CHAPTER 2

Basic Switch Concepts and Configuration

Objectives

Upon completion of this chapter, you will be able to answer the following questions:

- What are the principal Ethernet operations pertinent to a 100/1000/10000 Mbps LAN in the IEEE 802.3 standard?
- What are the functions that enable a switch to forward Ethernet frames in a LAN?
- How do you configure a switch for operation in a network designed to support voice, video, and data communication?
- How do you configure basic security on a switch that operates within a network designed to support voice, video, and data communication?

Key Terms

This chapter uses the following key terms. You can find the definitions in the Glossary.

read-only memory (ROM) *page 49*

organizational unique identifier (OUI) *page 49*

half duplex *page 49*

full duplex *page 49*

auto-MDIX *page 51*

floods *page 51*

virtual LAN (VLAN) *page 54*

propagation delay *page 54*

store-and-forward *page 59*

cut-through switching *page 59*

GUI *page 65*

Simple Network Management Protocol (SNMP) *page 65*

non-volatile RAM (NVRAM) *page 71*

Trivial File Transfer Protocol (TFTP) *page 80*

encryption *page 90*

spoof *page 100*

Cisco Discovery Protocol (CDP) *page 101*

In this chapter, you build upon the skills learned in *CCNA Exploration 4.0: Network Fundamentals*, reviewing and reinforcing these skills. You also learn about some key malicious threats to switches and learn to enable a switch with a secure initial configuration.

Introduction to Ethernet/802.3 LANs

In this section, you learn about key components of the Ethernet standard that play a significant role in the design and implementation of switched networks. You explore how Ethernet communications function and how switches play a role in the communication process.

Key Elements of Ethernet/802.3 Networks

Ethernet/802.3 networks rely on carrier sense multiple access/collision detect (CSMA/CD), unicast transmission, broadcast transmission, multicast transmission, duplex settings, switch port settings, and MAC address table management. We next review each of these concepts from *CCNA Exploration 4.0: Networking Fundamentals*.

CSMA/CD

Ethernet signals are transmitted to every host connected to the LAN using a special set of rules to determine which station can access the network. The set of rules that Ethernet uses is based on the IEEE carrier sense multiple access/collision detect (CSMA/CD) technology. Recall that CSMA/CD is used only with half-duplex communication typically found with hubs. Full-duplex ports do not use CSMA/CD.

In the CSMA/CD access method, all network devices that have messages to send must listen before transmitting. If a device detects a signal from another device, it waits for a specified amount of time before attempting to transmit. When there is no traffic detected, a device transmits its message. While this transmission is occurring, the device continues to listen for traffic or collisions on the LAN. After the message is sent, the device returns to its default listening mode.

If the distance between devices is such that the latency of the signals of one device means that signals are not detected by a second device, the second device may also start to transmit. The media now has two devices transmitting signals at the same time. The messages propagate across the media until they encounter each other. At that point, the signals mix and the messages are destroyed, a collision. Although the messages are corrupted, the jumble of remaining signals continues to propagate across the media.

When a device is in listening mode, it can detect when a collision occurs on the shared media because all devices can detect an increase in the amplitude of the signal above the normal level. When a collision occurs, the other devices in listening mode, as well as all the transmitting devices, detect the increase in the signal amplitude. Every device that is transmitting continues to transmit to ensure that all devices on the network detect the collision.

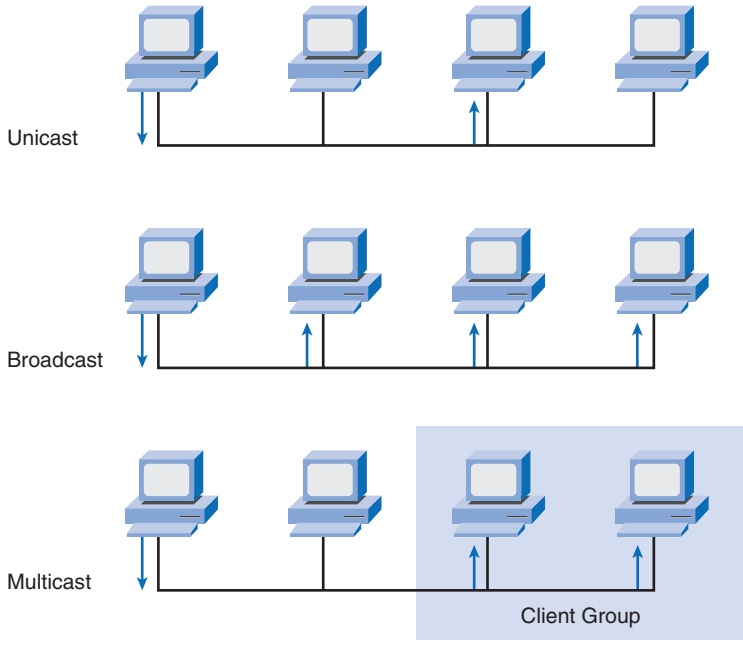
When a collision is detected, the transmitting devices send out a jamming signal. The jamming signal notifies the other devices of a collision so that they invoke a backoff algorithm. This backoff algorithm causes all devices to stop transmitting for a random amount of time, which allows the collision signals to subside.

After the delay has expired on a device, the device goes back into the "listening before transmit" mode. A random backoff period ensures that the devices that were involved in the collision do not try to send traffic again at the same time, which would cause the whole process to repeat. However, during the backoff period, a third device may transmit before either of the two involved in the collision have a chance to retransmit.

Ethernet Communications

Reference Figure 2-1 for the Ethernet communications discussion that follows. Communications in a switched LAN occur in three ways: unicast, broadcast, and multicast.

Figure 2-1 Ethernet Communications



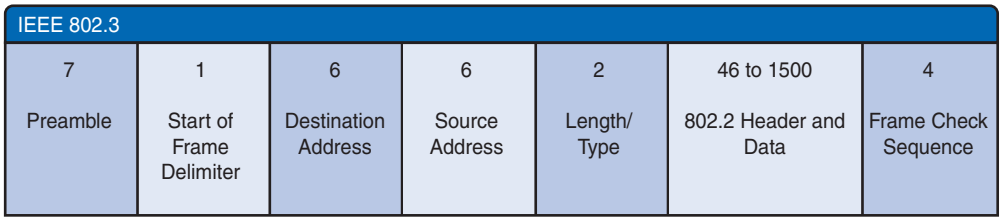
With unicast communication, a frame is sent from one host and addressed to one specific destination. In unicast transmission, there is just one sender and one receiver. Unicast transmission is the predominant form of transmission on LANs and within the Internet. Examples of unicast transmissions include HTTP, SMTP, FTP, and Telnet.

With broadcast communication, a frame is sent from one address to all other addresses. In this case, there is just one sender, but the information is sent to all connected receivers. Broadcast transmission is essential when sending the same message to all devices on the LAN. An example of a broadcast transmission is the address resolution query that the address resolution protocol (ARP) sends to all computers on a LAN.

With multicast communication, a frame is sent to a specific group of devices or clients. Multicast transmission clients must be members of a logical multicast group to receive the information. An example of multicast transmission is the video and voice transmissions associated with a network-based, collaborative business meeting.

To briefly review the Ethernet frame structure, recall that the Ethernet frame adds headers and trailers around the Layer 3 PDU to encapsulate the message being sent. Both the Ethernet header and trailer have several sections (or fields) of information that are used by the Ethernet protocol. Figure 2-2 shows the structure of the current Ethernet frame standard, the revised IEEE 802.3 (Ethernet).

Figure 2-2 Ethernet Frame



The Preamble (7 bytes) and Start Frame Delimiter (SFD) (1 byte) fields are used for synchronization between the sending and receiving devices. These first 8 bytes of the frame are used to get the attention of the receiving nodes. Essentially, the first few bytes tell the receivers to get ready to receive a new frame.

The Destination MAC Address field (6 bytes) is the identifier for the intended recipient. This address is used by Layer 2 to assist a device in determining whether a frame is addressed to it. The address in the frame is compared to the MAC address in the device. If there is a match, the device accepts the frame.

The Source MAC Address field (6 bytes) identifies the frame's originating NIC or interface. Switches use this address to add to their lookup tables.

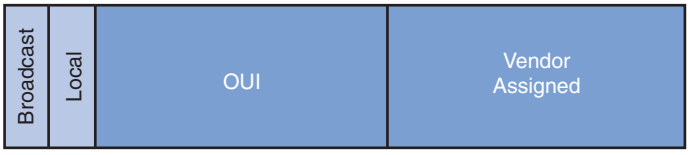
The Length/Type field (2 bytes) defines the exact length of the frame's data field. This field is used later as part of the Frame Check Sequence (FCS) to ensure that the message was received properly. Only a frame length or a frame type can be entered here. If the purpose of the field is to designate a type, the Type field describes which protocol is implemented. When a node receives a frame and the Length/Type field designates a type, the node determines which higher layer protocol is present. If the two-octet value is equal to or greater than 0x0600 hexadecimal or 1536 decimal, the contents of the Data Field are decoded according to the protocol indicated; if the two-byte value is less than 0x0600, the value represents the length of the data in the frame.

The Data and Pad fields (46 to 1500 bytes) contain the encapsulated data from a higher layer, which is a generic Layer 3 PDU, or more commonly, an IPv4 packet. All frames must be at least 64 bytes long (minimum length aides the detection of collisions). If a small packet is encapsulated, the Pad field is used to increase the size of the frame to the minimum size.

The FCS field (4 bytes) detects errors in a frame. It uses a cyclic redundancy check (CRC). The sending device includes the results of a CRC in the FCS field of the frame. The receiving device receives the frame and generates a CRC to look for errors. If the calculations match, no error has occurred. If the calculations do not match, the frame is dropped.

An Ethernet MAC address is a two-part 48-bit binary value expressed as 12 hexadecimal digits. The address formats might be similar to 00-05-9A-3C-78-00, 00:05:9A:3C:78:00, or 0005.9A3C.7800. All devices connected to an Ethernet LAN have MAC-addressed interfaces. The NIC uses the MAC address to determine whether a message should be passed to the upper layers for processing. The MAC address is permanently encoded into a ***read-only memory (ROM)*** chip on a NIC. This type of MAC address is referred to as a burned-in address (BIA). Some vendors allow local modification of the MAC address. The MAC address is made up of the ***organizational unique identifier (OUI)*** and the vendor assignment number. The OUI is the first part of a MAC address. It is 24 bits long and identifies the manufacturer of the NIC card. The IEEE regulates the assignment of OUI numbers. Within the OUI are 2 bits that have meaning only when used in the destination address, the broadcast or multicast bit and the locally administered address bit, shown in Figure 2-3.

Figure 2-3 OUI Composition



The broadcast or multicast bit in a MAC address indicates to the receiving interface that the frame is destined for all or a group of end stations on the LAN segment.

The locally administered address bit indicates whether the vendor-assigned MAC address can be modified locally.

The vendor-assigned part of the MAC address is 24 bits long and uniquely identifies the Ethernet hardware. It can be a BIA or it can be modified by software indicated by the local bit.

Duplex Settings

There are two types of duplex settings used for communications on an Ethernet network: ***half duplex*** and ***full duplex***.

Half-duplex communication relies on unidirectional data flow where sending and receiving data are not performed at the same time. This is similar to how walkie-talkies or two-way radios function in that only one person can talk at any one time. If someone talks while someone else is already speaking, a collision occurs. As a result, half-duplex communication implements CSMA/CD to help reduce the potential for collisions and detect them when they do happen. Half-duplex communications have performance issues due to the constant waiting, because data can flow in only one direction at a time. Half-duplex connections are typically found in older hardware, such as hubs. Nodes that are attached to hubs that share

their connection to a switch port must operate in half-duplex mode because the end computers must be able to detect collisions. Nodes can operate in a half-duplex mode if the NIC card cannot be configured for full-duplex operations. In this case, the port on the switch defaults to a half-duplex mode as well. Because of these limitations, full-duplex communication has replaced half-duplex in more current hardware.

In full-duplex communication, data flow is bidirectional, so data can be sent and received at the same time. The bidirectional support enhances performance by reducing the wait time between transmissions. Most Ethernet, Fast Ethernet, and Gigabit Ethernet NICs sold today offer full-duplex capability. In full-duplex mode, the collision-detect circuit is disabled. Frames sent by the two connected end nodes cannot collide because the end nodes use two separate circuits in the network cable. Each full-duplex connection uses only one port. Full-duplex connections require a switch that supports full duplex or a direct connection between two nodes that each support full duplex. Nodes that are directly attached to a dedicated switch port with NICs that support full duplex should be connected to switch ports that are configured to operate in full-duplex mode.

Standard, shared hub-based Ethernet configuration efficiency is typically rated at 50 to 60 percent of the 10 Mbps bandwidth. Full-duplex Fast Ethernet, compared to 10 Mbps bandwidth, offers 100 percent efficiency in both directions (100 Mbps transmit and 100 Mbps receive).

Switch Port Settings

A port on a switch needs to be configured with duplex settings that match the media type. Later in this chapter, you will configure duplex settings. The Cisco Catalyst switches have three settings:

- The **auto** option sets autonegotiation of duplex mode. With autonegotiation enabled, the two ports communicate to decide the best mode of operation.
- The **full** option sets full-duplex mode.
- The **half** option sets half-duplex mode.

For Fast Ethernet and 10/100/1000 ports, the default is auto. For 100BASE-FX ports, the default is full. The 10/100/1000 ports operate in either half- or full-duplex mode when they are set to 10 or 100 Mbps, but when set to 1,000 Mbps, they operate only in full-duplex mode.

Note

Autonegotiation can produce unpredictable results. By default, when autonegotiation fails, the Catalyst switch sets the corresponding switch port to half-duplex mode. This type of failure happens when an attached device does not support autonegotiation. If the device is manually configured to operate in half-duplex mode, it matches the default mode of the switch. However, autonegotiation errors can happen if the device is manually configured to operate in full-duplex mode. Having half-duplex on one end and full-duplex on the other causes late collision errors at the half-duplex end. To avoid this situation, manually set the duplex parameters of the switch to match the attached device. If the switch port is in full-duplex mode and the attached device is in half-duplex mode, check for FCS errors on the switch full-duplex port.

Additionally, you used to be required to use certain cable types (crossover, straight-through) when connecting between specific devices, switch-to-switch or switch-to-router. Instead, you can now use the **mdix auto** interface configuration command in the CLI to enable the automatic medium-dependent interface crossover ***auto-MDIX*** feature.

When the auto-MDIX feature is enabled, the switch detects the required cable type for copper Ethernet connections and configures the interfaces accordingly. Therefore, you can use either a crossover or a straight-through cable for connections to a copper 10/100/1000 port on the switch, regardless of the type of device on the other end of the connection.

The auto-MDIX feature is enabled by default on switches running Cisco IOS Release 12.2(18)SE or later. For releases between Cisco IOS Release 12.1(14)EA1 and 12.2(18)SE, the auto-MDIX feature is disabled by default. It is enabled by default on Catalyst 2960 and 3560 switches, but is not available as an option on Catalyst 2950 and 3550 switches.

Switch MAC Address Table

Switches use MAC addresses to direct network communications through their switch fabric to the appropriate port toward the destination node. The switch fabric is the integrated circuits and the accompanying machine programming that allows the data paths through the switch to be controlled. For a switch to know which port to use to transmit a unicast frame, it must first learn which nodes exist on each of its ports.

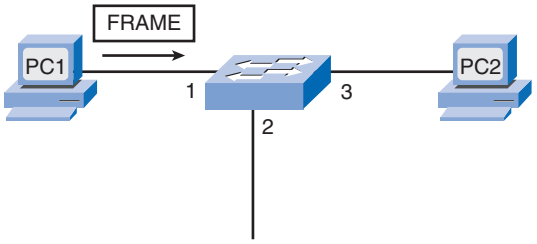
A switch determines how to handle incoming data frames by using its MAC address table. A switch builds its MAC address table by recording the MAC addresses of the nodes connected to each of its ports. After a MAC address for a specific node on a specific port is recorded in the address table, the switch then knows to send traffic destined for that specific node out the port mapped to that node for subsequent transmissions.

When an incoming data frame is received by a switch and the destination MAC address is not in the table, the switch forwards the frame out all ports, except for the port on which it was received. When the destination node responds, the switch records the node's MAC address in the address table from the frame's source address field. In networks with multiple interconnected switches, the MAC address tables record multiple MAC addresses for the ports connecting the switches that reflect the nodes beyond. Typically, switch ports used to interconnect two switches have multiple MAC addresses recorded in the MAC address table.

The following six steps describe the process used to populate the MAC address table on a switch:

1. The switch receives a broadcast frame from PC1 on Port 1, as seen in Figure 2-4.
2. The switch enters the source MAC address and the switch port that received the frame into the address table.
3. Because the destination address is a broadcast, the switch ***floods*** the frame to all ports, except the port on which it received the frame.

Figure 2-4 MAC Address Table Population



4. The destination device replies to the broadcast with a unicast frame addressed to PC1.
5. The switch enters the source MAC address of PC2 and the port number of the switch port that received the frame into the address table. The destination address of the frame and its associated port are found in the MAC address table.
6. The switch can now forward frames between source and destination devices without flooding, because it has entries in the address table that identify the associated ports.

Design Considerations for Ethernet/802.3 Networks

In this section, you learn about Ethernet design guidelines for hierarchical networks in small and medium-sized businesses. This section focuses on broadcast and collision domains and how they affect LAN designs.

Bandwidth and Throughput

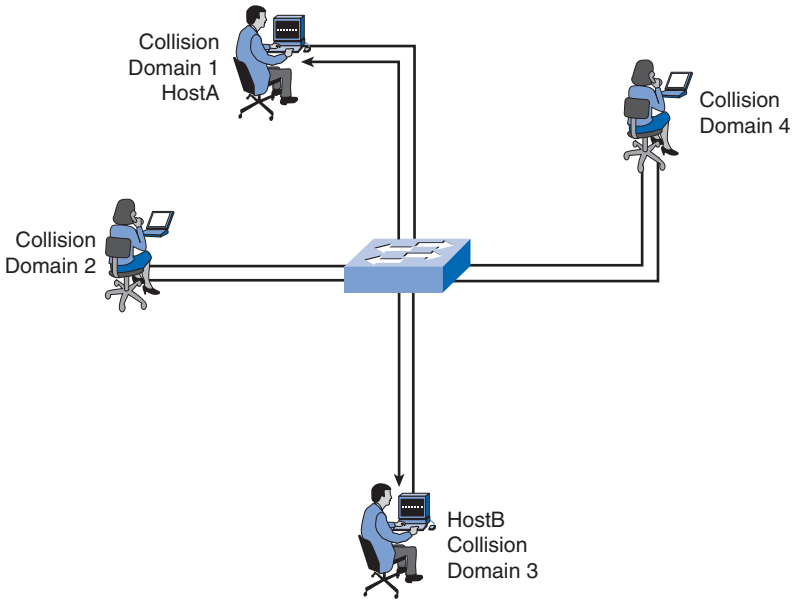
A major disadvantage of Ethernet 802.3 networks is collisions. Collisions occur when two hosts transmit frames simultaneously. When a collision occurs, the transmitted frames are corrupted or destroyed. The sending hosts stop sending further transmissions for a random period, based on the Ethernet 802.3 rules of CSMA/CD.

Because Ethernet has no way of controlling which node will be transmitting at any time, we know that collisions will occur when more than one node attempts to gain access to the network. Ethernet's resolution for collisions does not occur instantaneously. Also, a node involved in a collision cannot start transmitting until the matter is resolved. As more devices are added to the shared media, the likelihood of collisions increases. Because of this, it is important to understand that when stating that the bandwidth of the Ethernet network is 10 Mbps, full bandwidth for transmission is available only after any collisions have been resolved. The net throughput of the port (the average data that is effectively transmitted) will be considerably reduced as a function of how many other nodes want to use the network. A hub offers no mechanisms to either eliminate or reduce these collisions, and the available bandwidth that any one node has to transmit is correspondingly reduced. As a result, the number of nodes sharing the Ethernet network will have an effect on the throughput or productivity of the network.

Collision Domains

When expanding an Ethernet LAN to accommodate more users with more bandwidth requirements, the potential for collisions increases. To reduce the number of nodes on a given network segment, you can create separate physical network segments, called collision domains, as shown in Figure 2-5.

Figure 2-5 Collision Domains



The network area where frames originate and collide is called the collision domain. All shared media environments, such as those created by using hubs, are collision domains. When a host is connected to a switch port, the switch creates a dedicated connection. This connection is considered an individual collision domain because traffic is kept separate from all other traffic, thereby eliminating the potential for a collision. The figure shows unique collision domains in a switched environment. For example, if a 12-port switch has a device connected to each port, 12 collision domains are created.

As you now know, a switch builds a MAC address table by learning the MAC addresses of the hosts that are connected to each switch port. When two connected hosts want to communicate with each other, the switch uses the switching table to establish a connection between the ports. The circuit is maintained until the session is terminated. In Figure 2-5, HostA and HostB want to communicate with each other. The switch creates the connection

that is referred to as a microsegment. The microsegment behaves as if the network has only two hosts, one host sending and one receiving, providing maximum utilization of the available bandwidth.

Switches reduce collisions and improve bandwidth use on network segments because they provide dedicated bandwidth to each network segment.

Broadcast Domains

Although switches filter most frames based on MAC addresses, they do not filter broadcast frames. A collection of interconnected switches forms a single broadcast domain. Only a Layer 3 entity, such as a router, or a ***virtual LAN (VLAN)***, can bound a Layer 2 broadcast domain. Routers and VLANs are used to segment both collision and broadcast domains. The use of VLANs to segment broadcast domains is discussed in the next chapter.

When a device sends out a Layer 2 broadcast, the destination MAC address in the frame is set to all ones. By setting the destination to this value, all the devices accept and process the broadcasted frame.

The broadcast domain at Layer 2 is referred to as the MAC broadcast domain. The MAC broadcast domain consists of all devices on the LAN that receive frame broadcasts by a host on the LAN.

When a switch receives a broadcast frame, it forwards the frame to each of its ports, except the incoming port where the switch received the broadcast frame. Each attached device recognizes the broadcast frame and processes it. This leads to reduced network efficiency because a portion of the available bandwidth is utilized in propagating the broadcast traffic. When two switches are connected, the broadcast domain is increased.

Network Latency

Latency is the time that a frame or a packet takes to travel from the source to the destination. Users of network-based applications experience latency when they have to wait many minutes to access data stored in a data center or when a website takes many minutes to load in a browser. Latency has at least three sources.

First is the time it takes the source NIC to place voltage pulses on the wire and the time it takes the destination NIC to interpret these pulses. This is sometimes called NIC delay.

Second is the actual ***propagation delay*** as the signal takes time to travel through the cable. Typically, this is about 0.556 microseconds per 100 m for Cat 5 UTP. Longer cable and slower nominal velocity of propagation (NVP) result in more propagation delay.

Third, latency is added based on network devices that are in the path between two devices. These are either Layer 1, Layer 2, or Layer 3 devices.

Latency does not depend solely on distance and number of devices. For example, if three properly configured switches separate two computers, the computers may experience less

latency than if two properly configured routers separated them. This is because routers conduct more complex and time-intensive operations. For example, a router must analyze Layer 3 data, whereas switches just analyze the Layer 2 data. Because Layer 2 data is present earlier in the frame structure than the Layer 3 data, switches can process the frame more quickly. Switches also support the high transmission rates of voice, video, and data networks by employing application-specific integrated circuits (ASIC) to provide hardware support for many networking tasks. Additional switch features such as port-based memory buffering, port level QoS, and congestion management, also help to reduce network latency.

Switch-based latency may also be due to an oversubscribed switch fabric. Many entry level switches do not have enough internal throughput to manage full bandwidth capabilities on all ports simultaneously. The switch needs to be able to manage the amount of peak data expected on the network. As the switching technology improves, the latency through the switch is no longer the issue. The predominant cause of network latency in a switched LAN is more a function of the media, the routing protocols used, and the types of applications running on the network.

Network Congestion

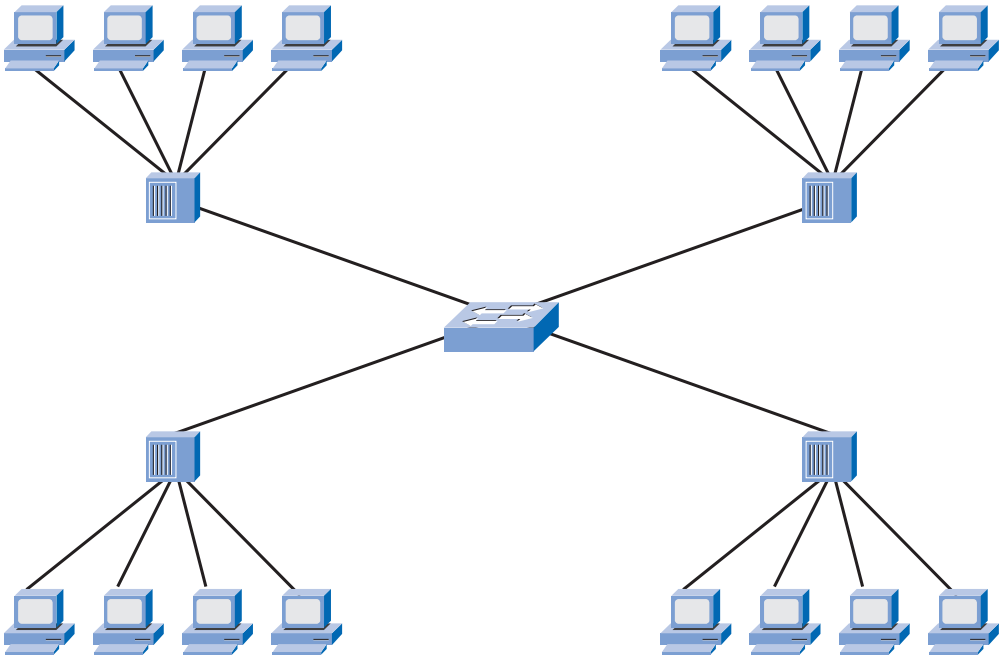
The primary reason for segmenting a LAN into smaller parts is to isolate traffic and to achieve better use of bandwidth per user. Without segmentation, a LAN quickly becomes clogged with traffic and collisions. The most common causes of network congestion are the following:

- **Increasingly powerful computer and network technologies:** Today, CPUs, buses, and peripherals are much faster and more powerful than those used in early LANs; therefore, they can send more data at higher rates through the network, and they can process more data at higher rates.
- **Increasing volume of network traffic:** Network traffic is now more common because remote resources are necessary to carry out basic work. Additionally, broadcast messages, such as address resolution queries sent out by ARP, can adversely affect end-station and network performance.
- **High-bandwidth applications:** Software applications are becoming richer in their functionality and are requiring more and more bandwidth. Desktop publishing, engineering design, video on demand (VoD), electronic learning (e-learning), and streaming video all require considerable processing power and speed.

LAN Segmentation

LANs are segmented into a number of smaller collision and broadcast domains using routers and switches. Previously, bridges were used, but this type of network equipment is rarely seen in a modern switched LAN. Figure 2-6 shows a switch segmenting a LAN into four collision domains.

Figure 2-6 Legacy LAN Segmentation



The broadcast domain in Figure 2-6 spans the entire network.

Although bridges and switches share many attributes, several distinctions differentiate these technologies. Bridges are generally used to segment a LAN into a couple of smaller segments. Switches are generally used to segment a large LAN into many smaller segments. Bridges have only a few ports for LAN connectivity, whereas switches have many.

Even though the LAN switch reduces the size of collision domains, all hosts connected to the switch are still in the same broadcast domain. Because routers do not forward broadcast traffic by default, they can be used to create broadcast domains. Creating additional, smaller broadcast domains with a router, as in Figure 2-7, reduces broadcast traffic and provides more available bandwidth for unicast communications. Each router interface connects to a separate network containing broadcast traffic within the LAN segment in which it originated.

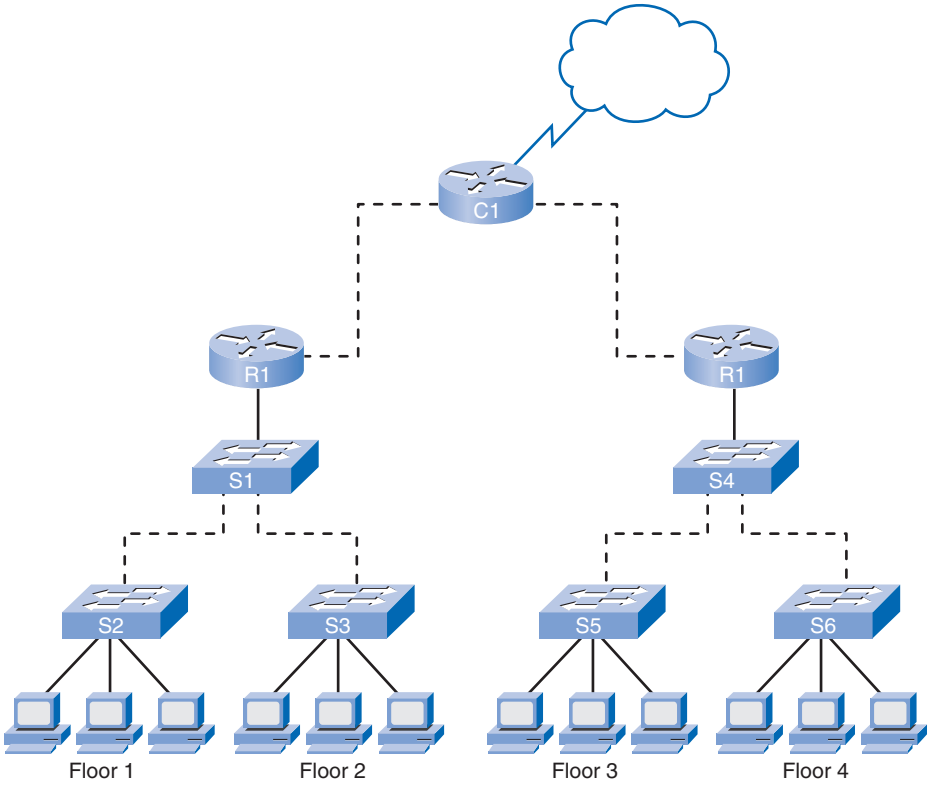
LAN Design Considerations

There are two primary considerations when designing a LAN: controlling network latency and removing bottlenecks.

When designing a network to reduce latency, you need to consider the latency caused by each device on the network. Switches can introduce latency on a network when oversubscribed on a busy network. For example, if a core level switch has to support 48 ports, each one capable of running at 1000 Mbps full duplex, the switch should support around 96

Gbps internal throughput if it is to maintain full wire speed across all ports simultaneously. In this example, the throughput requirements stated are typical of core-level switches, not of access-level switches.

Figure 2-7 Modern LAN Segmentation



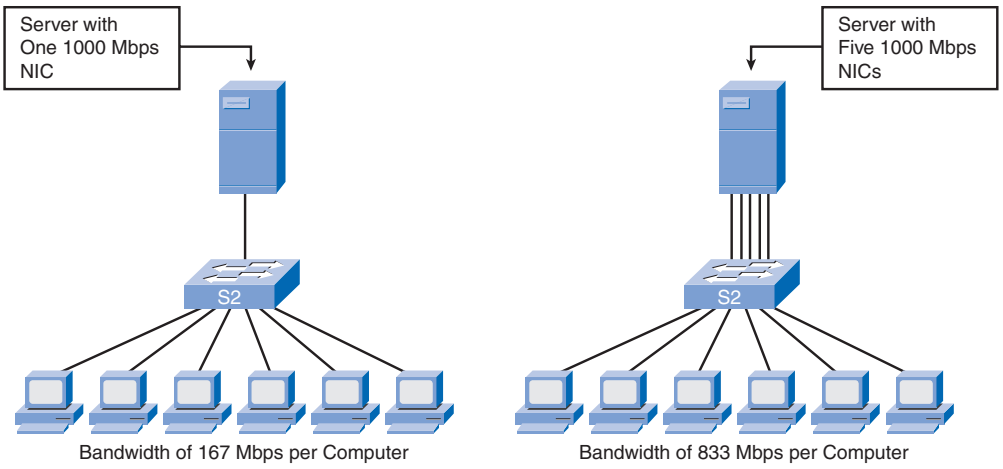
The use of higher layer devices can also increase latency on a network. When a Layer 3 device, such as a router, needs to examine the Layer 3 addressing information contained within the frame, it must read further into the frame than a Layer 2 device, which creates a longer processing time. Limiting the use of higher layer devices can help reduce network latency. However, appropriate use of Layer 3 devices helps prevent contention from broadcast traffic in a large broadcast domain or the high collision rate in a large collision domain.

The second LAN design consideration is bottlenecks in a network. Bottlenecks are places where high network congestion results in slow performance.

Figure 2-8 shows six computers connected to a switch; a single server is also connected to the same switch. Each workstation and the server are all connected using a 1000 Mbps NIC. What happens when all six computers try to access the server at the same time? Does each workstation get 1000 Mbps dedicated access to the server? No, all the computers have to share the 1000 Mbps connection that the server has to the switch. Cumulatively, the computers are capable of 6000 Mbps to the switch. If each connection was used at full capacity,

each computer would be able to use only 167 Mbps, one-sixth of the 1000 Mbps bandwidth. To reduce the bottleneck to the server, additional network cards can be installed, which increases the total bandwidth the server is capable of receiving. Figure 2-8 shows five NIC cards in the server and approximately five times the bandwidth. The same logic applies to network topologies. When switches with multiple nodes are interconnected by a single 1000 Mbps connection, a bottleneck is created at this single interconnect.

Figure 2-8 Network Bottlenecks



Higher capacity links (for example, upgrading from 100 Mbps to 1000 Mbps connections) and using multiple links leveraging link aggregation technologies (for example, combining two links as if they were one to double a connection's capacity) can help to reduce the bottlenecks created by interswitch links and router links. Although configuring link aggregation is outside the scope of this book, it is important to consider a device's capabilities when assessing a network's needs. How many ports and of what speed is the device capable? What is the internal throughput of the device? Can it handle the anticipated traffic loads considering its placement in the network?

Forwarding Frames Using a Switch

In this section, you learn methods that switches use to forward Ethernet frames on a network, what asymmetric switching is, how switches utilize memory buffering, and what Layer 3 switching means. Switches can operate in different modes that can have both positive or negative effects. Modern switches use asymmetric switching. Switches can use port-based or shared memory buffering. Distribution and core layer switches are capable of Layer 3 (and higher) switching.

Switch Forwarding Methods

In the past, switches used one of the following forwarding methods for switching data between network ports: ***store-and-forward*** or ***cut-through switching***. However, store-and-forward is the sole forwarding method used on current models of Cisco Catalyst switches.

In store-and-forward switching, when the switch receives the frame, it stores the data in buffers until the complete frame has been received. During the storage process, the switch analyzes the frame for information about its destination. In this process, the switch also performs an error check using the cyclic redundancy check trailer portion of the Ethernet frame.

CRC uses a mathematical formula, based on the number of 1 bits in the frame, to determine whether the received frame has an error. After confirming the integrity of the frame, the frame is forwarded out the appropriate port toward its destination. When an error is detected in a frame, the switch discards the frame. Discarding frames with errors reduces the amount of bandwidth consumed by corrupt data. Store-and-forward switching is required for quality of service (QoS) analysis on converged networks where frame classification for traffic prioritization is necessary. For example, voice-over-IP data streams need to have priority over web-browsing traffic.

In cut-through switching, the switch acts upon the data as soon as it is received, even if the transmission is not complete. The switch buffers just enough of the frame to read the destination MAC address so that it can determine which port to forward the data to. The destination MAC address is located in the first 6 bytes of the frame following the preamble. The switch looks up the destination MAC address in its switching table, determines the outgoing interface port, and forwards the frame onto its destination through the designated switch port. The switch does not perform any error checking on the frame. Because the switch does not have to wait for the entire frame to be completely buffered, and because the switch does not perform any error checking, cut-through switching is faster than store-and-forward switching. However, because the switch does not perform any error checking, it forwards corrupt frames through the network. The corrupt frames consume bandwidth while they are being forwarded. The destination NIC eventually discards the corrupt frames.

There are two variants of cut-through switching:

- **Fast-forward switching:** Fast-forward switching offers the lowest level of latency. Fast-forward switching immediately forwards a packet after reading the destination address. Because fast-forward switching starts forwarding before the entire packet has been received, there may be times when packets are relayed with errors. This occurs infrequently, and the destination network adapter discards the faulty packet upon receipt. In fast-forward mode, latency is measured from the first bit received to the first bit transmitted. Fast-forward switching is the typical cut-through method of switching.
- **Fragment-free switching:** In fragment-free switching, the switch stores the first 64 bytes of the frame before forwarding. Fragment-free switching can be viewed as a

compromise between store-and-forward switching and cut-through switching. The reason fragment-free switching stores only the first 64 bytes of the frame is that most network errors and collisions occur during the first 64 bytes. Fragment-free switching tries to enhance cut-through switching by performing a small error check on the first 64 bytes of the frame to ensure that a collision has not occurred before forwarding the frame. Fragment-free switching is a compromise between the high latency and high integrity of store-and-forward switching and the low latency and reduced integrity of cut-through switching.

Some switches are configured to perform cut-through switching on a per-port basis until a user-defined error threshold is reached, and then they automatically change to store-and-forward. When the error rate falls below the threshold, the port automatically changes back to cut-through switching.

Symmetric and Asymmetric Switching

LAN switching may be classified as symmetric or asymmetric based on the way in which bandwidth is allocated to the switch ports.

Symmetric switching provides switched connections between ports with the same bandwidth, such as all 100 Mbps ports or all 1 Gbps ports. An asymmetric LAN switch provides switched connections between ports of unlike bandwidth, such as a combination of 100 Mbps and 1 Gbps ports. Figure 2-9 contrasts symmetric and asymmetric switching.

Asymmetric switching enables more bandwidth to be dedicated to a server switch port to prevent a bottleneck. This allows smoother traffic flows where multiple clients are communicating with a server at the same time. Memory buffering is required on an asymmetric switch. For the switch to match the different data rates on different ports, entire frames are kept in the memory buffer and are moved to the port one after the other as required.

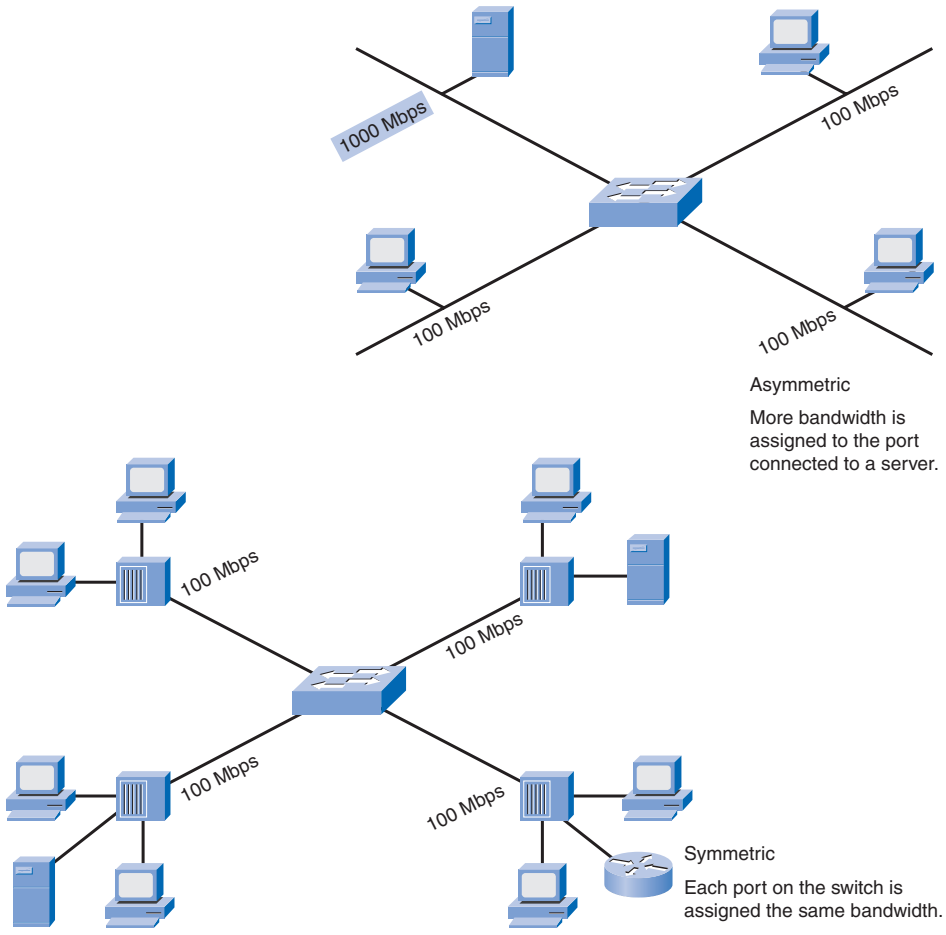
On a symmetric switch, all ports are of the same bandwidth. Symmetric switching is optimized for a reasonably distributed traffic load, such as in a peer-to-peer desktop environment.

A network manager must evaluate the needed amount of bandwidth for connections between devices to accommodate the data flow of network-based applications. Almost all recent Cisco Catalyst switches are asymmetric switches.

Memory Buffering

A switch analyzes some or all of a packet before it forwards it to the destination host based on the forwarding method. The switch stores the packet for the brief time in a memory buffer. In this section, you learn how two types of memory buffers are used during switch forwarding.

Figure 2-9 Symmetric Versus Asymmetric Switching



An Ethernet switch may use a buffering technique to store frames before forwarding them. Buffering may also be used when the destination port is busy due to congestion and the switch stores the frame until it can be transmitted. The use of memory to store the data is called memory buffering. Memory buffering is built in to the hardware of the switch and, other than increasing the amount of memory available, is not configurable.

There are two methods of memory buffering: port-based and shared memory.

In port-based memory buffering, frames are stored in queues that are linked to specific incoming ports. A frame is transmitted to the outgoing port only when all the frames ahead of it in the queue have been successfully transmitted. It is possible for a single frame to delay the transmission of all the frames in memory because of a busy destination port. This delay occurs even if the other frames could be transmitted to open destination ports.

Shared memory buffering deposits all frames into a common memory buffer that all the ports on the switch share. The amount of buffer memory required by a port is dynamically allocated. The frames in the buffer are linked dynamically to the destination port. This allows the packet to be received on one port and then transmitted on another port, without moving it to a different queue.

The switch keeps a map of frame-to-port links showing where a packet needs to be transmitted. The map link is cleared after the frame has been successfully transmitted. The number of frames stored in the buffer is restricted by the size of the entire memory buffer and is not limited to a single port buffer. This permits larger frames to be transmitted with fewer dropped frames. This is important to asymmetric switching, where frames are being exchanged between different rate ports.

Layer 2 and Layer 3 Switching

In this section, you review the concept of Layer 2 switching and learn about Layer 3 switching.

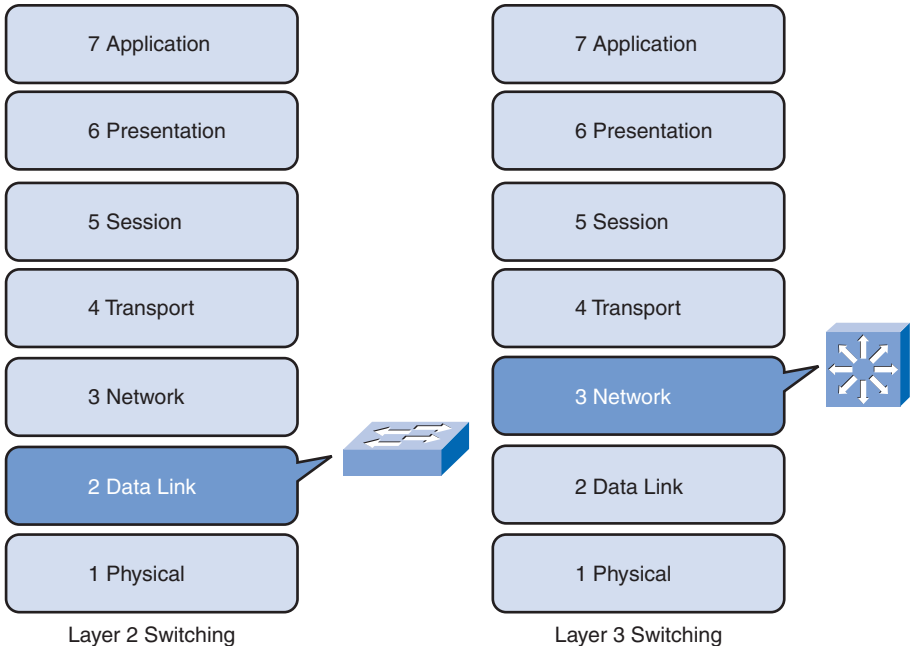
A Layer 2 LAN switch performs switching and filtering based only on the OSI data link layer (Layer 2) MAC address. A Layer 2 switch is completely transparent to network protocols and user applications. Recall that a Layer 2 switch builds a MAC address table that it uses to make forwarding decisions.

A Layer 3 switch, such as a Catalyst 3560 with an IP Services image, functions similarly to a Layer 2 switch, such as a Catalyst 2960, but instead of using only the Layer 2 MAC address information for forwarding decisions, a Layer 3 switch can also use IP address information. Figure 2-10 illustrates the icons reserved for Layer 2 and Layer 3 switches. Instead of learning only which MAC addresses are associated with each of its ports, a Layer 3 switch can also learn which IP addresses are associated with its interfaces. This allows the Layer 3 switch to direct traffic throughout the network based on IP address information.

Layer 3 switches are also capable of performing Layer 3 routing functions, reducing the need for dedicated routers on a LAN. Because Layer 3 switches have specialized switching hardware, they can typically route data as quickly as they can switch data.

It should be emphasized that Layer 3 switches do not completely replace the need for routers on a network. Routers perform additional Layer 3 services that Layer 3 switches are not capable of performing. Routers are also capable of performing packet-forwarding tasks not found on Layer 3 switches, such as establishing remote access connections to remote networks and devices. Dedicated routers are more flexible in their support of WAN interface cards (WIC), making them the preferred, and sometimes only, choice for connecting to a WAN. Layer 3 switches can provide basic routing functions in a LAN and reduce the need for dedicated routers.

Figure 2-10 Layer 2 and Layer 3 Switching



Switch Management Configuration

In this section, you review what you learned in *CCNA Exploration: Network Fundamentals* about how to navigate the various command-line interface modes. Despite the steady migration toward web-based graphical user interfaces as a means of device configuration, Cisco routers and switches are still primarily configured by entering commands in the command-line interface. Catalyst switch administration commonly includes management interface and default gateway configuration, speed and duplex configuration, HTTP access, MAC address table management, and configuration file management.

Navigating Command-Line Interface Modes

As a security feature, Cisco IOS Software separated the EXEC sessions into two access levels:

- **User EXEC:** Allows a person to access only a limited number of basic monitoring commands. User EXEC mode is the default mode you enter after logging in to a Cisco switch from the CLI. User EXEC mode is identified by the > prompt.
- **Privileged EXEC:** Allows a person to access all device commands, such as those used for configuration and management, and can be password-protected to allow only authorized users to access the device. Privileged EXEC mode is identified by the # prompt.

To change from user EXEC mode to privileged EXEC mode, enter the **enable** command. To change from privileged EXEC mode to user EXEC mode, enter the **disable** command. On a production network, the switch prompts for the password. Enter the correct password. By default, the password is not configured. Table 2-1 shows the Cisco IOS commands used to navigate from user EXEC mode to privileged EXEC mode and back again.

Table 2-1 Navigating Between User EXEC Mode and Privileged EXEC Mode

Description	CLI
Switch from user EXEC to privileged EXEC mode.	`switch> enable`
If a password has been set for privileged EXEC mode, you are prompted to enter it now.	`Password:<password>`
The # prompt signifies privileged EXEC mode.	`switch#`
Switch from privileged EXEC to user EXEC mode.	`switch# disable`
The > prompt signifies user EXEC mode.	`switch>`

After you have entered privileged EXEC mode on the Cisco switch, you can access other configuration modes. Cisco IOS Software uses a hierarchy of commands in its command-mode structure. Each command mode supports specific Cisco IOS commands related to a type of operation on the device.

There are many configuration modes. For now, you will explore how to navigate two common configuration modes: global configuration mode and interface configuration mode.

The example in Table 2-2 starts with the switch in privileged EXEC mode. To configure global switch parameters such as the switch hostname or the switch IP address used for switch management purposes, use global configuration mode. To access global configuration mode, enter the **configure terminal** command in privileged EXEC mode. The prompt changes to (config)#.

Table 2-2 Navigating to and from Global Configuration Mode and Interface Configuration Mode

Description	CLI
Switch from privileged EXEC mode to global configuration mode.	`switch# configure terminal`
The (config)# prompt signifies that the switch is in global configuration mode.	`switch(config)#`
Switch from global configuration mode to interface configuration mode for Fast Ethernet interface 0/1.	`switch(config)# interface fastethernet 0/1`

Table 2-2 Navigating to and from Global Configuration Mode and Interface Configuration Mode *continued*

Description	CLI
The (config-if)# prompt signifies that the switch is in the interface configuration mode.	`switch(config-if)#`
Switch from interface configuration mode to global configuration mode.	`switch(config-if)#` **`exit`**
The (config)# prompt signifies that the switch is in global configuration mode.	`switch(config)#`
Switch from global configuration mode to privileged EXEC mode.	`switch(config)#` **`exit`**
The # prompt signifies that the switch is in privileged EXEC mode.	`switch#`

Configuring interface-specific parameters is a common task. To access interface configuration mode from global configuration mode, enter the **interface** *interface-name* command. The prompt changes to (config-if)#. To exit interface configuration mode, use the **exit** command. The prompt switches back to (config)#, letting you know that you are in global configuration mode. To exit global configuration mode, enter the **exit** command again. The prompt switches to #, signifying privileged EXEC mode.

GUI-Based Alternatives to the CLI

Now we look at some graphical management alternatives for managing a Cisco switch. Using a ***GUI*** offers simplified switch management and configuration without in-depth knowledge of the Cisco CLI.

Cisco Network Assistant, shown in Figure 2-11, is a PC-based GUI network management application optimized for small- and medium-sized LANs. You can configure and manage groups of switches or standalone switches. The figure shows the management interface for Network Assistant. Cisco Network Assistant is available at no cost and can be downloaded from Cisco (CCO username/password required) at www.cisco.com/go/networkassistant.

The CiscoView device-management application displays a physical view of the switch that you can use to set configuration parameters and to view switch status and performance information. The CiscoView application, purchased separately, can be a standalone application or part of a ***Simple Network Management Protocol (SNMP)*** platform. Figure 2-12 shows the management interface for the CiscoView Device Manager. Learn more about CiscoView Device Manager at www.cisco.com/en/US/products/sw/cscowork/ps4565/prod_bulletin0900aecd802948b0.html.

Figure 2-11 Cisco Network Assistant

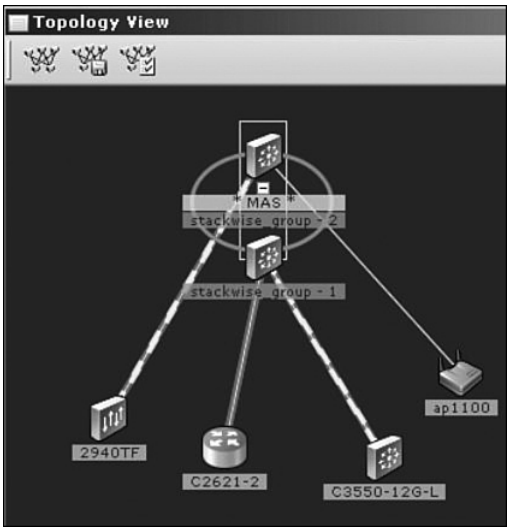
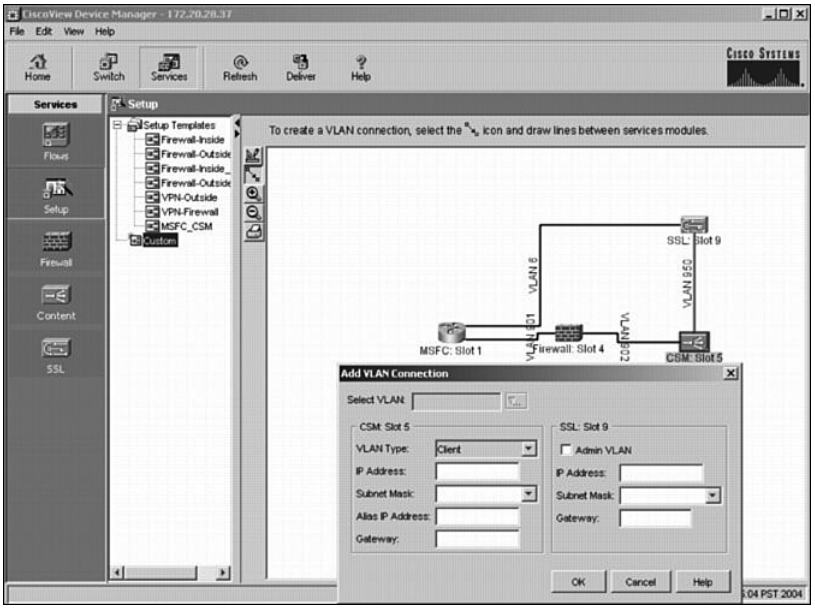
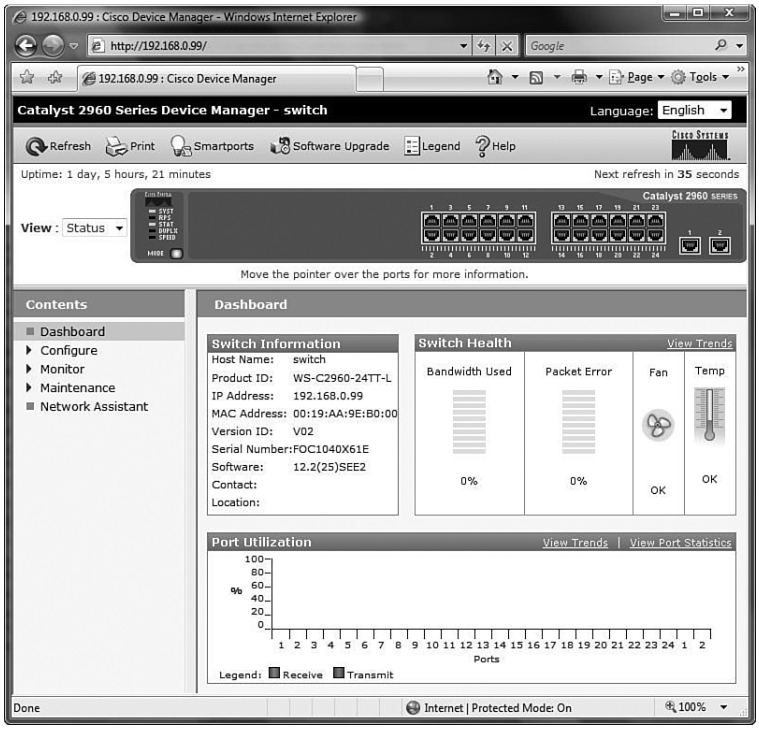


Figure 2-12 CiscoView



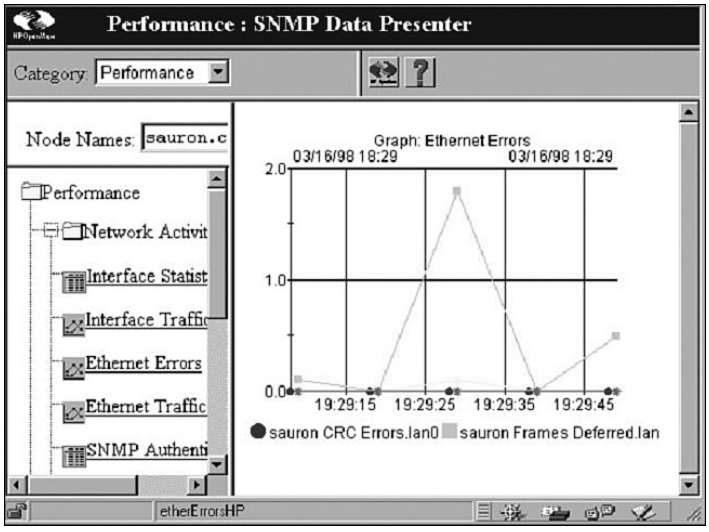
Cisco Device Manager, shown in Figure 2-13, is web-based software that is stored in the switch memory. You can use Device Manager to configure and manage switches. You can access Device Manager from anywhere in your network through a web browser. The figure shows the management interface.

Figure 2-13 Cisco Device Manager



You can manage switches from an SNMP-compatible management station, such as HP OpenView, shown in Figure 2-14.

Figure 2-14 HP OpenView



The switch is able to provide comprehensive management information and provide four remote monitoring (RMON) groups. SNMP network management is more common in large enterprise networks.

Learn more about HP OpenView at h20229.www2.hp.com/news/about/index.html.

Using the Help Facility

The Cisco IOS CLI offers two types of help:

- **Word help:** If you do not remember an entire command but do remember the first few characters, enter the character sequence followed by a question mark (**?**). Do not include a space before the question mark. A list of commands that start with the characters that you entered is displayed. For example, entering **sh?** returns a list of all commands that begin with the **sh** character sequence.
- **Command syntax help:** If you are unfamiliar with which commands are available in your current context within the Cisco IOS CLI, or if you do not know the parameters required or available to complete a given command, enter the **?** command. When only **?** is entered, a list of all available commands in the current context is displayed. If the **?** command is entered after a specific command, the command arguments are displayed. If <cr> is displayed, no other arguments are needed to make the command function. Make sure to include a space before the question mark to prevent the Cisco IOS CLI from performing word help rather than command syntax help. For example, enter **show ?** to get a list of the command options supported by the **show** command.

Table 2-3 shows examples of Cisco help functions.

Table 2-3 Context-Sensitive Help

Context	CLI
Example of command prompting. In this example, the help function provides a list of commands available in the current mode that start with **cl**.	`switch# cl?` `clear  clock`
Example of incomplete command.	`Switch# clock` `% Incomplete command.`
Example of symbolic translation.	`switch# clock % Unknown command or computer name, or unable to find computer address`

Context	CLI
Example of command prompting. Notice the space. In this example, the help function provides a list of subcommands associated with the **clock** command.	`Switch# clock ?` `set Set the time and date`
In this example, the help function provides a list of command arguments required with the **clock set** command.	`switch# clock set ?` `hh:mm:ss Current Time`

Using the example of setting the device clock, let's see how CLI help works. If the device clock needs to be set but the **clock** command syntax is not known, the context-sensitive help provides a means to check the syntax.

Context-sensitive help supplies the whole command even if you enter just the first part of the command, such as **cl?**.

If you enter the command **clock** followed by the Enter key, an error message indicates that the command is incomplete. To view the required parameters for the **clock** command, enter **?**, preceded by a space. In the **clock ?** example, the help output shows that the keyword **set** is required after **clock**.

If you now enter the command **clock set**, another error message appears, indicating that the command is still incomplete. Now add a space and enter the **?** command to display a list of command arguments that are available at that point for the given command.

The additional arguments needed to set the clock on the device are displayed: the current time using hours, minutes, and seconds. For an excellent resource on how to use the Cisco IOS CLI, visit www.cisco.com/univercd/cc/td/doc/product/software/ios124/124cg/hcf_c/ch10/index.htm.

Console error messages help identify problems when an incorrect command has been entered. Table 2-4 provides an example of error messages, what they mean, and how to get help when they are displayed.

Table 2-4 Console Error Messages

Example Error Message	Meaning	How to Get Help
`switch# cl` `% Ambiguous command: "cl"`	You did not enter enough characters for your device to recognize the command.	Reenter the command followed by a question mark (**?**), without a space between the command and the question mark. The possible keywords that you can enter with the command are displayed.

continues

Table 2-4 Console Error Messages *(continued)*

Example Error Message	Meaning	How to Get Help
`switch# clock` `% Incomplete command.`	You did not enter all the keywords or values required by this command.	Reenter the command followed by a question mark (**?**), with a space between the command and the question mark.

`switch# clock set aa:12:23`
`^`
`% Invalid input detected at '^' marker.`
		Enter a question mark (**?**) to display all the available commands or parameters.

Accessing the Command History

When you are configuring many interfaces on a switch, you can save time retyping commands by using the Cisco IOS command history buffer. In this section, you learn how to configure the command history buffer to support your configuration efforts.

The Cisco CLI provides a history or record of commands that have been entered. This feature, called command history, is particularly useful in helping recall long or complex commands or entries.

With the command history feature, you can complete the following tasks:

- Display the contents of the command buffer.
- Set the command history buffer size.
- Recall previously entered commands stored in the history buffer. There is a buffer for each configuration mode.

By default, command history is enabled, and the system records the last 10 command lines in its history buffer. You can use the **show history** command to view recently entered EXEC commands, as shown in Example 2-1.

Example 2-1 The **show history** Command

```
switch# show history
  enable
  show history
  enable
  config
  t
  confi
  t
  show history
switch#
```

The command history can be disabled for the current terminal session only by using the **terminal no history** command in user or privileged EXEC mode. When command history is disabled, the device no longer retains any previously entered command lines.

To revert the terminal history size back to its default value of 10 lines, enter the **terminal no history size** command in privileged EXEC mode. Table 2-5 provides an explanation and example of these Cisco IOS commands.

Table 2-5 Command History Buffer

Description	Command
Enables terminal history. This command can be run from either user or privileged EXEC mode.	`switch# terminal history`
Configures the terminal history size. The terminal history can maintain 0 to 256 command lines.	`switch# terminal history size 50`
Resets the terminal history size to the default value of 10 command lines.	`switch# terminal no history size`
Disables terminal history.	`switch# terminal no history`

Switch Boot Sequence

In this section, you learn the sequence of Cisco IOS commands that a switch executes from the off state to displaying the login prompt. After a Cisco switch is turned on, it goes through the following boot sequence:

The switch loads the boot loader software. The boot loader is a small program stored in ***non-volatile RAM (NVRAM)*** and is run when the switch is first turned on.

The boot loader does the following:

- Performs low-level CPU initialization. It initializes the CPU registers, which control where physical memory is mapped, the quantity of memory, and its speed.
- Performs power-on self-test (POST) for the CPU subsystem. It tests the CPU DRAM and the portion of the flash device that makes up the flash file system.
- Initializes the flash file system on the system board.
- Loads a default operating system software image into memory and boots the switch. The boot loader finds the Cisco IOS image on the switch by first looking in a directory that has the same name as the image file (excluding the .bin extension). If it does not find it there, the boot loader software searches each subdirectory before continuing the search in the original directory.

The operating system then initializes the interfaces using the Cisco IOS commands found in the operating system configuration file, config.text, stored in the switch flash memory.

The boot loader also provides access into the switch if the operating system cannot be used. The boot loader has a command-line facility that provides access to the files stored on flash memory before the operating system is loaded. From the boot loader command line, you can enter commands to format the flash file system, reinstall the operating system software image, or recover from a lost or forgotten password.

Prepare to Configure the Switch

The initial startup of a Catalyst switch requires the completion of the following steps:

How To

Step 1. Before starting the switch, verify the following:

- All network cable connections are secure.
- Your PC or terminal is connected to the console port.
- Your terminal emulator application, such as HyperTerminal, is running and configured correctly.

Step 2. Attach the power cable plug to the switch power supply socket. The switch starts. Some Catalyst switches, including the Cisco Catalyst 2960 series, do not have power buttons.

Step 3. Observe the boot sequence: When the switch is turned on, the POST begins. During POST, the LEDs blink while a series of tests determine that the switch is functioning properly. When the POST has completed, the SYST LED rapidly blinks green. If the switch fails POST, the SYST LED turns amber.

Observe the Cisco IOS software output text on the console.

During the initial startup of the switch, if POST failures are detected, they are reported to the console and the switch does not start. If POST completes successfully, and the switch has not been configured before, you are prompted to configure the switch.

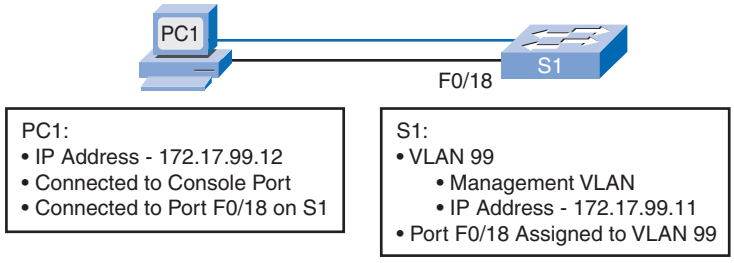
Basic Switch Configuration

A few key configuration sequences are typically carried out in the process of implementing a Layer 2 switch in a LAN. These include configuring the switch management interface, the default gateway, the duplex and speed of active interfaces, the support for HTTP access, and the management of the MAC address table.

Management Interface

An access layer switch is much like a PC in that you need to configure an IP address, a subnet mask, and a default gateway. To manage a switch remotely using TCP/IP, you need to assign the switch an IP address. In Figure 2-15, you want to manage S1 from PC1, a computer used for managing the network. To do this, you need to assign switch S1 an IP address. This IP address is assigned to a virtual interface called a virtual LAN (VLAN), and then it is necessary to ensure that the VLAN is assigned to a specific port or ports on the switch.

Figure 2-15 Switch Management Interface



The default configuration on the switch is to have the management of the switch controlled through VLAN 1. However, a best practice for basic switch configuration is to change the management VLAN to a VLAN other than VLAN 1. The implications and reasoning behind this action are explained in the next chapter. Figure 2-15 illustrates the use of VLAN 99 as the management VLAN; however, it is important to consider that an interface other than VLAN 99 can be used for the management interface.

Note

You will learn more about VLANs in the next chapter. Here the focus is on providing management access to the switch using an alternative VLAN. Some of the commands introduced here are explained more thoroughly in the next chapter. For now, VLAN 99 is created and assigned an IP address. Then the appropriate port on switch S1 is assigned to VLAN 99. Figure 2-15 also shows this configuration information.

To configure an IP address and subnet mask on the management VLAN of the switch, you must be in VLAN interface configuration mode. Use the command **interface vlan 99** and enter the IP address configuration command. You must use the **no shutdown** interface configuration command to make this Layer 3 interface operational. When you see "interface VLAN x", that refers to the Layer 3 interface associated with VLAN x. Only the management VLAN has an interface VLAN associated with it. Table 2-6 illustrates the configuration of the management interface on a Catalyst 2960 switch.

Table 2-6 Management Interface Configuration

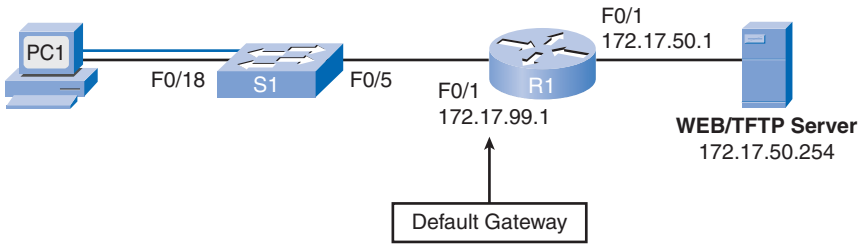
Description	Command
Enters global configuration mode.	`S1# configure terminal`
Enters the interface configuration mode for the VLAN 99 interface.	`S1(config)# interface vlan 99`
Configures the interface IP address.	`S1(config-if)# ip address 172.17.99.11 255.255.255.0`
Enables the interface.	`S1(config-if)# no shutdown`
Returns to global configuration mode.	`S1(config-if)# end`
Enters global configuration mode.	`S1# configure terminal`
Enters the interface to assign the VLAN.	`S1(config)# interface fastethernet 0/18`
Defines the VLAN membership mode for the port.	`S1(config-if)# switchport mode access`
Assigns the port to a VLAN.	`S1(config-if)# switchport access vlan 99`
Returns to privileged EXEC mode.	`S1(config-if)# end`
Saves the running configuration to the switch startup configuration.	`S1# copy running-config startup-config`

Note that a Layer 2 switch, such as the Cisco Catalyst 2960, permits only a single VLAN interface to be active at a time. This means that the Layer 3 interface, interface VLAN 99, is active, but the Layer 3 interface, interface VLAN 1, is not active.

Default Gateway

You need to configure the switch so that it can forward IP packets to distant networks. The default gateway is the mechanism for doing this. The switch forwards IP packets with destination IP addresses outside the local network to the default gateway. In Figure 2-16, the IP address of interface F0/1 on router R1, 172.17.99.1, is the default gateway for switch S1.

Figure 2-16 Default Gateway



To configure a default gateway for the switch, use the **ip default-gateway** command. Enter the IP address of the next-hop router interface that is directly connected to the switch where a default gateway is being configured. Make sure that you save the configuration running on a switch or router. Use the **copy running-config startup-config** command to back up your configuration.

Example 2-2 displays abbreviated output indicating that interface VLAN 99 has been configured with an IP address and subnet mask, and port F0/18 has been assigned to VLAN 99. You can see more about how to use the **switchport access vlan 99** command in Chapter 3. The **show ip interface brief** command is used to verify port operation and status.

Example 2-2 Verify Basic Switch Configuration

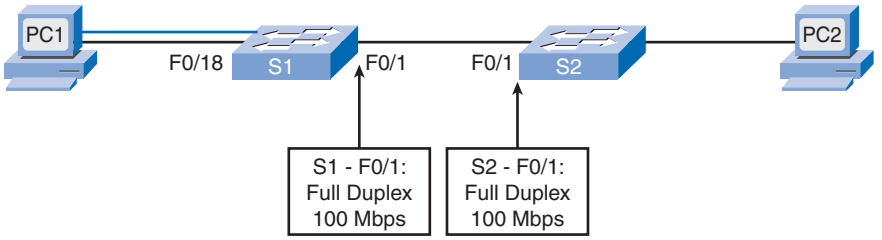
```
S1# show running-config
<output omitted>
!
interface FastEthernet0/18
 switchport access vlan 99
 switchport mode access
<output omitted>
!
interface Vlan99
 ip address 172.17.99.11 255.255.255.0
 no ip route-cache
!
ip default-gateway 172.17.99.1
!
<output omitted>
S1#
S1# show ip interface brief
Interface              IP-Address      OK?      Method      Status
Protocol
<output omitted>
Vlan99                 172.17.99.11    YES      manual      up           down
<output omitted>
FastEthernet0/18       unassigned      YES      unset       down         down
FastEthernet0/19       unassigned      YES      unset       down         down
<output omitted>
GigabitEthernet0/2     unassigned      YES      unset       down         down
S1#
```

Duplex and Speed

You can use the **duplex** interface configuration command to specify the duplex mode of operation for switch ports. You can manually set the duplex mode and speed of switch ports to avoid intervendor issues with autonegotiation. Although there can be issues when you

configure switch port duplex settings to **auto**, in Figure 2-17, switches S1 and S2 have the same duplex and speed settings resulting from the configuration in Example 2-3.

Figure 2-17 Duplex and Speed



Example 2-3 describes the steps to configure interface F0/1 on switch S1.

Example 2-3 duplex and speed Commands

```
S1# configure terminal
S1(config)# interface fastethernet 0/1
S1(config-if)# duplex auto
S1(config-if)# speed auto
S1(config-if)# end
S1# copy running-config startup-config
```

HTTP Access

Modern Cisco switches have a number of web-based configuration tools that require that the switch is configured as an HTTP server. These applications include the Cisco web browser user interface, Cisco router and Security Device Manager (SDM), and IP Phone and Cisco IP telephony service applications. Example 2-4 illustrates a basic configuration on Catalyst 2960 switch enabling HTTP access.

Example 2-4 HTTP Access

```
S1# configure terminal
S1(config)# ip http authentication enable
S1(config)# ip http server
```

To control who can access the HTTP services on the switch, you can optionally configure authentication. Authentication methods can be complex. You may have so many people using the HTTP services that you require a separate server specifically to handle user authentication. AAA and TACACS authentication are examples that use this type of enterprise authentication solutions. AAA and TACACS are authentication protocols that can be

used in networks to validate user credentials. It is very possible that you will require a less-complex authentication method, such as creating a local username database on the switch, coupled with the **ip http authentication enable** global configuration mode command, as in Example 2-4.

For more information on TACACS, visit www.cisco.com/en/US/tech/tk583/tk642/tsd_technology_support_sub-protocol_home.html. For more information on AAA, visit www.cisco.com/en/US/products/ps6350/products_configuration_guide_chapter09186a00804ec61e.html.

MAC Address Table Management

Switches use MAC address tables to determine how to forward traffic between ports. These MAC tables include dynamic and static addresses. The MAC address table is displayed with the **show mac-address-table** command; the output includes static and dynamic MAC addresses.

Note

In the past, the MAC address table was referred to as content addressable memory (CAM) or as the CAM table.

Dynamic addresses are source MAC addresses that the switch learns and then ages when they are not in use. You can change the aging time setting for MAC addresses. The default time is 300 seconds. Setting too short an aging time can cause addresses to be prematurely removed from the table. Then, when the switch receives a packet for an unknown destination, it floods the packet to all ports in the same VLAN as the receiving port. This unnecessary flooding can impact performance. Setting too long an aging time can cause the address table to be filled with unused addresses, which prevents new addresses from being learned.

The switch provides dynamic addressing by learning the source MAC address of each frame that it receives on each port and then adding the source MAC address and its associated port number to the MAC address table. As computers are added or removed from the network, the switch updates the MAC address table, adding new entries and aging out those that are not currently in use.

A network administrator can specifically assign static MAC addresses to certain ports. Static addresses are not aged out, and the switch always knows which port to send out traffic destined for that specific MAC address. As a result, there is no need to relearn or refresh which port the MAC address is connected to. One reason to implement static MAC addresses is to provide the network administrator complete control over access to the network. Only those devices that are known to the network administrator can connect to the network.

To create a static mapping in the MAC address table, use the **mac-address-table static** *mac-addr* **vlan** *vlan-id* **interface** *interface-id* command.

To remove a static mapping in the MAC address table, use the **no mac-address-table static** *mac-addr* **vlan** *vlan-id* **interface** *interface-id* command.

The maximum size of the MAC address table varies with different switch platforms. For example, the Catalyst 2960 series switch can store up to 8192 MAC addresses. There are other protocols that may limit the absolute number of MAC address available to a switch.

Verifying Switch Configuration

Now that you have performed the initial switch configuration, you should confirm that the switch has been configured correctly. In this section, you learn how to verify the switch configuration using various **show** commands.

When you need to verify the configuration of your Cisco switch, **show** commands are very useful. **show** commands are executed from privileged EXEC mode. Table 2-7 presents some of the key options for the **show** command that verify many of the configurable switch features. You will learn many additional **show** commands throughout this book.

Table 2-7 show Commands

Description	Command
Displays interface status and configuration for a single or all interfaces available on the switch.	**show interface** {*interface-id* | *cr*}
Displays contents of startup configuration.	**show startup-config**
Displays current operating configuration.	**show running-config**
Displays information about flash: file system.	**show flash:**
Displays system hardware and software status.	**show version**
Displays the session command history.	**show history**
Displays IP information. The **interface** option displays IP interface status and configuration. The **http** option displays HTTP information about Device Manager running on the switch. The **arp** option displays the IP ARP table.	**show ip** {*interface* | *http* | *arp*}
Displays the MAC forwarding table.	**show mac-address-table**

One of the more valuable **show** commands is the **show running-config** command, as illustrated in Example 2-5.

Example 2-5 show running-config Command

```
S1# show running-config
Building configuration...

Current configuration : 1664 bytes
!
version 12.2
<output omitted>
!
interface FastEthernet0/18
 switchport access vlan 99
 switchport mode access
<output omitted>
!
interface Vlan99
 ip address 172.17.99.11 255.255.255.0
 no ip route-cache
!
ip default-gateway 172.17.99.1
ip http server
!
!
<output omitted>
!
end
S1#
```

The **show running-config** command displays the configuration currently running on the switch. Use this command to verify that you have correctly configured the switch. Example 2-5 has shaded portions of the output of the S1 switch showing the following:

- Fast Ethernet 0/18 interface configured with the management VLAN 99
- VLAN 99 configured with an IP address of 172.17.99.11 255.255.255.0
- Default gateway set to 172.17.99.1
- HTTP server configured

Another commonly used command is the **show interfaces** command, which displays status and statistics information for the interfaces on the switch. The **show interfaces** command is used frequently while configuring and monitoring network devices. Recall that you can type partial commands at the command prompt and, as long as no other command option is the same, the Cisco IOS software interprets the command correctly. For example, you can use **show int** for this command. Example 2-6 shows output from the **show interfaces FastEthernet 0/1** command.

Example 2-6 show interfaces fastethernet 0/1 Command

```
S1# show interfaces fastEthernet 0/1
FastEthernet0/1 is up, line protocol is up
  Hardware is Fast Ethernet, address is 0019.aa9e.b001 (bia 0019.aa9e.b001)
  MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Auto-duplex, Auto-speed, media type is 10/100BaseTX
  input flow-control is off, output flow-control is unsupported
  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 multicast)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 watchdog, 0 multicast, 0 pause input
     0 input packets with dribble condition detected
     0 packets output, 0 bytes, 0 underruns
<output omitted>
S1#
```

The first shaded line in Example 2-6 indicates that the Fast Ethernet 0/1 interface is up and running. The next shaded line shows that the duplex and speed settings are set to auto.

Basic Switch Management

After a switch is up and running in a LAN, a switch administrator must still maintain the switch. This includes backing up and restoring switch configuration files, clearing configuration information, and deleting configuration files.

Backing Up and Restoring Switch Configuration Files

A typical job for an apprentice network technician is to load a switch with a configuration. In this topic, you learn how to load and store a configuration on the switch flash memory and to a ***Trivial File Transfer Protocol (TFTP)*** server.

You have already learned how to back up the running configuration of a switch to the startup configuration file. You have used the **copy running-config startup-config** privileged EXEC command to back up the configurations you have made so far. As you may already know, the running configuration is saved in RAM and the startup configuration is stored in the NVRAM portion of flash memory. When you issue the **copy running-config startup-config** command, the Cisco IOS software copies the running configuration to NVRAM so that when the switch boots, the startup-config file with your new configuration is loaded.

You do not always want to save configuration changes you make to the running configuration of a switch. For example, you might want to change the configuration for a short time period rather than permanently when testing out some configurations.

If you want to maintain multiple distinct startup-config files on the device, you can copy the configuration to different filenames, using the **copy startup-config flash:***filename* command. Storing multiple startup-config versions allows you to roll back to a point in time if your configuration has problems. Table 2-8 shows three examples of backing up the configuration to flash memory.

Table 2-8 Backing Up Configuration Files

Example	CLI
Formal version of Cisco IOS copy command. Confirm the destination filename. Press **Enter** to accept or **Crtl+C** to cancel.	`S1# copy system:running-config flash:startup-config` `Destination filename [startup-config]?`
Informal version of the copy command. The assumptions are that the running-config is running on the system and that the startup-config file will be stored in Flash NVRAM. Press **Enter** key to accept or **Crtl+C** to cancel.	`S1# copy running-config startup-config` `Destination filename [startup-config]?`
Back up the startup-config to a file stored in Flash NVRAM. Confirm the destination filename. Press **Enter** to accept or **Crtl+C** to cancel.	`S1# copy startup-config flash:config.bak1` `Destination filename [config.bak1]?`

The first is the formal and complete syntax. The second is the syntax commonly used. Use the first syntax when you are unfamiliar with the network device you are working with, and use the second syntax when you know that the destination is the Flash NVRAM installed on the switch. The third is the syntax used to save a copy of the startup-config file in flash.

Restoring a configuration is a simple process. You just need to copy the saved configuration over the current configuration. For example, if you had a saved configuration called config.bak1, you could restore it over your existing startup-config by entering the Cisco IOS command **copy flash:config.bak1 startup-config**. After the configuration has been restored

to the startup-config, you restart the switch with the **reload** command in privileged EXEC mode, as seen in Table 2-9; this reloads the switch with the new startup configuration.

Table 2-9 Restoring Configuration Files

Description	CLI
Copy the config.bak1 file stored in flash to the startup-configuration assumed to be stored in flash. Press Enter to accept or Crtl+C to cancel.	`S1# copy flash:config.bak1 startup-config` `Destination filename [startup-config]?`

Have the Cisco IOS restart the switch. If you have modified the running configuration file, you are asked to save it. Confirm with a "y" or an "n." To confirm the reload, press **Enter** to accept or **Crtl+C** to cancel.	`S1# reload`
	`System configuration has been modified.`
	`Save? [yes/no]: n`
	`Proceed with reload? [confirm]`

The **reload** command halts the system. Use the **reload** command after configuration information is entered into a file and saved to the startup configuration.

Note

You cannot reload from a virtual terminal if the switch is not set up for automatic booting. This restriction prevents the system from dropping to the ROM monitor (ROMMON), thereby taking the system out of the remote user's control.

After issuing the **reload** command, the system prompts you to answer whether to save the configuration. Normally you would indicate "yes," but in this particular case you need to answer "no." If you answered "yes," the file you just restored would be overwritten. In every case you need to consider whether the current running configuration is the one you want to be active after reload.

For more details on the **reload** command, review the Cisco IOS Configuration Fundamentals Command Reference, Release 12.4 found at this website: www.cisco.com/en/US/products/ps6350/products_command_reference_book09186a008042deb0.html.

Note

You also have the option of entering the **copy startup-config running-config** command. Unfortunately, this command does not entirely overwrite the running configuration; it only adds existing commands from the startup configuration to the running configuration. This can cause unintended results, so be careful when you do this.

Using a TFTP Server with Switch Configuration Files

After you have configured your switch with all the options you want to set, it is a good idea to back up the configuration on the network where it can then be archived along with the rest of

your network data being backed up nightly. Having the configuration stored safely off the switch protects it in the event that some major problem occurs with your switch.

Some switch configurations take several minutes to get working correctly. If you lost the configuration because of switch hardware failure, you need to configure a new switch. If a backup configuration exists for the failed switch, it can be loaded quickly onto the new switch. If no backup configuration exists, you must configure the new switch from scratch.

You can use TFTP to back up your configuration files over the network. Cisco IOS software comes with a built-in TFTP client that allows you to connect to a TFTP server on your network.

Note

Free TFTP server software packages are available on the Internet; you can use them if you do not already have a TFTP server running. One commonly used TFTP server is obtained from www.solarwinds.com.

To upload a configuration file from a switch to a TFTP server for storage, follow these steps:

How To

Step 1. Verify that the TFTP server is running on your network.

Step 2. Log in to the switch through the console port or a Telnet session. Ensure that the switch has connectivity with the TFTP server by using **ping**.

Step 3. Upload the switch configuration to the TFTP server. Specify the IP address or hostname of the TFTP server and the destination filename. The Cisco IOS command is **copy system:running-config tftp:**[[[*//location*]*/directory*]*/filename*] or **copy nvram:startup-config tftp:**[[[*//location*]*/directory*]*/filename*].

Example 2-7 shows an example of backing up a configuration file to a TFTP server.

Example 2-7 Using TFTP to Backup Switch Configuration Files

```
S1# copy system:running-config tftp://172.16.2.155/tokyo-config
Write file tokyo-config on host 172.16.2.155? [confirm]
Writing tokyo-config!!! [OK]
S1#
```

After the configuration is stored successfully on the TFTP server, it can be copied back to the switch using the following steps:

How To

Step 1. Copy the configuration file to the appropriate TFTP directory on the TFTP server if it is not already there.

Step 2. Verify that the TFTP server is running on your network.

Step 3. Log in to the switch through the console port or a Telnet session. Use **ping** to verify connectivity with the TFTP server.

Step 4. Download the configuration file from the TFTP server to configure the switch. Specify the IP address or hostname of the TFTP server and the name of the file to download. The Cisco IOS command is **copy tftp**:[[[*//location*]*/directory*]*/filename*] system:running-config or copy tftp:[[[*//location*]*/directory*]*/filename*] **nvram:startup-config**.

If the configuration file is downloaded onto the running-config, the commands are executed as the file is parsed line by line. If the configuration file is downloaded onto the startup-config, the switch must be reloaded for the changes to take effect.

Clearing Switch Configuration Information

You can clear the configuration information from the startup configuration. You might do this to prepare a used switch to be shipped to a customer or a different department and you want to ensure that the switch gets reconfigured. When you erase the startup configuration file and the switch reboots, it enters the setup program.

To clear the contents of your startup configuration, use the **erase nvram:** or the **erase startup-config** privileged EXEC command. Example 2-8 illustrates erasing the configuration files stored in NVRAM.

Example 2-8 Erasing Configuration Files in NVRAM

```
S1# erase nvram:
Erasing the nvram filesystem will remove all configuration files!
Continue? [confirm]
[OK]
Erase of nvram: complete
S1#
```

Caution:

You cannot restore the startup configuration file after it has been erased, so make sure that you have a backup of the configuration in case you need to restore it at a later point.

You may have been working on a complex configuration task and stored many backup copies of your files in flash. To delete a file from flash memory, use the **delete flash:***filename* privileged EXEC command. Depending on the setting of the **file prompt** global configuration command, you might be prompted for confirmation before you delete a file. By default, the switch prompts for confirmation when deleting a file.

After the configuration has been erased or deleted, you can reload the switch to initiate a new configuration for the switch.

Packet Tracer Activity

Configuring Basic Switch Management (2.3.8)

Use the Packet Tracer Activity to practice navigating command-line interface modes, using help functions, accessing the command history, configuring boot sequence parameters, setting speed and duplex settings, as well as managing the MAC address table and switch configuration file. Use file e3-2384.pka on the CD-ROM that accompanies this book to perform this activity using Packet Tracer.

Configuring Switch Security

Data is valuable and must be zealously guarded. The U.S. Federal Bureau of Investigation (FBI) estimates that businesses lose $67.2 billion annually because of computer-related crime. Personal customer data, in particular, sells for very high prices. The following are some current prices for stolen data:

- Automatic teller machine (ATM) or debit card with personal identification number (PIN): $500
- Driver's license number: $150
- Social Security number: $100
- Credit card number with expiration date: $15 to $20

In modern networks, security is integral to implementing any device, protocol, or technology. In this section you learn to help secure your LAN by configuring password options, login banners, Telnet and SSH, and port security. You learn common security attacks and tools for mitigating these attacks.

Configuring Password Options

Securing your switches starts with protecting them from unauthorized access. Next you will explore configuring passwords for the console line, virtual terminal lines, and access to privileged EXEC mode. You also learn how to encrypt and recover passwords on a switch.

Securing Console Access

You can perform all configuration options directly from the console. To access the console, you need to have local physical access to the device. If you do not secure the console port properly, a malicious user could compromise the switch configuration.

To secure the console port from unauthorized access, set a password on the console port using the **password** *password* line configuration mode command. Use the **line console 0** command to switch from global configuration mode to line configuration mode for console 0, which is the console port on Cisco switches. The prompt changes to (config-line)#, indicating that the switch is now in line configuration mode. From line configuration mode, you

can set the password for the console by entering the **password** *password* command. To ensure that a user on the console port is required to enter the password, use the **login** command. Even when a password is defined, it is not required to be entered until the **login** command has been issued.

Table 2-10 shows the commands used to configure and require the password for console access. Recall that you can use the **show running-config** command to verify your configuration. Before you complete the switch configuration, remember to save the running configuration file to the startup configuration.

Table 2-10 Securing Console Access

Description	Command
Switches from privileged EXEC mode to global configuration mode.	`S1# configure terminal`
Switches from global configuration mode to line configuration mode for console 0.	`S1(config)# line console 0`
Sets **cisco** as the password for the console 0 line on the switch.	`S1(config-line)# password cisco`
Sets the console line to require the password to be entered before access is granted.	`S1(config-line)# login`
Exits from line configuration mode and returns to privileged EXEC mode.	`S1(config-line)# end`

If you need to remove the password and remove the requirement to enter the password at login, use the following steps:

How To

Step 1. Switch from privileged EXEC mode to global configuration mode. Enter the **configure terminal** command.

Step 2. Switch from global configuration mode to line configuration mode for console 0. The command prompt (config-line)# indicates that you are in line configuration mode. Enter the command **line console 0**.

Step 3. Remove the password from the console line using the **no password** command.

Caution

If no password is defined and login is still enabled, there is no access to the console.

Step 4. Remove the requirement to enter the password at login to the console line using the **no login** command.

Step 5. Exit line configuration mode and return to privileged EXEC mode using the **end** command.

Securing Virtual Terminal Access

The vty lines on a Cisco switch allow you to access the device remotely. You can perform all configuration options using the vty lines. You do not need physical access to the switch to access the vty lines, so it is very important to secure the vty lines. Any user with network access to the switch can establish a vty remote terminal. If the vty lines are not properly secured, a malicious user could compromise the switch configuration.

To secure the vty lines from unauthorized access, you can set a vty password that is required before access is granted. To set the password on the vty lines, you must be in line configuration mode.

Many vty lines are available on a Cisco switch. Multiple ports permit more than one administrator to connect to and manage the switch. To secure all vty lines, make sure that a password is set and that login is enforced on all lines. Leaving some lines unsecured compromises security and allows unauthorized users to access the switch.

Use the **line vty 0 4** command to switch from global configuration mode to line configuration mode for vty lines 0 through 4.

Note

If the switch has more vty lines available, adjust the range to secure them all. For example, a Catalyst 2960 has lines 0 through 15 available.

Table 2-11 shows the commands used to configure and require the password for vty access. You can use the **show running-config** command to verify your configuration and the **copy running-config startup config** command to save your work.

Table 2-11 Securing Virtual Terminal Access

Description	Command
Switches from privileged EXEC mode to global configuration mode.	`S1# configure terminal`
Switches from global configuration mode to line configuration mode for vty terminals 0 through 15.	`S1(config)# line vty 0 15`
Sets **cisco** as the password for the vty lines on the switch.	`S1(config-line)# password cisco`
Sets the vty line to require the password to be entered before access is granted.	`S1(config-line)# login`
Exits from line configuration mode and returns to privileged EXEC mode.	`S1(config-line)# end`

If you need to remove the password and the requirement to enter the password at login, use the following steps:

How To

Step 1. Switch from privileged EXEC mode to global configuration mode. Enter the **configure terminal** command.

Step 2. Switch from global configuration mode to line configuration mode for vty lines 0 through 15. The command prompt (config-line)# indicates that you are in line configuration mode. Enter the command **line vty 0 15**.

Step 3. Remove the password from the console line using the **no password** command. Caution: If no password is defined and login is still enabled, there is no access to the console.

Step 4. Remove the requirement to enter the password at login to the console line using the **no login** command.

Step 5. Exit line configuration mode and return to privileged EXEC mode using the **end** command.

Securing Privileged EXEC Access

Privileged EXEC mode allows any user accessing that mode on a Cisco switch to configure any option available on the switch. You can also view all the currently configured settings on the switch, including some of the unencrypted passwords! For these reasons, it is important to secure access to privileged EXEC mode.

The **enable password** global configuration command allows you to specify a password to restrict access to privileged EXEC mode. However, one problem with the **enable password** command is that it stores the password in readable text in the startup-config and running-config files. If someone were to gain access to a stored startup-config file, or temporary access to a Telnet or console session that is logged in to privileged EXEC mode, that person could see the password. As a result, Cisco introduced a new password option to control access to privileged EXEC mode that stores the password in an encrypted format.

You can assign an encrypted form of the enable password, called the enable secret password, by entering the **enable secret** command with the desired password at the global configuration mode prompt. If the enable secret password is configured, it is used instead of the enable password, not in addition to it. There is also a safeguard built in to the Cisco IOS software that prevents you from setting the enable secret password to the same password that is used for the enable password.

Table 2-12 shows the commands used to configure privileged EXEC mode passwords. You can use the **show running-config** command to verify your configuration and the **copy running-config startup config** command to save your work.

Table 2-12 Securing Privileged EXEC Access

Description	Command
Switches from privileged EXEC mode to global configuration mode.	`S1# configure terminal`
Configures the enable secret password to enter privileged EXEC mode.	`S1(config)# enable secret password`
Exits from line configuration mode and returns to privileged EXEC mode.	`S1(config)# end`

If you need to remove the password requirement to access privileged EXEC mode, you can use the **no enable password** and **no enable secret** commands from global configuration mode.

Encrypting Switch Passwords

When configuring passwords in the Cisco IOS CLI, by default all passwords, except for the enable secret password, are stored in clear-text format within the startup-config and running-config files. Example 2-9 shows an abbreviated screen output from the **show running-config** command on the S1 switch. The clear-text passwords are shaded. It is universally accepted that passwords should be encrypted and not stored in clear-text format. The Cisco IOS command **service password-encryption** encrypts the passwords in the configuration file.

Example 2-9 Encrypting Passwords in the **running-config** File

```
<output omitted>
!
line con 0
 password cisco
 login
line vty 0 4
 password cisco
 no login
line vty 5 15
 password cisco
 no login
!
end

S1# configure terminal
S1(config)# service password-encryption
S1(config)# end
```

```
S1# show running-config
<output omitted>
!
line con 0
 password 7 030752180500
 login
line vty 0 4
 password 7 1511021F0725
 no login
line vty 5 15
 password 7 1511021F0725
 no login
!
end
```

When the **service password-encryption** command is entered from global configuration mode, all system passwords are stored in an encrypted form. As soon as the command is entered, all the currently set passwords are converted to encrypted passwords. At the bottom of Example 2-9, the encrypted passwords are shaded.

If you want to remove the requirement to store all system passwords in an encrypted format, enter the **no service password-encryption** command from global configuration mode. Removing password ***encryption*** does not convert currently encrypted passwords back into readable text. However, all newly set passwords are stored in clear-text format.

Note

The encryption standard used by the **service password-encryption** command is referred to as type 7. This encryption standard is very weak, and easily accessible tools exist on the Internet for decrypting passwords encrypted with this standard. Type 5 is more secure but must be invoked manually for each password configured.

Password Recovery

After you set passwords to control access to the Cisco IOS CLI, you need to make sure that you remember them. In case you have lost or forgotten access passwords, Cisco has a password recovery mechanism that allows administrators to gain access to their Cisco devices. The password recovery process requires physical access to the device.

You may not be able to actually recover the passwords on the Cisco device, especially if password encryption has been enabled, but you are able to reset them to a new value.

To recover the password on a Catalyst 2960 switch, use the following steps:

How To

Step 1. Connect a terminal or PC with terminal-emulation software to the switch console port.

Step 2. Set the line speed on the emulation software to 9600 baud.

Step 3. Power off the switch. Reconnect the power cord to the switch and within 15 seconds, press the Mode button while the System LED is still flashing green. Continue pressing the Mode button until the System LED turns briefly amber and then solid green. Then release the Mode button.

Step 4. Initialize the flash file system using the **flash_init** command.

Step 5. Load any helper files using the **load_helper** command.

Step 6. Display the contents of flash memory using the **dir flash:** command:

```
Directory of flash:
13 drwx 192 Mar 01 1993 22:30:48 c2960-lanbase-mz.122-25.FX
11 -rwx 5825 Mar 01 1993 22:31:59 config.text
18 -rwx 720 Mar 01 1993 02:21:30 vlan.dat
16128000 bytes total (10003456 bytes free)
```

Step 7. Rename the configuration file to config.text.old, which contains the password definition, using the **rename flash:config.text flash:config.text.old** command.

Step 8. Boot the system with the **boot** command.

Step 9. You are prompted to start the setup program. Enter **N** at the prompt and then, when the system prompts whether to continue with the configuration dialog, enter **N**.

Step 10. At the switch prompt, enter privileged EXEC mode using the **enable** command.

Step 11. Rename the configuration file to its original name using the **rename flash:config.text.old flash:config.text** command.

Step 12. Copy the configuration file into memory using the **copy flash:config.text system:running-config** command. After this command has been entered, the following is displayed on the console:

```
Source filename [config.text]?

Destination filename [running-config]?
```

Press **Return** in response to the confirmation prompts. The configuration file is now reloaded, and you can change the password.

Step 13. Enter global configuration mode using the **configure terminal** command.

Step 14. Change the password using the **enable secret** *password* command.

Step 15. Return to privileged EXEC mode using the **exit** command.

Step 16. Copy the running configuration to the startup configuration file using the **copy running-config startup-config** command.

Step 17. Reload the switch using the **reload** command.

Note

The password recovery procedure can be different depending on the Cisco switch series, so you should refer to the product documentation before you attempt a password recovery. See www.cisco.com/en/US/products/sw/iosswrel/ps1831/products_tech_note09186a00801746e6.shtml for password recovery procedures for each Cisco product.

Login Banners

The Cisco IOS command set includes a feature that allows you to configure messages that anyone logging on to the switch sees. These messages are called login banners and message of the day (MOTD) banners. In this topic, you learn how to configure them.

You can define a customized banner to be displayed before the username and password login prompts by using the **banner login** command in global configuration mode. Enclose the banner text in quotations or using a delimiter unique relative to any other character appearing in the banner string.

Table 2-13 shows the S1 switch being configured with a login banner "Authorized Personnel Only!"

Table 2-13 Securing Privileged EXEC Access

Description	Command
Switches from privileged EXEC mode to global configuration mode.	`S1# configure terminal`
Configures a login banner.	`S1(config)# banner login "Authorized Personnel Only!"`

To remove the login banner, enter the **no** form of this command in global configuration mode; for example, S1(config)# **no banner login**.

The MOTD banner displays on all connected terminals at login and is useful for sending messages that affect all network users (such as impending system shutdowns). The MOTD banner displays before the login banner if it is also configured.

Define the MOTD banner by using the **banner motd** command in global configuration mode. Enclose the banner text in quotations or with a delimiter that is unique relative to all the text enclosed by it.

Table 2-14 shows the S1 switch being configured with a MOTD banner to display "Device maintenance will be occurring on Friday!"

Table 2-14 Securing Privileged EXEC Access

Description	Command
Switches from privileged EXEC mode to global configuration mode.	`S1# configure terminal`
Configures a MOTD login banner.	`S1(config)# banner motd "Device maintenance will be occurring on Friday!"`

To remove the MOTD banner, enter the **no** format of this command in global configuration mode; for example S1(config)# **no banner motd**.

Configure Telnet and SSH

Older switches may not support secure communication with Secure Shell (SSH). This topic will help you choose between the Telnet and SSH methods of remotely accessing a vty on a Catalyst switch.

Telnet is the original method that was supported on early Cisco switch models. Telnet is a popular protocol used for terminal access because most current operating systems come with a Telnet client built in. However, Telnet is an insecure way of accessing a network device, because it sends all communications across the network in clear-text. Using network monitoring software, an attacker can read every keystroke that is sent between the Telnet client and the Telnet service running on the Cisco switch. Because of the security concerns of the Telnet protocol, SSH has become the preferred protocol for remotely accessing virtual terminal lines on a Cisco device.

SSH gives the same type of access as Telnet with the added benefit of security. Communication between the SSH client and SSH server is encrypted. SSH has gone through a few versions, with Cisco devices currently supporting both SSHv1 and SSHv2. It is recommended that you implement SSHv2 when possible, because it uses a more enhanced security encryption algorithm than SSHv1.

Configuring Telnet

Telnet is the default vty-supported protocol on a Cisco switch. When a management IP address is assigned to the Cisco switch, you can connect to it using a Telnet client. Initially, the vty lines are unsecured, allowing access by any user attempting to connect to them.

You have already learned how to secure access to the switch over the vty lines by requiring password authentication. This makes running the Telnet service a little more secure.

Because Telnet is the default transport for the vty lines, you do not need to specify it after the initial configuration of the switch has been performed. However, if you have switched the transport protocol on the vty lines to permit only SSH, you need to enable the Telnet protocol to permit Telnet access manually.

If you need to reenable the Telnet protocol on a Cisco 2960 switch, use the following command from vty line configuration mode: **transport input telnet** or **transport input all**. By permitting all transport protocols, you still permit SSH access to the switch as well as Telnet access.

Configuring SSH

SSH is a cryptographic security feature that is subject to export restrictions. To use this feature, a cryptographic image must be installed on your switch.

The SSH feature has an SSH server and an SSH integrated client, which are applications that run on the switch. You can use any SSH client running on a PC or the Cisco SSH client running on the switch to connect to a switch running the SSH server.

The switch supports SSHv1 or SSHv2 for the server component. The switch supports only SSHv1 for the client component.

SSH supports the Data Encryption Standard (DES) algorithm, the Triple DES (3DES) algorithm, and password-based user authentication. DES offers 56-bit encryption, and 3DES offers 168-bit encryption. Encryption takes time, but DES takes less time to encrypt text than 3DES. Typically, encryption standards are specified by the client, so if you have to configure SSH, ask which one to use. (A discussion of data encryption methods is beyond the scope of this book.)

To implement SSH, you need to generate RSA keys. RSA involves a public key, kept on a public RSA server, and a private key, kept only by the sender and receiver. The public key can be known to everyone and is used for encrypting messages. Messages encrypted with the public key can be decrypted only using the private key. This is known as asymmetric encryption and is discussed in greater detail in the *Accessing the WAN, CCNA Exploration Companion Guide*.

To configure a Catalyst 2960 switch as an SSH server, beginning in privileged EXEC mode, follow these steps:

Step 1. Enter global configuration mode using the **configure terminal** command.

Step 2. Configure a hostname for your switch using the **hostname** *hostname* command.

Step 3. Configure a host domain for your switch using the **ip domain-name** *domain-name* command.

Step 4. Enable the SSH server for local and remote authentication on the switch and generate an encrypted RSA key pair using the **crypto key generate rsa** command.

When you generate RSA keys, you are prompted to enter a modulus length. Cisco recommends using a modulus size of 1024 bits. A longer modulus length might be more secure, but it takes longer to generate and to use. This step completes a rudimentary configuration of an SSH server. The remaining steps describe several options available to fine-tune the SSH configuration.

Step 5. Return to privileged EXEC mode using the **end** command.

Step 6. Show the status of the SSH server on the switch using the **show ip ssh** or **show ssh** command.

Step 7. Enter global configuration mode using the **configure terminal** command.

Step 8. (Optional) Configure the switch to run SSHv1 or SSHv2 using the **ip ssh version** [**1** | **2**] command.

If you do not enter this command or do not specify keyword options **1** or **2**., the SSH server selects the latest SSH version supported by the SSH client. For example, if the SSH client supports SSHv1 and SSHv2, the SSH server selects SSHv2.

Step 9. Configure the SSH control parameters:

Specify the timeout value in seconds; the default is 120 seconds. The range is 0 to 120 seconds. For an SSH connection to be established, a number of phases must be completed, such as connection, protocol negotiation, and parameter negation. The timeout value applies to the amount of time the switch allows for a connection to be established.

By default, up to five simultaneous encrypted SSH connections for multiple CLI-based sessions over the network are available (session 0 to session 4). After the execution shell starts, the CLI-based session timeout value returns to the default of 10 minutes.

Specify the number of times that a client can reauthenticate to the server. The default is 3; the range is 0 to 5. For example, a user can allow the SSH session to sit for more than 10 minutes three times before the SSH session is terminated.

Repeat this step when configuring both parameters. To configure both parameters, use the **ip ssh** {**timeout** *seconds* | **authentication-retries** *number*} command.

Step 10. Return to privileged EXEC mode using the **end** command.

Step 11. Display the status of the SSH server connections on the switch using the **show ip ssh** or the **show ssh** command.

Step 12. (Optional) Save your entries in the configuration file using the **copy running-config startup-config** command.

To delete the RSA key pair, use the **crypto key zeroize rsa** global configuration command. After the RSA key pair is deleted, the SSH server is automatically disabled.

If you want to prevent non-SSH connections, add the **transport input ssh** command in line configuration mode to limit the switch to SSH connections only. Straight (non-SSH) Telnet connections are refused.

Example 2-10 demonstrates a set of commands to enable SSH on a Catalyst 2960 switch. The default version for SSH would be version 2, but we configure it anyway. This configuration prevents Telnet access on the vty lines. It is assumed that there are entries in the local username database and that a vty password has been configured. Step 3 and 4 in the preceding list provide an absolute minimum set of commands to enable SSH.

Example 2-10 Enabling the SSH Server on the Catalyst 2960

```
S1(config)# ip domain-name mydomain.com
S1(config)# crypto key generate rsa
S1(config)# ip ssh version 2
S1(config)# line vty 0 15
S1(config-line)# transport input ssh
```

For a detailed discussion on SSH, visit: www.cisco.com/en/US/tech/tk583/tk617/tsd_technology_support_protocol_home.html.

For an overview of RSA technology, visit en.wikipedia.org/wiki/Public-key_cryptography.

For a detailed discussion on RSA technology, visit: www.rsa.com/rsalabs/node.asp?id=2152.

Common Security Attacks

Unfortunately, basic switch security does not stop malicious attacks from occurring. In this section, you learn about a few common security attacks and how dangerous they are. This topic provides introductory-level information about security attacks. The details of how some of these common attacks work are beyond the scope of this book. If you would like to delve deeper into network security, refer to the *Accessing the WAN, CCNA Exploration Companion Guide*.

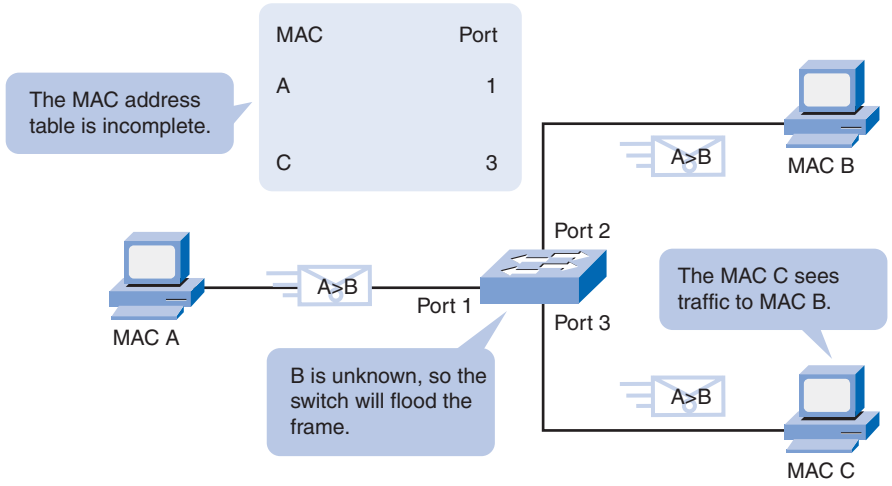
We proceed to explore some of the more common Layer 2 security attacks.

MAC Address Flooding

The MAC address table in a switch contains the MAC addresses available on a given physical port of a switch and the associated VLAN parameters for each. When a Layer 2 switch receives a frame, the switch looks in the MAC address table for the destination MAC address. All Catalyst switch models use a MAC address table for Layer 2 switching. As frames arrive on switch ports, the source MAC addresses are learned and recorded in the MAC address table. If an entry exists for the MAC address, the switch forwards the frame to the MAC address port designated in the MAC address table. If the MAC address does not exist, the switch forwards the frame out every other port on the switch. MAC address table overflow attacks are sometimes referred to as MAC flooding attacks. To understand the mechanism of a MAC address table overflow attack, we recall the basic operation of a switch.

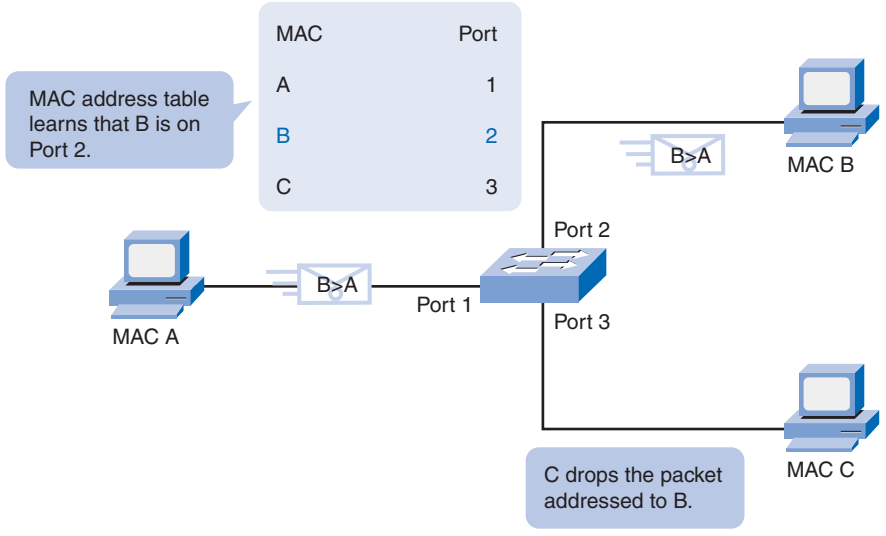
In Figure 2-18, Host A sends traffic to Host B. The switch receives the frames and looks up the destination MAC address in its MAC address table. If the switch cannot find the destination MAC in the MAC address table, the switch then copies the frame and sends it out every other switch port.

Figure 2-18 Switch Receives Unicast Frame



In Figure 2-19, Host B receives the frame and sends a reply to Host A. The switch then learns that the MAC address for Host B is located on port 2 and writes that information into the MAC address table.

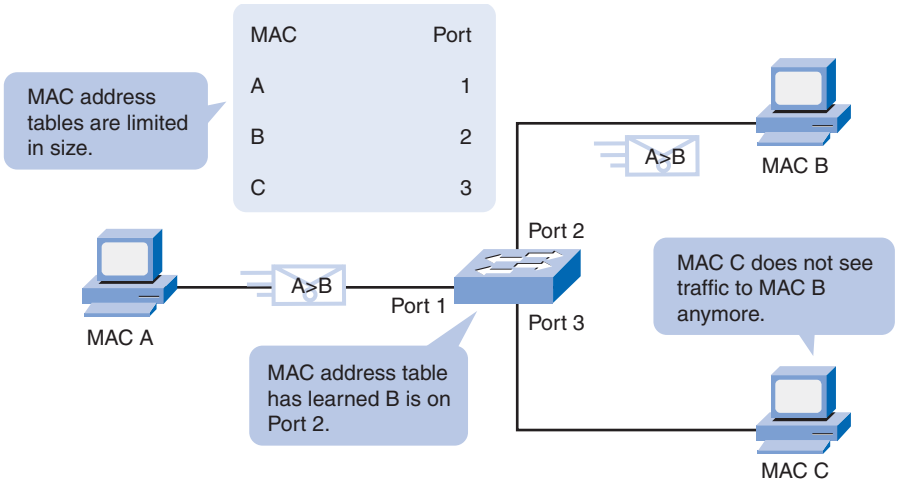
Figure 2-19 Host B Receives Unicast Frame



You see that Host C also receives the frame from Host A to Host B, but because the destination MAC address of that frame is Host B, Host C drops that frame.

In Figure 2-20, any frame sent now by Host A (or any other host) to Host B is forwarded to port 2 of the switch and not sent out every port.

Figure 2-20 Switch Forwards Frame Out Single Port

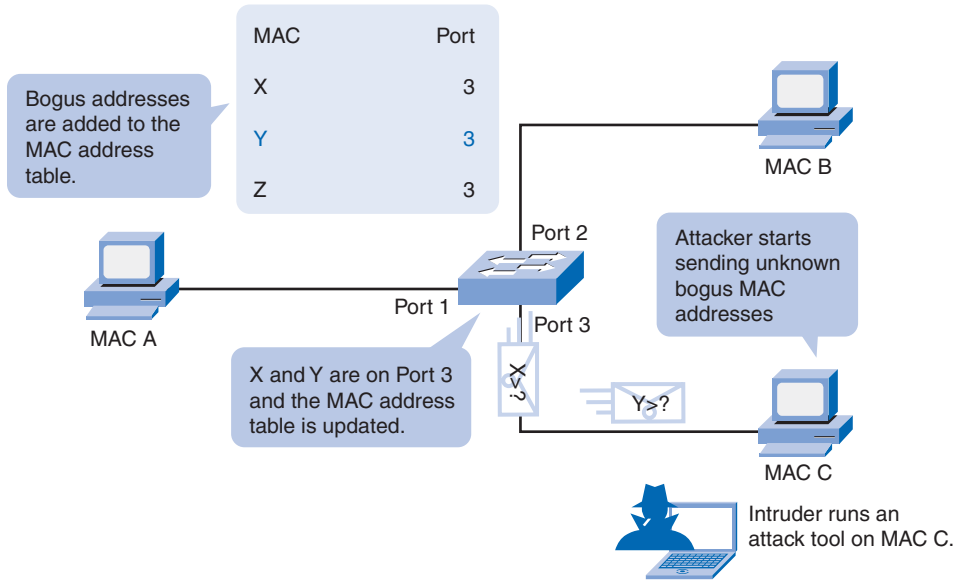


The key to understanding how MAC address table overflow attacks work is to know that MAC address tables are limited in size. MAC flooding makes use of this limitation to bombard the switch with fake source MAC addresses until the switch MAC address table is full. The switch then enters into what is known as a fail-open mode, starts acting as a hub, and broadcasts packets to all the machines on the network. As a result, the attacker can see all of the frames sent from a victim host to another host.

MAC flooding can be performed using a network attack tool. The network intruder uses the attack tool to flood the switch with a large number of invalid source MAC addresses until the MAC address table fills up. When the MAC address table is full, the switch floods all ports with incoming traffic because it cannot find the port number for a particular MAC address in the MAC address table. The switch, in essence, acts like a hub.

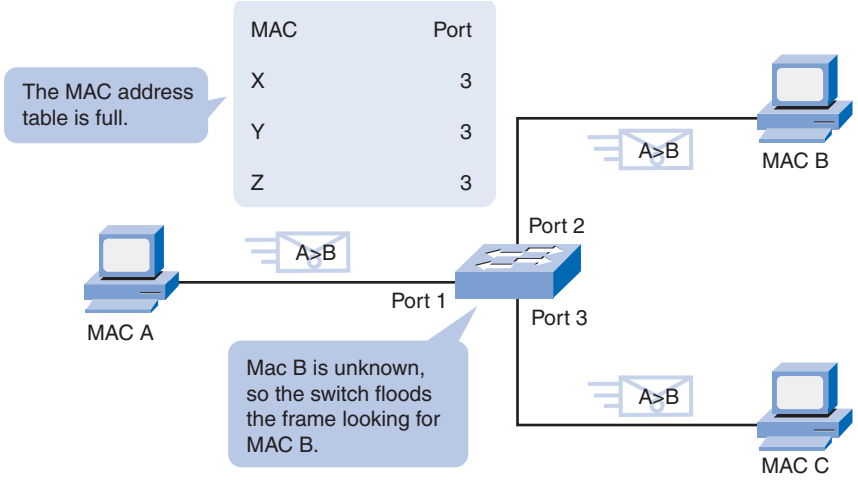
Some network attack tools can generate 155,000 MAC entries on a switch per minute. Depending on the switch, the maximum MAC address table size varies. In Figure 2-21, the attack tool is running on the host with MAC address C in the bottom right of the screen. This tool floods a switch with packets containing randomly generated source and destination MAC and IP addresses. Over a short period of time, the MAC address table in the switch fills up until it cannot accept new entries. When the MAC address table fills up with invalid source MAC addresses, the switch begins to forward all frames that it receives to every port.

Figure 2-21 Host C Sends Frames with Bogus Sources



As long as the network attack tool is left running, the MAC address table on the switch remains full. When this happens, the switch begins to send all received frames out every port so that frames sent from Host A to Host B are also sent out of port 3 on the switch, as shown in Figure 2-22.

Figure 2-22 Host C Sees All Frames Sent from Host A to Host B



Spoofing Attacks

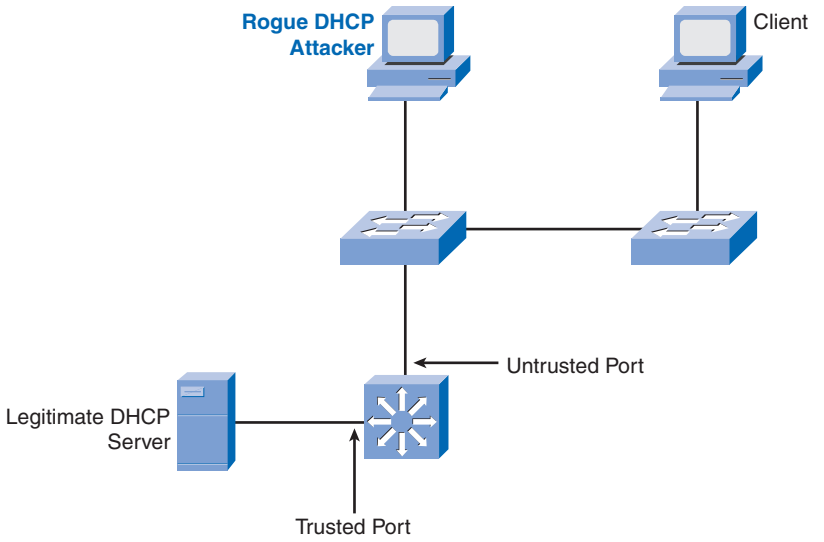
One way an attacker can gain access to network traffic is to ***spoof*** responses that would be sent by a valid DHCP server. The DHCP spoofing device replies to client DHCP requests. The legitimate server may also reply, but if the spoofing device is on the same segment as the client, its reply to the client may arrive first. The intruder DHCP reply offers an IP address and supporting information that designates the intruder as the default gateway or Domain Name System (DNS) server. In the case of a gateway, the clients then forward packets to the attacking device, which in turn, sends them to the desired destination. This is referred to as a man-in-the-middle attack, and it may go entirely undetected as the intruder intercepts the data flow through the network.

You should be aware of another type of DHCP attack called a DHCP starvation attack. The attacker PC continually requests IP addresses from a real DHCP server by changing the source MAC addresses of the requests. If successful, this kind of DHCP attack causes all the leases on the real DHCP server to be allocated, thus preventing the real users (DHCP clients) from obtaining an IP address.

To prevent DHCP attacks, use the DHCP snooping and port security features on the Cisco Catalyst switches.

DHCP snooping is a Cisco Catalyst feature that determines which switch ports can respond to DHCP requests. Ports are identified as trusted and untrusted, as illustrated in Figure 2-23. Trusted ports can source all DHCP messages; untrusted ports can source requests only. Trusted ports host a DHCP server or can be an uplink toward the DHCP server. If a rogue device on an untrusted port attempts to send a DHCP response packet into the network, the port is shut down. This feature can be coupled with DHCP options in which switch information, such as the port ID of the DHCP request, can be inserted into the DHCP request packet.

Figure 2-23 DHCP Snooping to Prevent DHCP Attacks



Untrusted ports are those not explicitly configured as trusted. A DHCP binding table is built for untrusted ports. Each entry contains a client MAC address, IP address, lease time, binding type, VLAN number, and port ID recorded as clients make DHCP requests. The table is then used to filter subsequent DHCP traffic. From a DHCP snooping perspective, untrusted access ports should not send any DHCP server responses.

These steps illustrate how to configure DHCP snooping on a Cisco IOS switch:

Step 1. Enable DHCP snooping using the **ip dhcp snooping** global configuration command.

Step 2. Enable DHCP snooping for specific VLANs using the **ip dhcp snooping vlan number** [*number*] command.

Step 3. Define ports as trusted or untrusted at the interface level by defining the trusted ports using the **ip dhcp snooping trust** command.

Step 4. (Optional) Limit the rate at which an attacker can continually send bogus DHCP requests through untrusted ports to the DHCP server using the **ip dhcp snooping limit rate** *rate* command.

CDP Attacks

The ***Cisco Discovery Protocol (CDP)*** is a proprietary protocol that all Cisco devices can be configured to use. CDP discovers other Cisco devices that are directly connected, which allows the devices to autoconfigure their connection in some cases, simplifying configuration and connectivity. CDP messages are not encrypted.

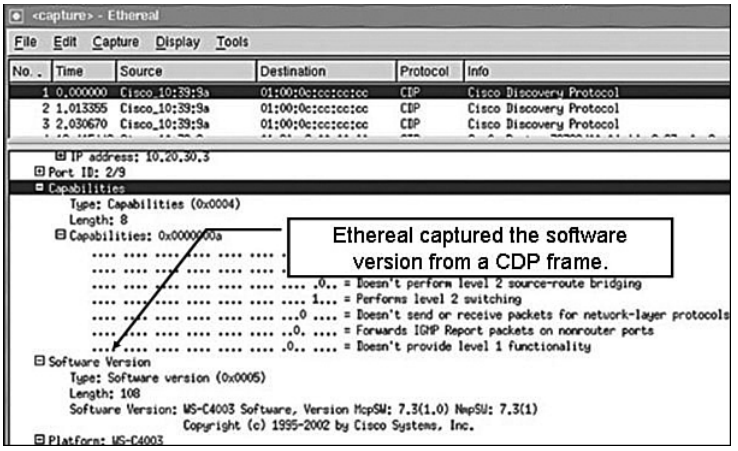
By default, most Cisco devices have CDP enabled. CDP information is sent in periodic broadcasts that are updated locally in each device's CDP database. Because CDP is a Layer 2 protocol, it is not propagated by routers.

CDP contains information about the device, such as the IP address, software version, platform, capabilities, and the native VLAN. When this information is available to an attacker, they can use it to find exploits to attack your network, typically in the form of a Denial of Service (DoS) attack.

Figure 2-24 is a portion of a packet capture showing the inside of a CDP packet. The Cisco IOS Software version discovered via CDP, in particular, would allow the attacker to research and determine whether there were any security vulnerabilities specific to that particular version of code. Also, because CDP is unauthenticated, an attacker could craft bogus CDP packets and have them received by the attacker's directly connected Cisco device.

To address this vulnerability, it is recommended that you disable the use of CDP on devices that do not need to use it.

Figure 2-24 CDP Packet Capture



Telnet Attacks

The Telnet protocol can be used by an attacker to gain remote access to a Cisco switch. You have configured a login password for vty lines and set the lines to require password authentication to gain access. This ensures an essential and basic level of security to help protect the switch from unauthorized access. However, it is not a secure method of securing access to the vty lines. There are tools available that allow an attacker to launch a brute-force password-cracking attack against the vty lines on the switch.

The first phase of a brute-force password attack starts with the attacker using a list of common passwords and a program designed to try to establish a Telnet session using each word on the dictionary list. Because your passwords do not resemble any dictionary words, you are safe for now. In the second phase of a brute-force attack, the attacker uses a program that creates sequential character combinations in an attempt to "guess" the password. Given enough time, a brute force password attack can crack almost any passwords used.

The simplest thing that you can do to limit the vulnerability to brute-force password attacks is to change your passwords frequently and use strong passwords, randomly mixing upper and lowercase letters with other alphanumeric characters. More advanced configurations allow you to limit who can communicate with the vty lines by using access lists, but that is beyond the scope of this book.

Another type of Telnet attack is the DoS attack. In a DoS attack, the attacker exploits a flaw in the Telnet server software running on the switch that renders the Telnet service unavailable. This sort of attack is mostly a nuisance because it prevents an administrator from performing switch management functions.

Vulnerabilities in the Telnet service that permit DoS attacks to occur are usually addressed in security patches that are included in newer Cisco IOS revisions. If you are experiencing a

DoS attack against the Telnet service, or any other service on a Cisco device, check to see if a newer Cisco IOS revision is available.

Last, if an attacker uses a MAC flooding attack, for example, by using any packet capture software, the attacker may then capture the Telnet password as you type it.

Security Tools

After you have configured switch security, you need to verify that you have not left any weakness for an attacker to exploit. Network security is a complex and evolving set of technologies. In this section, you are introduced to how network security tools are used to protect a network from malicious attacks.

Network security tools help you to test your network for various weaknesses. They are tools that allow you to play the role of both a hacker and a network security analyst. Using these tools, you can launch an attack and audit the results to determine how to adjust your security policies to prevent specific attacks.

The features used within network security tools are many and varied. For example, network security tools formerly focused only on the services of listening on the network and examined these services for flaws. Today, viruses and worms are able to propagate because of flaws in mail clients and web browsers. Modern network security tools not only detect the remote flaws of the hosts on the network, but also determine whether application-level flaws exist, such as missing patches on client computers. Network security extends beyond network devices, all the way to the desktop of users. Security auditing and penetration testing are two basic functions that network security tools perform.

Network security tools allow you to perform a security audit of your network. A security audit reveals what sort of information an attacker can gather simply by monitoring network traffic. Network security-auditing tools allow you to flood the MAC table with bogus MAC addresses. Then you can audit the switch ports as the switch starts flooding traffic out all ports as the legitimate MAC address mappings are aged out and replaced with more bogus MAC address mappings. In this way, you can determine which ports are compromised and have not been correctly configured to prevent this type of attack.

Timing is an important factor in performing a successful audit. Different switches support varying numbers of MAC addresses in their MAC address tables. It can be tricky to determine the ideal amount of spoofed MAC addresses to throw out on the network. You also have to contend with the age-out period of the MAC table. If the spoofed MAC addresses start to age out while you are performing your network audit, valid MAC addresses start to populate the MAC table, limiting the data that you can monitor with a network-auditing tool.

Network security tools can also be used for penetration testing against your network. This allows you to identify weaknesses within the configuration of your networking devices. There are numerous attacks that you can perform, and most tool suites come with extensive

documentation detailing the syntax needed to execute the desired attack. Because these types of tests can have adverse effects on the network, they are carried out under very controlled conditions, following documented procedures detailed in a comprehensive network security policy. Of course, if you have a lab-based network, you can arrange to try your own network penetration tests.

In the next section, you learn how to implement port security on your Cisco switches so that you can ensure these network security tests do not reveal any flaws in your security configuration.

A secure network really is a process, not a product. You cannot just enable a switch with a secure configuration and declare the job to be done. To say you have a secure network, you need to have a comprehensive network security plan defining how to regularly verify that your network can withstand the latest malicious network attacks. The changing landscape of security risks means that you need auditing and penetration tools that can be updated to look for the latest security risks. Common features of a modern network security tool include the following:

- **Service identification:** Tools that are used to target hosts using the Internet Assigned Numbers Authority (IANA) port numbers. These tools should also be able to discover an FTP server running on a nonstandard port or a web server running on port 8080. The tool should also be able to test all the services running on a host.
- **Support of SSL services:** Testing services that use SSL level security, including HTTPS, SMTPS, IMAPS, and security certificates.
- **Nondestructive and destructive testing:** Performing nondestructive security audits on a routine basis that do not compromise or only moderately compromise network performance. The tools should also let you perform destructive audits that significantly degrade network performance. Destructive auditing allows you to see how well your network withstands attacks from intruders.
- **Database of vulnerabilities:** Vulnerabilities change with time.

Network security tools need to be designed so that they can plug into a module of code and then run a test for a specific vulnerability. In this way, a large database of vulnerabilities can be maintained and uploaded to the tool to ensure that the most recent vulnerabilities are being tested.

You can use network security tools to

- Capture chat messages
- Capture files from NFS traffic
- Capture HTTP requests in Common Log Format
- Capture mail messages in Berkeley mbox format
- Capture passwords

- Display captured URLs in browser in real-time
- Flood a switched LAN with random MAC addresses
- Forge replies to DNS address or pointer queries
- Intercept packets on a switched LAN

Configuring Port Security

A switch that does not provide port security allows an attacker to attach a system to an unused, enabled port and to perform information gathering or to launch attacks. A switch can be configured to act like a hub, which means that every system connected to the switch can potentially view all network traffic passing through the switch to all systems connected to the switch. Thus, an attacker could collect traffic that contains usernames, passwords, or configuration information about the systems on the network.

All switch ports or interfaces should be secured before the switch is deployed. Port security limits the number of valid MAC addresses allowed on a 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 to that port, the workstation attached to that port is assured the full bandwidth of the port, and only that workstation with that particular secure MAC address can successfully communicate through that switch port.

If a port is configured as a secure port and the maximum number of secure MAC addresses is reached, a security violation occurs when the MAC address of a workstation attempting to access the port is different from any of the identified secure MAC addresses. Summarizing, you should implement security on all switch ports to

- Specify a group of valid MAC addresses allowed on a port.
- Allow only one MAC address to access the port at a time.
- Specify that the port automatically shuts down if unauthorized MAC addresses are detected.

There are a number of ways to configure port security. The following describes the ways you can configure port security on a Cisco switch:

- **Static secure MAC addresses:** MAC addresses are manually configured by using the **switchport port-security mac-address** *mac-address* interface configuration command. MAC addresses configured in this way are stored in the address table and are added to the running configuration on the switch.
- **Dynamic secure MAC addresses:** MAC addresses are dynamically learned and stored only in the address table. MAC addresses configured in this way are removed when the switch restarts.

- **Sticky secure MAC addresses:** You can configure a port to dynamically learn MAC addresses and then save these MAC addresses to the running configuration.

Sticky secure MAC addresses have the following characteristics:

- When you enable sticky learning on an interface by using the **switchport port-security mac-address sticky** interface configuration 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 and adds all sticky secure MAC addresses to the running configuration.
- If you disable sticky learning by using the **no switchport port-security mac-address sticky** interface configuration command, the sticky secure MAC addresses remain part of the running configuration but are removed from the address table. The addresses that were removed can be dynamically reconfigured and added to the address table as dynamic addresses.
- When you configure sticky secure MAC addresses by using the **switchport port-security mac-address sticky** *mac-address* interface configuration command, these addresses are added to the address table and the running configuration. If port security is disabled, the sticky secure MAC addresses remain in the running configuration.
- If you save the sticky secure MAC addresses in the configuration file, when the switch restarts or the interface shuts down, the interface does not need to relearn these addresses. If you do not save the sticky secure addresses, they are lost. If sticky learning is disabled, the sticky secure MAC addresses are converted to dynamic secure addresses and are removed from the running configuration.
- If you disable sticky learning and enter the **switchport port-security mac-address sticky** *mac-address* interface configuration command, an error message appears, and the sticky secure MAC address is not added to the running configuration.

It is a security violation when either of these situations occurs:

- The maximum number of secure MAC addresses have been added to the address table, and a station whose MAC address is not in the address table attempts to access the interface.
- An address learned or configured on one secure interface is seen on another secure interface in the same VLAN.

You can configure the interface for one of three violation modes, based on the action to be taken if a violation occurs.

- **protect:** When the number of secure MAC addresses reaches the limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses or increase the number of maximum allowable addresses. You are not notified that a security violation has occurred.

- **restrict:** When the number of secure MAC addresses reaches the limit allowed on the port, packets with unknown source addresses are dropped until you remove a sufficient number of secure MAC addresses or increase the number of maximum allowable addresses. In this mode, you are notified that a security violation has occurred. Specifically, an SNMP trap is sent, a syslog message is logged, and the violation counter increments.
- **shutdown:** In this mode, a port security violation causes the interface to immediately become error-disabled and turns off the port LED. It also sends an SNMP trap, logs a syslog message, and increments the violation counter. When a secure port is in the error-disabled state, you can bring it out of this state by entering the **shutdown** followed by the **no shutdown** interface configuration commands. This is the default mode.

The effect of each mode is summarized in Table 2-15.

Table 2-15 Port Security Violation Modes

Violation Mode	Forwards Traffic	Sends SNMP Trap	Sends Syslog Message	Displays Error Message	Increases Violation Counter	Shuts Down Port
Protect	No	No	No	No	No	No
Restrict	No	Yes	Yes	No	Yes	No
Shutdown	No	Yes	Yes	No	Yes	Yes

The ports on a Catalyst switch are preconfigured with defaults. Table 2-16 summarizes the default port security configuration.

Table 2-16 Port Security Default Settings

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.
Sticky address learning	Disabled.

Table 2-17 shows the Cisco IOS CLI commands needed to configure port security on the interface F0/18 of switch S1. Notice that the example does not specify a violation mode. In this example, the violation mode defaults to **shutdown**.

Table 2-17 Port Security Command Syntax

Description	Command
Enters global configuration mode.	`S1# configure terminal`
Specifies the type and number of the physical interface to configure—for example, fastEthernet 0/18—and enters interface configuration mode.	`S1(config)# interface fastEthernet 0/18`
Sets the interface mode as access. An interface in the dynamic desirable default mode cannot be configured as a secure port.	`S1(config-if)# switchport mode access`
Enables port security on the interface.	`S1(config-if)# switchport port-security`
Returns to privileged EXEC mode.	`S1# end`

Table 2-18 shows how to enable sticky port security on interface F0/18 of switch S1. Recall that you can configure the maximum number of secure MAC addresses. In this example, you see the Cisco IOS command syntax used to set the maximum number of MAC addresses to 50. The violation mode is again set to **shutdown** by default.

Table 2-18 Port Security Command Syntax with Sticky Addresses

Description	Command
Enters global configuration mode.	`S1# configure terminal`
Specifies the type and number of the physical interface to configure.	`S1(config)# interface fastEthernet 0/18`
Sets the interface mode as access.	`S1(config-if)# switchport mode access`
Enables port security on the interface.	`S1(config-if)# switchport port-security`
Sets the maximum number of secure addresses to 50.	`S1(config-if)# switchport port-security maximum 50`
Enables sticky learning.	`S1(config-if)# switchport port-security mac-address sticky`
Returns to privileged EXEC mode.	`S1# end`

Other port security settings exist that you may find useful. For a complete listing of port security configuration options, visit: cisco.com/en/US/docs/switches/lan/catalyst2950/software/release/12.1_19_ea1/configuration/guide/swtrafc.html#wp1038501.

After you have configured port security for your switch, you should verify that it has been configured correctly. You need to check each interface to verify that you have set the port security correctly. You also have to check to make sure that you have configured any static MAC addresses correctly.

To display port security settings for the switch or for the specified interface, use the **show port-security** [**interface** *interface-id*] command, as illustrated in Example 2-11.

Example 2-11 Verifying Port Security

```
S1# show port-security interface fastEthernet 0/18
Port Security                   :Enabled
Port Status                     :Secure-down
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           :0
Last Source Address:Vlan       :0000.0000.0000:0
Security Violation Count       :0
```

The output displays the following:

- Maximum allowed number of secure MAC addresses for each interface
- Number of secure MAC addresses on the interface
- Number of security violations that have occurred
- Violation mode

To display all secure MAC addresses configured on all switch interfaces or on a specified interface with aging information for each, use the **show port-security** [**interface** *interface-id*] **address** command, as illustrated in Example 2-12.

Example 2-12 Verifying Secure MAC Addresses

```
S1# show port-security address
      Secure Mac Address Table
-----------------------------------------------------------------------
Vlan    Mac Address         Type                Ports     Remaining Age (mins)
99       0050.BAA6.06CE     SecureConfigured    Fa0/18    -
-----------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     : 0
Max Addresses limit in System (excluding one mac per port) : 8320
```

Securing Unused Ports

Securing unused switch ports is a security best practice for switch configuration. Here you learn a simple Cisco IOS command to secure unused switch ports. A method many administrators use to help secure their networks from unauthorized access is to disable all unused ports on a network switch. For example, imagine that a Cisco 2960 switch has 24 ports. If three Fast Ethernet connections are in use, good security practice demands that you disable the 21 unused ports. Example 2-13 shows partial output for this configuration.

Example 2-13 Shutdown Unused Ports

```
interface FastEthernet0/4
 shutdown
!
interface FastEthernet0/5
 shutdown
!
interface FastEthernet0/6
 shutdown
!
<output omitted>
!
interface FastEthernet0/18
 switchport mode access
 switchport port-security
```

It is simple to disable multiple ports on a switch. Navigate to each unused port and issue this Cisco IOS **shutdown** command. A better way to shut down multiple ports is to use the **interface range** command. If a port needs to be activated, you can manually enter the **no shutdown** command on that interface.

The process of enabling and disabling ports can become a tedious task, but the value in terms of enhancing security on your network is well worth the effort. In the next chapter you will also see that it is a security best practice to configure all unused switch ports to be members of a "black hole" VLAN, which is a dummy VLAN that is not used anywhere in the switched LAN.

Packet Tracer Activity

Configure Switch Security (2.4.7)

Use the Packet Tracer Activity to configure basic switch commands and then configure and test port security. Use File e3-2472.pka on the CD-ROM that accompanies this book to perform this activity using Packet Tracer.

Summary

In this chapter, we discussed IEEE 802.3 Ethernet communication using unicast, broadcast, and multicast traffic. Early implementations of Ethernet networks needed to use CSMA/CD to help prevent and detect collisions between frames on the network. Duplex settings and LAN segmentation improve performance and reduce the need for CSMA/CD.

LAN design is a process; the intended result of LAN design is a determination of how a LAN is to be implemented. LAN design considerations include collision domains, broadcast domains, network latency, and LAN segmentation.

We discussed how switch forwarding methods influence LAN performance and latency. Memory buffering plays a role in switch forwarding, symmetric and asymmetric switching, and multilayer switching.

An introduction to navigating the Cisco IOS CLI on a Cisco Catalyst 2960 switch was presented. Built-in help functions are used to identify commands and command options. The Cisco IOS CLI maintains a command history that allows you to more quickly configure repetitive switch functions.

We discussed the initial switch configuration and how to verify the switch configuration. Backing up a switch configuration and restoring a switch configuration are key skills for anyone administering a switch.

We learned how to secure access to the switch: implementing passwords to protect console and virtual terminal lines, implementing passwords to limit access to privileged EXEC mode, configuring password encryption, and enabling SSH. There are a number of security risks common to Cisco Catalyst switches, many of which are mitigated by using port security.

Labs

The labs available in the companion *LAN Switching and Wireless, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-202-8) provide hands-on practice with the following topics introduced in this chapter:

Lab 2-1: Basic Switch Configuration (2.5.1)

In this lab, you examine and configure a standalone LAN switch. Although a switch performs basic functions in its default out-of-the-box condition, a network administrator should modify a number of parameters to ensure a secure and optimized LAN. This activity introduces you to the basics of switch configuration.

Lab 2-2: Managing Switch Operating System and Configuration Files (2.5.2)

In this lab, you create and save a basic switch configuration, set up a TFTP server, back up the switch Cisco IOS Software to the TFTP server and restore it, back up and restore a switch configuration to the TFTP server, upgrade the Cisco IOS Software from a TFTP server, and recover the password for a 2960 switch.

Lab 2-3: Managing Switch Operating System and Configuration Files—Challenge (2.5.3)

In this lab, you explore file management and password recovery procedures on a Cisco Catalyst switch.

Many of the hands-on labs include Packet Tracer Companion Activities, where you can use Packet Tracer to complete a simulation of the lab. Look for this icon in *LAN Switching and Wireless, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-202-8) for hands-on labs that have a Packet Tracer Companion.

Check Your Understanding

Complete all the review questions listed here to test your understanding of the topics and concepts in this chapter. Answers are listed in the Appendix, "Check Your Understanding and Challenge Questions Answer Key."

1. What does the following error message signify?

```
R2# clock set 19:56:00 04 8
                          ^
% Invalid input detected at '^' marker
```

   A. A parameter is missing.
   B. The command was entered in the wrong CLI mode.
   C. The data of one of the parameters is incorrect.
   D. The command is ambiguous.

2. What is the effect of entering the **banner login #Authorized Personnel Only!#** command?

   A. **#Authorized Personnel Only!** appears after the user logs in.
   B. **Authorized Personnel Only!** appears only when the user makes a Telnet connection.
   C. **#Authorized Personnel Only!#** appears only when the user enters global configuration mode.
   D. **Authorized Personnel Only!** appears before the username and password login prompts for any connection.

3. Which three options correctly associate the command with the paired behavior? (Choose three.)

   A. **switchport port-security violation protect**: Frames with unknown source addresses are dropped and a notification is sent.

   B. **switchport port-security violation restrict:** Frames with unknown source addresses are dropped and no notification is sent.

   C. **switchport port-security violation shutdown:** Frames with unknown source addresses result in the port becoming error-disabled and a notification is sent.

   D. **switchport port-security mac-address sticky:** Allows dynamically learned MAC addresses to be stored in the running-configuration.

   E. **switchport port-security maximum:** Defines the number of MAC addresses associated with a port.

4. Refer to Figure 2-25. An Ethernet switch has built the MAC address table shown. What action will the switch take when it receives the frame shown at the bottom of the exhibit?

Figure 2-25 MAC Address Table

Station	Interface1	Interface2	Interface3	Interface4
00-00-3D-1F-11-01			X	
00-00-3D-1F-11-02				X
00-00-3D-1F-11-03	X			

Destination	Source	Data	CRC
00-00-3D-1F-11-03	00-00-3D-1F-11-01		

   A. Forward the frame out all interfaces.

   B. Forward the frame out all interfaces except Interface3.

   C. Discard the frame.

   D. Forward the frame out Interface1.

   E. Forward the frame out Interface2.

   F. Forward the frame out Interface3.

5. What can be determined from the following command output?

```
Switch# show version
<output omitted>
Compiled Wed 18-May-07 22:31
<output omitted>
Running Standard Image
```

```
24 FastEthernet/IEEE 802.3 interface(s)
2 Gigabit Ethernet/IEEE 802.3 interface(s)

32K bytes of flash-simulated non-volatile configuration memory.
<output omitted>
```

A. The system has 32 KB of NVRAM.

B. The switch has 24 physical ports

C. The system was last restarted on May 18, 2005.

D. The Cisco IOS is a nonstandard image.

6. What advantage does SSH offer over Telnet when remotely connecting to a device?

A. Encryption

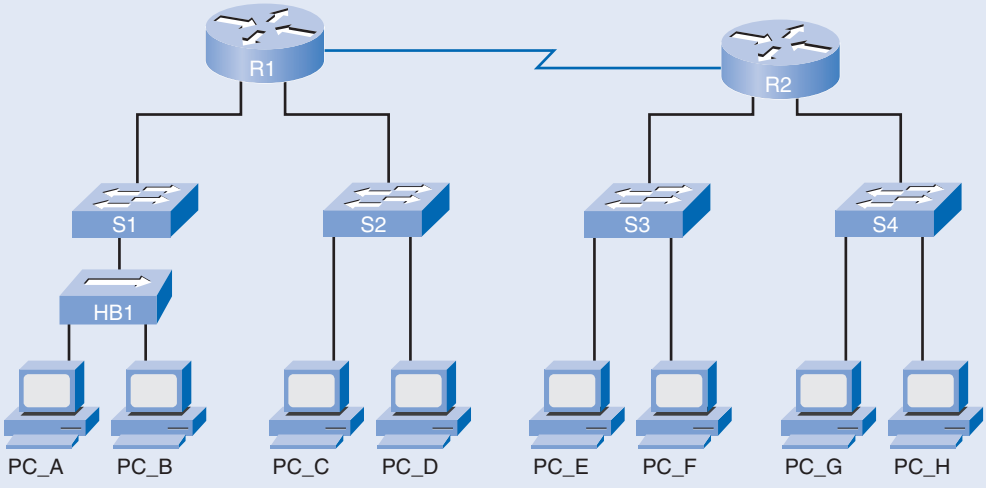
B. More connection lines

C. Connection-oriented services

D. Username and password authentication

7. Refer to Figure 2-26. How many collision and broadcast domains are displayed in the network?

Figure 2-26 Collision and Broadcast Domains



A. 8 collision, 2 broadcast

B. 8 collision, 3 broadcast

C. 11 collision, 4 broadcast

D. 13 collision, 2 broadcast

8. Which option correctly associates the Layer 2 security attack with the description?

   A. **MAC address flooding:** Broadcast requests for IP addresses with spoofed MAC addresses.

   B. **DHCP starvation**: Using proprietary Cisco protocols to gain information about a switch.

   C. **CDP attack:** The attacker fills the switch MAC address table with invalid MAC addresses.

   D. **Telnet attack**: Using brute force password attacks to gain access to a switch.

9. Which three statements are true about the CSMA/CD access method? (Choose three.)

   A. In an Ethernet LAN, each station continuously listens for traffic on the medium to determine when gaps between frame transmissions occur and then sends the frame.

   B. In an Ethernet LAN, stations may begin transmitting anytime they detect that the network is quiet (there is no traffic).

   C. In the CSMA/CD process, priorities are assigned to particular stations, and the station with the highest priority transmits frames on the medium.

   D. If a collision occurs in an Ethernet LAN, transmitting stations stop transmitting and wait a random length of time before attempting to retransmit the frame.

   E. If a collision occurs in an Ethernet LAN, only the station with the highest priority continues to transmit, and the rest of the stations wait a random length of time before attempting to retransmit the frame.

   F. In an Ethernet LAN, all stations execute a backoff algorithm based on their assigned priorities before they transmit frames on the medium.

10. How does the Ethernet switch process the incoming traffic using port-based memory buffering?

    A. The frames are stored in queues that are linked to specific incoming ports.

    B. The frames are stored in queues that are linked to specific outgoing ports.

    C. The frames are transmitted to the outgoing port immediately.

    D. The frames are stored in queues that are linked to the common memory area.

11. What are two key features of an Ethernet switch with Layer 2 capabilities? (Choose two.)

    A. Full-duplex operation

    B. Broadcast and multicast traffic management

    C. Security through access lists

    D. Layer 3 routing functions

    E. Filtering based on MAC address

    F. Network address translation (NAT)

12. The network administrator wants to configure an IP address on a Cisco switch. How does the network administrator assign the IP address?

A. In privileged EXEC mode
B. On the switch interface FastEthernet0/0
C. On the management VLAN
D. On the physical interface connected to the router or next-hop device

13. Why should a default gateway be assigned to a switch?

A. So that there can be remote connectivity to the switch via such programs as Telnet and ping
B. So that frames can be sent through the switch to the router
C. So that frames generated from workstations and destined for remote networks can pass to a higher level
D. So that other networks can be accessed from the command prompt of the switch

14. Which two tasks does autonegotiation in an Ethernet network accomplish? (Choose two.)

A. Sets the link speed
B. Sets the IP address
C. Sets the link duplex mode
D. Sets MAC address assignments on switch port
E. Sets the ring speed

15. What is the effect of entering the SW1(config-if)# **duplex full** command on a Fast Ethernet switch port?

A. The connected device communicates in two directions, but only one direction at a time.
B. The switch port returns to its default configuration.
C. If the connected device is also set for full duplex, it participates in collision-free communication.
D. The efficiency of this configuration is typically rated at 50 to 60 percent.
E. The connected device should be configured as half duplex.

16. Which term describes the time delay between a frame being sent from a source device and received on a destination device?

A. Bandwidth
B. Latency
C. Attenuation
D. Time-to-live
E. Frame check sequence

17. Which option correctly associates the command with the description?

    A. **copy startup-config running-config:** Copy the current running configuration to a TFTP server.

    B. **copy running-config tftp:** Save the current running configuration as the startup configuration.

    C. **copy tftp startup-config:** Restore a configuration from a TFTP server to the running configuration.

    D. **copy tftp running-config:** Restore the startup configuration to the running system.

    E. **copy startup-config tftp:** Restore the configuration from a TFTP server to the startup configuration.

    F. **copy running-config startup config:** Save the current running configuration to the startup configuration

18. Which three options correctly associate the command with the description? (Choose three.)

    A. **enable:** Enter the global configuration mode.

    B. **configure terminal:** Enter configuration mode for the console line.

    C. **line vty 0 15:** Set a password.

    D. **line console 0:** Enter configuration mode for the console line.

    E. **password cisco:** Set a password.

    F. **username admin password cisco:** Enable AAA.

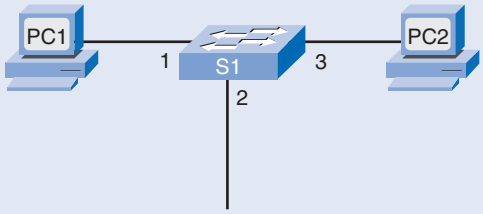
    G. **login:** Permit login.

Challenge Questions and Activities

Complete all the review questions listed here to test your understanding of the topics and concepts in this chapter. Answers are listed in the Appendix, "Check Your Understanding and Challenge Questions Answer Key."

1. Refer to Figure 2-27. There are six steps in the process of a switch learning a MAC address for the purposes of forwarding Ethernet frames. Put the following six steps in order by placing the appropriate number in the blank.

Figure 2-27 Learning MAC Addresses



_____The intended destination device replies to the broadcast with a unicast frame addressed to PC 1.

_____The switch enters the source MAC address and the switch port that received the frame into the address table.

_____The switch enters the source MAC address of PC 2 and the port number of the switch port that received the frame into the address table. The destination address of the frame and its associated port is found in the MAC address table.

_____The switch can now forward frames between source and destination devices without flooding, because it has entries in the address table that identify the associated ports.

_____Because the destination address is a broadcast, the switch floods the frame to all ports, except the port on which it received the frame.

_____The switch receives an ARP broadcast frame from PC 1 on Port 1.

2. List the two principal switch forwarding methods and the two primary methods of memory buffering in switches.

_____

_____

3. From the following output, what is the likely reason for interface VLAN 99 displaying "up/down" as its status?

```
S1# show running-config
<output omitted>
!
interface FastEthernet0/18
 switchport access vlan 99
 switchport mode access
<output omitted>
!
interface Vlan99
 ip address 172.17.99.11 255.255.255.0
 no ip route-cache
```

```
!
<output omitted>
S1# show ip interface brief
Interface              IP-Address      OK? Method Status            Protocol
<output omitted>
Vlan99                 172.17.99.11    YES NVRAM  up                up
<output omitted>
FastEthernet0/18       unassigned      YES unset  down              down
FastEthernet0/19       unassigned      YES unset  down              down
<output omitted>
GigabitEthernet0/2     unassigned      YES unset  down              down
```

4. From the following configuration, which two commands are unnecessary for a basic SSH configuration providing remote access for SSH clients? (Choose two.)

```
Switch(config)# ip domain-name mydomain.com
Switch(config)# crypto key generate rsa
Switch(config)# ip ssh version 2
Switch(config)# line vty 0 15
Switch(config-if)# transport input ssh
```

5. List and describe the three port security violation modes.

Look for this icon in *LAN Switching and Wireless, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-202-8) for instructions on how to perform the Packet Tracer Skills Integration Challenge for this chapter.