAN map on Switch A to drop all HTTP traffic moving from Host X (IP address 10.1.1.32) to Host Y (IP address 10.1.1.34) at Switch A and not bridge the traffic to Switch B. To configure this scenario, you would do the following:

First, define an IP access list http to permit (match) any TCP traffic on the HTTP port, as follows:

```
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 a VLAN access map named map2 so that traffic that matches the http access list is dropped and all other IP traffic is forwarded, as follows:

```
Switch(config)# vlan access-map map2 10
Switch(config-access-map)# match ip address http
Switch(config-access-map)# action drop
Switch(config-access-map)# 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 the VLAN access map named map2 to VLAN 1, as follows:

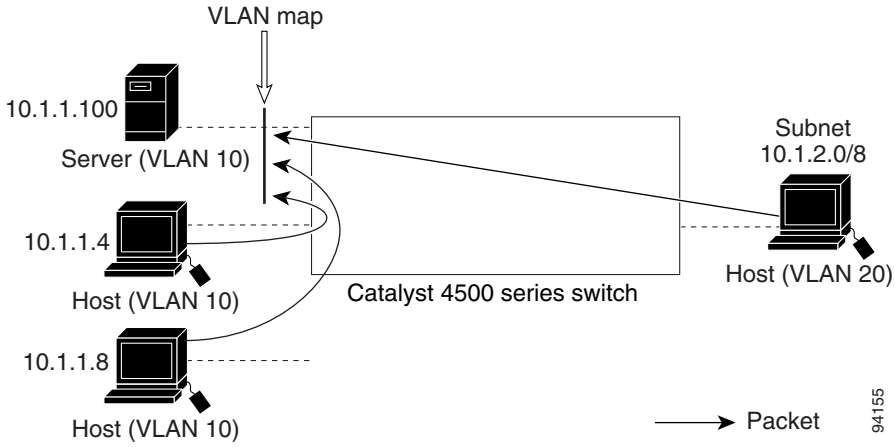
```
Switch(config)# vlan filter map2 vlan 1
```

Denying Access to a Server on Another VLAN

Figure 32-4 shows how to restrict access to a server on another VLAN. In this example, server 10.1.1.100 in VLAN 10 has the following access restrictions:

- Hosts in subnet 10.1.2.0/8 in VLAN 20 should not have access.
- Hosts 10.1.1.4 and 10.1.1.8 in VLAN 10 should not have access.

Figure 32-4 Deny Access to a Server on Another VLAN



This procedure configures ACLs with VLAN maps to deny access to a server on another VLAN. The VLAN map SERVER 1_ACL denies access to hosts in subnet 10.1.2.0/8, host 10.1.1.4, and host 10.1.1.8. Then it permits all other IP traffic. In Step 3, VLAN map SERVER1 is applied to VLAN 10.

To configure this scenario, you could take the following steps:

Step 1 Define the IP ACL to match and permit the correct packets.

```
Switch(config)# ip access-list extended SERVER1_ACL
Switch(config-ext-nacl))# permit ip 10.1.2.0 0.0.0.255 host 10.1.1.100
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 the ACL to drop IP packets that match SERVER1_ACL and forward IP packets that do not match the ACL.

```
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 VLAN Access Map Information

To display information about VLAN access maps or VLAN filters, perform one of these tasks.

Command	Purpose
`Switch# show vlan access-map [mapname]`	Show information about all VLAN access-maps or the specified access map.
`Switch# show vlan filter [access-map name | vlan vlan-id]`	Show information about all VLAN filters or about a specified VLAN or VLAN access map.

This is a sample output of the **show vlan access-map** command:

```
Switch# show vlan access-map
Vlan access-map "map_1" 10
  Match clauses:
     ip address: ip1
  Action:
     drop
Vlan access-map "map_1" 20
  Match clauses:
     mac address: mac1
  Action:
     forward
Vlan access-map "map_1" 30
  Match clauses:
  Action:
     drop
```

Note Sequence 30 does not have a match clause. All packets (IP as well as non-IP) will be matched against it and dropped.

This is a sample output of the **show vlan filter** command:

```
Switch# show vlan filter
VLAN Map map_1 is filtering VLANs:
  20-22
```

Using VLAN Maps with Router ACLs

If the VLAN map has a match clause for a packet type (IP or MAC) and the packet does not match the type, the default is to drop the packet. If there is no match clause in the VLAN map, and no action is specified, the packet is forwarded if it does not match any VLAN map entry.

Note You cannot combine VLAN maps or input router ACLs with port ACLs on a switch.

Guidelines for Using Router ACLs and VLAN Maps

Use these guidelines when you need to use a router ACL and a VLAN map on the same VLAN.

Because the switch hardware performs one lookup for each direction (input and output), you must merge a router ACL and a VLAN map when they are configured on the same VLAN. Merging the router ACL with the VLAN map can significantly increase the number of ACEs.

When possible, try to write the ACL so that all entries have a single action except for the final, default action. You should write the ACL using one of these two forms:

permit...
permit...
permit...
deny ip any any

or

deny...
deny...
deny...
permit ip any any

To define multiple permit or deny actions in an ACL, group each action type together to reduce the number of entries.

If you need to specify the full-flow mode and the ACL contains both IP ACEs and TCP/UDP/ICMP ACEs with Layer 4 information, put the Layer 4 ACEs at the end of the list. Doing this gives priority to the filtering of traffic based on IP addresses.

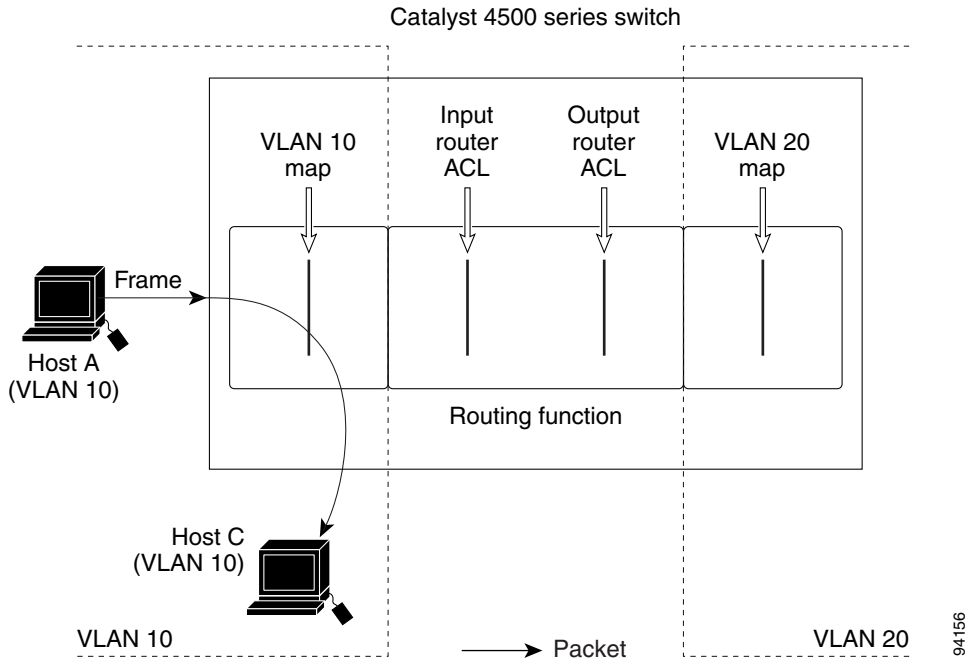
Examples of Router ACLs and VLAN Maps Applied to VLANs

These examples show how router ACLs and VLAN maps are applied on a VLAN to control the access of switched, bridged, routed, and multicast packets. Although the following illustrations show packets being forwarded to their destination, each time a packet crosses a line indicating a VLAN map or an ACL, the packet could be dropped rather than forwarded.

ACLs and Switched Packets

Figure 32-5 shows how an ACL processes packets that are switched within a VLAN. Packets switched within the VLAN are not processed by router ACLs.

Figure 32-5 Applying ACLs on Switched Packets

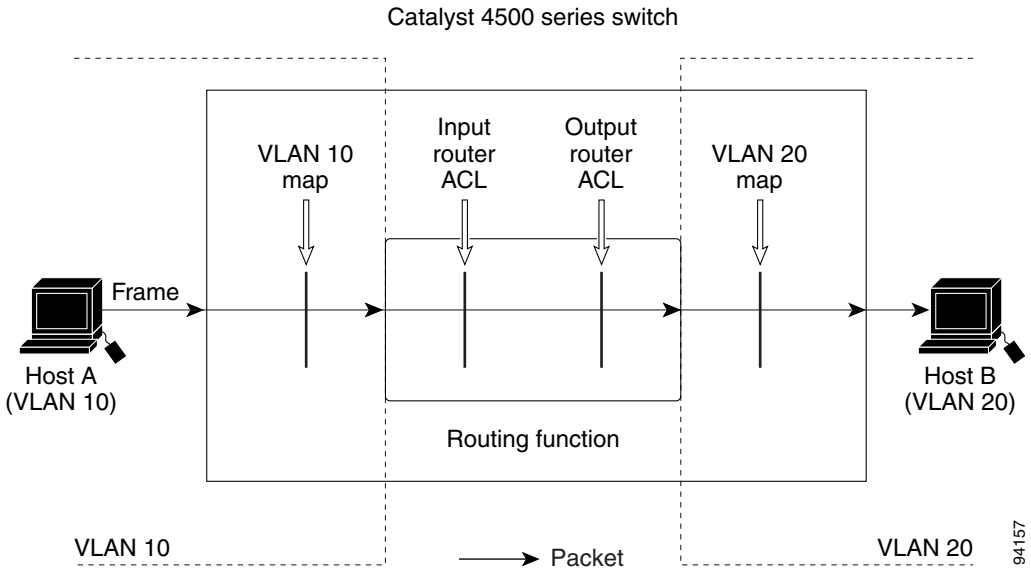


ACLs and Routed Packets

Figure 32-6 shows how ACLs are applied on routed packets. For routed packets, the ACLs are applied in this order:

1. VLAN map for input VLAN
2. Input router ACL
3. Output router ACL
4. VLAN map for output VLAN

Figure 32-6 Applying ACLs on Routed Packets



Configuring PACLs

This section describes how to configure PACLs, which are used to control filtering on Layer 2 interfaces. PACLs can filter traffic to or from Layer 2 interfaces based on Layer 3 information, Layer 4 head information or non-IP Layer 2 information.

This section contains the following topics:

Creating a PACL

To create a PACL and apply it to one or more interfaces, perform this task:

Step 1 Create the standard or extended IP ACLs or named MAC extended ACLs that you want to apply to the interface.

Step 2 Use the **ip access-group** or **mac access-group interface** command to apply a IP ACL or MAC ACL to one or more Layer 2 interfaces.

PACL Configuration Guidelines

Consider the following guidelines when configuring PACLs:

- There can be at most one IP access list and MAC access list applied to the same Layer 2 interface per direction.
- The IP access list filters only IP packets, whereas the MAC access list filters only non-IP packets.
- The number of ACLs and ACEs that can be configured as part of a PACL are bounded by the hardware resources on the switch. Those hardware resources are shared by various ACL features (for example, RACL, VACL) that are configured on the system. If there are insufficient hardware resources to program PACL in hardware, the actions for input and output PACLs differ:
  - For input PACLs, some packets are sent to CPU for software forwarding.
  - For output PACLs, the PACL is disabled on the port.
- These restrictions pertain to output PACLs only:
  - If there are insufficient hardware resources to program the PACL, the output PACL is not applied to the port, and you receive a warning message.
  - If an output PACL is configured on a Layer 2 port, then neither a VACL nor a Router ACL can be configured on the VLANs to which the Layer 2 port belongs.

    If any VACL or Router ACL is configured on the VLANs to which the Layer 2 port belongs, the output PACL cannot be configured on the Layer 2 port. That is, PACLs and VLAN-based ACLs (VACL and Router ACL) are mutually exclusive on Layer 2 ports.
- The input IP ACL logging option is supported, although logging is not supported for output IP ACLs, and MAC ACLs.
- The access group mode can change the way PACLs interact with other ACLs. To maintain consistent behavior across Cisco platforms, use the default access group mode.

Configuring IP and MAC ACLs on a Layer 2 Interface

Only IP or MAC ACLs can be applied to Layer 2 physical interfaces. Standard (numbered, named) and Extended (numbered, named) IP ACLs, and Extended Named MAC ACLs are also supported.

To apply IP or MAC ACLs on a Layer 2 interface, perform this task:

	Command	Purpose
Step 1	`Switch# configure t`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface*	Enters interface config mode.
Step 3	`Switch(config-if)# [no] {ip | mac } access-group {name | number| in| out}`	Applies numbered or named ACL to the Layer 2 interface. The NO prefix deletes the IP or MAC ACL from the Layer 2 interface.
Step 4	`Switch(config)# show running-config`	Displays the access list configuration.

The following example shows how to configure the Extended Named IP ACL simple-ip-acl to permit all TCP traffic and implicitly deny all other IP traffic:

```
Switch(config)# ip access-list extended simple-ip-acl
Switch(config-ext-nacl)# permit tcp any any
Switch(config-ext-nacl)# end
```

The following example shows how to configure the Extended Named MACL simple-mac-acl to permit source host 000.000.011 to any destination host:

```
Switch(config)# mac access-list extended simple-mac-acl
Switch(config-ext-macl)# permit host 000.000.011 any
Switch(config-ext-macl)# end
```

Using PACL with Access-Group Mode

You can use the access group mode to change the way PACLs interact with other ACLs. For example, if a Layer 2 interface belongs to VLAN100, VACL (VLAN filter) V1 is applied on VLAN100, and PACL P1 is applied on the Layer 2 interface. In this situation, you must specify how P1 and V1 impact the traffic with the Layer 2 interface on VLAN100. In a per-interface fashion, the **access-group mode** command can be used to specify one of the desired behaviors that are defined below.

The following modes are defined:

- prefer port mode—If PACL is configured on a Layer 2 interface, then PACL takes effect and overwrites the effect of other ACLs (Router ACL and VACL). If no PACL feature is configured on the Layer 2 interface, other features applicable to the interface are merged and applied on the interface. This is the default access group mode.
- prefer vlan mode—VLAN-based ACL features take effect on the port provided they have been applied on the port and no PACLs are in effect. If no VLAN-based ACL features are applicable to the Layer 2 interface, then the PACL feature already on the interface is applied.
- merge mode—Merges applicable ACL features before they are programmed into the hardware.

Note Because output PACLs are mutually exclusive with VACL and Router ACLs, the access group mode does not change the behavior of output traffic filtering.

Configuring Access-group Mode on Layer 2 Interface

To configure an access mode on a Layer 2 interface, perform this task:

	Command	Purpose
Step 1	`Switch# configure t`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface*	Enters interface config mode.
Step 3	`Switch(config-if)# [no] access-group mode {prefer {port | vlan} | merge}`	Applies numbered or named ACL to the Layer 2 interface. The no prefix deletes the IP or MAC ACL from the Layer 2 interface.
Step 4	`Switch(config)# show running-config`	Displays the access list configuration.

This example shows how to merge and apply features other than PACL on the interface:

```
Switch# configure t
Switch(config)# interface interface
Switch(config-if)# access-group mode prefer port
```

This example shows how to merge applicable ACL features before they are programmed into hardware:

```
Switch# configure t
Switch(config)# interface interface
Switch(config-if)# access-group mode merge
```

Applying ACLs to a Layer 2 Interface

To apply IP and MAC ACLs to a Layer 2 interface, perform one of these tasks:

Command	Purpose
`Switch(config-if)# ip access-group ip-acl {in | out}`	Applies an IP ACL to the Layer 2 interface
`Switch(config-if)# mac access-group mac-acl {in | out}`	Applies a MAC ACL to the Layer 2 interface.

Note Supervisor Engines III and Supervisor Engine IV running on a Catalyst 4500 series switch support both input and output PACLs on an interface.

This example applies the extended named IP ACL simple-ip-acl to interface FastEthernet 6/1 ingress traffic:

```
Switch# configure t
Switch(config)# interface fastEthernet 6/1
Switch(config-if)# ip access-group simple-ip-acl in
```

This example applies the extended named MAC ACL simple-mac-acl to interface FastEthernet 6/1 egress traffic:

```
Switch# configure t
Switch(config)# interface fastEthernet 6/1
Switch(config-if)# mac access-group simple-mac-acl out
```

Displaying an ACL Configuration on a Layer 2 Interface

To display information about an ACL configuration on Layer 2 interfaces, perform one of these tasks:

Command	Purpose
`Switch# show ip interface [interface-name]`	Shows the IP access group configuration on the interface.
`Switch# show mac access-group interface [interface-name]`	Shows the MAC access group configuration on the interface.
`Switch# show access-group mode interface [interface-name]`	Shows the access group mode configuration on the interface.

This example shows that the IP access group simple-ip-acl is configured on the inbound direction of interface fa6/1:

```
Switch# show ip interface fast 6/1
FastEthernet6/1 is up, line protocol is up
  Inbound  access list is simple-ip-acl
  Outgoing access list is not set
```

This example shows that MAC access group simple-mac-acl is configured on the inbound direction of interface fa6/1:

```
Switch# show mac access-group interface fast 6/1
Interface FastEthernet6/1:
   Inbound access-list is simple-mac-acl
   Outbound access-list is not set
```

This example shows that access group merge is configured on interface fa6/1:

```
Switch# show access-group mode interface fast 6/1
Interface FastEthernet6/1:
   Access group mode is: merge
```

Using PACL with VLAN Maps and Router ACLs

For output PACLs, there is no interaction with VACL or output Router ACLs. (See the restrictions listed in the "PACL Configuration Guidelines" section on page 32-23.) For input PACLs, however, the interaction with Router ACLs and VACLs depends on the interface access group mode as shown in Table 32-1.

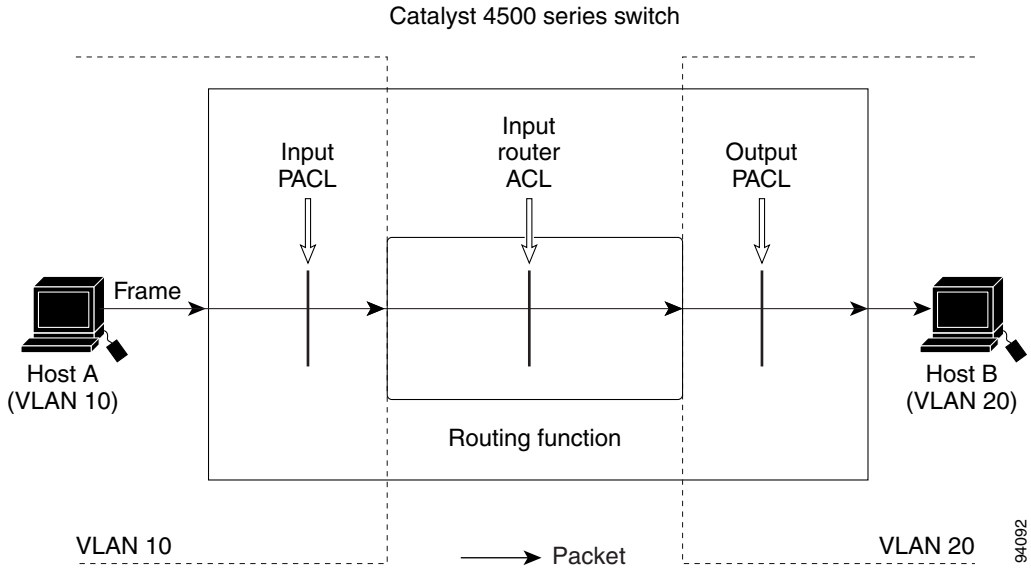
Table 32-1 Interaction Between PACLs, VACLs and Router ACLs

ACL Type(s)	Input PACL		
	prefer port mode	prefer vlan mode	merge mode
1. Input Router ACL	PACL applied	Input Router ACL applied	PACL, Input Router ACL (merged) applied in order (ingress)
2. VACL	PACL applied	VACL applied	PACL, VACL (merged) applied in order (ingress)
3. VACL + Input Router ACL	PACL applied	VACL + Input Router ACL applied	PACL, VACL, Input Router ACL (merged) applied in order (ingress)

Each ACL Type listed in Table 32-1 is synonymous with a different scenario, as explained in the following discussion.

Scenario 1: Host A is connected to an interface in VLAN 20, which has an SVI configured. The interface has input PACL configured, and the SVI has input Router ACL configured as shown in Figure 32-7:

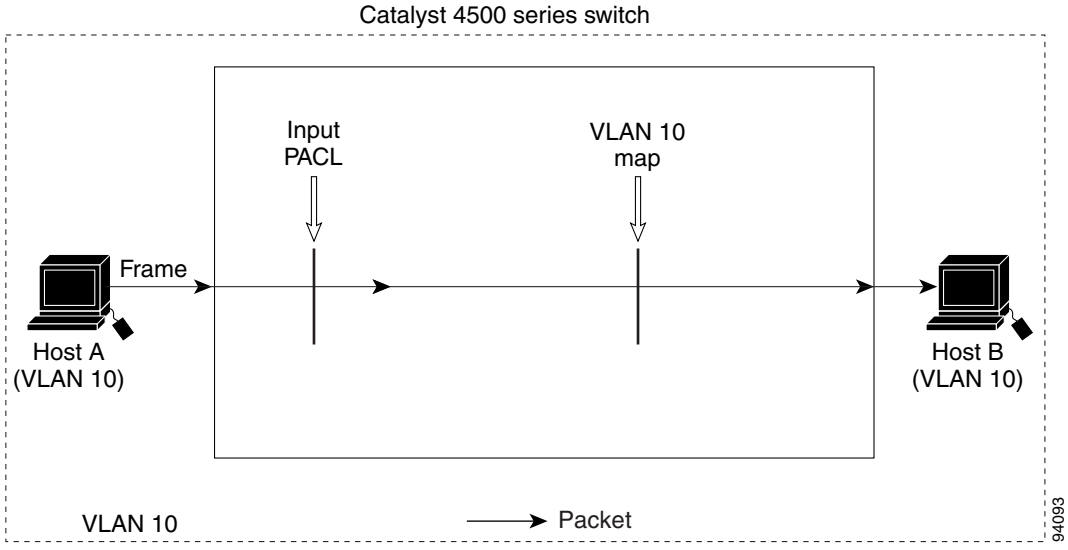
Figure 32-7 Scenario 1: PACL Interaction with an Input Router ACL



If the interface access group mode is prefer port, then only the input PACL is applied on the ingress traffic from Host A. If the mode is prefer vlan, then only the input Router ACL is applied to ingress traffic from Host A that requires routing. If the mode is merge, then the input PACL is first applied to the ingress traffic from Host A, and the input Router ACL is applied on the traffic that requires routing.

Scenario 2: Host A is connected to an interface in VLAN 10, which has a VACL (VLAN Map) configured and an input PACL configured as shown in Figure 32-8:

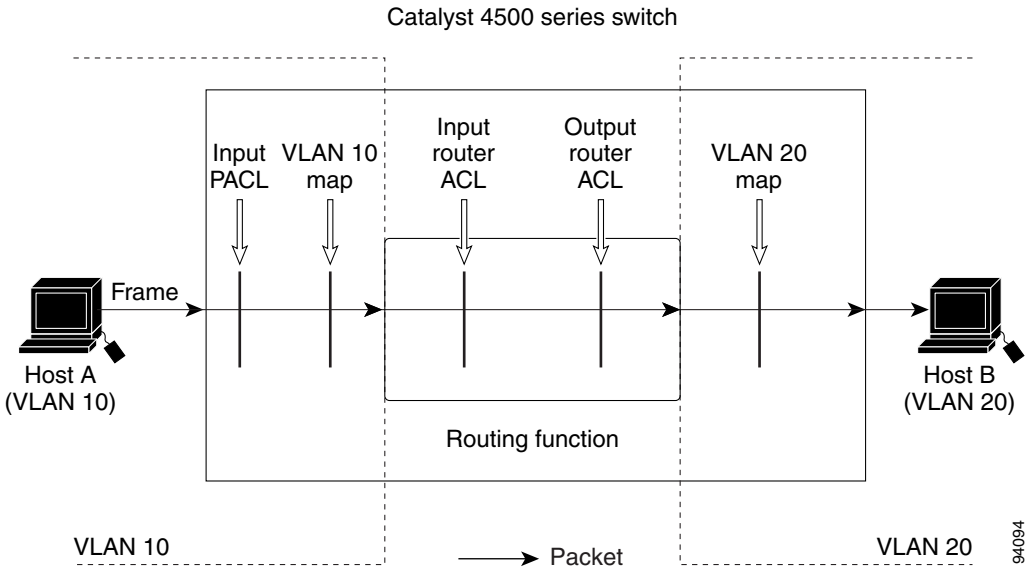
Figure 32-8 Scenario 2: PACL Interaction with a VACL



If the interface access group mode is prefer port, then only the input PACL is applied on the ingress traffic from Host A. If the mode is prefer vlan, then only the VACL is applied to the ingress traffic from Host A. If the mode is merge, the input PACL is first applied to the ingress traffic from Host A, and the VACL is applied on the traffic.

Scenario 3: Host A is connected to an interface in VLAN 10, which has a VACL and an SVI configured. The SVI has an input Router ACL configured and the interface has an input PACL configured, as shown in Figure 32-9:

Figure 32-9 Scenario 3: VACL and Input Router ACL



If the interface access group mode is prefer port, then only the input PACL is applied on the ingress traffic from Host A. If the mode is prefer vlan, then the merged results of the VACL and the input Router ACL are applied to the ingress traffic from Host A. If the mode is merge, the input PACL is first applied to the ingress traffic from Host A, the VACL is applied on the traffic and finally, and the input Router ACL is applied to the traffic that needs routing. (that is, the merged results of the input PACL, VACL, and input Router ACL are applied to the traffic).

CHAPTER 33

Configuring Private VLANs

This chapter describes private VLANs (PVLANs) on Catalyst 4500 series switches. It also provides restrictions, procedures, and configuration examples.

This chapter includes the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of PVLANs

PVLANs provide Layer 2 isolation between ports within the same PVLAN. There are three types of PVLAN ports:

- Promiscuous—A promiscuous port can communicate with all interfaces, including the isolated and community ports within a PVLAN.
- Isolated—An isolated port has complete Layer 2 separation from the other ports within the same PVLAN, but not from the promiscuous ports. PVLANs block all traffic to isolated ports except traffic from promiscuous ports. Traffic from isolated port is forwarded only to promiscuous ports.
- Community—Community ports communicate among themselves and with their promiscuous ports. These interfaces are separated at Layer 2 from all other interfaces in other communities or isolated ports within their PVLAN.

Because trunks can support the VLANs carrying traffic between isolated, community, and promiscuous ports, isolated and community port traffic might enter or leave the switch through a trunk interface.

PVLAN ports are associated with a set of supporting VLANs that are used to create the PVLAN structure. A PVLAN uses VLANs three ways:

- As a primary VLAN—Carries traffic from promiscuous ports to isolated, community, and other promiscuous ports in the same primary VLAN.
- As an isolated VLAN—Carries traffic from isolated ports to a promiscuous port.
- As a community VLAN—Carries traffic between community ports and to promiscuous ports. You can configure multiple community VLANs in a PVLAN.

Isolated and community VLANs are called secondary VLANs. You can extend PVLANs across multiple devices by trunking the primary, isolated, and community VLANs to other devices that support PVLANs.

In a switched environment, you can assign an individual PVLAN and associated IP subnet to each individual or common group of end stations. The end stations need to communicate with a default gateway only to gain access outside the PVLAN. With end stations in a PVLAN, you can do the following:

- Designate which ports will be connected to end stations. For example, interfaces connected to servers as isolated ports prevent any communication at Layer 2.
- Designate the interfaces to which the default gateway(s) and selected end stations (for example, backup servers or LocalDirector) are attached as promiscuous ports to allow all end stations access.
- Reduce VLAN and IP subnet consumption, because you can prevent traffic between end stations even though they are in the same VLAN and IP subnet.

Note A promiscuous port can service only one primary VLAN. A promiscuous port can service one isolated or many community VLANs.

With a promiscuous port, you can connect a wide range of devices as access points to a PVLAN. For example, you can connect a promiscuous port to the server port of a LocalDirector to connect an isolated VLAN or a number of community VLANs to the server. LocalDirector can load balance the servers present in the isolated or community VLANs, or you can use a promiscuous port to monitor or back up all the PVLAN servers from an administration workstation.

PVLAN Trunks

A PVLAN trunkport can carry multiple secondary and non-PVLANs. Packets are received and transmitted with secondary or regular VLAN tags on the PVLAN trunk ports.

PVLAN trunk port behavior is the same as PVLAN isolated or community port behavior, except that PVLANs can tag packets and carry multiple secondary and regular VLANs.

Note Only IEEE 802.1q encapsulation is supported.

PVLANs and VLAN ACL/QoS

PVLAN ports use primary and secondary VLANs, as follows:

- A packet received on a PVLAN host port belongs to the secondary VLAN.
- A packet received on a PVLAN trunk port belongs to the secondary VLAN if the packet is tagged with a secondary VLAN or if the packet is untagged and the native VLAN on the port is a secondary VLAN.

A packet received on a PVLAN host or trunk port and assigned to a secondary VLAN is bridged on the secondary VLAN. Because of this bridging, the secondary VLAN ACL as well as the secondary VLAN QoS (on input direction) apply.

When a packet is transmitted out of a PVLAN host or trunk port, the packet logically belongs to the primary VLAN. This relationship applies even though the packet may be transmitted with the secondary VLAN tagging for PVLAN trunk ports. In this situation, the primary VLAN ACL and the primary VLAN QoS on output apply to the packet.

How to Configure PVLANs

To configure a PVLAN, follow this procedure:

Step 1 Set VTP mode to transparent. See the "Disabling VTP (VTP Transparent Mode)" section on page 24-9.

Step 2 Create the secondary VLANs. See the "Configuring a VLAN as a PVLAN" section on page 33-5.

Step 3 Create the primary VLAN. See the "Configuring a VLAN as a PVLAN" section on page 33-5.

Step 4 Associate the secondary VLAN to the primary VLAN. See the "Associating a Secondary VLAN with a Primary VLAN" section on page 33-6.

Note Only one isolated VLAN can be mapped to a primary VLAN, but more than one community VLAN can be mapped to a primary VLAN.

Step 5 Configure an interface to an isolated or community port. See the "Configuring a Layer 2 Interface as a PVLAN Host Port" section on page 33-8.

Step 6 Associate the isolated port or community port to the primary-secondary VLAN pair. See the "Associating a Secondary VLAN with a Primary VLAN" section on page 33-6.

Step 7 Configure an interface as a promiscuous port. See the "Configuring a Layer 2 Interface as a PVLAN Promiscuous Port" section on page 33-7.

Step 8 Map the promiscuous port to the primary-secondary VLAN pair. See the "Configuring a Layer 2 Interface as a PVLAN Promiscuous Port" section on page 33-7.

These sections describe how to configure PVLANs:

PVLAN Configuration Guidelines and Restrictions

Follow these guidelines when configuring PVLANs:

- To configure a PVLAN correctly, enable VTP in transparent mode.
- Do not include VLAN 1 or VLANs 1002 through 1005 in PVLANs.

- Use only PVLAN commands to assign ports to primary, isolated, or community VLANs.

  Layer 2 interfaces on primary, isolated, or community VLANs are inactive in PVLANs. Layer 2 trunk interfaces remain in the STP forwarding state.

- You cannot configure Layer 3 VLAN interfaces for secondary VLANs.

  Layer 3 VLAN interfaces for isolated and community (secondary) VLANs are inactive while the VLAN is configured as an isolated or community VLAN.

- Do not configure PVLAN ports as EtherChannel.

  EtherChannel ports in PVLANs are inactive.

- Do not configure private VLAN ports as EtherChannels. While a port is part of the private VLAN configuration, its associated EtherChannel configuration is inactive.

- Do not apply dynamic access control entries (ACEs) to primary VLANs.

  Cisco IOS dynamic ACL configuration applied to a primary VLAN is inactive while the VLAN is part of the PVLAN configuration.

- To prevent spanning tree loops due to misconfigurations, enable PortFast on the PVLAN trunk ports with the **spanning-tree portfast trunk** command.

- Any VLAN ACL configured on a secondary VLAN is effective in the input direction, and any VLAN ACL configured on the primary VLAN associated with the secondary VLAN is effective in the output direction.

- You can stop Layer 3 switching on an isolated or community VLAN by deleting the mapping of that VLAN with its primary VLAN.

- PVLAN ports can be on different network devices as long as the devices are trunk-connected and the primary and secondary VLANs remain associated with the trunk.

- Isolated ports on two different devices cannot communicate with each other, but community VLAN ports can.

- Private VLANs support the following SPAN features:

  - You can configure a private VLAN port as a SPAN source port.
  - You can use VLAN-based SPAN (VSPAN) on primary, isolated, and community VLANs or use SPAN on only one VLAN to monitor egress or ingress traffic separately.

  For more information about SPAN, see Chapter 37, “Configuring SPAN and RSPAN.”

- A primary VLAN can be associated with multiple community VLANs, but only one isolated VLAN.

- An isolated or community VLAN can be associated with only one primary VLAN.

- If you delete a VLAN used in a private VLAN configuration, the private VLAN ports associated with the VLAN become inactive.

- VTP does not support private VLANs. You must configure private VLANs on each device in which you plan to use private VLAN ports.

- To maintain the security of your PVLAN configuration and avoid other use of VLANs configured as PVLANs, configure PVLANs on all intermediate devices, even if the devices have no PVLAN ports.

- Prune the PVLANs from trunks on devices that carry no traffic in the PVLANs.

- With port ACLS functionality available, you can apply Cisco IOS ACLS to secondary VLAN ports and Cisco IOS ACLS to PVLANS (VACLs). For more information on VACLs, see Chapter 32, “Configuring Network Security with ACLs.”

- You can apply different quality of service (QoS) configurations to primary, isolated, and community VLANs. (See Chapter 26, "Configuring QoS.") Cisco IOS ACLs applied to the Layer 3 VLAN interface of a primary VLAN automatically apply to the associated isolated and community VLANs.
- On a PVLAN trunk port a secondary VLAN ACL is applied on ingress traffic and a primary VLAN ACL is applied on egress traffic.
- On a promiscuous port the primary VLAN ACL is applied on ingress traffic.
- PVLAN trunk ports support only IEEE 802.1q encapsulation.
- You cannot change the VTP mode to client or server for PVLANs.
- An isolated or community VLAN can have only one primary VLAN associated with it.
- VTP does not support PVLANs. You must configure PVLANs on each device where you want PVLAN ports.
- Community VLANs cannot be propagated or carried over private VLAN trunks.

Configuring a VLAN as a PVLAN

To configure a VLAN as a PVLAN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# vlan vlan_ID` `Switch(config-vlan)# private-vlan {community | isolated | primary}`	Configures a VLAN as a PVLAN. • This command does not take effect until you exit VLAN configuration submode. • You can use the **no** keyword to clear PVLAN status.
Step 3	`Switch(config-vlan)# end`	Exits VLAN configuration mode.
Step 4	`Switch# show vlan private-vlan [type]`	Verifies the configuration.

This example shows how to configure VLAN 202 as a primary VLAN and verify the configuration:

```
Switch# configure terminal
Switch(config)# vlan 202
Switch(config-vlan)# private-vlan primary
Switch(config-vlan)# end
Switch# show vlan private-vlan

Primary Secondary Type              Interfaces
------- --------- ----------------- ------------------------------------------
202               primary
```

This example shows how to configure VLAN 303 as a community VLAN and verify the configuration:

```
Switch# configure terminal
Switch(config)# vlan 303
Switch(config-vlan)# private-vlan community
Switch(config-vlan)# end
Switch# show vlan private-vlan

Primary Secondary Type              Interfaces
------- --------- ----------------- ------------------------------------------
202               primary
        303       community
```

This example shows how to configure VLAN 440 as an isolated VLAN and verify the configuration:

```
Switch# configure terminal
Switch(config)# vlan 440
Switch(config-vlan)# private-vlan isolated
Switch(config-vlan)# end
Switch# show vlan private-vlan

Primary Secondary Type              Interfaces
------- --------- ----------------- ------------------------------------------
202               primary
        303       community
        440       isolated
```

Associating a Secondary VLAN with a Primary VLAN

To associate secondary VLANs with a primary VLAN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# vlan primary_vlan_ID`	Enters VLAN configuration mode for the primary VLAN.
Step 3	`Switch(config-vlan)# [no] private-vlan association {secondary_vlan_list | add secondary_vlan_list | remove secondary_vlan_list}`	Associates the secondary VLAN with the primary VLAN. The list can contain only one VLAN. You can use the **no** keyword to clear all secondary associations.
Step 4	`Switch(config-vlan)# end`	Exits VLAN configuration mode.
Step 5	`Switch# show vlan private-vlan [type]`	Verifies the configuration.

When you associate secondary VLANs with a primary VLAN, note the following:

- The *secondary_vlan_list* parameter cannot contain spaces. It can contain multiple comma-separated items. Each item can be a single private VLAN ID or a hyphenated range of private VLAN IDs.
- The *secondary_vlan_list* parameter can contain multiple community VLAN IDs.
- The *secondary_vlan_list* parameter can contain only one isolated VLAN ID.
- Enter a *secondary_vlan_list* or use the **add** keyword with a *secondary_vlan_list* to associate secondary VLANs with a primary VLAN.
- Use the **remove** keyword with a *secondary_vlan_list* to clear the association between secondary VLANs and a primary VLAN.
- The command does not take effect until you exit VLAN configuration submode.

This example shows how to associate community VLANs 303 through 307 and 309 and isolated VLAN 440 with primary VLAN 202 and verify the configuration:

```
Switch# configure terminal
Switch(config)# vlan 202
Switch(config-vlan)# private-vlan association 303-307,309,440
Switch(config-vlan)# end
Switch# show vlan private-vlan
```

```
Primary Secondary Type              Interfaces
------- --------- ----------------- ----------------------------------------
202     303       community
202     304       community
202     305       community
202     306       community
202     307       community
202     309       community
202     440       isolated
        308       community
```

Note The secondary VLAN 308 has no associated primary VLAN.

Configuring a Layer 2 Interface as a PVLAN Promiscuous Port

To configure a Layer 2 interface as a PVLAN promiscuous port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the LAN interface to configure.
Step 3	`Switch(config-if)# switchport mode private-vlan {host | promiscuous | trunk}`	Configures a Layer 2 interface as a PVLAN promiscuous port.
Step 4	`Switch(config-if)# [no] switchport private-vlan mapping primary_vlan_ID {secondary_vlan_list | add secondary_vlan_list | remove secondary_vlan_list}`	Maps the PVLAN promiscuous port to a primary VLAN and to selected secondary VLANs. You can use the **no** keyword to delete all associations from the primary VLAN.
Step 5	`Switch(config-if)# end`	Exits configuration mode.
Step 6	`Switch# show interfaces {fastethernet | gigabitethernet} slot/port switchport`	Verifies the configuration.

When you configure a Layer 2 interface as a PVLAN promiscuous port, note the following:

- The *secondary_vlan_list* parameter cannot contain spaces. It can contain multiple comma-separated items. Each item can be a single PVLAN ID or a hyphenated range of PVLAN IDs.
- Enter a *secondary_vlan_list* or use the **add** keyword with a *secondary_vlan_list* to map the secondary VLANs to the PVLAN promiscuous port.
- Use the **remove** keyword with a *secondary_vlan_list* to clear the mapping between secondary VLANs and the PVLAN promiscuous port.

This example shows how to configure interface FastEthernet 5/2 as a PVLAN promiscuous port, map it to a PVLAN, and verify the configuration:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/2
Switch(config-if)# switchport mode private-vlan promiscuous
Switch(config-if)# switchport private-vlan mapping 200 2
Switch(config-if)# end
```

```
Switch#show interfaces fastethernet 5/2 switchport
Name:Fa5/2
Switchport:Enabled
Administrative Mode:private-vlan promiscuous
Operational Mode:private-vlan promiscuous
Administrative Trunking Encapsulation:negotiate
Operational Trunking Encapsulation:native
Negotiation of Trunking:Off
Access Mode VLAN:1 (default)
Trunking Native Mode VLAN:1 (default)
Voice VLAN:none
Administrative Private VLAN Host Association:none
Administrative Private VLAN Promiscuous Mapping:200 (VLAN0200) 2 (VLAN0002)
Private VLAN Trunk Native VLAN:none
Administrative Private VLAN Trunk Encapsulation:dot1q
Administrative Private VLAN Trunk Normal VLANs:none
Administrative Private VLAN Trunk Private VLANs:none
Operational Private VLANs:
  200 (VLAN0200) 2 (VLAN0002)
Trunking VLANs Enabled:ALL
Pruning VLANs Enabled:2-1001
Capture Mode Disabled
Capture VLANs Allowed:ALL
```

Configuring a Layer 2 Interface as a PVLAN Host Port

To configure a Layer 2 interface as a PVLAN host port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the LAN port to configure.
Step 3	`Switch(config-if)# switchport mode private-vlan {host | promiscuous} | trunk`	Configures a Layer 2 interface as a PVLAN host port.
Step 4	`Switch(config-if)# [no] switchport private-vlan host-association primary_vlan_ID secondary_vlan_ID`	Associates the Layer 2 interface with a PVLAN. You can use the **no** keyword to delete all associations from the primary VLAN.
Step 5	`Switch(config-if)# end`	Exits configuration mode.
Step 6	`Switch# show interfaces {fastethernet | gigabitethernet} slot/port switchport`	Verifies the configuration.

This example shows how to configure interface FastEthernet 5/1 as a PVLAN host port and verify the configuration:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/1
Switch(config-if)# switchport mode private-vlan host
Switch(config-if)# switchport private-vlan host-association 202 440
Switch(config-if)# end
```

```
Switch#show interfaces fastethernet 5/1 switchport
Name: Fa5/1
Switchport: Enabled
Administrative Mode: private-vlan host
Operational Mode: private-vlan host
Administrative Trunking Encapsulation: negotiate
Operational Trunking Encapsulation: native
Negotiation of Trunking: Off
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Voice VLAN: none
Appliance trust: none
Administrative Private Vlan
  Host Association: 202 (VLAN0202) 440 (VLAN0440)
  Promiscuous Mapping: none
  Trunk encapsulation : dot1q
  Trunk vlans:
Operational private-vlan(s):
  2 (VLAN0202) 3 (VLAN0440)
Trunking VLANs Enabled: ALL
Pruning VLANs Enabled: 2-1001
Capture Mode Disabled
Capture VLANs Allowed: ALL
```

Configuring a Layer 2 Interface as a PVLAN Trunk Port

To configure a Layer 2 interface as a PVLAN trunk port, perform this task:

	Command	Purpose
Step 1	`Switch> enable`	Enters privileged EXEC mode.
Step 2	`Switch# configure terminal`	Enters global configuration mode.
Step 3	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Specifies the LAN port to configure.
Step 4	`Switch(config-if)# switchport mode private-vlan {host | promiscuous | trunk}`	Configures a Layer 2 interface as a PVLAN trunk port for multiple secondary VLANs.
Step 5	`Switch(config-if)# [no] switchport private-vlan association trunk primary_vlan_ID secondary_vlan_ID`	Configures association between primary VLANs and secondary VLANs the PVLAN trunk port with a PVLAN. **Note** Multiple PVLAN pairs can be specified using this command so that a PVLAN trunk port can carry multiple secondary VLANs. If an association is specified for the existing primary VLAN, the existing association is replaced. If there is no trunk association, any packets received on secondary VLANs are dropped. You can use the **no** keyword to delete all associations from the primary VLAN.
Step 6	`Switch(config-if)# [no] switchport private-vlan trunk allowed vlan vlan_list all | none | [add | remove | except] vlan_atom[,vlan_atom...]`	Configures a list of allowed normal VLANs on a PVLAN trunk port. You can use the **no** keyword to remove all allowed normal VLANs on a PVLAN trunk port.

	Command	Purpose
Step 7	`Switch(config-if)# [no] switchport private-vlan trunk native vlan vlan_id`	Configures a VLAN to which untagged packets (as in IEEE 802.1Q tagging) are assigned on a PVLAN trunk port. If there is no native VLAN configured, all untagged packets are dropped. If the native VLAN is a secondary VLAN and the port does not have the association for the secondary VLAN, the untagged packets are dropped. You can use the **no** keyword to remove all native VLANs on a PVLAN trunk port.
Step 8	`Switch(config-if)# end`	Exits configuration mode.
Step 9	`Switch# show interfaces {fastethernet | gigabitethernet} slot/port switchport`	Verifies the configuration.

This example shows how to configure interface FastEthernet 5/1 as a PVLAN trunk port, maps VLAN0202 to VLAN0440, and configures the PVLAN trunk:

```
Switch# configure terminal
Switch(config)# interface fastethernet 5/1
Switch(config-if)# switchport private-vlan association trunk 202 440
Switch(config-if)# switchport mode private-vlan trunk
Switch(config-if)# end

Switch#show interfaces fastethernet 5/1 switchport
Name: Fa5/1
Switchport: Enabled
Administrative Mode: private-vlan trunk
Operational Mode: private-vlan trunk
Administrative Trunking Encapsulation: negotiate
Operational Trunking Encapsulation: dot1q
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Voice VLAN: none
Appliance trust: none
Administrative Private Vlan
  Host Association: 202 (VLAN0202) 440 (VLAN0440)
  Promiscuous Mapping: none
  Trunk encapsulation : dot1q
  Trunk vlans:
    202 (VLAN0202) 440 (VLAN0440)
Operational private-vlan(s):
  202 (VLAN0202) 440 (VLAN0440)
Trunking VLANs Enabled: ALL
Pruning VLANs Enabled: 2-1001
Capture Mode Disabled
Capture VLANs Allowed: ALL
```

Permitting Routing of Secondary VLAN Ingress Traffic

Note Isolated and community VLANs are both called secondary VLANs.

To permit routing of secondary VLAN ingress traffic, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface vlan` *primary_vlan_ID*	Enters interface configuration mode for the primary VLAN.
Step 3	`Switch(config-if)# [no] private-vlan mapping` *primary_vlan_ID* {*secondary_vlan_list* | **add** *secondary_vlan_list* | **remove** *secondary_vlan_list*}	To permit routing on the secondary VLAN ingress traffic, map the secondary VLAN to the primary VLAN. You can use the **no** keyword to delete all associations from the primary VLAN.
Step 4	`Switch(config-if)# end`	Exits configuration mode.
Step 5	`Switch# show interface private-vlan mapping`	Verifies the configuration.

When you permit routing on the secondary VLAN ingress traffic, note the following:

- The **private-vlan mapping** interface configuration command only affects private VLAN ingress traffic that is Layer 3 switched.
- The *secondary_vlan_list* parameter cannot contain spaces. It can contain multiple comma-separated items. Each item can be a single private VLAN ID or a hyphenated range of private VLAN IDs.
- Enter a *secondary_vlan_list* parameter or use the **add** keyword with a *secondary_vlan_list* parameter to map the secondary VLANs to the primary VLAN.
- Use the **remove** keyword with a *secondary_vlan_list* parameter to clear the mapping between secondary VLANs and the primary VLAN.

This example shows how to permit routing of secondary VLAN ingress traffic from private VLANs 303 through 307, 309, and 440 and verify the configuration:

```
Switch# configure terminal
Switch(config)# interface vlan 202
Switch(config-if)# private-vlan mapping add 303-307,309,440
Switch(config-if)# end
Switch# show interfaces private-vlan mapping
Interface Secondary VLAN Type
--------- -------------- -----------------
vlan202   303            community
vlan202   304            community
vlan202   305            community
vlan202   306            community
vlan202   307            community
vlan202   309            community
vlan202   440            isolated

Switch#
```

Port Unicast and Multicast Flood Blocking

This chapter describes how to configure multicast and unicast flood blocking on the Catalyst 4500 series switch. This chapter contains these topics:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of Flood Blocking

Occasionally, unknown unicast or multicast traffic is flooded to a switch port because a MAC address has timed out or has not been learned by the switch. (This condition is especially undesirable for a private VLAN isolated port.) To guarantee that no unicast and multicast traffic is flooded to the port, use the **switchport block unicast** and **switchport block multicast** commands to enable flood blocking on the switch.

Note The flood blocking feature is supported on all switched ports (including PVLAN ports) and is applied to all VLANs on which the port is forwarding.

Configuring Port Blocking

By default, a switch floods packets with unknown destination MAC addresses to all ports. If unknown unicast and multicast traffic is forwarded to a switch port, there might be security issues. To prevent forwarding such traffic, you can configure a port to block unknown unicast or multicast packets.

Note Blocking of unicast or multicast traffic is not automatically enabled on a switch port; you must explicitly configure it.

Blocking Flooded Traffic on an Interface

Note The interface can be a physical interface (for example, GigabitEthernet 1/1) or an EtherChannel group (such as port-channel 5). When you block multicast or unicast traffic for a port channel, it is blocked on all ports in the port channel group.

To disable the flooding of multicast and unicast packets to an interface, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and enter the type and number of the switchport interface (for example, GigabitEthernet 1/1).
Step 3	`Switch(config-if)# switchport block multicast`	Blocks unknown multicast forwarding to the port.
Step 4	`Switch(config-if)# switchport block unicast`	Blocks unknown unicast forwarding to the port.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show interface interface-id switchport`	Verifies your entry.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to block unicast and multicast flooding on a GigabitEthernet interface 0/1 and how to verify the configuration:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet0/1
Switch(config-if)# switchport block multicast
Switch(config-if)# switchport block unicast
Switch(config-if)# end
Switch# show interface gigabitethernet1/1 switchport
Name: Gi1/3
Switchport: Enabled

<output truncated>

Port Protected: On
Unknown Unicast Traffic: Not Allowed
Unknown Multicast Traffic: Not Allowed

Broadcast Suppression Level: 100
Multicast Suppression Level: 100
Unicast Suppression Level: 100
```

Resuming Normal Forwarding on a Port

To resume normal forwarding on a port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and enter the type and number of the switchport interface (GigabitEthernet1/1)**.**
Step 3	`Switch(config-if)# no switchport block multicast`	Enables unknown multicast flooding to the port.
Step 4	`Switch(config-if)# no switchport block unicast`	Enables unknown unicast flooding to the port.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show interface interface-id switchport`	Verifies your entry.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

CHAPTER 35

Configuring Port-Based Traffic Control

This chapter describes how to configure port-based traffic control on the Catalyst 4500 series switch.

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

This chapter consists of these sections:

Overview of Storm Control

This section contains the following subsections:

Storm control prevents LAN interfaces from being disrupted by a broadcast storm. A broadcast storm occurs when broadcast packets flood the subnet, creating excessive traffic and degrading network performance. Errors in the protocol-stack implementation or in the network configuration can cause a broadcast storm.

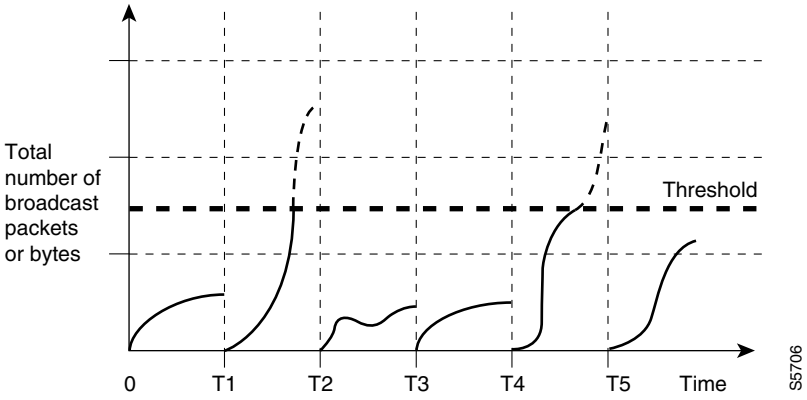
Note Storm control is supported in hardware on all ports on the WS-X4516 supervisor engine. In contrast, the supervisor engines WS-X4515, WS-X4014, and WS-X4013+ support storm control in hardware on non-blocking gigabit ports and in software on all other ports, implying that the counters for these interfaces are approximate and computed. Multicast storm control is only supported on the WS-X4516 supervisor engine.

Hardware-based Storm Control Implementation

Broadcast suppression uses filtering that measures broadcast activity in a subnet over a one-second interval and compares the measurement with a predefined threshold. If the threshold is reached, further broadcast activity is suppressed for the duration of the interval. Broadcast suppression is disabled by default.

Figure 35-1 shows the broadcast traffic patterns on a LAN interface over a given interval. In this example, broadcast suppression occurs between times T1 and T2 and between T4 and T5. During those intervals, the amount of broadcast traffic exceeded the configured threshold.

Figure 35-1 Storm Control Example - Hardware-based Implementation



The broadcast suppression threshold numbers and the time interval combination make the broadcast suppression algorithm work with different levels of granularity. A higher threshold allows more broadcast packets to pass through.

Broadcast suppression on the Catalyst 4500 series switches is implemented in hardware. The suppression circuitry monitors packets passing from a LAN interface to the switching bus. If the packet destination address is broadcast, then the broadcast suppression circuitry tracks the current count of broadcasts within the one-second interval, and when a threshold is reached, it filters out subsequent broadcast packets.

Because hardware broadcast suppression uses a bandwidth-based method to measure broadcast activity, the most significant implementation factor is setting the percentage of total available bandwidth that can be used by broadcast traffic. Because packets do not arrive at uniform intervals, the one-second interval during which broadcast activity is measured can affect the behavior of broadcast suppression.

Software-based Storm Control Implementation

When storm control is enabled on an interface, the switch monitors packets received on the interface and determines whether or not the packets are broadcast. The switch monitors the number of broadcast packets received within a one-second time interval. When the interface threshold is met, all incoming data traffic on the interface is dropped. This threshold is specified as a percentage of total available bandwidth that can be used by broadcast traffic. If the lower threshold is specified, all data traffic is forwarded as soon as the incoming traffic falls below that threshold.

Enabling Storm Control

To enable storm control, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface interface-id`	Enters interface configuration mode and enter the port to configure.
Step 3	`Switch(config-if)# storm-control broadcast level [high level] [lower level]`	Configures broadcast storm control. Specifies the upper threshold levels for broadcast traffic. The storm control action occurs when traffic utilization reaches this level. (Optional) Specifies the falling threshold level. The normal transmission restarts (if the action is filtering) when traffic drops below this level for interfaces that support software-based suppression. **Note** For ports that perform hardware-based suppression, the lower threshold is ignored.
Step 4	`Switch(config-if)# storm-control action {shutdown | trap}`	Specifies the action to be taken when a storm is detected. The default is to filter out the broadcast traffic and not to send out traps. The **shutdown** keyword sets the port to error-disable state during a storm. If the recover interval is not set, the port remains in shutdown state. **Note** The **trap** keyword generates an SNMP trap when a storm is detected. This keyword is available but not supported in the 12.1(19)EW release.
Step 5	`Switch(config-if)# exit`	Returns to configuration mode.
Step 6	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 7	`Switch# show storm-control [interface] broadcast`	Displays the number of packets suppressed.
Step 8	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

The following example shows how to enable storm control on interface.

```
Switch# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# int fa3/1
Switch(config-if)# storm-control broadcast level 50
Switch(config-if)# end
Switch# write memory
Building configuration...

00:11:06: %SYS-5-CONFIG_I: Configured from console by consoleCompressed configuration from
5394 bytes to 1623 bytes[OK]
Switch#sh  stor
Switch#sh  storm-control
Interface  Filter State   Upper    Lower    Current
---------  -------------  -------  -------  -------
Fa3/1      Forwarding      50.00%   50.00%    0.00%
Switch#
```

Disabling Storm Control

To disable storm control, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# interface` *interface-id*	Enters interface configuration mode and enter the port to configure.
Step 3	`Switch(config-if)# no storm-control broadcast level`	Disables port storm control.
Step 4	`Switch(config-if)# no storm-control action {shutdown | trap}`	Disables the specified storm control action and returns to default filter action.
Step 5	`Switch(config-if)# exit`	Returns to configuration mode.
Step 6	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 7	`Switch# show storm-control broadcast`	Verifies your entries.
Step 8	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

The following example shows how to disable storm control on interface.

```
Switch# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# int fa3/1
Switch(config-if)# no storm-control broadcast level
Switch(config-if)# end
Switch# wr
Building configuration...

00:12:09: %SYS-5-CONFIG_I: Configured from console by consoleCompressed configuration from
5357 bytes to 1594 bytes[OK]
Switch# sh sto
Switch# sh storm-control
Interface  Filter State   Upper    Lower    Current
---------  -------------  -------  -------  -------
Switch#
```

Displaying Storm Control

Note Use the **show interface capabilities** command to determine the mode in which storm control is supported on an interface.

The following example shows an interface that supports broadcast suppression in software (sw).

```
Switch# show interfaces g4/4 capabilities
show interfaces g4/4 capabilities
GigabitEthernet4/4
  Model:                 WS-X4418-Gbic
  Type:                  1000BaseSX
```

```
  Speed:                 1000
  Duplex:                full
  Trunk encap. type:     802.1Q
  Trunk mode:            on,off,desirable,nonegotiate
  Channel:               yes
  Broadcast suppression: percentage(0-100), sw
  Flowcontrol:           rx-(off,on,desired),tx-(off,on,desired)
  VLAN Membership:       static, dynamic
  Fast Start:            yes
  Queuing:               rx-(N/A), tx-(4q1t, Shaping)
  CoS rewrite:           yes
  ToS rewrite:           yes
  Inline power:          no
  SPAN:                  source/destination
  UDLD:                  yes
  Link Debounce:         no
  Link Debounce Time:    no
  Port Security:         yes
  Dot1x:                 yes
  Maximum MTU:           1552 bytes (Baby Giants)
  Media Type:            no

Switch#
```

The following example shows an interface that supports broadcast suppression in hardware (hw).

```
Switch# show interfaces g4/1 capabilities
show interfaces g4/1 capabilities
GigabitEthernet4/1
  Model:                 WS-X4418-Gbic
  Type:                  No Gbic
  Speed:                 1000
  Duplex:                full
  Trunk encap. type:     802.1Q,ISL
  Trunk mode:            on,off,desirable,nonegotiate
  Channel:               yes
  Broadcast suppression: percentage(0-100), hw
  Flowcontrol:           rx-(off,on,desired),tx-(off,on,desired)
  VLAN Membership:       static, dynamic
  Fast Start:            yes
  Queuing:               rx-(N/A), tx-(4q1t, Sharing/Shaping)
  CoS rewrite:           yes
  ToS rewrite:           yes
  Inline power:          no
  SPAN:                  source/destination
  UDLD:                  yes
  Link Debounce:         no
  Link Debounce Time:    no
  Port Security:         yes
  Dot1x:                 yes
  Maximum MTU:           1552 bytes (Baby Giants)
  Media Type:            no

Switch#
```

Note Use the **show interfaces counters storm-control** command to display a count of discarded packets.

```
Switch# show interfaces counters storm-control

Port        BcastSuppLevel    TotalSuppressedPackets
Gi4/4              2.00%                        0
Switch#
```

Note Use the **show storm-control** command to display the configured thresholds and status of storm on an interface.

```
Switch# show storm-control

Interface  Filter State   Upper    Lower    Current
---------  -------------  -------  -------  -------
Gi4/4      Forwarding       2.00%    2.00%    N/A
Switch
```

Note In the example shown above, "current" represents the percentage of traffic suppressed at a given instant, and the value is N/A for ports that perform suppression in hardware.

Multicast Storm Control

When a large amount of broadcast (and/or multicast) packets congest a network, the event is referred to as a broadcast storm. A LAN broadcast storm affects network performance and could paralyze the whole network.

Note Multicast storm control is only available on WS-X4016 supervisors; only a hardware-based solution is provided.

Multicast Suppression on the WS-X4516 Supervisor Engine

Multicast suppression can be enabled on a WS-X4516 supervisor engine for all ports that have storm control enabled. Multicast suppression applies to all ports that have broadcast suppression configured on them. It also applies to ports that will be configured for broadcast storm-control in the future; you cannot suppress multicast traffic only. Beginning in Release 12.2(18)EW, the counters displayed with the **show interface counters storm-control** command will include any multicast packets that were dropped.

You cannot provide separate thresholds for broadcast and/or multicast traffic. The threshold you configure for broadcast suppression applies to both the incoming multicast traffic and broadcast traffic. Moreover, the configuration is common and must be set for each interface.

To enable multicast suppression, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# [no] storm-control broadcast include multicast`	Enable multicast suppression.
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.

The following example shows how to enable multicast suppression on ports that have broadcast suppression enabled already:

```
Switch# configuration terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# storm-control broadcast include multicast
Switch(config)# end
Switch#
```

Multicast Suppression on the WS-X4515, WS-X4014, and WS-X4013+ Supervisor Engines

Hardware does not provide support for multicast suppression on the WS-X4515, WS-X4014, and WS-X4013+ supervisor engines. One consequence of using software-based broadcast suppression on these modules is that all incoming data packets are dropped. Irrespective of your selecting to configure broadcast suppression only, multicast packets are filtered as well on stub and blocking gigabit ports. The non blocking gigabit ports that do provide broadcast suppression in hardware also do not filter multicast packets.

CHAPTER 36

Environmental Monitoring and Power Management

This chapter describes power management and environmental monitoring features in the Catalyst 4500 series switches. It provides guidelines, procedures, and configuration examples.

This chapter consists of the following major sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Understanding Environmental Monitoring

This section contains the following subsections:

Environmental monitoring of chassis components provides early warning indications of possible component failure. This warning helps you to ensure the safe and reliable operation of your system and avoid network interruptions.

This section describes how to monitor critical system components so that you can identify and rapidly correct hardware-related problems.

Using CLI Commands to Monitor your Environment

Use the **show environment** CLI command to monitor the system. This section gives a basic overview of the command and keywords you will need.

Enter the **show environment** [**alarm** | **status** | **temperature**] command to display system status information. Keyword descriptions are listed in Table 36-1.

Table 36-1 show environment Keyword Descriptions

Keyword	Purpose
alarm	Displays environmental alarms for the system.
status	Displays field-replaceable unit (FRU) operational status and power and power supply fan sensor information.
temperature	Displays temperature of the chassis.

The following example shows how to display the environment conditions. This output indicates that the power supplies are different. The switch will use only one power supply and disable the other.

```
Switch# show environment
no alarm

Chassis Temperature                    = 35 degrees Celsius
Chassis Over Temperature Threshold     = 75 degrees Celsius
Chassis Critical Temperature Threshold = 95 degrees Celsius

Power                                                 Fan     Inline
Supply  Model No          Type       Status           Sensor  Status
------  ----------------  ---------  -----------      ------  ------
PS1     PWR-C45-2800AC    AC 2800W   good             good    good
➔ PS2     PWR-C45-1000AC    AC 1000W   err-disable      good    n.a.

*** Power Supplies of different types have been detected***
Switch#
```

System Alarms

The system has two types of alarms: major and minor. A major alarm indicates a critical problem that could lead to system shutdown. A minor alarm is informational—it alerts you to a problem that could turn critical if corrective action is not taken.

When the system issues an alarm (major or minor) that indicates an over-temperature condition, the switch does not cancel the alarm nor take any action (such as module reset or shutdown) for five minutes. If the temperature falls 5 degrees Celsius below the alarm threshold during this period, the alarm is canceled.

An LED on the supervisor indicates if an alarm has been issued. See Table 36-2 for more information.

Note Refer to the *Catalyst 4500 Series Switch Module Installation Guide* for additional information on LEDs, including the supervisor engine system LED.

Table 36-2 Alarms for Supervisor Engine and Switching Modules

Event	Alarm Type	Supervisor LED Color	Description and Action
Supervisor engine temperature sensor exceeds major threshold[1]	Major	Red	Syslog message. If the over-temperature condition is not corrected, the system shuts down after 5 min. Alarm threshold: • Chassis critical temperature threshold = 95°C
Supervisor fails power on self-test (POST)	Major	Red	Syslog message. The supervisor fails to come up.
Chassis fan tray fails	Major	Red	If not corrected, the system shuts down in 5 minutes.
Supervisor engine temperature sensor exceeds minor threshold	Minor	Orange	Syslog message. Monitor the condition. Alarm threshold: • Chassis over temperature threshold = 75°C
No problems	None	Green	

1. Temperature sensors monitor key supervisor engine components, including daughter cards.

Power Management

This section describes the power management feature in the Catalyst 4500 and Catalyst 4006 series switches and includes the following major sections:

- Power Management for the Catalyst 4500 Series Switches, page 36-3
- Power Management for the Catalyst 4006 Switch, page 36-10
- Power Consumption of Chassis Components, page 36-14

Power Management for the Catalyst 4500 Series Switches

You can select from several different power supplies to ensure that you have enough power for the modules installed in your switch. The Catalyst 4500 series switches support the following power supplies:

- Fixed Wattage—This power supply always delivers a fixed amount of Power over Ethernet (PoE) and system power.
  - 1000 W AC (not recommended on the Catalyst 4510R series switch)
  - 1400 W AC—Data-only and does not support PoE (Required for Catalyst 4510R series switch)
  - 2800 W AC—Supports PoE

- Variable Wattage—These power supplies automatically adjusts the wattage to accommodate PoE and system power requirements.
  - 1300 W AC—Supports PoE.
  - 1400 W DC—Supports up to 1400 W of system power and variable amounts of PoE, depending on the input feed to the power supply. See "Special Considerations for the 1400 W DC Power Supply" section on page 36-9 for more information.

When you insert power supplies in your switch, use power supplies that are of the same wattage. If you mix power supplies, the switch will use the one it recognizes first and ignore the other power supply. The power supply status displays as err-disable and the summary displays as all zeros (0) for wattage values in the output for the **show power** command.

The following example shows the output for the **show power** command for mixed power supplies:

```
Switch# show power
Power                                               Fan     Inline
Supply  Model No           Type       Status        Sensor  Status
------  -----------------  ---------  ------------  ------  ------
PS1     PWR-C45-2800AC     AC 2800W   good          good    good
➔ PS2     PWR-C45-1000AC     AC 1000W   err-disable   good    n.a.

*** Power Supplies of different type have been detected***

Power supplies needed by system    :1
Power supplies currently available :1

Power Summary                       Maximum
 (in Watts)              Used       Available
----------------------   ----      ---------
System Power (12V)        328          1360
Inline Power (-50V)         0          1400
Backplane Power (3.3V)     10            40
----------------------   ----
Total Used                338 (not to exceed Total Maximum Available = 750)
Switch#
```

Power Management Modes

The Catalyst 4500 series switches support two power management modes:

- Redundant mode—Redundant mode uses one power supply as a primary power supply and the second power supply as a back-up. If the primary power supply fails, the second power supply immediately supports the switch without any disruption in the network. Both power supplies must be the same wattage. A single power supply must have enough power to support the switch configuration.
- Combined mode—Combined mode uses the power from all installed power supplies to support the switch configuration power requirements. However, combined mode has no power redundancy. If a power supply fails, one or more modules might shut down.

Note On the Catalyst 4510R series switch, the 1000W AC power supply is not enough to support redundant mode for all possible configurations. It is able to support redundant mode for limited configurations that require less than 1000W.

Note The 1400W DC power supply supports combined mode for data power. It does not support combined mode for PoE power.

Selecting a Power Management Mode

By default, a switch is set to redundant mode. In the **show power** command, if the **power supplies needed by system** is 1, the switch is in redundant mode; if the **power supplies needed by system** is 2, the switch is in combined mode.

Your switch hardware configuration will dictate which power supply or supplies you should use. For example, if your switch configuration requires more power than a single power supply provides, use the combined mode. In combined mode, however, the switch has no power redundancy. Consider the following possibilities:

- The supervisor engine consumes 110 W, the fan boxes for the Catalyst 4503 switch consume 30 W each, the fan boxes for the Catalyst 4506 and Catalyst 4507 switches consume 50 W each, the backplane for the Catalyst 4503 and Catalyst 4506 switches consumes 10 W, and the backplane for the Catalyst 4507 switch consumes 40 W.
- 1000 W can support a fully loaded Catalyst 4503 switch with no powered device support.
- 1300 W can support a fully loaded Catalyst 4503 switch with Cisco powered devices.
- Each PoE port on a WS-X4148-RJ45V module requires 6.3 W. Five fully loaded WS-X4148-RJ45V modules in a switch comprise 240 ports. This configuration requires 1512 W of PoE, plus 300 W for the modules.

See Table 36-4 on page 36-14 for Catalyst 4500 series module power requirements.

Power Management Limitations in Catalyst 4500 Family Switches

It is possible to configure a switch that requires more power than the power supplies provide. The two ways you could configure a switch to exceed the power capabilities are as follows:

- The power requirements for the installed modules exceed the power provided by the power supplies.

  If you insert a single power supply and then set the switch to combined mode, the switch displays this error message:

  ```
  Insufficient power supplies present for specified configuration.
  ```

  This error message also displays in the output for the **show power** command. This error message displays because, by definition, combined mode requires that two working power supplies be installed in your switch.

  If the power requirements for the installed modules exceeds the power provided by the power supplies, the switch displays this error message:

  ```
  Insufficient power available for the current chassis configuration.
  ```

  This error message also appears in the **show power** command output.

  If you attempt to insert additional modules into your switch and exceed the power supply, the switch immediately places the newly inserted module into reset mode, and the switch displays these error messages:

  ```
  Module has been inserted
  Insufficient power supplies operating.
  ```

Additionally, if you power down a functioning switch and insert an additional module or change the module configuration so that the power requirements exceed the available power, one or more modules enter reset mode when you power on the switch again.

- The power requirements for the PoE exceed the PoE provided by the power supplies.

  If you have too many IP phones drawing power from the system, power to IP phones is cut, and some phones may be powered down to reduce the power requirements to match the power supplies.

In the first scenario (power requirements exceed the power supplied), the system attempts to resolve this power usage limitation by evaluating the type and number of modules installed. During the evaluation cycle, beginning from the bottom of the chassis, the system puts the modules that it is unable to support (for lack of power) into reset mode. The supervisor engine and modules for which there is adequate power always remain enabled, with no disruption of network connectivity. Modules placed in reset mode still consume some power and can be removed from the chassis to further reduce power requirements. If you configure the chassis correctly, the system will not enter the evaluation cycle.

A module in reset mode continues to draw power as long as it is installed in the chassis; you can use the **show power module** command to determine how much power is required to bring the module online.

To compute the power requirements for your system and verify that your system has enough power, add the power consumed by the supervisor engine module(s), the fan box(es), and the installed modules (including PoE). For PoE, total the requirements for all the phones. See the "Power Consumption of Chassis Components" section on page 36-14 for more information on the power consumption for the various components of your switch.

The 802.3af-compliant PoE modules can consume up to 20 W of PoE to power FPGAs and other hardware components on the module. Be sure to add at least 20 W to your PoE requirements for each 802.3af-compliant PoE module to ensure that the system has adequate power for the PDs connected to the switch.

On the WS-X4148-RJ45V PoE module, PoE consumption cannot be measured. Therefore, for all PoE calculations, the PoE consumption on this module is presumed to be equal to its administrative PoE.

You can use the **show module** command to verify which modules are active and which, if any, have been placed in reset.

The following example shows the **show module** command output for a system with inadequate power for all installed modules. The system does not have enough power for Module 5; the "Status" displays it as "PwrDeny."

If the PoE that is consumed by the module is more than 50 W above the PoE you allocated using the **power inline consumption default** command, the "Status" displays as "PwrOver." If the PoE consumed by the module is more than 50 W above the PoE module limit, the "Status" displays as "PwrFault."

```
Switch# show module
Mod  Ports Card Type                              Model              Serial No.
---+-----+--------------------------------------+------------------+-----------
 1      2  1000BaseX (GBIC) Supervisor(active)    WS-X4014           JAB054109GH
 2      6  1000BaseX (GBIC)                       WS-X4306           00000110
 3     18  1000BaseX (GBIC)                       WS-X4418           JAB025104WK
➔ 5      0  Not enough power for module           WS-X4148-FX-MT     00000000000
 6     48  10/100BaseTX (RJ45)                    WS-X4148           JAB023402RP

 M MAC addresses                    Hw  Fw           Sw               Status
--+--------------------------------+---+------------+----------------+---------
 1 005c.9d1a.f9d0 to 005c.9d1a.f9df 0.5 12.1(11br)EW 12.1(20020313:00 Ok
 2 0010.7bab.9920 to 0010.7bab.9925 0.2                               Ok
 3 0050.7356.2b36 to 0050.7356.2b47 1.0                               Ok
➔ 5 0001.64fe.a930 to 0001.64fe.a95f 0.0                               PwrDeny
 6 0050.0f10.28b0 to 0050.0f10.28df 1.0                               Ok
Switch#
```

Configuring Redundant Mode on a Catalyst 4500 Series Switch

By default, the power supplies in a Catalyst 4500 series switch are set to operate in redundant mode. To effectively use redundant mode, follow these guidelines:

- Use two power supplies of the same type.
- If you have the power management mode set to redundant mode and only one power supply installed, your switch will accept the configuration but operates without redundancy.

Caution If you have power supplies with different types or different wattages installed in your switch, the switch will not recognize one of the power supplies and will not have power redundancy.

- For fixed power supplies, choose a power supply that by itself is powerful enough to support the switch configuration.
- For variable power supplies, choose a power supply that provides enough power so that the chassis and PoE requirements are less than the maximum available power. Variable power supplies automatically adjust the power resources at startup to accommodate the chassis and PoE requirements. Modules are brought up first, followed by IP phones.
- The maximum available power for chassis and PoE for each power supply are listed in Table 36-3 on page 36-9.

To configure redundant mode on your Catalyst 4500 series switch, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# power redundancy-mode redundant`	Sets the power management mode to redundant mode.
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show power supplies`	Verifies the power redundancy mode for the switch.

Note The **power redundancy-mode redundant** command is not supported on a Catalyst 4006 switch.

The following example shows how to set the power management mode to redundant mode.

```
Switch (config)# power redundancy-mode redundant
Switch (config)# end
Switch#
```

The following example shows how to display the current power redundancy mode. The power supplies needed by system: 1 indicates that the switch is in redundant mode.

```
Switch# show power supplies
Power supplies needed by system :1
Switch#
```

Configuring Combined Mode on a Catalyst 4500 Series Switch

If your switch configuration requires more power than a single power supply can provide, set the power management mode to combined mode. Combined mode utilizes the available power for both power supplies; however, your switch will have no power redundancy.

To effectively use combined mode, follow these guidelines:

- Use power supplies of the same type and wattage (fixed or variable and AC or DC).
- If you use power supplies with different types or wattages, the switch will utilize only one of the power supplies.
- For variable power supplies, choose a power supply that provides enough power so that the chassis and PoE requirements are less than the maximum available power. Variable power supplies automatically adjust the power resources at startup to accommodate the chassis and PoE requirements.
- The 1400 W DC power supply does not support combined mode. If you set the power budget to 2, the switch disregards this setting.
- If you have the power management mode set to combined mode and only one power supply installed, your switch will accept the configuration, but power is available from only one power supply.
- When your switch is configured to combined mode, the total available power is not the mathematical sum of the individual power supplies. The power supplies have a predetermined current sharing ratio (See Table 36-3 on page 36-9 for more information.)
- The maximum available power for chassis and PoE for each power supply are listed in Table 36-3 on page 36-9.

To configure combined mode on your Catalyst 4500 series switch, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# power redundancy-mode combined`	Sets the power management mode to combined mode.
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show power supplies`	Verifies the power redundancy mode for the switch.

Note The **power redundancy-mode combined** command does not work on a Catalyst 4006 switch.

The following example shows how to set the power management mode to combined mode.

```
Switch (config)# power redundancy-mode combined
Switch (config)# end
Switch#
```

The following example shows how to display the current power redundancy mode. The power supplies needed by system: 2 indicates that the switch is in combined mode.

```
Switch# show power supplies
Power supplies needed by system :2
Switch#
```

Available Power for Catalyst 4500 Series Switches Power Supplies

Table 36-3 lists the power available for use in the various Catalyst 4500 series switches power supplies. When your switch is configured to combined mode, the total available power in not the mathematical sum of the individual power supplies. The power supplies have a sharing ratio predetermined by the hardware. In combined mode, the total power available is P + (P * sharing-ratio), where P is the amount of power in the power supply.

Table 36-3 Available Power for Switch Power Supplies

Power Supply	Redundant Mode (W)	Combined Mode (W)	Sharing Ratio
1000 W AC	Chassis[1] = 1000 PoE = 0	Chassis = 1667 PoE = 0	2/3
1300 W AC	Chassis (max) = 1000 PoE (max) = 800 Chassis + PoE + Backplane ≤ 1300	Chassis (min) = 767 PoE (max) = 1333 Chassis (max) = 1667 PoE (min) = 533 Chassis + PoE + Backplane ≤ 2200	2/3
1400 W DC	Chassis (min) = 200 Chassis (max) = 1360 PoE (max)[2] = (DC Input[3] - [Chassis (min) + Backplane] / 0.75) * 0.96	Chassis = 2267[4] PoE[5]	Chassis—2/3 PoE—0
1400 W AC	Chassis = 1360 PoE = 0[6]	Chassis = 2473 PoE = 0	9/11
2800 W AC	Chassis = 1360 PoE = 1400	Chassis = 2473 PoE = 2333	Chassis[7]—9/11 PoE[8]—2/3

1. Chassis power includes power for the supervisor(s), all line cards, and the fan tray.
2. The efficiency for the 1400 W DC power supply is 0.75, and 0.96 is applied to PoE.
3. DC input can vary for the 1400 W DC power supply and is configurable. For more information, see “Special Considerations for the 1400 W DC Power Supply” on page 9.
4. Not available for PoE.
5. Not available for PoE.
6. No voice power.
7. Data-only.
8. Inline power.

Special Considerations for the 1400 W DC Power Supply

Caution Do not mix the 1400 W DC power supply with any other power supply, even for a hot swap or other short-term emergency. Doing so can seriously damage your switch.

Keep in mind the following guidelines when using a 1400 W DC power supply with your Catalyst 4500 series switch:

- The 1400 W DC power supply works with a variety of DC sources. The DC input can vary from 300 W to 7500 W. Refer to the power supply documentation for additional information.
- The supervisor engine cannot detect the DC source plugged into the 1400 W DC power supply. If you are using the 1400 W DC power supply, use the **power dc input** command to set the DC input power. For more information on this command, see the "Configuring the DC Input for a Power Supply" section on page 36-10.
- The software automatically adjusts between system power (for modules, backplane, and fans) and PoE. Although PoE is 96 percent efficient, system power has only 75 percent efficiency. For example, each 120 W of system power requires 160 W from the DC input. This requirement is reflected in the "Power Used" column of the output for the **show power available** command.
- The 1400 W DC power supply does not support combined mode. If you set the power budget to 2 (combined mode), the switch allows you to configure combined modes but disregards the setting and remains in redundant mode.
- The 1400 W DC power supply has a separate power on/off switch for PoE. The power supply fan status and main power supply status are tied together. If either of them fails, both the power supply and its fan report as bad/off. You should verify that the main power is on before turning on the power for the inline switch. In addition, you should verify that the power for the inline switch is off before turning off the main power.

Configuring the DC Input for a Power Supply

To configure the DC input power for the 1400 W DC power supply or a power shelf, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode
Step 2	`Switch(config)# power dc input watts`	Sets the capacity of the DC input source.
Step 3	`Switch(config)# end`	Exits configuration mode.

The same configuration is applied to both power slots. For example, if you set the **dc power input** to 1000 W, the switch expects 1000 W as the external DC source for both slot 1and slot 2 (if present) respectively.

The following example shows how to set the external DC power source to 1000 W:

```
Switch# configure terminal
Switch (config)# power dc input 1000
Switch (config)# end
Switch#
```

Power Management for the Catalyst 4006 Switch

The power management feature for the Catalyst 4006 switch is designed to support an optimized Catalyst 4006 chassis with a limited module configuration on a reduced number of power supplies.

The Catalyst 4006 chassis supports only the 400 W AC, 400 W DC, and 650 W DC power supplies and allows you to mix AC-input and DC-input power supplies in the same chassis. In systems with redundant power supplies, both power supplies should be of the same wattage. If you mix a 400 W power supply

and a 650 W power supply, the switch performs as if there were two 400 W power supplies. For detailed information on supported power supply configurations for each chassis, refer to the *Catalyst 4000 Series Installation Guide*.

Each Catalyst 4500 series module has different power requirements; thus, some switch configurations require more power than 1+1 redundancy mode (a single power supply) can provide. In those configurations, redundancy requires three power supplies. Redundant and nonredundant power configurations are discussed in later sections of this chapter.

The Catalyst 4006 switch contains holding bays for up to three power supplies. You need two primary power supplies to operate a fully loaded Catalyst 4006 chassis. You can set the power redundancy to two primary plus one redundant power supply (2+1 redundancy mode) or to one primary plus one redundant power supply (1+1 redundancy mode). The 1+1 redundancy mode might not support a fully loaded chassis.

If your switch has only two power supplies and is in 2+1 redundancy mode (the default mode), there is no redundancy. You can create redundancy with only two power supplies by setting the power redundancy to operate in 1+1 redundancy mode (one primary plus one redundant power supply). However, 1+1 redundancy will not support all configurations.

The 1+1 redundancy mode is designed and optimized for the following hardware configurations:

- One Catalyst 4006 chassis with a WS-X4014 supervisor engine with two 400 W power supplies (in 1+1 redundancy mode) and four WS-X4148-RJ or WS-X4148-RJ21 modules
- One Catalyst 4006 chassis with a WS-X4014 supervisor engine with two 650 W power supplies (in 1+1 redundancy mode) and five WS-X4148-RJ or WS-X4148-RJ21 modules

Although other configurations are possible, we do not recommend that you use them without careful consideration of the power usage in the system. For example, other similar and possible configurations may consist of four modules that consume less power, and the total module power usage does not exceed the absolute maximum power usage for the system.

The supervisor engine uses 110 W, the fan box uses 25 W, and the backplane does not consume any power. The system total load for the modules + supervisor + fan cannot total more than the power supplied by the power supply. The 1+1 redundancy mode might not support a fully loaded chassis and, therefore, one slot of the chassis *might be empty.* An attempt to use five modules risks an oversubscription of available power.

If you opt to use the 1+1 redundancy mode, the type and number of modules supported are limited by the power available from a single power supply. To determine the power consumption for each module in your chassis, see the "Power Consumption of Chassis Components" section on page 36-14.

To choose a 1+1 redundancy configuration, you must change the system configuration from the default 2+1 redundancy mode to 1+1 redundancy mode by using the **power supplies required 1** command. The **power supplies required 1** command sets the power redundancy to 1+1 redundancy mode. In the 1+1 redundancy mode, the nonredundant power available to the system is the power of the single weakest power supply. The second power supply installed in your switch provides full redundancy.

Limitations of the 1+1 Redundancy Mode

If you attempt to configure the system to operate in 1+1 redundancy mode, and you have more modules installed in the chassis than a single power supply can handle, the system displays the following error message:

```
Insufficient power supplies for the specified configuration
```

This message will also appear in the **show power** command output.

If you are already operating in 1+1 redundancy mode with a valid module configuration and you attempt to insert additional modules that require more power than the single power supply provides, the system immediately places the newly inserted module into reset mode and issues these error messages:

```
Module has been inserted
Insufficient power supplies operating
```

Additionally, if a chassis that has been operating in 1+1 redundancy mode with a valid module configuration is powered down, and you insert a module or change the module configuration inappropriately and power on the switch again, the module(s) in the chassis (at boot up) that require more power than is available, are placed into reset mode.

A module in reset mode continues to draw power as long as it is installed in the chassis and as long as the **show module** command output indicates that there is not enough power for the module to be brought out of reset mode.

A single power supply provides 400 W or 650 W. Two 400 W power supplies provide 725 W. Two 650 W power supplies supply only 750 W. The 750 W limit is a restriction on the power supply cooling capacity for the Catalyst 4006 switches.

If you mix a 400 W power supply and a 650 W power supply, the switch performs as if there were two 400 W power supplies. If you have one 400 W power supply and one 650 W power supply in 1+1 redundancy mode, and a second 650 W power supply is set as the backup, the system performs as if there were 400 W. If the 400 W power supply fails, the backup 650 W power supply comes into service; however, the switch still has only 400 W available. You need to remove the failed 400 W power supply for the switch to make use of the 650 W available.

To compute the power requirements for your system and verify that your system has enough power, add up the power consumed by the supervisor engine module, the fan box, and the installed modules. (See the "Power Consumption of Chassis Components" section on page 36-14 for more information on the power consumption for the various components of your switch.) For 1+1 redundancy mode, verify that the total is less than 400 W or 650 W, depending on the power supplies installed in your switch. The following examples are provided to further explain the use of power supplies.

The following configuration requires a minimum of 395 W:

- WS-X4014 supervisor engine—110 W
- Four WS-X4148-RJ modules—65 W each (260 W total—the optimized module configuration)
- Fan box—25 W

This configuration requires less than the maximum that a single power supply can provide in 1+1 redundancy mode.

The following configuration requires more power than a single 400 W power supply can provide:

- WS-X4014 supervisor engine—110 W
- Two WS-X4148-RJ modules in slots 2 and 3—65 W each (130 W total)
- Two WS-X4448-GB-LX modules in slots 4 and 5—90 W each (180 W total)
- Fan box—25 W

This configuration requires 445 W and cannot be used in 1+1 redundancy mode for a 400 W power supply. A single 650 W power supply provides enough power for 1+1 redundancy mode for this configuration.

The following configuration requires more power than either a single 400 W or 650 W power supply can provide:

- WS-X4014 supervisor engine—110 W
- Five 48-port 100BASE-FX modules in slots 2 through 6—120 W each (600 W total)
- Fan box—25 W

This configuration requires 735 W and cannot be used in 1+1 redundancy mode for either a 400 W or 650 W power supply.

Remember, when considering the 1+1 redundancy mode, you must carefully plan the configuration of the module power usage of your chassis. An incorrect configuration will momentarily disrupt your system during the evaluation cycle. To avoid this disruption, carefully plan your configuration to ensure that it is within the power limits, or return to the default 2+1 redundancy configuration by installing a third power supply in your switch and setting the power redundancy to 2+1 redundancy mode.

Use the **power supplies required 2** command to set the power redundancy to the 2+1 redundancy mode.

Setting the Power Redundancy Mode

To configure the power redundancy mode on a Catalyst 4006 switch, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters configuration mode.
Step 2	`Switch(config)# power supplies required {1 | 2}`	Sets the power redundancy mode.
Step 3	`Switch(config)# end`	Exits configuration mode.
Step 4	`Switch# show power`	Verifies the power redundancy mode and the current power usage for the switch.

Note The **power supplies required** command is not supported on a Catalyst 4500 series switch.

The default power redundancy mode is 2 (2+1) redundancy mode.

The following example shows how to set the power redundancy mode to 1 (1+1 redundancy mode).

```
Switch (config)# power supplies required 1
Switch (config)# end
Switch#
```

The following example shows how to display the current power status of system components and the power redundancy mode. The **Power supplies needed by system: 1** indicates that the switch is in 1+1 redundancy mode:

```
Switch# show power supplies
Power supplies needed by system :1
Switch#
```

The following example shows the **show module** command output for a system with inadequate power for all installed modules. The system does not have enough power for Module 5; the "Status" displays it as "PwrDeny."

```
Switch# show module

Mod  Ports Card Type                              Model              Serial No.
---+-----+--------------------------------------+------------------+-----------
 1      2  1000BaseX (GBIC) Supervisor(active)    WS-X4014           JAB054109GH
 2      6  1000BaseX (GBIC)                       WS-X4306           00000110
 3     18  1000BaseX (GBIC)                       WS-X4418           JAB025104WK
 5      0  Not enough power for module            WS-X4148-FX-MT     00000000000
 6     48  10/100BaseTX (RJ45)V, Cisco/IEEE       WS-X4248-RJ45V     JAB074804LE

 M MAC addresses                    Hw  Fw           Sw               Status
--+--------------------------------+---+------------+----------------+---------
 1 005c.9d1a.f9d0 to 005c.9d1a.f9df 0.5 12.1(11br)EW 12.1(20020313:00 Ok
 2 0010.7bab.9920 to 0010.7bab.9925 0.2                               Ok
 3 0050.7356.2b36 to 0050.7356.2b47 1.0                               Ok
 5 0001.64fe.a930 to 0001.64fe.a95f 0.0                               PwrDeny
 6 000d.edc6.dac0 to 000d.edc6.daef 2.0                               Ok
Switch#
```

Power Consumption of Chassis Components

For power consumption of common Catalyst 4000 family modules, see Table 36-4.

Enter the **show power** command to display the current power redundancy and the current system power usage.

Table 36-4 Power Consumption for Catalyst 4000 Family Components

Module	Power Consumed During Operation (W)	Power Consumed in Reset Mode (W)
Supervisor Engine II-Plus	110	110
Supervisor Engine III	110	110
Supervisor Engine IV	145	145
Supervisor Engine V	170	170
Catalyst 4003 fan box	20	20
Catalyst 4006 fan box	30	30
Catalyst 4503 fan box	30	30
Catalyst 4506 and 4507R fan box	50	50
Catalyst 4510R fan box	80	80
Catalyst 4006 switch backplane	0	0
Catalyst 4503 switch backplane	10	10
Catalyst 4506 switch backplane	10	10
Catalyst 4507R switch backplane	40	40
Catalyst 4510R switch backplane	160	160

Table 36-4 Power Consumption for Catalyst 4000 Family Components (continued)

Module	Power Consumed During Operation (W)	Power Consumed in Reset Mode (W)
2-port 1000BASE-X (GBIC) Gigabit Ethernet WS-X4302-GB	8	5
6-port 1000BASE-X (GBIC) Gigabit Ethernet WS-X4306-GB	35	30
32-port 10/100 Fast Ethernet RJ-45 WS-X4232-RJ-XX	50	35
24-port 100BASE-FX Fast Ethernet switching module WS-X4124-FX-MT	90	75
48-port 100BASE-BX10-D line card WS-X4148-FE-BD-LC	88	10
48-port 100BASE-LX10 Fast Ethernet MT-RJ single-mode fiber switching module WS-X4148-FE-LX-MT	115	10
32-port 10/100 Fast Ethernet RJ-45, plus 2-port 1000BASE-X (GBIC) Gigabit Ethernet WS-4232-GB-RJ	55	35
32-port 10/100-Mbps plus 2-port 1000BASE-X Layer 3 Ethernet routing module WS-4232-L3	120	70
48-port 100BASE-FX Fast Ethernet switching module WS-4148-FX-MT	120	10
18-port server switching 1000BASE-X (GBIC) Gigabit Ethernet WS-4418-GB	80	50
Catalyst 4006 Backplane Channel Module WS-X4019	10	10
48-port 10/100 Fast Ethernet RJ-45 WS-X4148-RJ	65	40
12-port 1000BASE-T Gigabit Ethernet, plus 2-port 1000BASE-X (GBIC) Gigabit Ethernet WS-X4412-2GB-T	110	70
24-port 1000BASE-X Gigabit Ethernet WS-X4424-GB-RJ45	90	50
48-port 1000BASE-X Gigabit Ethernet WS-X4448-GB-RJ45	120	72
48-port 1000BASE-X Gigabit Ethernet WS-X4448-GB-LX	90	50
48-port Telco 10/100BASE-TX switching module WS-X4148-RJ21	65	40
48-port PoE 10/100BASE-TX switching module WS-X4148-RJ45V	60	50

Table 36-4 Power Consumption for Catalyst 4000 Family Components (continued)

Module	Power Consumed During Operation (W)	Power Consumed in Reset Mode (W)
4-port MT-RJ Uplink module WS-U4504-FX-MT	10	10
48-port PoE 10/100 BASE-TX switching module WS-X4248-RJ21V	60	25
48-port PoE 10/100BASE-TX switching module WS-X4248-RJ45V	60	25
48-port 10/100/1000BASE-T Gigabit Ethernet WS-X4548-GB-RJ45	60	25
48-port PoE 10/100/1000BASE-T switching module WS-X4548-GB-RJ45V	60	25
Catalyst 4500 series switch Access Gateway Module WS-X4604-GWY	120	60
Backplane channel module WS-X4019	10	10

Configuring Power Over Ethernet

This section contains the following subsections:

The Catalyst 4006 switch and the Catalyst 4500 series switches can sense if a powered device is connected to a PoE module. The Catalyst 4006 switch and Catalyst 4500 series switches can supply PoE to the powered device if there is no power on the circuit. The powered device can also be connected to an AC power source and supply its own power to the voice circuit. If there is power on the circuit, the switch does not supply it.

Note A powered device is any device connected to the switch that requires external power or can utilize PoE, for example, an access point or Cisco IP phone.

Power Management Modes

If your switch has a module capable of providing PoE to end stations, you can set each interface on the module to automatically detect and apply PoE if the end station requires power.

The Catalyst 4500 series switch has three PoE modes:

- **auto**—PoE interface. The supervisor engine directs the switching module to power up the interface *only* if the switching module discovers the phone and the switch has enough power. You can specify the maximum wattage that is allowed on the interface. If you do not specify a wattage, then the switch will deliver no more than the hardware-supported maximum value. This mode has no effect if the interface is not capable of providing PoE.
- **static**—High priority PoE interface. The supervisor engine preallocates power to the interface, even when nothing is connected, guaranteeing that there will be power for the interface. You can specify the maximum wattage that is allowed on the interface. If you do not specify a wattage, then the switch preallocates the hardware-supported maximum value. If the switch does not have enough power for the allocation, the command will fail. The supervisor engine directs the switching module to power up the interface *only* if the switching module discovers the powered device.
- **never**—Data interface only The supervisor engine never powers up the interface, even if an unpowered phone is connected. This mode is only needed when you want to make sure power is never applied to a PoE-capable interface.

The switch allocates PoE to the interfaces configured to static mode before it allocates power to the interfaces configured to auto mode. In the event of insufficient PoE due to a partial power supply failure, interfaces configured to auto mode are shutdown before interfaces configured to static mode.

The switch can measure the actual PoE consumption for an 802.3af-compliant PoE module, and displays this in the **show power module** command. The switch cannot measure the actual PoE consumption for the WS-X4148-RJ45V module nor for an individual interface on an 802.3af-compliant PoE module. For more information, see the "Displaying the PoE Consumed by a Module" section on page 36-22

On the WS-X4148-RJ45V PoE module, PoE consumption cannot be measured. Therefore, for all PoE calculations, the PoE consumption on this module is presumed to be equal to its administrative PoE.

For most users, the default configuration of "auto" works well, providing plug and play capability. No further configuration is required. However, to make an interface higher priority or data only, or to specify a maximum wattage, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects the interface to configure.
Step 2	`Switch(config-if)# power inline {auto [max milli-watts] | never | static [max milli-watts]}`	The **auto** keyword sets the interface to automatically detect and supply power to the powered device. This is the default configuration. The **static** keyword sets the interface to higher priority than auto. If necessary, you can use the **max** keyword to specify the maximum wattage allowed on the interface (4000 to 15400 milliwatts). Use the **never** keyword to disable detection and power for the PoE capable interface.
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show power inline {fastethernet | gigabitethernet} slot/port`	Displays the PoE state for the switch.

If you set a non-PoE-capable interface to automatically detect and apply power, an error message indicates that the configuration is not valid.

The following example shows how to set the Fast Ethernet interface 4/1 to automatically detect PoE and send power through that interface:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 4/1
Switch(config-if)# power inline auto
Switch(config-if)# end
```

This example shows how to verify the PoE configuration for the Fast Ethernet interface 4/1:

```
Switch# show power inline fastethernet 4/1
Available:677(w)  Used:11(w)  Remaining:666(w)

Interface Admin  Oper            Power(Watts)     Device              Class
                              From PS    To Device
--------- ------ ---------- ---------- ---------- ------------------- -----
Fa4/1     auto   on         11.2       10.0       Ieee PD             0

Interface  AdminPowerMax   AdminConsumption
             (Watts)           (Watts)
---------- --------------- --------------------
Fa4/1                 15.4                 10.0
Switch#
```

The following example shows how to configure an interface so that it never supplies power through the interface:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 5/2
Switch(config-if)# power inline never
Switch(config-if)# end
Switch#
```

Configuring Power Consumption for Powered Devices on an Interface

By default, when the switch detects a powered device on an interface, it assumes the powered device consumes the maximum the port can provide (7W on a legacy Power over Ethernet (PoE) linecard and 15.4W on the IEEE PoE linecards introduced in Release 12.2(20)EW). Then, when the switch receives a CDP packet from the powered device, the wattage automatically adjusts downward to the specific amount required by that device. Normally, this automatic adjustment works well, and no further configuration is required or recommended. However, you can specify the powered device's consumption for the entire switch (or for a particular interface) to provide extra functionality from your switch. This is useful when CDP is disabled or not available.

When using PoE, pairs 2 and 3 (pins 1, 2, 3, and 6) of the four pairs in a standard UTP cable are used for both the Ethernet data signals and the DC power at the same time. In DC, PoE flows from pair 3 (pins 3 and 6) to the device using PoE and back to pair 2 (pins 1 and 2) while the Ethernet port transmits differential signals in pair 2 (between pins 1 and 2). This method of supplying DC power is sometimes called "phantom power" because the power signals travel over the same two pairs used to transmit Ethernet signals. The inline power signals are transparent to the Ethernet signals and do not interfere with each other. The main electrical parameter that affects inline power operation and performance is the DC resistance of the cable. The inline power method is designed to work with category 3 cable and above, up to 100 meters.

PoE has been tested and found to work with the IBM Token Ring STP cable (100 meters) when used with a Token Ring to Fast Ethernet adapter.

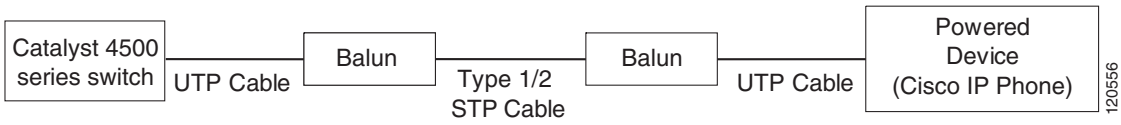
When you use PoE modules with type 1/2 shielded twisted pair (STP) cable configurations (90 and 125 meters), the modules perform the same as with Category 5 cable for the IEEE 802.3af standard at 10 and 100 Mb/s.

The following adapters have been tested and are the only ones supported by Cisco:

- LanTel Silver Bullet (SB-LN/VIP-DATA adapter)
- BIP-1236/S (BATM)
- RIT P/N 13712017
- RIT balun with integrated unshielded twisted pair (UTP) cable, 6 and 24 foot lengths

The following topology is supported:

Figure 36-1 Supported Adapter Topology



In Figure 36-1, a Catalyst 4500 series switch is connected to a balun through a short length of Category 5 UTP cable. Type 1 or Type 2 STP cable connects this balun to a second balun. A short length of Category 5 UTP cable connects the second balun to another Powered Device (such as a Cisco IP phone)

Note When manually configuring the consumption for powered devices, you need to account for the power loss over the cable between the switch and the powered device.

To change the power consumption for the entire switch, perform this task:

	Command	Purpose
Step 1	`Switch(config)# [no] power inline consumption default milli-watts`	Sets the PoE consumption (in milliwatts) of all powered devices connected to the switch. The power consumption can range from 4000 to 15,400. To re-enable the automatic adjustment of consumption, either use the **no** keyword or specify 15,400 milliwatts.
Step 2	`Switch(config)# end`	Exits configuration mode.
Step 3	`Switch# show power inline consumption default`	Displays the administrative PoE consumption of powered devices connected to the switch. The administrative PoE is not the measured PoE value.

This example shows how to set the default PoE consumption of all powered devices connected to the switch to 5000 milliwatts:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# power inline consumption default 5000
Switch(config)# end
Switch#
```

This example shows how to verify the PoE consumption:

```
Switch# show power inline consumption default
Default PD consumption : 5000 mW
Switch#
```

To change the power consumption of a single powered device, perform this task:

	Command	Purpose
Step 1	`Switch(config)# interface {fastethernet | gigabitethernet} slot/port`	Selects the interface to configure.
Step 2	`Switch(config-if)# [no] power inline consumption milli-watts`	Sets the PoE consumption (in milliwatts) of the powered device connected to a specific interface. The power consumption can range from 4000 to 15,400. To re-enable the automatic adjustment of consumption, either use the **no** keyword or specify 15,400 milliwatts
Step 3	`Switch(config-if)# end`	Exits configuration mode.
Step 4	`Switch# show power inline consumption {fastethernet | gigabitethernet} slot/port`	Displays the PoE consumption for the interface.

This example shows how to set the PoE consumption to 5000 milliwatts for Fast Ethernet interface 4/1 regardless what is mandated by the 802.3af class of the discovered device, or by any CDP packet received from the powered device:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface fastethernet 4/1
Switch(config-if)# power inline consumption 5000
Switch(config-if)# end
Switch#
```

This example shows how to verify the PoE consumption for a given interface:

```
Switch# show power inline fastethernet 4/1
Available:677(w)  Used:11(w)  Remaining:666(w)

Interface Admin  Oper            Power(Watts)     Device              Class
                              From PS    To Device
--------- ------ ---------- ---------- ---------- ------------------- -----

Fa4/1     auto   on         11.2       10.0       Ieee PD             0

Interface  AdminPowerMax   AdminConsumption
             (Watts)           (Watts)
---------- --------------- --------------------

Fa4/1                 15.4                 10.0
Switch#
```

Intelligent Power Management

All Catalyst 4500 PoE-capable modules use Intelligent Power Management to provision power on each interface. When a powered device (PD) is attached to a PoE-capable port, the port will detect the PD and provision power accordingly. If a Cisco PD is used, the switch and PD negotiate power using CDP packets to determine the precise amount of power needed by the PD. If the PD is 802.3af compatible,

the difference between what is mandated by the 802.3af class and what is actually needed by the PD is returned to the power budget for use by additional devices. In this way, power negotiation allows customers to stretch their power budget and use it more effectively.

Power negotiation also enables the interoperability of newer Cisco powered devices with older legacy PoE-capable ports from Cisco. Newer Cisco PDs do not consume more than what the switch port can provide.

Powering Down a Module

If your system does not have enough power for all modules installed in the switch, you can power down a module, and place it in **reset** mode. To power down a module, perform this task:

Command	Purpose
`Switch(config)# no hw-module module num power`	Turns power down to the specified module by placing it in **reset** mode.

To power on a module that has been powered down, perform this task:

Command	Purpose
`Switch(config)# hw-module module num power`	Turns power on to the specified module.

This example shows how to power down module 6:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# no hw-module module 6 power
Switch(config)# end
Switch#
```

Displaying the Operational Status for an Interface

Each interface has an operational status which reflects the PoE status for an interface. The operational status for an interface is defined as one of the following:

- on—Power is supplied by the port.
- off—Power is not supplied by the port. If a powered device is connected to an interface with external power, the switch does not recognize the powered device. The “Device” column in the **show power inline** command displays as n/a.
- Power-deny—The supervisor engine does not have enough power to allocate to the port, or the power that is configured for the port is less than the power required by the port; power is not being supplied by the port.
- err-disable—The port is unable to provide power to the connected device that is configured in static mode.
- faulty—The port failed diagnostics tests.

You can use the **show power inline** command to view the operational status for an interface.

This example shows how to display the operational status for all interfaces on module 3.

```
Switch# show power inline module 3
Available:677(w)  Used:117(w)  Remaining:560(w)

Interface Admin  Oper            Power(Watts)     Device              Class
                              From PS    To Device
--------- ------ ---------- ---------- ---------- ------------------- -----

Fa3/1     auto   on         17.3       15.4       Ieee PD             0
Fa3/2     auto   on         4.5        4.0        Ieee PD             1
Fa3/3     auto   on         7.1        6.3        Cisco IP Phone 7960 0
Fa3/4     auto   on         7.1        6.3        Cisco IP Phone 7960 n/a
Fa3/5     auto   on         17.3       15.4       Ieee PD             0
Fa3/6     auto   on         17.3       15.4       Ieee PD             0
Fa3/7     auto   on         4.5        4.0        Ieee PD             1
Fa3/8     auto   on         7.9        7.0        Ieee PD             2
Fa3/9     auto   on         17.3       15.4       Ieee PD             3
Fa3/10    auto   on         17.3       15.4       Ieee PD             4
Fa3/11    auto   off        0          0          n/a                 n/a
Fa3/12    auto   off        0          0          n/a                 n/a
Fa3/13    auto   off        0          0          n/a                 n/a
Fa3/14    auto   off        0          0          n/a                 n/a
Fa3/15    auto   off        0          0          n/a                 n/a
Fa3/16    auto   off        0          0          n/a                 n/a
Fa3/17    auto   off        0          0          n/a                 n/a
Fa3/18    auto   off        0          0          n/a                 n/a

--------- ------ ---------- ---------- ---------- ------------------- -----

Totals:          10   on    117.5      104.6
Switch#
```

This example shows how to display the operational status for Fast Ethernet interface 4/1:

```
Switch#show power inline fa4/1
Available:677(w)  Used:11(w)  Remaining:666(w)

Interface Admin  Oper            Power(Watts)     Device              Class
                              From PS    To Device
--------- ------ ---------- ---------- ---------- ------------------- -----

Fa4/1     auto   on         11.2       10.0       Ieee PD             0

Interface  AdminPowerMax   AdminConsumption
             (Watts)           (Watts)
---------- --------------- --------------------

Fa4/1                15.4                 10.0
Switch#
```

Displaying the PoE Consumed by a Module

The switch can measure the actual PoE consumption for an 802.3af-compliant PoE module, and it displays the measured PoE in both the **show power module** and **show power detail** commands. The switch cannot measure the actual PoE consumption for the WS-X4148-RJ45V module, nor can it display the consumption of an individual interface on an 802.3af-compliant PoE module.

The 802.3af-compliant PoE modules can consume up to 20 W of PoE to power FPGAs and other hardware components on the module. Be sure to add at least 20 W to your PoE requirements for each 802.3af-compliant PoE module to ensure that the system has adequate power for the PDs connected to the switch.

On the WS-X4148-RJ45V PoE module, PoE consumption cannot be measured. Therefore, for all PoE calculations, the PoE consumption on this module is presumed to be equal to its administrative PoE.

The example below displays the PoE consumption for an 802.3af-compliant module using the **show power module** command.

The "Inline Power Oper" column displays the amount of PoE consumed by the powered devices that are attached to the module, in addition to the PoE consumed by the FPGAs and other hardware components on the module. The "Inline Power Admin" column displays only the amount of PoE allocated by the powered devices attached to the module.

Note The operating PoE consumption for an 802.3af-compliant module can be non-zero, even when there are no powered devices attached to the module, because of the PoE consumed by FPGAs and other hardware components on the module. In addition, the operating PoE can vary due to fluctuations in the PoE consumed by the hardware components.

```
Switch# show power module
Watts Used of System Power (12V)
Mod   Model               currently  out of reset  in reset
----  ------------------  ---------  ------------  --------
 1    WS-X4013+              110         110          110
 3    WS-X4448-GB-LX          90          90           50
 4    WS-X4418                80          80           50
 5    WS-X4248-RJ45V          65          65           25
 6    WS-X4248-RJ45V          65          65           25
 7    WS-4548-GB-RJ45         58          58           15
 --   Fan Tray                50          --           --
----------------------   ---------  ------------   -------
       Total                518         468          275

                         Inline Power Admin  Inline Power Oper
Mod   Model                  PS     Device       PS     Device  Efficiency
----  ------------------  ----------------    ----------------- ----------
 1    WS-X4013+              -        -          -        -           -
 3    WS-X4448-GB-LX         -        -          -        -           -
 4    WS-X4418               -        -          -        -           -
 5    WS-X4248-RJ45V        24       22         22       20          89
 6    WS-X4248-RJ45V         0        0         17       15          89
 7    WS-4548-GB-RJ45        -        -          -        -           -
----------------------  ----------------    ---------------- ----------
       Total                24       22         39       35
Switch#
```

The example below displays the PoE consumption for an 802.3af-compliant module using the **show power detail** command.

The "Inline Power Oper" column displays the amount of PoE consumed by the powered devices that are attached to the module, in addition to the PoE consumed by the FPGAs and other hardware components on the module. The "Inline Power Admin" column displays only the amount of PoE allocated by the powered devices attached to the module.

Note The operating PoE consumption for an 802.3af-compliant module can be non-zero, even when there are no powered devices attached to the module, because of the PoE consumed by FPGAs and other hardware components on the module. In addition, the operating PoE can vary due to fluctuations in the PoE consumed by the hardware components.

```
switch# show power detail
Power                                              Fan      Inline
Supply  Model No           Type       Status       Sensor   Status
------  -----------------  ---------  -----------  -------  -------
PS1     PWR-C45-1300ACV    AC 1300W   good         good     good
PS2     none               --         --           --       --

Power supplies needed by system    :1
Power supplies currently available :1

Power Summary                       Maximum
 (in Watts)              Used      Available
----------------------   ----      ---------
System Power (12V)        518         1000
Inline Power (-50V)        24          742
Backplane Power (3.3V)     40           40
----------------------   ----
Total Used                582 (not to exceed Total Maximum Available = 1300)


                           Watts Used of System Power (12V)
Mod   Model               currently  out of reset  in reset
----  ------------------   ---------  ------------  --------
 1    WS-X4013+              110         110          110
 3    WS-X4448-GB-LX          90          90           50
 4    WS-X4418                80          80           50
 5    WS-X4248-RJ45V          65          65           25
 6    WS-X4248-RJ45V          65          65           25
 7    WS-4548-GB-RJ45         58          58           15
 --   Fan Tray                50          --           --
----------------------   ---------  ------------   -------
       Total                 518         468          275

                        Inline Power Admin  Inline Power Oper
Mod   Model                PS     Device       PS     Device  Efficiency
----  ------------------  -----------------    ---------------- ----------
 1    WS-X4013+              -        -          -        -           -
 3    WS-X4448-GB-LX         -        -          -        -           -
 4    WS-X4418               -        -          -        -           -
 5    WS-X4248-RJ45V        24       22         22       20          89
 6    WS-X4248-RJ45V         0        0         22       20          89
 7    WS-4548-GB-RJ45        -        -          -        -           -
----------------------  -----------------    ---------------- ----------
       Total                24       22         44       40
Switch#
```

CHAPTER 37

Configuring SPAN and RSPAN

This chapter describes how to configure the Switched Port Analyzer (SPAN) and Remote SPAN (RSPAN) on the Catalyst 4500 series switches. SPAN selects network traffic for analysis by a network analyzer, such as a SwitchProbe device or other Remote Monitoring (RMON) probe.

This chapter consists of the following sections:

Note For complete syntax and usage information for the switch commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm.

Overview of SPAN and RSPAN

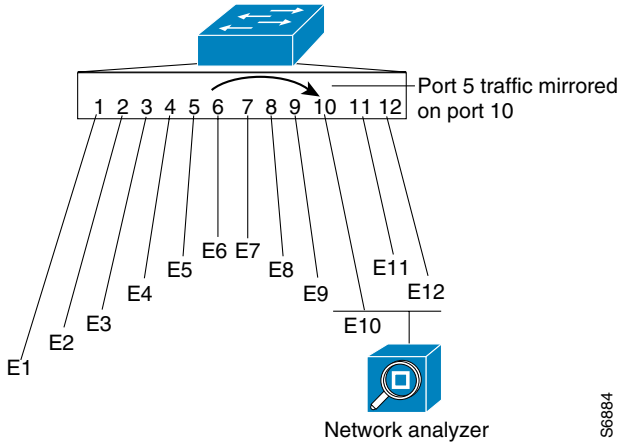
This sections includes the following subsections:

SPAN mirrors traffic from one or more source interfaces on any VLAN or from one or more VLANs to a destination interface for analysis. In Figure 37-1, all traffic on Ethernet interface 5 (the source interface) is mirrored to Ethernet interface 10. A network analyzer on Ethernet interface 10 receives all network traffic from Ethernet interface 5 without being physically attached to it.

For SPAN configuration, the source interfaces and the destination interface must be on the same switch.

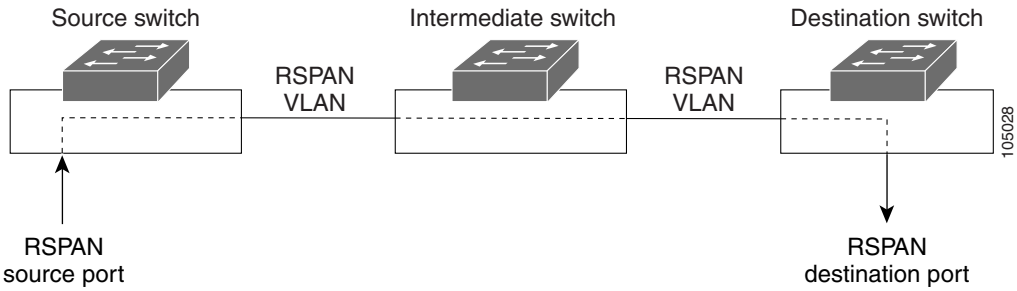
SPAN does not affect the switching of network traffic on source interfaces; copies of the packets received or transmitted by the source interfaces are sent to the destination interface.

Figure 37-1 Example SPAN Configuration



RSPAN extends SPAN by enabling remote monitoring of multiple switches across your network. 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 SPAN traffic from the sources is copied onto the RSPAN VLAN and then forwarded over trunk ports that are carrying the RSPAN VLAN to any RSPAN destination sessions monitoring the RSPAN VLAN, as shown in Figure 37-2.

Figure 37-2 Example of RSPAN Configuration



SPAN and RSPAN do not affect the switching of network traffic on source ports or source VLANs; a copy of the packets received or sent by the sources is sent to the destination. Except for traffic that is required for the SPAN or RSPAN session, by default, destination ports do not receive or forward traffic.

You can use the SPAN or RSPAN destination port to forward transmitted 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.

SPAN and RSPAN Concepts and Terminology

This section describes concepts and terminology associated with SPAN and RSPAN configuration and includes the following subsections:

SPAN Session

A local SPAN session associates a destination port with source ports. You can monitor incoming or outgoing traffic on a series or range of ports and source VLANs. An RSPAN session associates source ports and source VLANs across your network with an RSPAN VLAN. The destination source is the RSPAN VLAN.

You configure SPAN sessions by using parameters that specify the source of network traffic to monitor.

You can configure multiple SPAN or RSPAN sessions with separate or overlapping sets of SPAN sources. Both switched and routed ports can be configured as SPAN sources or destination ports.

An RSPAN source session associates SPAN source ports or VLANs with a destination RSPAN VLAN. An RSPAN destination session associates an RSPAN VLAN with a destination port.

SPAN sessions do not interfere with the normal operation of the switch; however, an oversubscribed SPAN destination (for example, a 10-Mbps port monitoring a 100-Mbps port) results in dropped or lost packets.

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.

A SPAN session remains inactive after system startup until the destination port is operational.

Traffic Types

SPAN sessions include these traffic types:

- Receive (Rx) SPAN—The goal of receive (or ingress) SPAN is to monitor as much as possible all 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. You can monitor a series or range of ingress ports or VLANs in a SPAN session.

  On tagged packets (Inter-Switch Link [ISL] or IEEE 802.1Q), the tagging is removed at the ingress port. At the destination port, if tagging is enabled, the packets appear with the ISL or 802.1Q headers. If no tagging is specified, packets appear in the native format.

  Packets that are modified because of routing are copied without modification for Rx SPAN; that is, the original packet is copied. Packets that are modified because of quality of service (QoS)—for example, modified Differentiated Services Code Point (DSCP)—are copied with modification for Rx SPAN.

Some features that can cause a packet to be dropped during receive processing have no effect on 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), IP standard and extended output ACLs for unicast and ingress QoS policing, VLAN maps, ingress QoS policing, and policy-based routing. Switch congestion that causes packets to be dropped also has no effect on SPAN.

- Transmit (Tx) SPAN—The goal of transmit (or egress) SPAN is to monitor as much as possible all packets sent by the source interface after the switch performs all modification and processing. After the packet is modified, the source sends a copy of each packet to the destination port for that SPAN session. You can monitor a range of egress ports in a SPAN session.

  Packets that are modified because of routing—for example, with a time-to-live (TTL) or MAC-address modification—are duplicated at the destination port. On packets that are modified because of QoS, the modified packet might not have the same DSCP (IP packet) or CoS (non-IP packet) as the SPAN source.

  Some features that can cause a packet to be dropped during transmit processing might also affect the duplicated copy for SPAN. These features include VLAN maps, IP standard and extended output ACLs on multicast packets, and egress QoS policing. In the case of output ACLs, if the SPAN source drops the packet, the SPAN destination would also drop the packet. In the case of egress QoS policing, if the SPAN source drops the packet, the SPAN destination might not drop it. If the source port is oversubscribed, the destination ports will have different dropping behavior.
- Both—In a SPAN session, you can monitor a single port series or a range of ports for both received and sent packets.

Source Port

A source port (also called a monitored port) is a switched or routed port that you monitor for network traffic analysis. In a single local SPAN session or RSPAN source session, you can monitor source port traffic, such as received (Rx), transmitted (Tx), or bidirectional (both). 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.

A source port has these characteristics:

- It can be any port type (for example, EtherChannel, Fast Ethernet, Gigabit Ethernet, and so forth).
- It can be monitored in multiple SPAN sessions.
- It cannot be a destination port.
- Each source port can be configured with a direction (ingress, egress, or both) to monitor. For EtherChannel sources, the monitored direction would apply to all physical ports in the group.
- Source ports can be in the same or different VLANs.
- For VLAN SPAN sources, all active ports in the source VLAN are included as source ports.

You can configure 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. Only switched traffic in the selected VLANs is sent to the destination port. This feature affects only traffic forwarded to the destination SPAN port and does not affect the switching of normal traffic. This feature is not allowed in sessions with VLAN sources.

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 and VLANs.

A destination port has these characteristics:

- A destination port must reside on the same switch as the source port (for a local SPAN session).
- A destination port can be any Ethernet physical port.
- A destination port 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.)
- A destination port cannot be a source port.
- A destination port cannot be an EtherChannel group.
- A destination port can be a physical port that is assigned to an EtherChannel group, even if the EtherChannel group has been specified as a SPAN source. The port is removed from the group while it is configured as a SPAN destination port.
- The port does not transmit any traffic except that traffic required for the SPAN session unless learning is enabled. If learning is enabled, the port will also transmit traffic directed to hosts that have been learned on the destination port.
- If ingress traffic forwarding is enabled for a network security device, the destination port forwards traffic at Layer 2.
- A destination port does not participate in spanning tree while the SPAN session is active.
- When it is a destination port, 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.
- A destination port receives copies of sent and received traffic for all monitored source ports. If a destination port is oversubscribed, it could become congested. This congestion could affect traffic forwarding on one or more of the source ports.

VLAN-Based SPAN

VLAN-based SPAN (VSPAN) is the monitoring of the network traffic in one or more VLANs.

Use these guidelines for VSPAN sessions:

- Traffic on RSPAN VLANs is not monitored by VLAN-based SPAN sessions.
- 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.
- VLAN pruning and the VLAN allowed list have no effect on SPAN monitoring.
- VSPAN monitors only traffic that enters the switch, not traffic that is routed between VLANs. For example, if a VLAN is being Rx-monitored, and the multilayer switch routes traffic from another VLAN to the monitored VLAN, that traffic is not monitored and is not received on the SPAN destination port.

- You cannot use filter VLANs in the same session with VLAN sources.
- You can monitor only Ethernet VLANs.

SPAN Traffic

You can use local SPAN to monitor all network traffic, including multicast and bridge protocol data unit (BPDU) packets, Cisco Discovery Protocol (CDP), VLAN Trunk Protocol (VTP), Dynamic Trunking Protocol (DTP), Spanning Tree Protocol (STP), and Port Aggregation Protocol (PAgP) packets. You cannot use RSPAN to monitor Layer 2 protocols. (See the "RSPAN Configuration Guidelines" section on page 37-16 for more information.)

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 sources a1 Rx monitor and the a2 Rx and Tx monitor to destination port d1. If a packet enters the switch through a1 and is switched to a2, both incoming and outgoing packets are sent to destination port d1. Both packets are the same (unless a Layer-3 rewrite occurs, in which case the packets are different because of the added Layer 3 information).

SPAN and RSPAN Session Limits

You can configure up to two simultaneous SPAN sessions containing ingress sources and up to four simultaneous SPAN sessions containing egress sources. Bidirectional sources count as both ingress and egress. RSPAN destination sessions count as a session containing an ingress source.

Default SPAN and RSPAN Configuration

Table 37-1 shows the default SPAN and RSPAN configuration.

Table 37-1 Default SPAN and RSPAN Configuration

Feature	Default Setting
SPAN state	Disabled.
Source port traffic to monitor	Both received and sent traffic (**both**).
Filters	All VLANs, all packet types, all address types.
Encapsulation type (destination port)	Native form (no encapsulation type header).
Ingress forwarding (destination port)	Disabled.
Host learning (destination port)	Disabled.

Configuring SPAN

The following sections describe how to configure SPAN:

Note Entering SPAN configuration commands does not clear previously configured SPAN parameters. You must enter the **no monitor session** command to clear configured SPAN parameters.

SPAN Configuration Guidelines and Restrictions

Follow these guidelines and restrictions when configuring SPAN:

- You must use a network analyzer to monitor interfaces.
- You cannot mix source VLANs and filter VLANs within a SPAN session. You can have source VLANs or filter VLANs, but not both at the same time.
- EtherChannel interfaces can be SPAN source interfaces; they cannot be SPAN destination interfaces.
- When you specify source interfaces and do not specify a traffic type (Tx, Rx, or both), “both” is used by default.
- If you specify multiple SPAN source interfaces, the interfaces can belong to different VLANs.
- You must enter the **no monitor session** *number* command with no other parameters to clear the SPAN session *number*.
- The **no monitor** command clears all SPAN sessions.
- SPAN destinations never participate in any spanning tree instance. SPAN includes BPDUs in the monitored traffic, so any BPDUs seen on the SPAN destination are from the SPAN source.

Configuring SPAN Sources

To configure the source for a SPAN session, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session {session_number} {source {interface <interface_list> | {vlan vlan_IDs | cpu [queue queue_ids] } [rx | tx | both]`	Specifies the SPAN session number (1 through 6), the source interfaces (FastEthernet or GigabitEthernet), VLANs (1 through 4094), whether or not traffic received or sent from the CPU is copied to the session destination, and the traffic direction to be monitored. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-list*, specifies the source port to monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel** *port-channel-number*). For *vlan_IDs*, specifies the source VLAN. For *queue_ids*, specifies the queue(s) involved. (Optional) [**,** | **-**] Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional). Queues may be identified either by number or by name. Queue names may subsume multiple numbered queues for convenience. Use the **no** keyword to restore the defaults.

This example shows how to configure SPAN session 1 to monitor bidirectional traffic from source interface Fast Ethernet 5/1:

```
Switch(config)# monitor session 1 source interface fastethernet 5/1
```

This example shows how to configure sources with differing directions within a SPAN session:

```
Switch(config)# monitor session 1 source interface fa2/3 rx
Switch(config)# monitor session 1 source interface fa2/2 tx
Switch(config)#
```

Configuring SPAN Destinations

To configure the destination for a SPAN session, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session <session_number> destination interface <interface> [encapsulation {isl | dot1q}] [ingress [vlan vlan_IDs] [learning}]`	Specifies the SPAN session number (1 through 6) and the destination interfaces or VLANs. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface*, specifies the destination interface. For *vlan_IDs*, specifies the destination VLAN. Use the **no** keyword to restore the defaults.

This example shows how to configure interface Fast Ethernet 5/48 as the destination for SPAN session 1:

```
Switch(config)# monitor session 1 destination interface fastethernet 5/48
```

Monitoring Source VLANs on a Trunk Interface

To monitor specific VLANs when the SPAN source is a trunk interface, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session {session_number} filter {vlan vlan_IDs [, | - ]} | {packet-type {good | bad}} | {address-type {unicast | multicast | broadcast} [rx | tx | both]}`	Monitors specific VLANs when the SPAN source is a trunk interface. The filter keyword restricts monitoring to traffic that is on the specified VLANs; it is typically used when monitoring a trunk interface. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan_IDs*, specifies the VLAN. Monitoring is established through all the ports in the specified VLANs Use the **no** keyword to restore the defaults.

This example shows how to monitor VLANs 1 through 5 and VLAN 9 when the SPAN source is a trunk interface:

```
Switch(config)# monitor session 2 filter vlan 1 - 5 , 9
```

Configuration Scenario

This example shows how to use the commands described in this chapter to completely configure and unconfigure a span session. Assume that you want to monitor bidirectional traffic from source interface Fast Ethernet 4/10, which is configured as a trunk interface carrying VLANs 1 through 4094. Moreover, you want to monitor only traffic in VLAN 57 on that trunk. Using Fast Ethernet 4/15 as your destination interface, you would enter the following commands:

```
Switch(config)# monitor session 1 source interface fastethernet 4/10
Switch(config)# monitor session 1 filter vlan 57
Switch(config)# monitor session 1 destination interface fastethernet 4/15
```

You are now monitoring traffic from interface Fast Ethernet 4/10 that is on VLAN 57 out of interface FastEthernet 4/15. To disable the span session enter the following command:

```
Switch(config)# no monitor session 1
```

Verifying a SPAN Configuration

This example shows how to verify the configuration of SPAN session 2:

```
Switch# show monitor session 2
Session 2
---------
Source Ports:
    RX Only:       Fa5/12
    TX Only:       None
    Both:          None
Source VLANs:
    RX Only:       None
    TX Only:       None
    Both:          None
Destination Ports: Fa5/45
Filter VLANs:      1-5,9
Switch#
```

CPU Port Sniffing

When configuring a SPAN session, you can specify the CPU (or a subset of CPU queues) as a SPAN source. Queues may be specified either by number or by name. When such a source is specified, traffic going to the CPU through one of the specified queues is mirrored and sent out of the SPAN destination port in the session. This traffic includes both control packets and regular data packets that are sent to or from the CPU (due to software forwarding).

You can mix the CPU source with either regular port sources or VLAN sources.

To configure CPU source sniffing, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session {session_number} {source {interface interface_list | {vlan vlan_IDs | cpu [queue queue_ids] } [rx | tx | both]`	Specifies that the CPU will cause traffic received by or sent from the CPU to be copied to the destination of the session. The **queue** identifier optionally allows sniffing-only traffic (received) on the specified CPU queue(s). For *session_number*, specifies the session number identified with this SPAN session (1 through 6). For *interface-list*, specifies the source port to monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel** *port-channel-number*). For *vlan_IDs*, specifies the source VLAN. For *queue_ids*, specifies the queue(s) involved. (Optional) [**,** | **-**] Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional). Queues may be identified either by number or by name. Queue names may subsume multiple numbered queues for convenience. Use the **no** keyword to restore the defaults.

This example shows how to configure a CPU source to sniff all packets received by the CPU:

```
Switch(config)# monitor session 1 source cpu rx
```

This example shows how to use queue names and queue number ranges for the CPU as a SPAN source:

```
Switch(config)# monitor session 2 source cpu queue control-packet rx
Switch(config)# monitor session 3 source cpu queue 21 -23 rx
```

Encapsulation Configuration

When configuring a SPAN destination port, you can explicitly specify the encapsulation type used by the port. Packets sent out the port are tagged in accordance with the specified mode. (The encapsulation mode also controls how tagged packets are handled when the ingress packet option is enabled.) The Catalyst 4500 series switch supervisor engines support ISL encapsulation and 802.1q encapsulation, as well as untagged packets. The "replicate" encapsulation type (in which packets are transmitted from the destination port using whatever encapsulation applied to the original packet) is not supported. If no encapsulation mode is specified, the port default is untagged. To view the task of configuring encapsulation, see the command table below.

Ingress Packets

When ingress is enabled, the SPAN destination port accepts incoming packets (potentially tagged depending on the specified encapsulation mode) and switches them normally. When configuring a SPAN destination port, you can specify whether or not the ingress feature is enabled and what VLAN to use to switch untagged ingress packets. (Specifying an ingress VLAN is not required when ISL encapsulation is configured, as all ISL encapsulated packets have VLAN tags.) Although the port is STP forwarding, it does not participate in the STP, so use caution when configuring this feature lest a spanning-tree loop be introduced in the network. When both ingress and a trunk encapsulation are specified on a SPAN destination port, the port will go forwarding in all active VLANs. Configuring a non-existent VLAN as an ingress VLAN is not allowed.

By default, host learning is disabled on SPAN destination ports with ingress enabled. The port is also removed from VLAN floodsets, so regular traffic will not be switched out of the destination port. If learning is enabled, however, then traffic for hosts learned on the destination port will be switched out the destination port. It is also possible to configure static host entries (including a static ARP entry and a static entry in the MAC-address table) on SPAN destination ports.

Note This configuration will not work if the SPAN session does not have a source configured; the session is half configured with only the SPAN destination port.

To configure ingress packets and encapsulation, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session <session_number> destination interface <interface> [encapsulation {isl | dot1q}] [ingress [vlan vlan_IDs] [learning]]`	Specifies the configuration of the ingress packet and the encapsulation type of the destination port. For *session_number*, specifies the session number identified with this SPAN session (1 through 6). For *interface*, specifies the destination interface. For *vlan_IDs*, specifies the destination VLAN. Use the **no** keyword to restore the defaults.

This example shows how to configure a destination port with 802.1q encapsulation and ingress packets using native VLAN 7:

```
Switch(config)# monitor session 1 destination interface fastethernet 5/48
encapsulation dot1q ingress vlan 7
```

With this configuration, traffic from SPAN sources associated with session 1 would be copied out of interface Fast Ethernet 5/48, with 802.1q encapsulation. Incoming traffic would be accepted and switched, with untagged packets being classified into VLAN 7.

Access List Filtering

When configuring a SPAN session, you can apply access list filtering. Access list filtering applies to all packets passing through a SPAN destination port that might be sniffed in the egress or ingress direction. Access list filters are allowed on local SPAN sessions only. If the SPAN destination is an RSPAN VLAN, the access list filter is rejected.

Note Access list filtering is available in Release 12.2(20)EW and later releases.

ACL Configuration Guidelines

You can configure ACLs on a SPAN session. Use these guidelines for ACL/SPAN sessions:

- If an ACL is associated with a SPAN session, the rules associated with that ACL are applied against all packets exiting the SPAN destination interface. Rules pertaining to other VACLs or RACLs previously associated with the SPAN destination interface are not applied.
- Only one ACL can be associated with a SPAN session.
- When no ACLs are applied to packets exiting a SPAN destination interface, all traffic is permitted regardless of the PACLs, VACLs, or RACLs that have been previously applied to the destination interface or VLAN to which the SPAN destination interface belongs.
- If an ACL is removed from a SPAN session, all traffic is permitted once again.
- If SPAN configuration is removed from the SPAN session, all rules associated with the SPAN destination interface are applied once again.
- If a SPAN destination port is configured as a trunk port and the VLANs to which it belongs have ACLs associated with them, the traffic is not subjected to the VACLs.
- ACL configuration applies normally to the RSPAN VLAN and to trunk ports carrying the RSPAN VLAN. This configuration enables the user to apply VACLs on RSPAN VLANs. If a user attempts to configure an ACL on a SPAN session with the destination port as an RSPAN VLAN, the configuration is rejected.
- If CAM resources are exhausted and packets are passed to the CPU for lookup, any output port ACLs associated with a SPAN session are not applied.
- If a named IP ACL is configured on a SPAN session before an ACL is created, the configuration is accepted, and the software creates an empty ACL with no ACEs. (An empty ACL permits all packets.) Subsequently, the rules can be added to the ACL.
- The ACLs associated with a SPAN session are applied on the destination interface on output.

- No policing is allowed on traffic exiting SPAN ports.
- Only IP ACLs are supported on SPAN sessions.

Configuring Access List Filtering

To configure access list filtering, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session {session_number} filter {ip access-group [name | id] }{vlan vlan_IDs [, | - ] } | {packet-type {good | bad}} | {address-type {unicast | multicast | broadcast} [rx | tx | both]}`	Specifies filter sniffing based on the access list. For *session_number*, specify the session number identified with this SPAN session (1 through 6). You can specify either a name or a numeric ID for the access list. For *name*, specify the IP access list name. For *id*, specify a standard <1 to 199> or extended <1300-2699> IP access list.

Note IP access lists must be created in configuration mode as described in the chapter "Configuring Network Security with ACLs."

This example shows how to configure IP access group 10 on a SPAN session and verify that an access list has been configured:

```
Switch(config)# monitor session 1 source interface fa6/1 both
Switch(config)# monitor session 1 destination interface fa6/2
Switch(config)# monitor session 1 filter vlan 1
Switch(config)# monitor session 1 filter ip access-group 10
Switch(config)# exit
Switch# show monitor

Session 1
---------
Type              : Local Session
Source Ports      :
    Both          : Fa6/1
Destination Ports : Fa6/2
    Encapsulation : Native
          Ingress : Disabled
         Learning : Disabled
Filter VLANs      : 1
IP Access-group   : 10
```

Packet Type Filtering

When configuring a SPAN session, you can specify packet filter parameters similar to VLAN filters. When specified, the packet filters indicate types of packets that may be sniffed. If no packet filters are specified, packets of all types may be sniffed. Different types of packet filters may be specified for ingress and egress traffic.

There are two categories of packet filtering: packet-based (good, error) or address-based (unicast/multicast/broadcast). Packet-based filters can only be applied in the ingress direction. Packets are classified as broadcast, multicast, or unicast by the hardware based on the destination address.

Note When filters of both types are configured, only packets that pass both filters are spanned. For example, if you set both "error" and "multicast," only multicast packets with errors will be spanned.

To configure packet type filtering, perform this task:

Command	Purpose
`Switch(config)# [no] monitor session {session_number} filter {vlan vlan_IDs [, | - ] } | {packet-type {good | bad}} | {address-type {unicast | multicast | broadcast} [rx | tx | both]}`	Specifies filter sniffing of the specified packet types in the specified directions. For *session_number*, specifies the session number identified with this SPAN session (1 through 6). For *vlan_IDs*, specifies the VLAN. You can specify both Rx and Tx type filters, as well as specify multiple type filters at the same time (such as **good** and **unicast** to only sniff non-error unicast frames). As with VLAN filters, if no type or filter is specified, then the session will sniff all packet types. Use the **no** keyword to restore the defaults.

This example shows how to configure a session to accept only unicast packets in the ingress direction:

```
Switch(config)# monitor session 1 filter address-type unicast rx
```

Configuration Example

The following is an example of SPAN configuration using some of the SPAN enhancements.

In the example below, you configure a session to sniff unicast traffic arriving on interface Gi1/1. The traffic is mirrored out of interface Gi1/2 with ISL encapsulation. Ingress traffic is permitted.

```
Switch(config)# monitor session 1 source interface gi1/1 rx
Switch(config)# monitor session 1 destination interface gi1/2 encapsulation isl ingress
Switch(config)# monitor session 1 filter address-type unicast rx
Switch(config)# exit
Switch# show monitor

Session 1
---------
Type              : Local Session
Source Ports      :
    RX Only       : Gi1/1
Destination Ports : Gi1/2
    Encapsulation : ISL
          Ingress : Enabled
        Learning  : Disabled
Filter Addr Type  :
    RX Only       : Unicast
```

Configuring RSPAN

This section describes how to configure RSPAN on your switch and it contains this configuration information:

RSPAN Configuration Guidelines

Follow these guidelines when configuring RSPAN:

Note Since 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.

Note You can apply an output access control list (ACL) to RSPAN traffic to selectively filter or monitor specific packets. Specify these ACLs on the RSPAN VLAN in the RSPAN source switches.

- RSPAN sessions can coexist with SPAN sessions within the limits described in the "SPAN and RSPAN Session Limits" section on page 37-6.
- 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 all participating switches support the VLAN remote-span feature. Access ports on the RSPAN VLAN are silently disabled.
- You should create an RSPAN VLAN before configuring an RSPAN source or 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.
- Because RSPAN traffic is carried across a network on an RSPAN VLAN, the original VLAN association of the mirrored packets is lost. Therefore, RSPAN can only support forwarding of traffic from an IDS device onto a single user-specified VLAN.

Creating an RSPAN Session

First create an RSPAN VLAN that does not exist for the RSPAN session in any of the switches that will participate in RSPAN. With VTP enabled in the network, you can create the RSPAN VLAN in one switch, and then VTP propagates it to the other switches in the VTP domain for VLAN-IDs that are lower than 1005.

Use VTP pruning to get efficient flow of RSPAN traffic, or manually delete the RSPAN VLAN from all trunks that do not need to carry the RSPAN traffic.

To start an RSPAN source session and to specify the source (monitored) ports and the destination RSPAN VLAN, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# no monitor session {session_number | all | local | remote}`	Clears any existing RSPAN configuration for the session. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). Specifies **all** to remove all RSPAN sessions, **local** to remove all local sessions, or **remote** to remove all remote SPAN sessions.
Step 3	`Switch(config)# [no] monitor session {session_number} {source {interface <interface_list> | {vlan vlan_IDs | cpu [queue queue_ids]} [rx | tx | both]`	Specifies the RSPAN session and the source port (monitored port). For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-list*, specifies the source port to monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel** *port-channel-number*). For *vlan-IDs*, specifies the source VLAN or VLANs to monitor. Valid VLANs are in the range from 1 to 4094. For *queue_ids*, specifies either a set of CPU queue numerical identifiers from 1 to 32, or a named queue. (Optional) [**,** | **-**] Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional).
Step 4	`Switch(config)# monitor session session_number destination remote vlan vlan-ID`	Specifies the RSPAN session and the destination remote VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan-ID*, specifies the RSPAN VLAN to carry the monitored traffic to the destination port.

	Command	Purpose
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to clear any existing RSPAN configuration for session 1, configure RSPAN session 1 to monitor multiple source interfaces, and configure the destination RSPAN VLAN.

```
Switch(config)# no monitor session 1
Switch(config)# monitor session 1 source interface fastEthernet3/10 tx
Switch(config)# monitor session 1 source interface fastEthernet3/2 rx
Switch(config)# monitor session 1 source interface fastEthernet3/3 rx
Switch(config)# monitor session 1 source interface port-channel 102 rx
Switch(config)# monitor session 1 destination remote vlan 901
Switch(config)# end
```

Creating an RSPAN Destination Session

To create an RSPAN destination session and to specify the source RSPAN VLAN and the destination port, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# monitor session session_number source remote vlan vlan-ID`	Specifies the RSPAN session and the source RSPAN VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan-ID*, specifies the source RSPAN VLAN to monitor.
Step 3	`Switch(config)# [no] monitor session <session_number> destination interface <interface> [encapsulation {isl | dot1q}] [ingress [vlan vlan_IDs] [learning]]`	Specifies the RSPAN session and the destination interface. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface*, specifies the destination interface. For *vlan_IDs*, specifies the ingress VLAN, if necessary. (Optional) **[, | -]** Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both sent and received traffic. Only received (**rx**) traffic can be monitored on additional source ports. • **isl**—Use ISL encapsulation. • **dot1q**—Use 802.1Q encapsulation.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.

	Command	Purpose
Step 5	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to configure VLAN 901 as the source remote VLAN and port 5 as the destination interface:

```
Switch(config)# monitor session 1 source remote vlan 901
Switch(config)# monitor session 1 destination interface gigabitEthernet1/2
Switch(config)# end
```

Creating an RSPAN Destination Session and Enabling Ingress Traffic

To create an RSPAN destination session, to specify the source RSPAN VLAN, and to enable ingress traffic on the destination port for a network security device (such as a Cisco IDS [Intrusion Detection System] sensor appliance), perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# monitor session {session_number} source vlan vlan_IDs`	Specifies the RSPAN session and the source RSPAN VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan_IDs*, specifies the source VLAN or VLANs to monitor. Valid VLANs are in the range from 1 to 4094.

	Command	Purpose
Step 3	`Switch(config)# [monitor session session_number destination interface interface-id [encapsulation {dot1q [ingress vlan vlan id] | ISL [ingress]} | ingress vlan vlan id] [learning]]`	Specifies the RSPAN session, the destination port, the packet encapsulation, and the ingress VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-id*, specifies the destination port. Valid interfaces include physical interfaces. (Optional) Specifies the encapsulation of the packets transmitted on the RSPAN destination port. If no encapsulation is specified, all transmitted packets will be sent in native format (untagged). • Enter **encapsulation dot1q** to send native VLAN packets untagged, and all other VLAN **tx** packets tagged **dot1q**. • Enter **encapsulation isl** to send all **tx** packets encapsulated using ISL. (Optional) Specifies whether forwarding is enabled for ingress traffic on the RSPAN destination port. • For native (untagged) and **dot1q** encapsulation, specify **ingress vlan** *vlan id* to enable ingress forwarding with *vlan id* as the native VLAN; *vlan id* will also be used as the native VLAN for transmitted packets. • Specify **ingress** to enable ingress forwarding when using ISL encapsulation. • Specify **learning** to enable learning when ingress is enabled.
Step 4	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 5	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 6	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to configure VLAN 901 as the source remote VLAN and how to configure the destination port for ingress traffic on VLAN 5 by using a security device that supports 802.1Q encapsulation:

```
Switch(config)# monitor session 1 source remote vlan 901
Switch(config)# monitor session 1 destination interface gigabitEthernet1/2 ingress vlan 5
Switch(config)# end
```

Removing Ports from an RSPAN Session

To remove a port as an RSPAN source for a session, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# [no] monitor session {session_number} {source {interface interface_list | {vlan vlan_IDs | cpu [queue queue_ids]} [rx | tx | both]`	Specifies the characteristics of the RSPAN source port (monitored port) to remove. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-list*, specifies the source port to no longer monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel** *port-channel-number*). For *vlan_IDs*, specifies the source vlan or vlans to monitor. Valid VLANs are in the range from 1 to 4094. For *queue_ids*, specifies either a set of CPU queue numerical identifiers from 1 to 32, or a named queue. (Optional) [**,** | **-**] Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional).
Step 3	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 4	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 5	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

This example shows how to remove port 1 as an RSPAN source for RSPAN session 1:

```
Switch(config)# no monitor session 1 source interface gigabitEthernet1/1
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 gigabitEthernet1/1 rx
```

The monitoring of traffic received on port 1 is disabled, but traffic transmitted from this port continues to be monitored.

Specifying VLANs to Monitor

VLAN monitoring is similar to port monitoring. To specify VLANs to monitor, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# no monitor session {session_number | all | local | remote}`	Clears any existing SPAN configuration for the session. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). Specify **all** to remove all SPAN sessions, **local** to remove all local sessions, or **remote** to remove all remote SPAN sessions.
Step 3	`Switch(config)# [no] monitor session {session_number} {source {interface interface_list | {vlan vlan_IDs | cpu [queue queue_ids]} [rx | tx | both]`	Specifies the RSPAN session and the source VLANs (monitored VLANs). You can monitor only received (**rx**) traffic on VLANs. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-list*, specifies the source port to no longer monitor. Valid interfaces include physical interfaces and port-channel logical interfaces (**port-channel** *port-channel-number*). For *vlan-IDs*, the range is 1 to 4094; do not enter leading zeros. For *queue_ids*, specifies the source queue. (Optional) **[, | -]** Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional).
Step 4	`Switch(config)# monitor session session_number destination remote vlan vlan-id`	Specifies the RSPAN session, the destination remote VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan-id*, specifies the RSPAN VLAN to carry the monitored traffic to the destination port.
Step 5	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 6	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 7	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To remove one or more source VLANs from the RSPAN session, use the **no monitor session** *session_number* **source vlan** *vlan-id* **rx** global configuration command.

This example shows how to clear any existing configuration on RSPAN session 2, configure RSPAN session 2 to monitor received traffic on all ports belonging to VLANs 1 through 3, and send it to destination remote VLAN 902. The configuration is then modified to also monitor received 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 remote vlan 902
Switch(config)# monitor session 2 source vlan 10 rx
Switch(config)# end
```

Specifying VLANs to Filter

To limit RSPAN source traffic to specific VLANs, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# no monitor session {session_number | all | local | remote}`	Clears any existing SPAN configuration for the session. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). Specify **all** to remove all SPAN sessions, **local** to remove all local sessions, or **remote** to remove all remote SPAN sessions.
Step 3	`Switch(config)# [no] monitor session {session_number} {source {interface interface_list | {vlan vlan_IDs | cpu [queue queue_ids]} [rx | tx | both]`	Specifies the characteristics of the source port (monitored port) and RSPAN session. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *interface-list*, specifies the source port to monitor. The interface specified must already be configured as a trunk port. For *vlan-IDs*, the range is 1 to 4094; do not enter leading zeros. For *queue_ids*, specifies the source queue. (Optional) [**,** | **-**] Specifies a series or range of interfaces. Enter a space after the comma; enter a space before and after the hyphen. (Optional) Specifies the direction of traffic to monitor. If you do not specify a traffic direction, the source interface sends both transmitted (Tx) and received (Rx) traffic. Only received traffic can be monitored on additional source ports. • **Rx**—Monitor received traffic. • **Tx**—Monitor transmitted traffic. • **both**—Monitor both received and transmitted traffic (bidirectional).

	Command	Purpose
Step 4	`Switch(config)# monitor session session_number filter vlan vlan-id [, | -]`	Limits the RSPAN source traffic to specific VLANs. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan-id*, the range is 1 to 4094; do not enter leading zeros. (Optional) Use a comma (**,**) to specify a series of VLANs or use a hyphen (**-**) to specify a range of VLANs. Enter a space after the comma; enter a space before and after the hyphen.
Step 5	`Switch(config)# monitor session session_number destination remote vlan vlan-id`	Specifies the RSPAN session, the destination remote VLAN. For *session_number*, specifies the session number identified with this RSPAN session (1 through 6). For *vlan-id*, specifies the RSPAN VLAN to carry the monitored traffic to the destination port.
Step 6	`Switch(config)# end`	Returns to privileged EXEC mode.
Step 7	`Switch# show monitor [session session_number]`	Verifies your entries.
Step 8	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

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 clear any existing configuration on RSPAN session 2, configure RSPAN session 2 to monitor traffic received on trunk port 4, and send traffic for only VLANs 1 through 5 and 9 to destination remote VLAN 902.

```
Switch(config)# no monitor session 2
Switch(config)# monitor session 2 source interface gigabitethernet1/1 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 status of the current SPAN or RSPAN configuration, use the **show monitor** privileged EXEC command.

This example displays the output for the **show monitor** command for SPAN source session 1:

```
Switch# show monitor session 1
Session 1
---------
Type: Local Source Session
Source Ports:
    RX Only:  Fa3/13
    TX Only:       None
    Both:          None
```

```
Source VLANs:
    RX Only:       None
    TX Only:       None
    Both:          None
Source RSPAN VLAN: None
Destination Ports: None
    Encapsulation: DOT1Q
    Ingress:Enabled, default VLAN=5
Filter VLANs:      None
Dest RSPAN VLAN: None
Ingress : Enabled, default VLAN=2
Learning : Disabled
```

Configuring NetFlow Statistics Collection

This chapter describes how to configure NetFlow statistics on the Catalyst 4500 series switches. It also provides guidelines, procedures, and configuration examples.

Note This feature is only available if the NetFlow Services Card (WS-F4531) is present.

Note For complete syntax and usage information for the commands used in this chapter, refer to the *Catalyst 4500 Series Switch Cisco IOS Command Reference* and related publications at http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/index.htm. Refer to the "NetFlow Solutions Guide" for more detailed information on NetFlow usage and management.

The following topics are included:

Overview of NetFlow Statistics Collection

This section contains the following subsections:

A network flow is defined as a unidirectional sequence of packets between a given source and destination endpoints. Network flows are highly granular; flow endpoints are identified both by an IP address and transport layer application port numbers. NetFlow also utilizes the IP type and the input interface identifier to uniquely identify flows.

NetFlow statistics is a global traffic monitoring feature that allows flow-level monitoring of all IPv4-routed traffic through the switch. Collected statistics can be exported to an external device (NetFlow Collector/Analyzer) through the NetFlow Data Export (NDE). Network planners can selectively enable NetFlow statistics (and NDE) on a per-device basis to gain traffic performance, control, or accounting benefits in specific network locations. Traffic monitoring does not need to be operating on each device in the network.

Information Derived from Hardware

Information available in a typical NetFlow record from hardware includes the following:

- the packet and byte counts
- start and end timestamps
- source and destination IP addresses
- IP protocol
- source and destination port numbers.

Information Derived from Software

The software infers the following fields:

- Input identifier
- Output identifier
- Routing information, including next-hop address, origin and peer AS, source and destination prefix mask

Determining the Input and Output interface and AS Numbers

The input and output interface values determined by the software, however, are not guaranteed to be accurate in the specific situations explained below. The input and output interface values are correct when Policy Based Routing (PBR) is not used. There are simple symmetric routing scenarios, and no load balancing schemes are applied by an adjacent upstream router.

Software determines the output interface information by looking up the FIB (Forwarding Information Base) entry in the default FIB table (based on the destination IP address). From this FIB entry, the software gains access to the destination AS number for this destination IP address, as well as the appropriate adjacency that stores the interface information. Therefore, the output interface is based solely on the destination IP address. If load balancing is enabled on the switch, instead of looking at the adjacency in the FIB entry, the load balancing hash will be applied to access the appropriate FIB path and access the appropriate adjacency. Although this process will typically yield correct results, a potential inaccuracy can occur when using a PBR that shares IP addresses with the default FIB table. Under these circumstances, there would then be multiple FIB table entries and associated adjacencies for the same destination IP address.

Similarly, the input interface and the source AS number for the source IP address are determined by looking up the FIB entry in the default FIB table based on the source IP address. Therefore, the input interface is based solely on the source IP address and a reverse lookup is done to determine to which interface a packet with this IP destination address needs to be routed. This process assumes that the

forwarding paths are symmetrical. However, if this process yields multiple input interfaces, a deterministic algorithm will be applied to pick one of them—the one with the lowest IP address. Although this process typically yields correct values, there are scenarios where the values are inaccurate:

- If load balancing is being applied by an upstream adjacent router, one input interface must be chosen arbitrarily out of the multiple input interfaces available. This action is necessary because the input interface that would be used depends on the type of load balancing algorithm being deployed by the adjacent upstream router. It is not always feasible to know the algorithm. Therefore, all flow statistics will be attributed to one input interface. Software selects the interface with the lowest IP subnet number.
- In an asymmetric routing scheme, where the traffic for an IP subnet might be received on an interface that is different from the interface where packets are sent to this IP subnet, the inferences noted previously for selecting an input interface, based on a reverse lookup, would be incorrect and cannot be verified. The reason is that RPF-based forwarding is not supported in the Catalyst 4500 series switch Cisco IOS-based supervisor engines.
- If PBR (Policy Based Routing) is enabled on the switch and the flow is destined to an address that resides in the PBR range or is sourced from an address that resides in the PBR range, the information will be incorrect. In this case, the input and output interface will most likely point to the default route (if configured) or will have no value at all (NULL).
- In the case of detecting DOS attacks, even if the route is symmetrical, it might not yield the correct results because there may be multiple paths to the destination, which is the source of the attacks.

VLAN Statistics

The NetFlow Services module, in combination with the Catalyst 4500 series switch Supervisor Engine IV, provides the capability of reporting VLAN statistics for routed traffic in and out of a VLAN, as well as Layer 2 output VLAN statistics. The CLI output for a specific VLAN is shown below:

```
cat4k-sup4-2# sh vlan counters or show vlan id 22 count
* Multicast counters include broadcast packets
Vlan Id                                          :22
L2 Unicast Packets                               :38
L2 Unicast Octets                                :2432
L3 Input Unicast Packets                         :14344621
L3 Input Unicast Octets                          :659852566
L3 Output Unicast Packets                        :8983050
L3 Output Unicast Octets                         :413220300
L3 Output Multicast Packets                      :0
L3 Output Multicast Octets                       :0
L3 Input Multicast Packets                       :0
L3 Input Multicast Octets                        :0
L2 Multicast Packets                             :340
L2 Multicast Octets                              :21760
```

Caveat for the NetFlow Feature

The NetFlow Services module has hardware limitations that restrict the platform support to a subset of all NetFlow fields. Specifically, the following fields will not be supported:

- TCP Flags
- ToS

Configuring NetFlow Statistics Collection

To configure NetFlow Switching, complete the tasks in these sections:

Checking for Required Hardware

Note The Catalyst 4500 series switches require WS-F4531 daughter cards and the Catalyst 4500 series switch Supervisor Engine IV to support the NetFlow statistics collection.

To ensure that the necessary hardware is enabled, issue the **show module** command, as follows:

```
Switch# show module all
Chassis Type : WS-C4507R

Power consumed by backplane : 40 Watts

Mod Ports Card Type                              Model
Serial No.
---+-----+--------------------------------------+------------------+-----------
1     2  1000BaseX (GBIC) Supervisor(active)    WS-X4515
JAB062604KB
2     2  1000BaseX (GBIC) Supervisor(standby)   WS-X4515
JAB062408CB
6    48  10/100BaseTX (RJ45)                    WS-X4148
JAB032305UH

M MAC addresses                    Hw  Fw           Sw               Status
--+--------------------------------+---+------------+----------------+---------
1 0001.6442.2c00 to 0001.6442.2c01 0.4 12.1(14r)EW( 12.1(20030513:00 Ok
2 0001.6442.2c02 to 0001.6442.2c03 0.4 12.1(14r)EW( 12.1(20030513:00 Ok
6 0050.3ed8.6780 to 0050.3ed8.67af 1.6 12.1(14r)EW( 12.1(20030513:00 Ok

Mod  Submodule               Model             Serial No.   Hw   Status
----+----------------------+-----------------+------------+----+---------
1   Netflow Services Card   WS-F4531          JAB062209CG  0.2  Ok
2   Netflow Services Card   WS-F4531          JAB062209AG  0.2  Ok

Switch#
```

Note Enabling this feature does not impact the hardware-forwarding performance of the switch.

The effective size of the hardware flow “cache” table is 64 kilobytes. If more than 64 kilobytes flows are active simultaneously, statistics may be lost for some of the flows.

The effective size of the software flow table is 256 kilobytes. The NetFlow software manages the consistency between the hardware and software tables, keeping the hardware table open by purging inactive hardware flows to the software table.

User-configured timeout settings dictate when the flows are purged and exported through NDE from the software cache. Hardware flow management ensures consistency between hardware flow purging and the user-configured timeout settings.

Software-forwarded flows are also monitored. Moreover, statistics will overflow if any flow receives traffic at a sustained rate exceeding 2 gigabits per second. Generally, this situation should not occur because a port cannot transmit at a rate higher than 1 gigabit per second.

Note By design, even if the timeout settings are high, flows will automatically "age out" as they approach their statistics limit.

Enabling NetFlow Statistics Collection

Note Netflow Flow Statistics are disabled by default.

To enable NetFlow switching, first configure the switch for IP routing as described in the IP configuration chapters in the *Cisco IOS IP and IP Routing Configuration Guide*. After you configure IP routing, perform one of these tasks:

Command	Purpose
`Switch(config)# ip flow ingress`	Enables Netflow switching for IP routing.
`Switch(config)# ip flow ingress infer-fields`	Enables Netflow with inferred input/output interfaces and source/destination BGP as information. The **inter-fields** option must be configured for AS information to be determined. **Note** This CLI will be shown only if you are using either the NetFlow Services Card (WS-F4531) or the Supervisor Engine V-10GE.

Exporting NetFlow Statistics

To configure the switch to export NetFlow statistics to a workstation when a flow expires, perform one of these tasks:

Command	Purpose
`Switch(config)# ip flow-export destination {hostname | ip-address} udp-port`	(Required) Configures the router to export NetFlow cache entries to a specific destination (for example, a workstation). **Note** You can specify multiple destinations.
`Switch(config)# ip flow-export version {1 | {5 [origin-as | peer-as]}}`	(Optional) Configures the router to export NetFlow cache entries to a workstation if you are using receiving software that requires version 1 or 5. Version 1 is the default. **origin-as** causes NetFlow to determine the origin Border Gateway Protocol (BGP) autonomous system of both the source and the destination hosts of the flow. **peer-as** causes NetFlow to determine the peer BGP autonomous system of both the input and output interfaces of the flow.
`Switch(config)# ip flow-export source <interface>`	(Optional) Specifies an interface whose IP address will be used as the source IP address in the IP header of the NetFlow Data Export (NDE) packet. Default is the NDE output interface.

Managing NetFlow Statistics Collection

You can display and clear NetFlow statistics, including IP flow switching cache information and flow information, such as the protocol, total flow, flows per second, and so forth. You can also use the resulting information to obtain information about your switch traffic.

To manage NetFlow switching statistics, perform one or both of following tasks:

Command	Purpose
`Switch# show ip cache flow`	Displays the NetFlow switching statistics.
`Switch# clear ip flow stats`	Clears the NetFlow switching statistics.

Configuring an Aggregation Cache

Aggregation of NetFlow statistics is typically performed by NetFlow collection tools on management workstations. By extending this support to the Catalyst 4500 series switch, you are now able to do the following:

- Reduce the required bandwidth between the router and workstations, as fewer NDE packets are exported.
- Reduce the number of collection workstations required.
- Provide visibility to aggregated flow statistics at the CLI.

To configure an aggregation cache, you must enter the aggregation cache configuration mode, and you must decide which type of aggregation scheme you would like to configure: autonomous system, destination prefix, protocol prefix, or source prefix aggregation cache. Once you define the aggregation scheme, define the operational parameters for that scheme. More than one aggregation cache can be configured concurrently.

To configure an aggregation cache, perform this task:

	Command	Purpose
Step 1	`Router(config)# ip flow-aggregation cache as`	Enters aggregation cache configuration mode and enables an aggregation cache scheme (autonomous system, destination-prefix, prefix, protocol-port, or source-prefix).
Step 2	`Router(config-flow-cache)# cache timeout inactive 199`	Specifies the number of seconds (in this example, 199) in which an inactive entry is allowed to remain in the aggregation cache before it is deleted.
Step 3	`Router(config-flow-cache)# cache timeout active 45`	Specifies the number of minutes (in this example, 45) in which an active entry is active.
Step 4	`Router(config-flow-cache)# export destination 10.42.41.1 9991`	Enables the data export.
Step 5	`Router(config-flow-cache)# enabled`	Enables aggregation cache creation.

Verifying Aggregation Cache Configuration and Data Export

To verify the aggregation cache information, perform this task:

Command	Purpose
`Router# show ip cache flow aggregation destination-prefix`	Displays the specified aggregation cache information.

To confirm data export, perform the following task:

Command	Purpose
`Router# show ip flow export`	Displays the statistics for the data export including the main cache and all other enabled caches.

Configuring a NetFlow Minimum Prefix Mask for Router-Based Aggregation

The minimum prefix mask specifies the shortest subnet mask that will be used for aggregating flows within one of the IP-address based aggregation caches (e.g. source-prefix, destination-prefix, prefix). In these caches, flows are aggregated based upon the IP address (source, destination, or both, respectively) and masked by the longer of the Minimum Prefix mask and the subnet mask of the route to the source/destination host of the flow (as found in the switch routing table).

Note The default value of the minimum mask is zero. The configurable range for the minimum mask is from 1 to 32. You should chose an appropriate value depending on the traffic. A higher value for the minimum mask will provide more detailed network addresses, but it may also result in increased number of flows in the aggregation cache.

To configure a minimum prefix mask for the Router-Based Aggregation feature, perform the tasks described in the following sections. Each task is optional.

- Configuring the Minimum Mask of a Prefix Aggregation Scheme
- Configuring the Minimum Mask of a Destination-Prefix Aggregation Scheme
- Configuring the Minimum Mask of a Source-Prefix Aggregation Scheme
- Monitoring and Maintaining Minimum Masks for Aggregation Schemes

Configuring the Minimum Mask of a Prefix Aggregation Scheme

To configure the minimum mask of a prefix aggregation scheme, perform this task:

	Command	Purpose
Step 1	`Router(config)# ip flow-aggregation cache prefix`	Configures the prefix aggregation cache.
Step 2	`Router(config-flow-cache)# mask source minimum value`	Specifies the minimum value for the source mask.
Step 3	`Router(config-flow-cache)# mask destination minimum value`	Specifies minimum value for the destination mask.

Configuring the Minimum Mask of a Destination-Prefix Aggregation Scheme

To configure the minimum mask of a destination-prefix aggregation scheme, perform this task:

	Command	Purpose
Step 1	`Router(config)# ip flow-aggregation cache destination-prefix`	Configures the destination aggregation cache.
Step 2	`Router(config-flow-cache)# mask destination minimum value`	Specifies the minimum value for the destination mask.

Configuring the Minimum Mask of a Source-Prefix Aggregation Scheme

To configure the minimum mask of a source-prefix aggregation scheme, perform this task:

	Command	Purpose
Step 1	`Router(config)# ip flow-aggregation cache source-prefix`	Configures the source-prefix aggregation cache.
Step 2	`Router(config-flow-cache)# mask source minimum value`	Specifies the minimum value for the source mask.

Monitoring and Maintaining Minimum Masks for Aggregation Schemes

To view the configured value of the minimum mask, use the following commands for each aggregation scheme, as needed:

Command	Purpose
`Router# show ip cache flow aggregation prefix`	Displays the configured value of the minimum mask in the prefix aggregation scheme.
`Router# show ip cache flow aggregation destination-prefix`	Displays the configured value of the minimum mask in the destination-prefix aggregation scheme.
`Router# show ip cache flow aggregation source-prefix`	Displays the configured value of the minimum mask in the source-prefix aggregation scheme.

Configuring NetFlow Aging Parameters

You can control when flows are purged from the software flow cache (and, if configured, reported through NDE) with the configuration aging parameters, **Active** and **Inactive**, of the **ip flow-cache timeout** command.

Active Aging specifies the period of time in which a flow should be removed from the software flow cache after the flow is created. Generally, this parameter is used to periodically notify external collection devices about active flows. This parameter operates independently of existing traffic on the flow. Active timeout settings tend to be on the order of minutes (default is 30min).

Inactive Aging specifies how long after the last packet is seen a flow is removed. The Inactive parameter clears the flow cache of "stale" flows thereby preventing new flows from starving (due to lack of resources). Inactive timeout settings tend to be on the order of seconds (default is 15sec).

NetFlow Statistics Collection Configuration Example

The following example shows how to modify the configuration to enable NetFlow switching. It also shows how to export the flow statistics for further processing to UDP port 9991 on a workstation with the IP address of 40.0.0.2. In this example, existing NetFlow statistics are cleared, thereby ensuring that the **show ip cache flow** command displays an accurate summary of the NetFlow switching statistics:

```
Switch# config t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# ip route-cache flow
Switch(config)# ip flow-export destination 40.0.0.2 9991
Switch(config)# ip flow-export version 5
Switch(config)# end
Switch# show ip flow export
```

```
Flow export is enabled
  Exporting flows to 40.0.0.2 (9991)
  Exporting using source IP address 40.0.0.1
  Version 5 flow records
  2 flows exported in 1 udp datagrams
  0 flows failed due to lack of export packet
  0 export packets were sent up to process level
  0 export packets were dropped due to no fib
  0 export packets were dropped due to adjacency issues
  0 export packets were dropped due to fragmentation failures
  0 export packets were dropped due to encapsulation fixup failures
Switch#
Switch# show ip cache flow

IP Flow Switching Cache, 17826816 bytes
  0 active, 262144 inactive, 4 added
  14 ager polls, 0 flow alloc failures
  Active flows timeout in 1 minutes
  Inactive flows timeout in 10 seconds
  last clearing of statistics 15:48:37
Protocol         Total    Flows   Packets Bytes  Packets Active(Sec) Idle(Sec)
--------         Flows     /Sec     /Flow  /Pkt     /Sec     /Flow     /Flow
UDP-other            1      0.0         3    46      0.0       0.0      10.3
IP-other             1      0.0       100    38      0.0       0.0      10.2
Total:               2      0.0        51    38      0.0       0.0      10.2

SrcIf         SrcIPaddress    DstIf         DstIPaddress    Pr SrcP DstP  Pkts
Switch#
```

NetFlow Configuration Examples

This section provides the following basic configuration examples:

- Sample NetFlow Enabling Schemes, page 38-10
- Sample NetFlow Aggregation Configurations, page 38-11
- Sample NetFlow Minimum Prefix Mask Router-Based Aggregation Schemes, page 38-12

Sample NetFlow Enabling Schemes

Note Enabling NetFlow on a per interface basis is not supported on a Catalyst 4500 switch.

This example shows how to enable NetFlow globally:

```
Switch# configure terminal
Switch(config)# ip flow ingress
```

This example shows how to enable NetFlow with support for inferred fields:

```
Switch# configure terminal
Switch(config)# ip flow ingress infer-fields
```

Sample NetFlow Aggregation Configurations

This section provides the following aggregation cache configuration examples:

Autonomous System Configuration

This example shows how to configure an autonomous system aggregation cache with an inactive timeout of 200 seconds, a cache active timeout of 45 minutes, an export destination IP address of 10.42.42.1, and a destination port of 9992:

```
Switch(config)# ip flow-aggregation cache as
Switch(config-flow-cache)# cache timeout inactive 200
Switch(config-flow-cache)# cache timeout active 45
Switch(config-flow-cache)# export destination 10.42.42.1 9992
Switch(config-flow-cache)# enabled
```

Destination Prefix Configuration

This example shows how to configure a destination prefix aggregation cache with an inactive timeout of 200 seconds, a cache active timeout of 45 minutes, an export destination IP address of 10.42.42.1, and a destination port of 9992:

```
Switch(config)# ip flow-aggregation cache destination-prefix
Switch(config-flow-cache)# cache timeout inactive 200
Switch(config-flow-cache)# cache timeout active 45
Switch(config-flow-cache)# export destination 10.42.42.1 9992
Switch(config-flow-cache)# enabled
```

Prefix Configuration

This example shows how to configure a prefix aggregation cache with an inactive timeout of 200 seconds, a cache active timeout of 45 minutes, an export destination IP address of 10.42.42.1, and a destination port of 9992:

```
Switch(config)# ip flow-aggregation cache prefix
Switch(config-flow-cache)# cache timeout inactive 200
Switch(config-flow-cache)# cache timeout active 45
Switch(config-flow-cache)# export destination 10.42.42.1 9992
Switch(config-flow-cache)# enabled
```

Protocol Port Configuration

This example shows how to configure a protocol port aggregation cache with an inactive timeout of 200 seconds, a cache active timeout of 45 minutes, an export destination IP address of 10.42.42.1, and a destination port of 9992:

```
Switch(config)# ip flow-aggregation cache protocol-port
Switch(config-flow-cache)# cache timeout inactive 200
Switch(config-flow-cache)# cache timeout active 45
Switch(config-flow-cache)# export destination 10.42.42.1 9992
Switch(config-flow-cache)# enabled
```

Source Prefix Configuration

This example shows how to configure a source prefix aggregation cache with an inactive timeout of 200 seconds, a cache active timeout of 45 minutes, an export destination IP address of 10.42.42.1, and a destination port of 9992:

```
Switch(config)# ip flow-aggregation cache source-prefix
Switch(config-flow-cache)# cache timeout inactive 200
Switch(config-flow-cache)# cache timeout active 45
Switch(config-flow-cache)# export destination 10.42.42.1 9992
Switch(config-flow-cache)# enabled
```

Sample NetFlow Minimum Prefix Mask Router-Based Aggregation Schemes

This section provides examples for the NetFlow minimum prefix mask aggregation cache configuration:

- Prefix Aggregation Scheme
- Destination-Prefix Aggregation Scheme
- Source-Prefix Aggregation Scheme

Prefix Aggregation Scheme

This is an example of a prefix aggregation cache configuration:

```
!
ip flow-aggregation cache prefix
mask source minimum 24
mask destination minimum 28
```

In this example, assume the following configuration:

```
ip route 118.42.20.160 255.255.255.224 110.42.13.2
ip route 122.16.93.160 255.255.255.224 111.22.21.2
```

Both routes have a 27-bit subnet mask in the routing table on the switch.

Flows travelling from the 118.42.20.160 subnet to the 122.16.93.160 subnet whose source IP addresses match with a mask of 27 bits and whose destination IP addresses match with a mask of 28 bits are aggregated together in the cache statistics.

Destination-Prefix Aggregation Scheme

This is an example of a destination-prefix aggregation cache configuration:

```
!
ip flow-aggregation cache destination-prefix
mask destination minimum 32
!
```

Source-Prefix Aggregation Scheme

This is an example of a source-prefix aggregation cache configuration:

```
ip flow-aggregation cache source-prefix
mask source minimum 30
!
```

APPENDIX A

Acronyms

Table A-1 defines the acronyms used in this publication.

Table A-1 Acronyms

Acronym	Expansion
ACE	access control entry
ACL	access control list
AFI	authority and format identifier
Agport	aggregation port
ALPS	Airline Protocol Support
AMP	Active Monitor Present
APaRT	Automated Packet Recognition and Translation
ARP	Address Resolution Protocol
AV	attribute value
AVVID	Architecture for Voice, Video and Integrated Data
BDD	binary decision diagrams
BECN	backward explicit congestion notification
BGP	Border Gateway Protocol
BPDU	bridge protocol data unit
BRF	bridge relay function
BSC	Bisync
BSTUN	Block Serial Tunnel
BUS	broadcast and unknown server
BVI	bridge-group virtual interface
CAM	content-addressable memory
CAR	committed access rate
CCA	circuit card assembly
CDP	Cisco Discovery Protocol
CEF	Cisco Express Forwarding
CGMP	Cisco Group Management Protocol

Table A-1 Acronyms (continued)

Acronym	Expansion
CHAP	Challenge Handshake Authentication Protocol
CIR	committed information rate
CIST	Common and Internal Spanning Tree
CLI	command-line interface
CLNS	Connection-Less Network Service
CMNS	Connection-Mode Network Service
COPS	Common Open Policy Server
COPS-DS	Common Open Policy Server Differentiated Services
CoS	class of service
CPLD	Complex Programmable Logic Device
CRC	cyclic redundancy check
CRF	concentrator relay function
CST	Common Spanning Tree
CUDD	University of Colorado Decision Diagram
DBL	Dynamic Buffer Limiting
DCC	Data Country Code
dCEF	distributed Cisco Express Forwarding
DDR	dial-on-demand routing
DE	discard eligibility
DEC	Digital Equipment Corporation
DFI	Domain-Specific Part Format Identifier
DFP	Dynamic Feedback Protocol
DISL	Dynamic Inter-Switch Link
DLC	Data Link Control
DLSw	Data Link Switching
DMP	data movement processor
DNS	Domain Name System
DoD	Department of Defense
DOS	denial of service
DRAM	dynamic RAM
DSAP	destination service access point
DSCP	differentiated services code point
DSPU	downstream SNA Physical Units
DTP	Dynamic Trunking Protocol
DTR	data terminal ready
DXI	data exchange interface

Table A-1 Acronyms (continued)

Acronym	Expansion
EAP	Extensible Authentication Protocol
EARL	Enhanced Address Recognition Logic
EEPROM	electrically erasable programmable read-only memory
EHSA	enhanced high system availability
EHT	Explicit Host Tracking
EIA	Electronic Industries Association
ELAN	Emulated Local Area Network
EOBC	Ethernet out-of-band channel
ESI	end-system identifier
FECN	forward explicit congestion notification
FM	feature manager
FRU	field replaceable unit
FSM	feasible successor metrics
GARP	General Attribute Registration Protocol
GMRP	GARP Multicast Registration Protocol
GVRP	GARP VLAN Registration Protocol
HSRP	Hot Standby Routing Protocol
ICC	Inter-card Communication
ICD	International Code Designator
ICMP	Internet Control Message Protocol
IDB	interface descriptor block
IDP	initial domain part or Internet Datagram Protocol
IFS	IOS File System
IGMP	Internet Group Management Protocol
IGRP	Interior Gateway Routing Protocol
ILMI	Integrated Local Management Interface
IP	Internet Protocol
IPC	interprocessor communication
IPX	Internetwork Packet Exchange
IS-IS	Intermediate System-to-Intermediate System Intradomain Routing Protocol
ISL	Inter-Switch Link
ISO	International Organization of Standardization
LAN	local area network
LANE	LAN Emulation
LAPB	Link Access Procedure, Balanced

Table A-1 Acronyms (continued)

Acronym	Expansion
LDA	Local Director Acceleration
LCP	Link Control Protocol
LEC	LAN Emulation Client
LECS	LAN Emulation Configuration Server
LEM	link error monitor
LER	link error rate
LES	LAN Emulation Server
LLC	Logical Link Control
LTL	Local Target Logic
MAC	Media Access Control
MACL	MAC Access Control
MD5	Message Digest 5
MFD	multicast fast drop
MIB	Management Information Base
MII	media-independent interface
MLS	Multilayer Switching
MLSE	maintenance loop signaling entity
MOP	Maintenance Operation Protocol
MOTD	message-of-the-day
MLSE	maintenance loops signaling entity
MRM	multicast routing monitor
MSDP	Multicast Source Discovery Protocol
MST	Multiple Spanning Tree
MSTI	MST instance
MTU	maximum transmission unit
MVAP	multiple VLAN access port
NBP	Name Binding Protocol
NCIA	Native Client Interface Architecture
NDE	NetFlow Data Export
NET	network entity title
NetBIOS	Network Basic Input/Output System
NFFC	NetFlow Feature Card
NMP	Network Management Processor
NSAP	network service access point
NTP	Network Time Protocol
NVRAM	nonvolatile RAM

Table A-1 Acronyms (continued)

Acronym	Expansion
OAM	Operation, Administration, and Maintenance
ODM	order dependent merge
OSI	Open System Interconnection
OSPF	open shortest path first
PACL	Port Access Control List
PAE	port access entity
PAgP	Port Aggregation Protocol
PBD	packet buffer daughterboard
PBR	Policy Based Routing
PC	Personal Computer
PCM	pulse code modulation
PCR	peak cell rate
PDP	policy decision point
PDU	protocol data unit
PEP	policy enforcement point
PGM	Pragmatic General Multicast
PHY	physical sublayer
PIB	policy information base
PIM	Protocol Independent Multicast
PoE	Power over Internet
PPP	Point-to-Point Protocol
PRID	Policy Rule Identifiers
PVST+	Per VLAN Spanning Tree+
QM	QoS manager
QoS	quality of service
RADIUS	Remote Access Dial-In User Service
RAM	random-access memory
RCP	Remote Copy Protocol
RGMP	Router-Ports Group Management Protocol
RIB	routing information base
RIF	Routing Information Field
RMON	remote network monitor
ROM	read-only memory
ROMMON	ROM monitor
RP	route processor or rendezvous point
RPC	remote procedure call

Table A-1 Acronyms (continued)

Acronym	Expansion
RPF	reverse path forwarding
RPR	Route Processor Redundancy
RSPAN	remote SPAN
RST	reset
RSVP	ReSerVation Protocol
SAID	Security Association Identifier
SAP	service access point
SCM	service connection manager
SCP	Switch-Module Configuration Protocol
SDLC	Synchronous Data Link Control
SGBP	Stack Group Bidding Protocol
SIMM	single in-line memory module
SLB	server load balancing
SLCP	Supervisor Line-Card Processor
SLIP	Serial Line Internet Protocol
SMDS	Software Management and Delivery Systems
SMF	software MAC filter
SMP	Standby Monitor Present
SMRP	Simple Multicast Routing Protocol
SMT	Station Management
SNAP	Subnetwork Access Protocol
SNMP	Simple Network Management Protocol
SPAN	Switched Port Analyzer
SSTP	Cisco Shared Spanning Tree
STP	Spanning Tree Protocol
SVC	switched virtual circuit
SVI	switched virtual interface
TACACS+	Terminal Access Controller Access Control System Plus
TARP	Target Identifier Address Resolution Protocol
TCAM	Ternary Content Addressable Memory
TCL	table contention level
TCP/IP	Transmission Control Protocol/Internet Protocol
TFTP	Trivial File Transfer Protocol
TIA	Telecommunications Industry Association
TopN	Utility that allows the user to analyze port traffic by reports
TOS	type of service

Table A-1 Acronyms (continued)

Acronym	Expansion
TLV	type-length-value
TTL	Time To Live
TVX	valid transmission
UDLD	UniDirectional Link Detection Protocol
UDP	User Datagram Protocol
UNI	User-Network Interface
UTC	Coordinated Universal Time
VACL	VLAN access control list
VCC	virtual channel circuit
VCI	virtual circuit identifier
VCR	Virtual Configuration Register
VINES	Virtual Network System
VLAN	virtual LAN
VMPS	VLAN Membership Policy Server
VPN	virtual private network
VRF	VPN routing and forwarding
VTP	VLAN Trunking Protocol
VVID	voice VLAN ID
WFQ	weighted fair queueing
WRED	weighted random early detection
WRR	weighted round-robin
XNS	Xerox Network System

Symbols

Numerics

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V