Network Design Training Course

สำนักวิทยบริการและเทคโนโลยีสารสนเทศ
มหาวิทยาลัยเทคโนโลยีราชมงคลพระนคร

Itarun Pitimon Ph.D.
ipv9@duck.com

Agenda

https://ipv9.me/JEw

1st Day:

- แนะนำระบบเครือข่าย (Introduction to Networking)
- OSI and TCP/IP Protocol Fundamental
- Switch Architecture, Operation, Configure and Management
- Lab:
  - Ethernet Switch basic configure
  - Allied Telesis switch configure

2nd Day:

- Ethernet Frame Format
- Configuring VLANs and Trunking
- Spanning Tree Protocol (STP), Link Aggregation Control Protocol (LACP) and switch Security
- การบรรยายเทคโนโลยีภาพรวมผลิตภัณฑ์และโซลูชันของ Allied Telesis
- Lab:
  - Vlan and Trunking , Port Security
  - AMF for Allied Telesis

2nd Day

Ethernet Frame Format

Session I

MAC Sublayer

The MAC sublayer is responsible for data encapsulation and accessing the media.

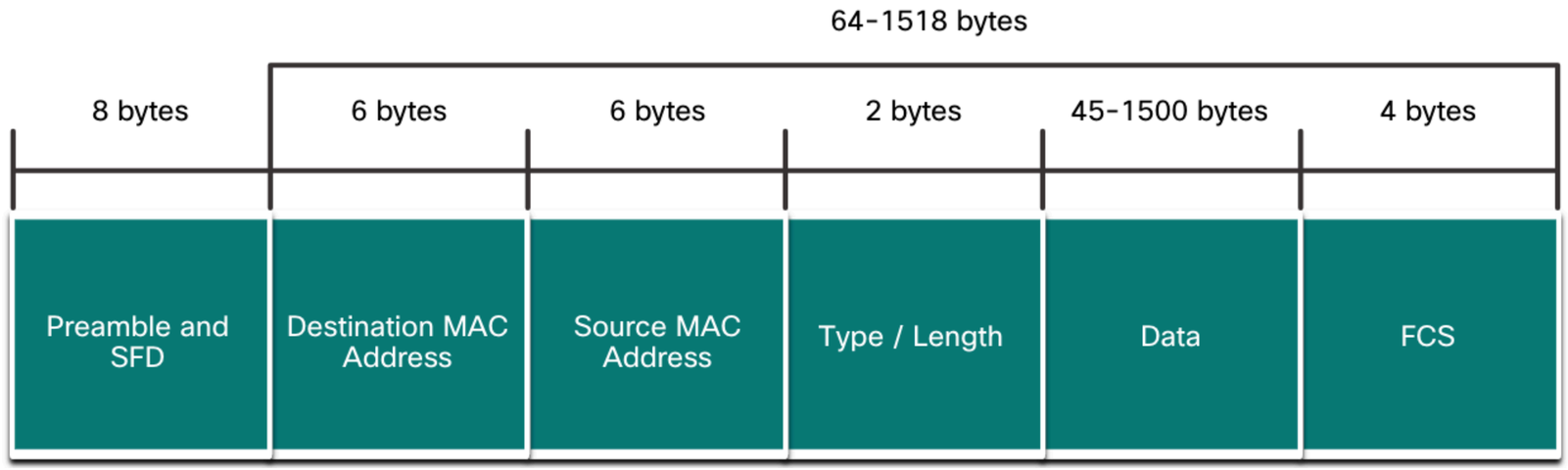
Data Encapsulation

IEEE 802.3 data encapsulation includes the following:

1. **Ethernet frame** - This is the internal structure of the Ethernet frame.
2. **Ethernet Addressing** - The Ethernet frame includes both a source and destination MAC address to deliver the Ethernet frame from Ethernet NIC to Ethernet NIC on the same LAN.
3. **Ethernet Error detection** - The Ethernet frame includes a frame check sequence (FCS) trailer used for error detection.

Ethernet Frame Fields

- The minimum Ethernet frame size is 64 bytes and the maximum is 1518 bytes. The preamble field is not included when describing the size of the frame.
- Any frame less than 64 bytes in length is considered a “collision fragment” or “runt frame” and is automatically discarded. Frames with more than 1500 bytes of data are considered “jumbo” or “baby giant frames”.
- If the size of a transmitted frame is less than the minimum, or greater than the maximum, the receiving device drops the frame. Dropped frames are likely to be the result of collisions or other unwanted signals. They are considered invalid. Jumbo frames are usually supported by most Fast Ethernet and Gigabit Ethernet switches and NICs.

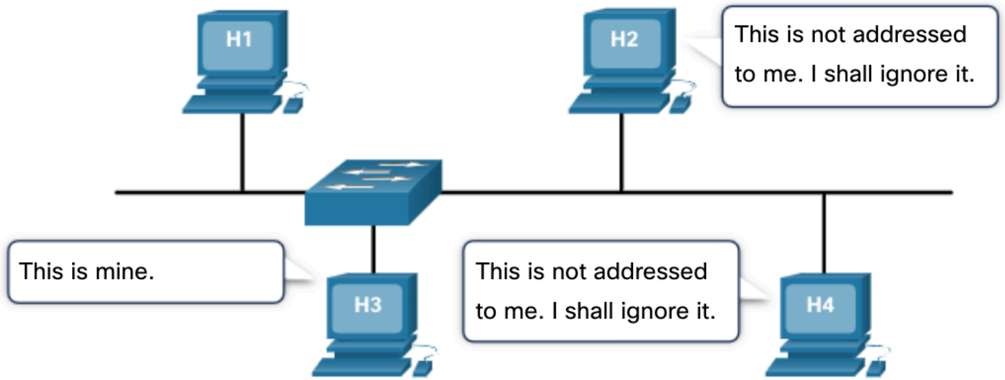


Frame Processing

- When a device is forwarding a message to an Ethernet network, the Ethernet header include a Source MAC address and a Destination MAC address.
- When a NIC receives an Ethernet frame, it examines the destination MAC address to see if it matches the physical MAC address that is stored in RAM. If there is no match, the device discards the frame. If there is a match, it passes the frame up the OSI layers, where the de-encapsulation process takes place.

Note: Ethernet NICs will also accept frames if the destination MAC address is a broadcast or a multicast group of which the host is a member.

- Any device that is the source or destination of an Ethernet frame, will have an Ethernet NIC and therefore, a MAC address. This includes workstations, servers, printers, mobile devices, and routers.

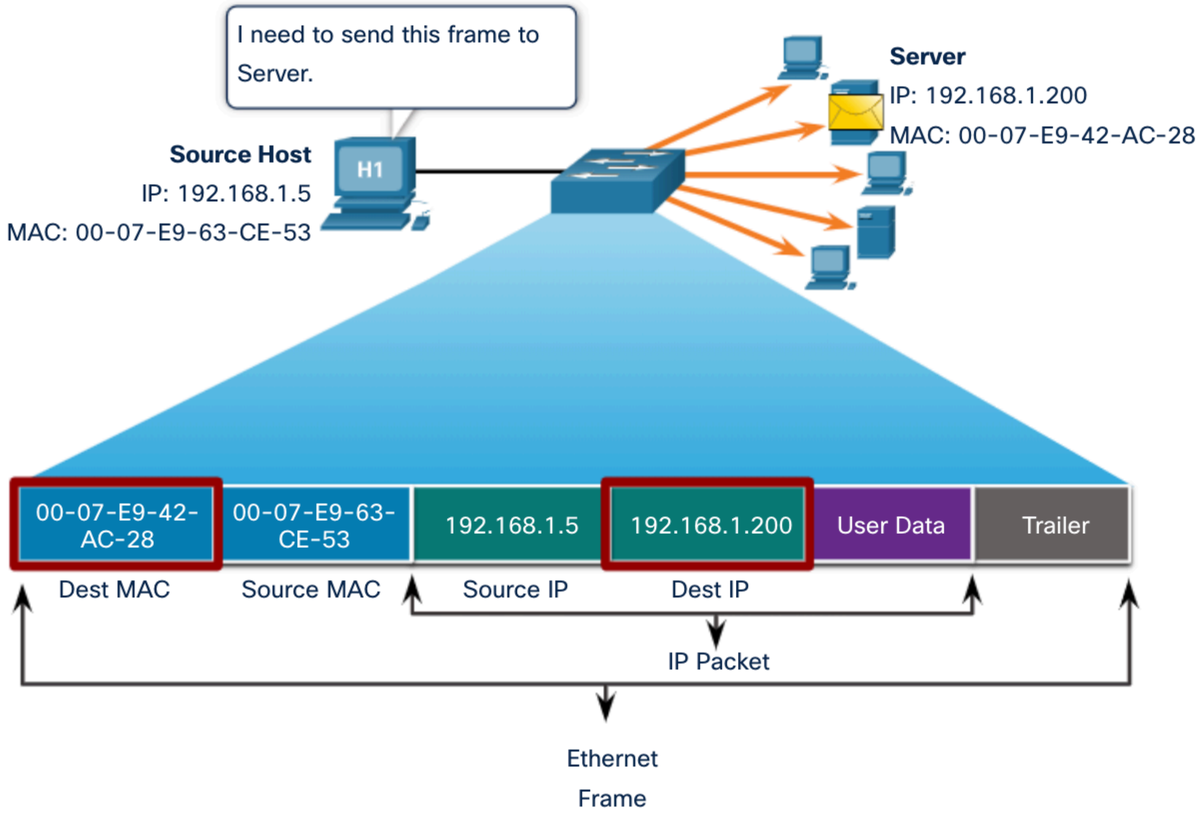


Unicast MAC Address

In Ethernet, different MAC addresses are used for Layer 2 unicast, broadcast, and multicast communications.

- A unicast MAC address is the unique address that is used when a frame is sent from a single transmitting device to a single destination device.
- The process that a source host uses to determine the destination MAC address associated with an IPv4 address is known as Address Resolution Protocol (ARP). The process that a source host uses to determine the destination MAC address associated with an IPv6 address is known as Neighbor Discovery (ND).

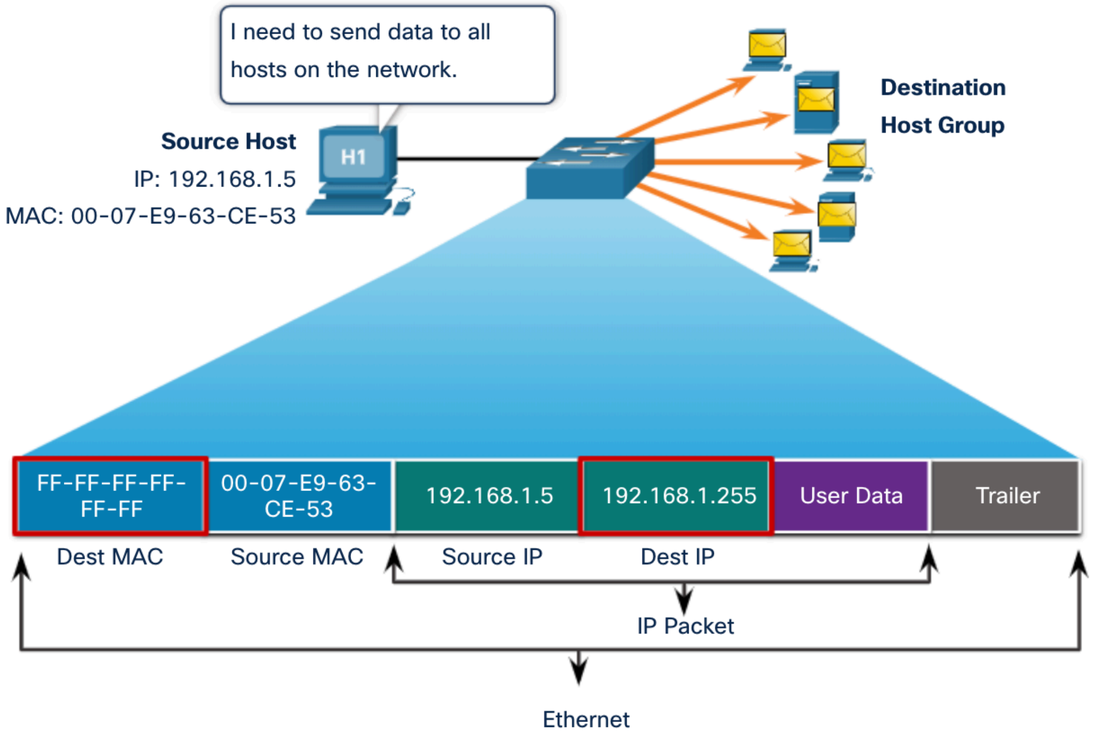
Note: The source MAC address must always be a unicast.



Broadcast MAC Address

An Ethernet broadcast frame is received and processed by every device on the Ethernet LAN. The features of an Ethernet broadcast are as follows:

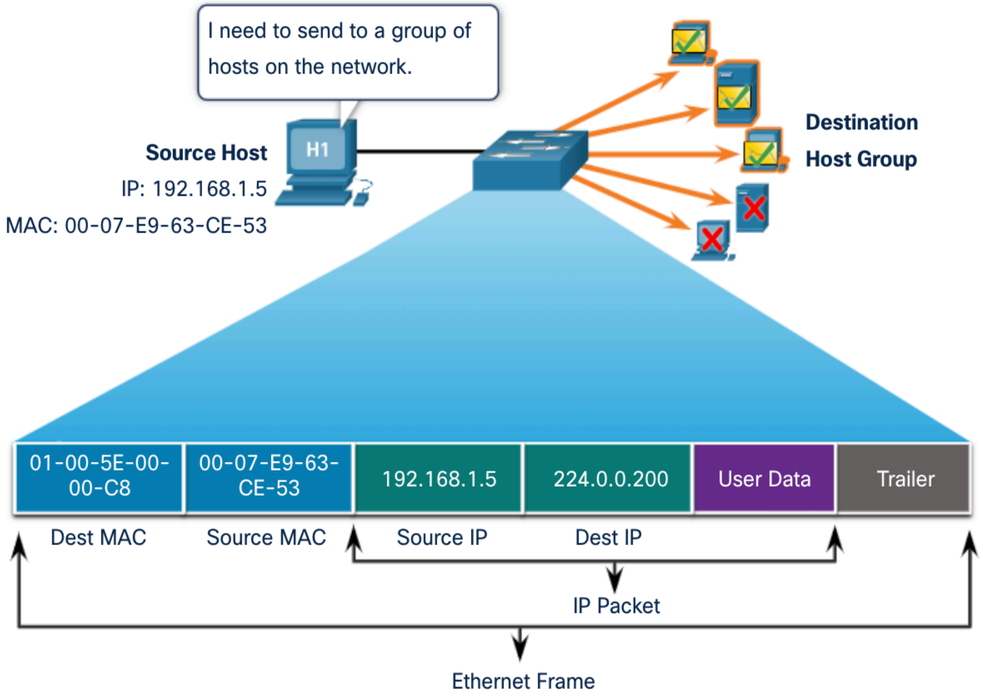
- It has a destination MAC address of FF-FF-FF-FF-FF-FF in hexadecimal (48 ones in binary).
- It is flooded out all Ethernet switch ports except the incoming port. It is not forwarded by a router.
- If the encapsulated data is an IPv4 broadcast packet, this means the packet contains a destination IPv4 address that has all ones (1s) in the host portion. This numbering in the address means that all hosts on that local network (broadcast domain) will receive and process the packet.



Multicast MAC Address

An Ethernet multicast frame is received and processed by a group of devices that belong to the same multicast group.

- There is a destination MAC address of 01-00-5E when the encapsulated data is an IPv4 multicast packet and a destination MAC address of 33-33 when the encapsulated data is an IPv6 multicast packet.
- There are other reserved multicast destination MAC addresses for when the encapsulated data is not IP, such as Spanning Tree Protocol (STP).
- It is flooded out all Ethernet switch ports except the incoming port, unless the switch is configured for multicast snooping. It is not forwarded by a router, unless the router is configured to route multicast packets.
- Because multicast addresses represent a group of addresses (sometimes called a host group), they can only be used as the destination of a packet. The source will always be a unicast address.
- As with the unicast and broadcast addresses, the multicast IP address requires a corresponding multicast MAC address.



Frame Forwarding

Switching in Networking

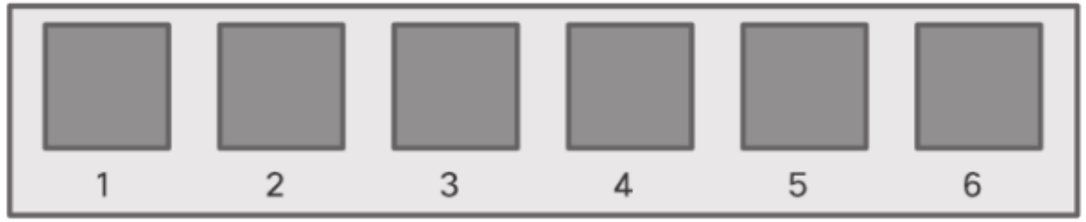
Two terms are associated with frames entering or leaving an interface:

- **Ingress** – entering the interface
- **Egress** – exiting the interface

A switch forwards based on the ingress interface and the destination MAC address.

A switch uses its MAC address table to make forwarding decisions.

Note: A switch will never allow traffic to be forwarded out the interface it received the traffic.



Port Table

Destination Addresses	Port
EE	1
AA	2
BA	3
EA	4
AC	5
AB	6

The Switch MAC Address Table

A switch will use the destination MAC address to determine the egress interface.

Before a switch can make this decision it must learn what interface the destination is located.

A switch builds a MAC address table, also known as a Content Addressable Memory (CAM) table, by recording the source MAC address into the table along with the port it was received.

The Switch Learn and Forward Method

The switch uses a two step process:

Step 1. Learn – Examines Source Address

- Adds the source MAC if not in table
- Resets the time out setting back to 5 minutes if source is in the table

Step 2. Forward – Examines Destination Address

- If the destination MAC is in the MAC address table it is forwarded out the specified port.
- If a destination MAC is not in the table, it is flooded out all interfaces except the one it was received.

Switch Forwarding Methods

Switches use software on application-specific-integrated circuits (ASICs) to make very quick decisions.

A switch will use one of two methods to make forwarding decisions after it receives a frame:

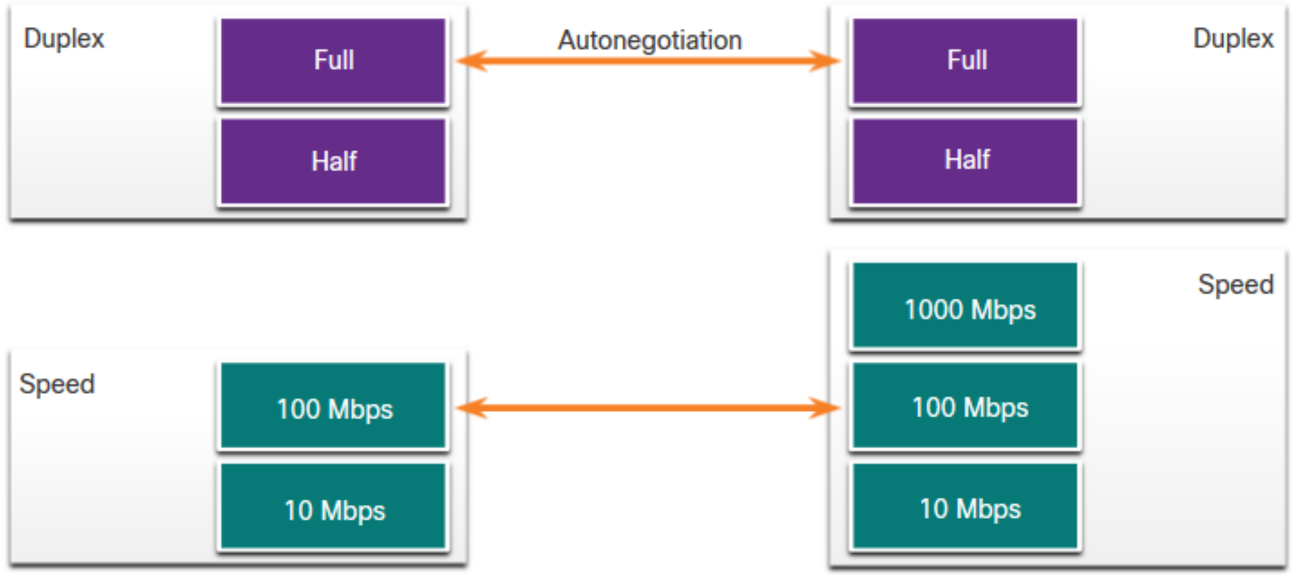
- **Store-and-forward switching** - Receives the entire frame and ensures the frame is valid. Store-and-forward switching is Cisco's preferred switching method.
- **Cut-through switching** – Forwards the frame immediately after determining the destination MAC address of an incoming frame and the egress port.

Switching Domains

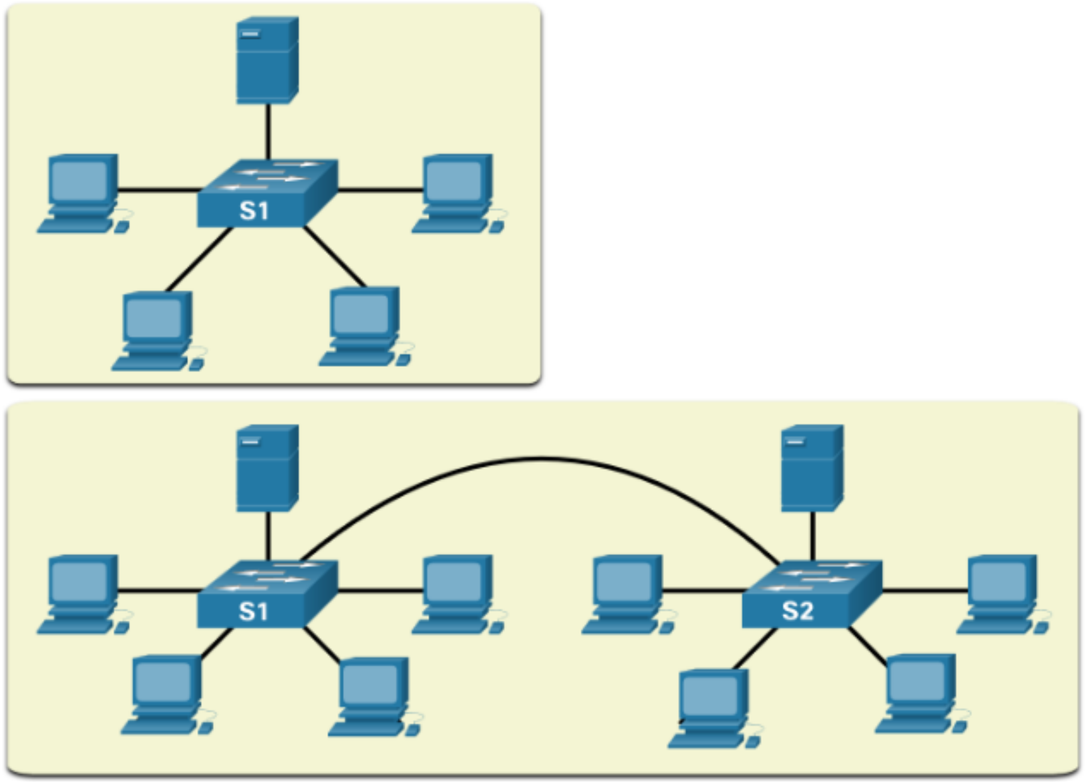
Collision Domains

Switches eliminate collision domains and reduce congestion.

- When there is full duplex on the link the collision domains are eliminated.
- When there is one or more devices in half-duplex there will now be a collision domain.
  - There will now be contention for the bandwidth.
  - Collisions are now possible.
- Most devices, including Cisco and Microsoft use auto-negotiation as the default setting for duplex and speed.



Broadcast Domains



- A broadcast domain extends across all Layer 1 or Layer 2 devices on a LAN.
  - Only a layer 3 device (router) will break the broadcast domain, also called a MAC broadcast domain.
  - The broadcast domain consists of all devices on the LAN that receive the broadcast traffic.
- When the layer 2 switch receives the broadcast it will flood it out all interfaces except for the ingress interface.
- Too many broadcasts may cause congestion and poor network performance.
- Increasing devices at Layer 1 or layer 2 will cause the broadcast domain to expand.

Alleviated Network Congestion

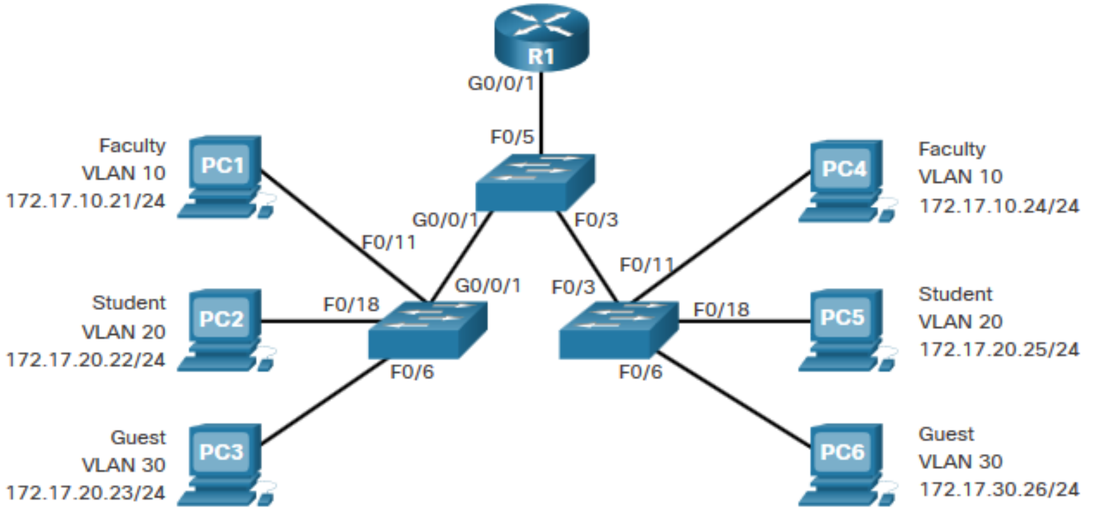
Switches use the MAC address table and full-duplex to eliminate collisions and avoid congestion.

Features of the switch that alleviate congestion are as follows:

Protocol	Function
Fast Port Speeds	Depending on the model, switches may have up to 100Gbps port speeds.
Fast Internal Switching	This uses fast internal bus or shared memory to improve performance.
Large Frame Buffers	This allows for temporary storage while processing large quantities of frames.
High Port Density	This provides many ports for devices to be connected to LAN with less cost. This also provides for more local traffic with less congestion.

Overview of VLANs

Benefits of a VLAN Design



Benefits of using VLANs are as follows:

Benefits	Description
Smaller Broadcast Domains	Dividing the LAN reduces the number of broadcast domains
Improved Security	Only users in the same VLAN can communicate together
Improved IT Efficiency	VLANs can group devices with similar requirements, e.g. faculty vs. students
Reduced Cost	One switch can support multiple groups or VLANs
Better Performance	Small broadcast domains reduce traffic, improving bandwidth
Simpler Management	Similar groups will need similar applications and other network resources

Types of VLANs

Default VLAN

VLAN 1 is the following:

- The default VLAN
- The default Native VLAN
- The default Management VLAN
- Cannot be deleted or renamed

Note: While we cannot delete VLAN1 Cisco will recommend that we assign these default features to other VLANs

```
Switch# show vlan brief
VLAN Name                Status    Ports
---- ----------------- -------  -------------------
1    default             active   Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                  Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                  Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                  Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                  Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                  Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                  Gi0/1, Gi0/2
1002 fddi-default                      act/unsup
1003 token-ring-default                act/unsup
1004 fddinet-default                   act/unsup
1005 trnet-default                     act/unsup
```

Types of VLANs (Cont.)

Data VLAN

- Dedicated to user-generated traffic (email and web traffic).
- VLAN 1 is the default data VLAN because all interfaces are assigned to this VLAN.

Native VLAN

- This is used for trunk links only.
- All frames are tagged on an 802.1Q trunk link except for those on the native VLAN.

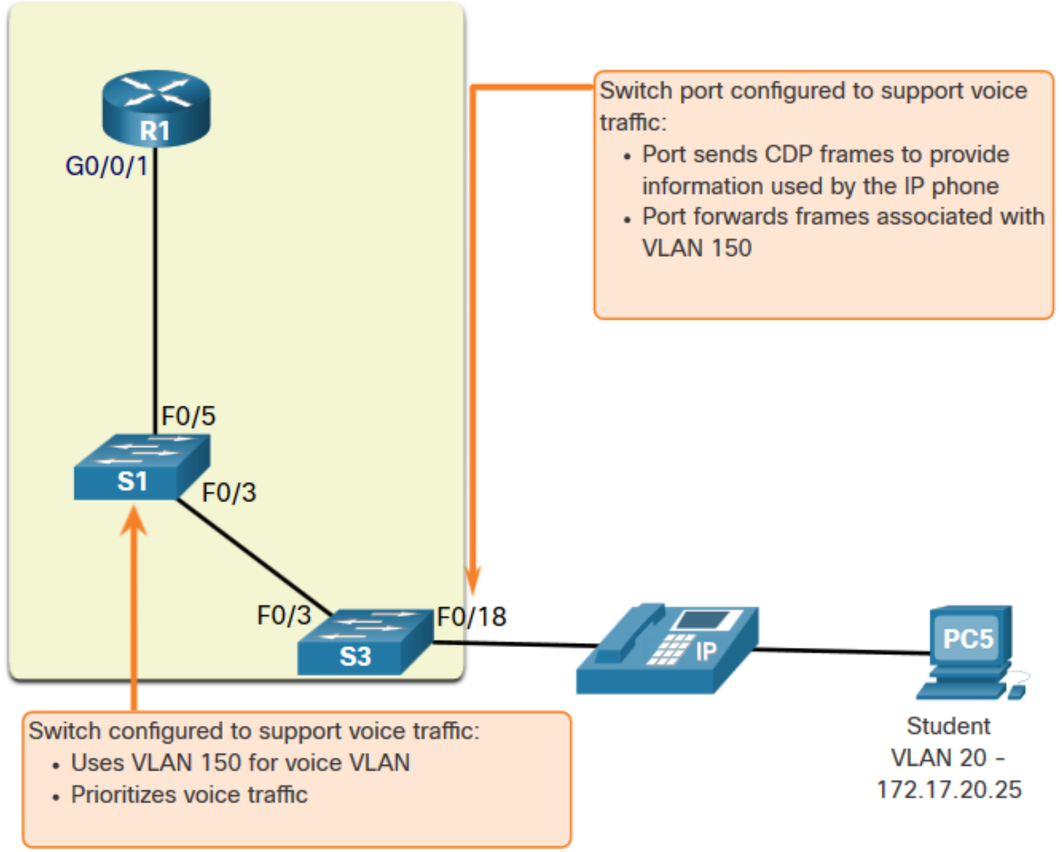
Management VLAN

- This is used for SSH/Telnet VTY traffic and should not be carried with end user traffic.
- Typically, the VLAN that is the SVI for the Layer 2 switch.

Types of VLANs (Cont.)

Voice VLAN

- A separate VLAN is required because Voice traffic requires:
  - Assured bandwidth
  - High QoS priority
  - Ability to avoid congestion
  - Delay less that 150 ms from source to destination
- The entire network must be designed to support voice.



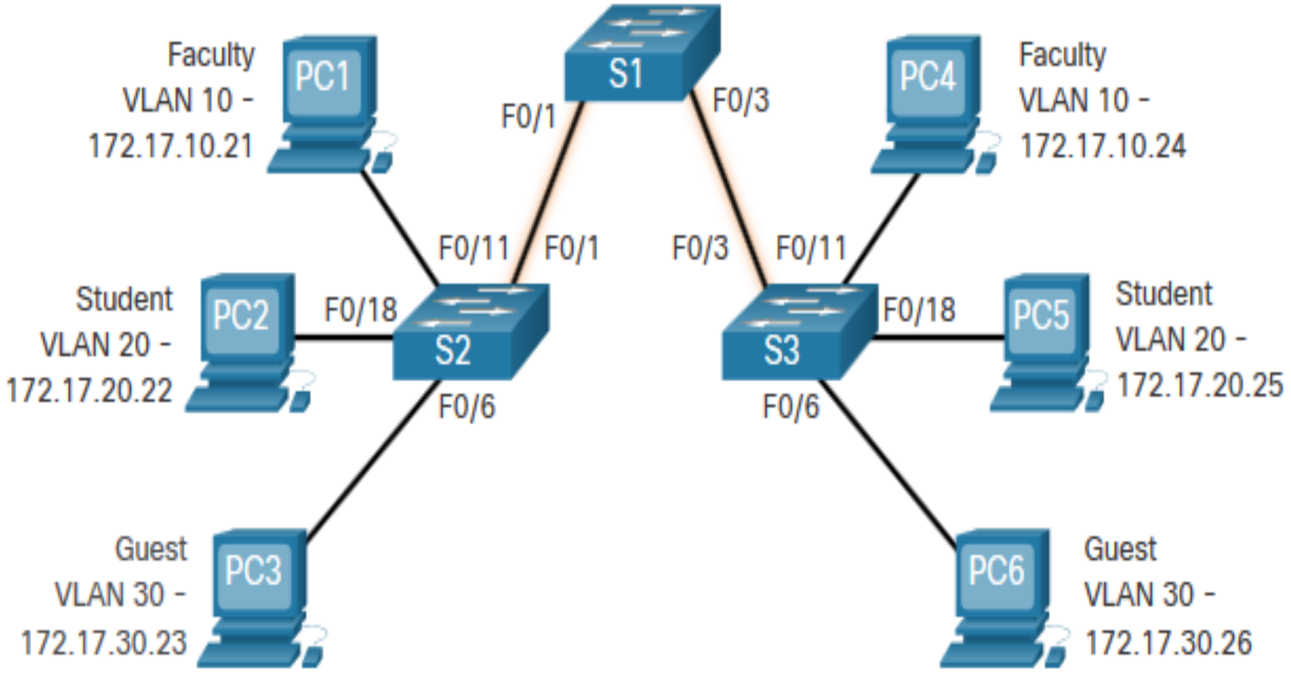
VLANs in a Multi-Switched Environment

Defining VLAN Trunks

A trunk is a point-to-point link between two network devices.

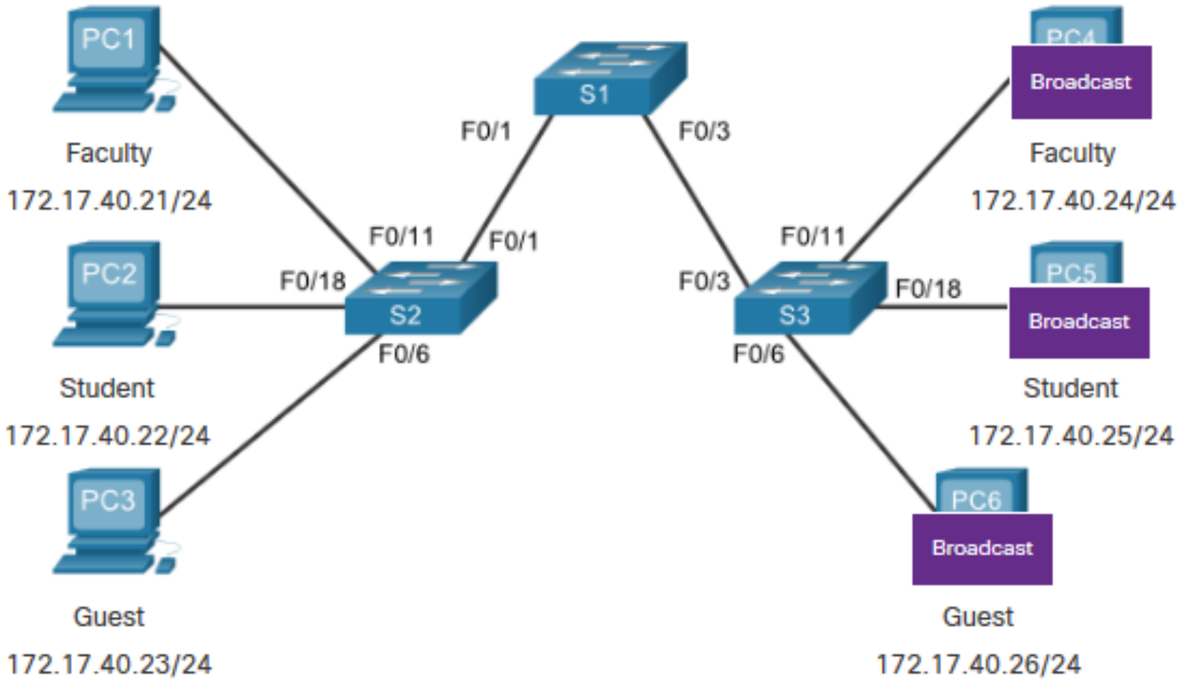
Cisco trunk functions:

- Allow more than one VLAN
- Extend the VLAN across the entire network
- By default, supports all VLANs
- Supports 802.1Q trunking



Networks without VLANs

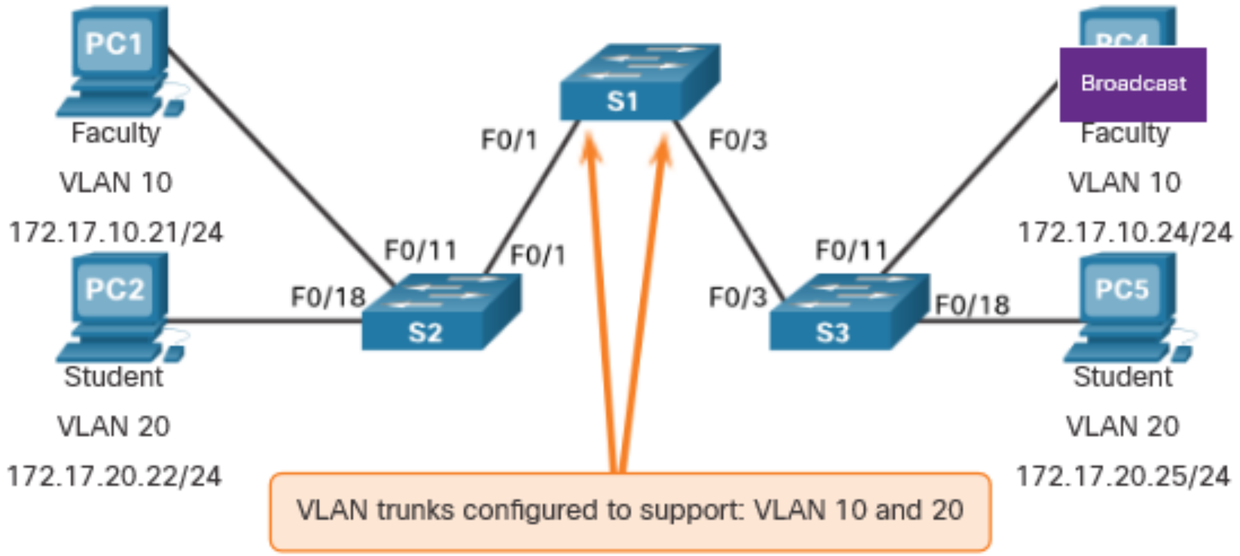
Without VLANs, all devices connected to the switches will receive all unicast, multicast, and broadcast traffic.



PC1 sends out a local Layer 2 broadcast. The switches forward the broadcast frame out all available ports.

Networks with VLANs

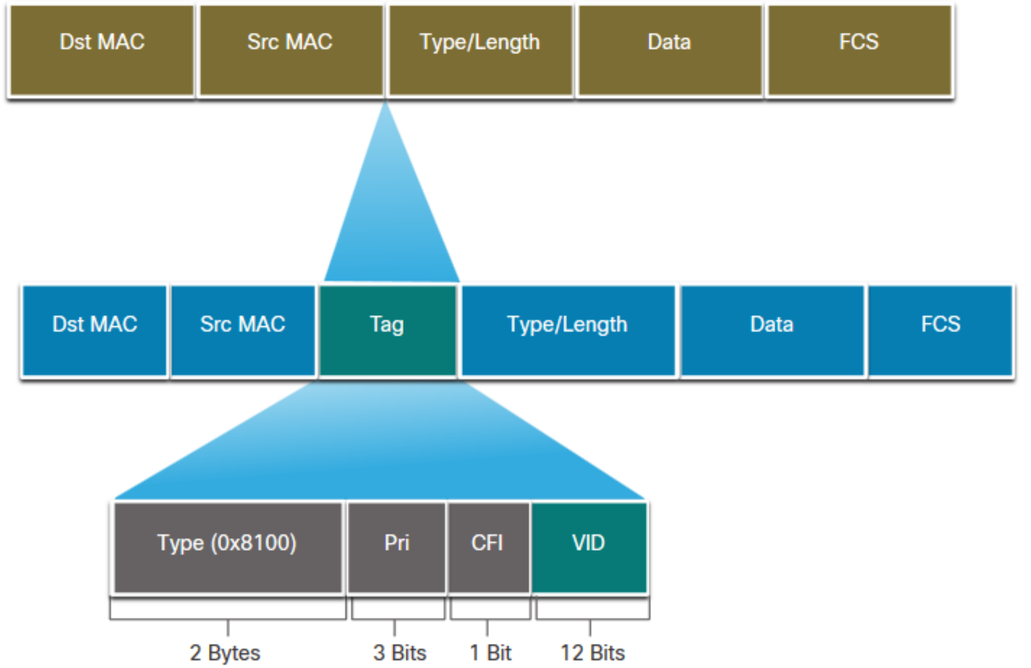
With VLANs, unicast, multicast, and broadcast traffic is confined to a VLAN. Without a Layer 3 device to connect the VLANs, devices in different VLANs cannot communicate.



PC1 sends out a local Layer 2 broadcast. The switches forward the broadcast frame only out ports configured for VLAN10.

VLAN Identification with a Tag

- The IEEE 802.1Q header is 4 Bytes
- When the tag is created the FCS must be recalculated.
- When sent to end devices, this tag must be removed and the FCS recalculated back to its original number.

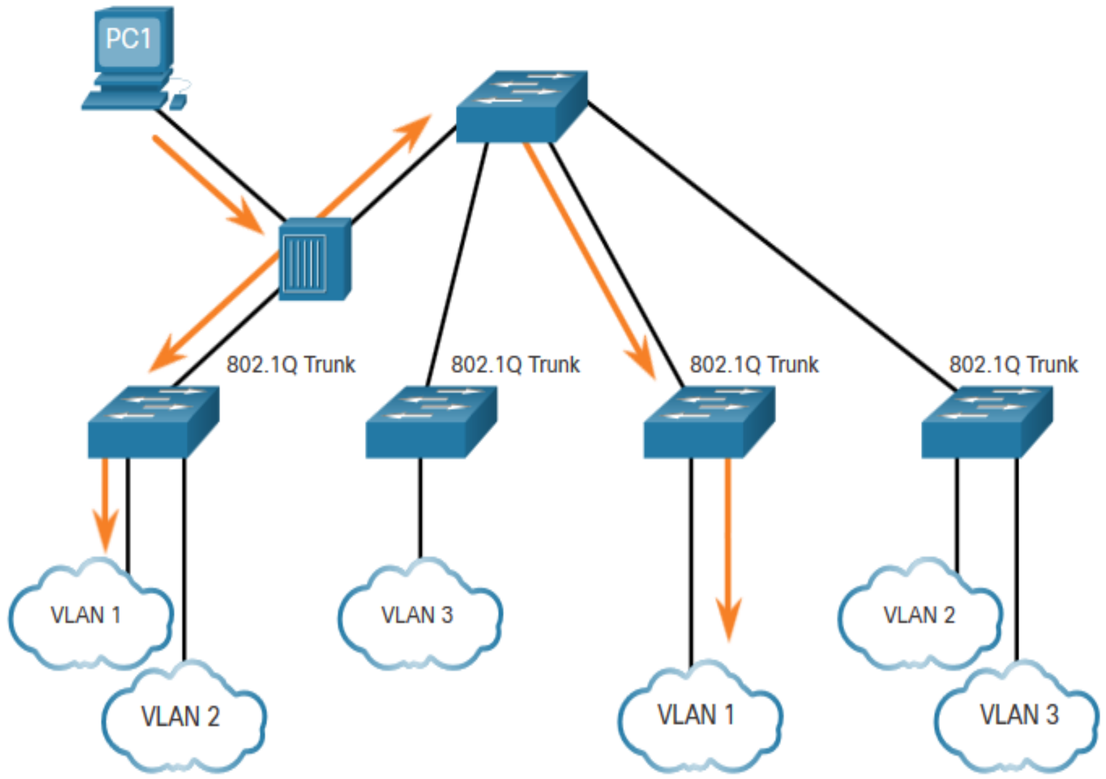


802.1Q VLAN Tag Field	Function
Type	• 2-Byte field with hexadecimal 0x8100 • This is referred to as Tag Protocol ID (TPID)
User Priority	• 3-bit value that supports
Canonical Format Identifier (CFI)	• 1-bit value that can support token ring frames on Ethernet
VLAN ID (VID)	• 12-bit VLAN identifier that can support up to 4096 VLANs

Native VLANs and 802.1Q Tagging

802.1Q trunk basics:

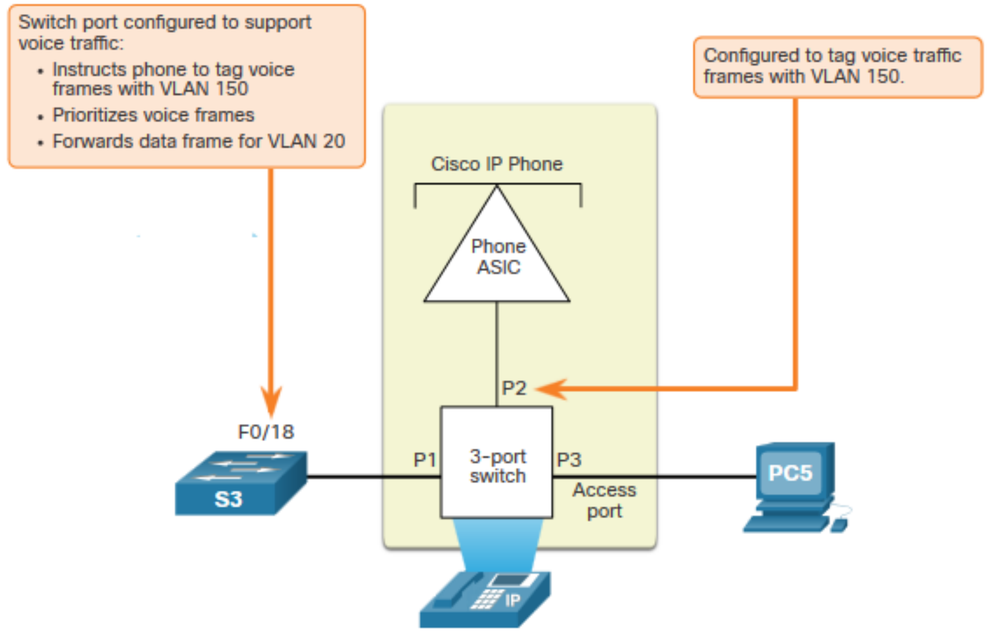
- Tagging is typically done on all VLANs.
- The use of a native VLAN was designed for legacy use, like the hub in the example.
- Unless changed, VLAN1 is the native VLAN.
- Both ends of a trunk link must be configured with the same native VLAN.
- Each trunk is configured separately, so it is possible to have a different native VLANs on separate trunks.



Voice VLAN Tagging

The VoIP phone is a three port switch:

- The switch will use CDP to inform the phone of the Voice VLAN.
- The phone will tag its own traffic (Voice) and can set Cost of Service (CoS). CoS is QoS for layer 2.
- The phone may or may not tag frames from the PC.



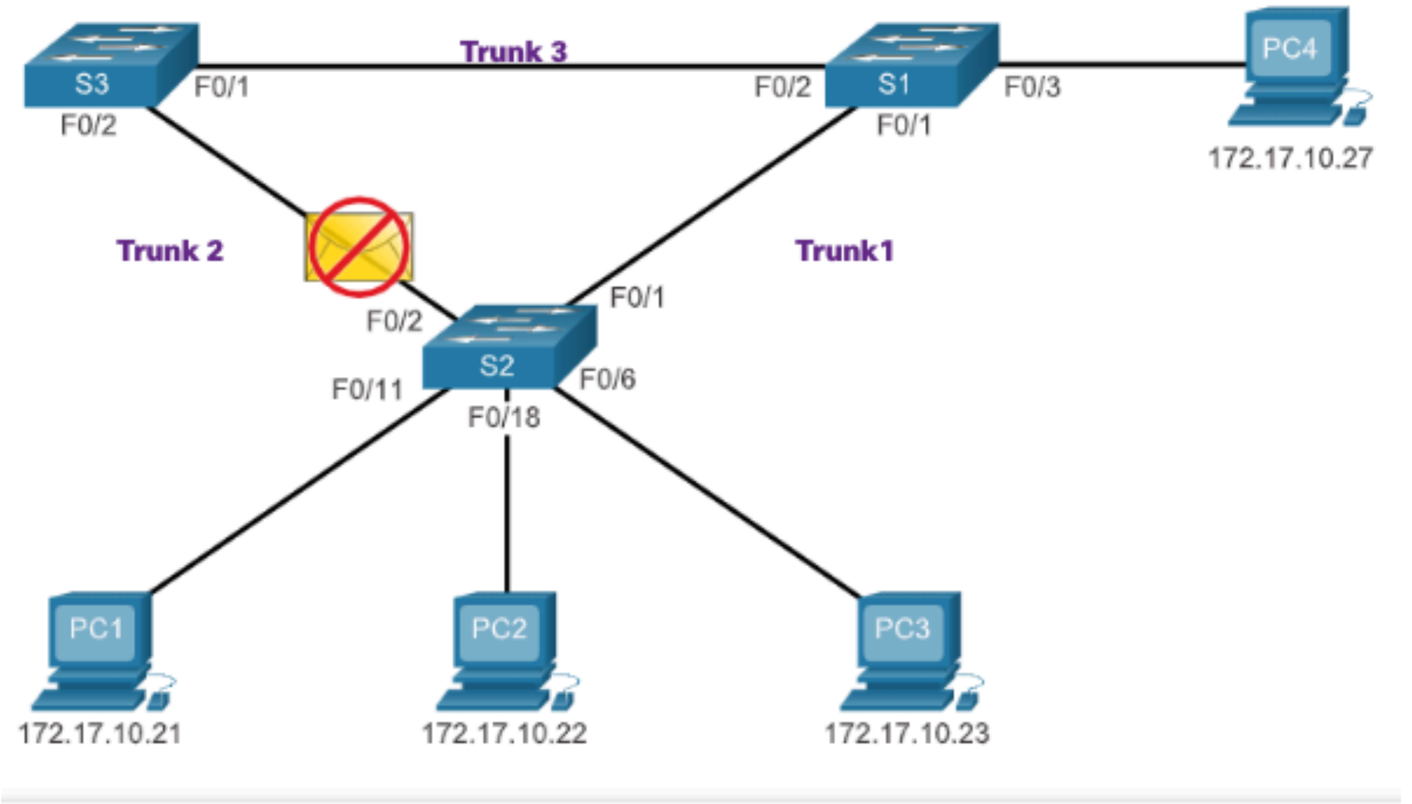
Traffic	Tagging Function
Voice VLAN	tagged with an appropriate Layer 2 class of service (CoS) priority value
Access VLAN	can also be tagged with a Layer 2 CoS priority value
Access VLAN	is not tagged (no Layer 2 CoS priority value)

Purpose of STP

Purpose of STP

Spanning Tree Protocol

- Spanning Tree Protocol (STP) is a loop-prevention network protocol that allows for redundancy while creating a loop-free Layer 2 topology.
- STP logically blocks physical loops in a Layer 2 network, preventing frames from circling the network forever.

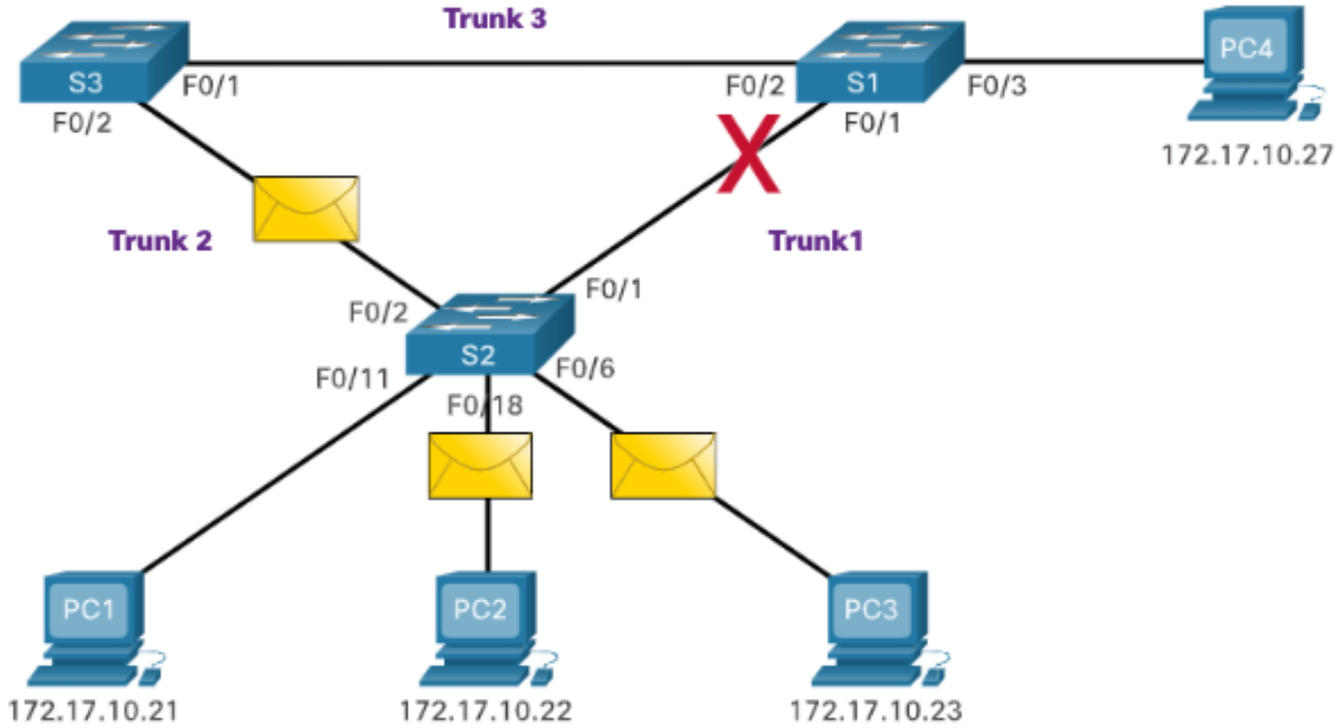


S2 drops the frame because it received it on a blocked port.

Purpose of STP

STP Recalculation

STP compensates for a failure in the network by recalculating and opening up previously blocked ports.



STP Operations

Steps to a Loop-Free Topology

Using the STA, STP builds a loop-free topology in a four-step process:

1. Elect the root bridge.
2. Elect the root ports.
3. Elect designated ports.
4. Elect alternate (blocked) ports.

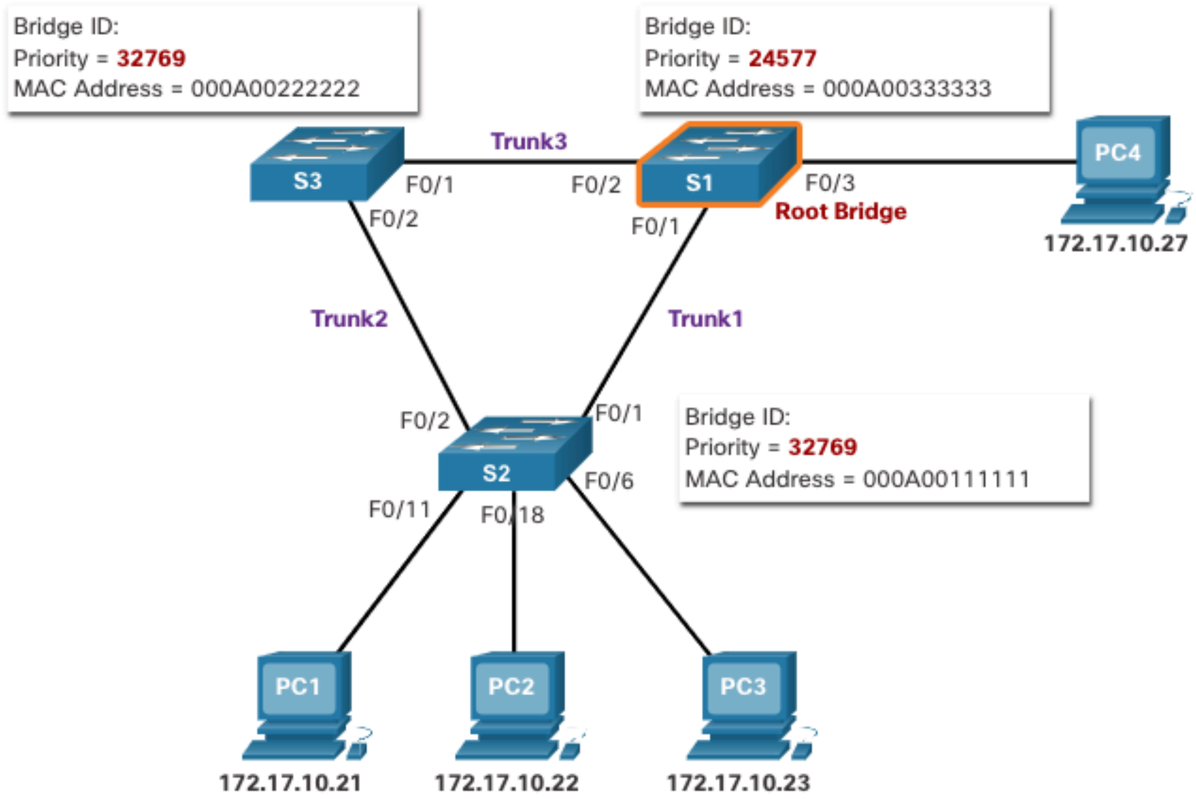
- During STA and STP functions, switches use Bridge Protocol Data Units (BPDUs) to share information about themselves and their connections. BPDUs are used to elect the root bridge, root ports, designated ports, and alternate ports.
- Each BPDU contains a bridge ID (BID) that identifies which switch sent the BPDU. The BID is involved in making many of the STA decisions including root bridge and port roles.
- The BID contains a priority value, the MAC address of the switch, and an extended system ID. The lowest BID value is determined by the combination of these three fields.

Steps to a Loop-Free Topology (Cont.)

- **Bridge Priority:** The default priority value for all Cisco switches is the decimal value 32768. The range is 0 to 61440 in increments of 4096. A lower bridge priority is preferable. A bridge priority of 0 takes precedence over all other bridge priorities.
- **Extended System ID:** The extended system ID value is a decimal value added to the bridge priority value in the BID to identify the VLAN for this BPDU.
- **MAC address:** When two switches are configured with the same priority and have the same extended system ID, the switch having the MAC address with the lowest value, expressed in hexadecimal, will have the lower BID.

1. Elect the Root Bridge

- The STA designates a single switch as the root bridge and uses it as the reference point for all path calculations. Switches exchange BPDUs to build the loop-free topology beginning with selecting the root bridge.
- All switches in the broadcast domain participate in the election process. After a switch boots, it begins to send out BPDU frames every two seconds. These BPDU frames contain the BID of the sending switch and the BID of the root bridge, known as the Root ID.
- The switch with the lowest BID will become the root bridge. At first, all switches declare themselves as the root bridge with their own BID set as the Root ID. Eventually, the switches learn through the exchange of BPDUs which switch has the lowest BID and will agree on one root bridge.



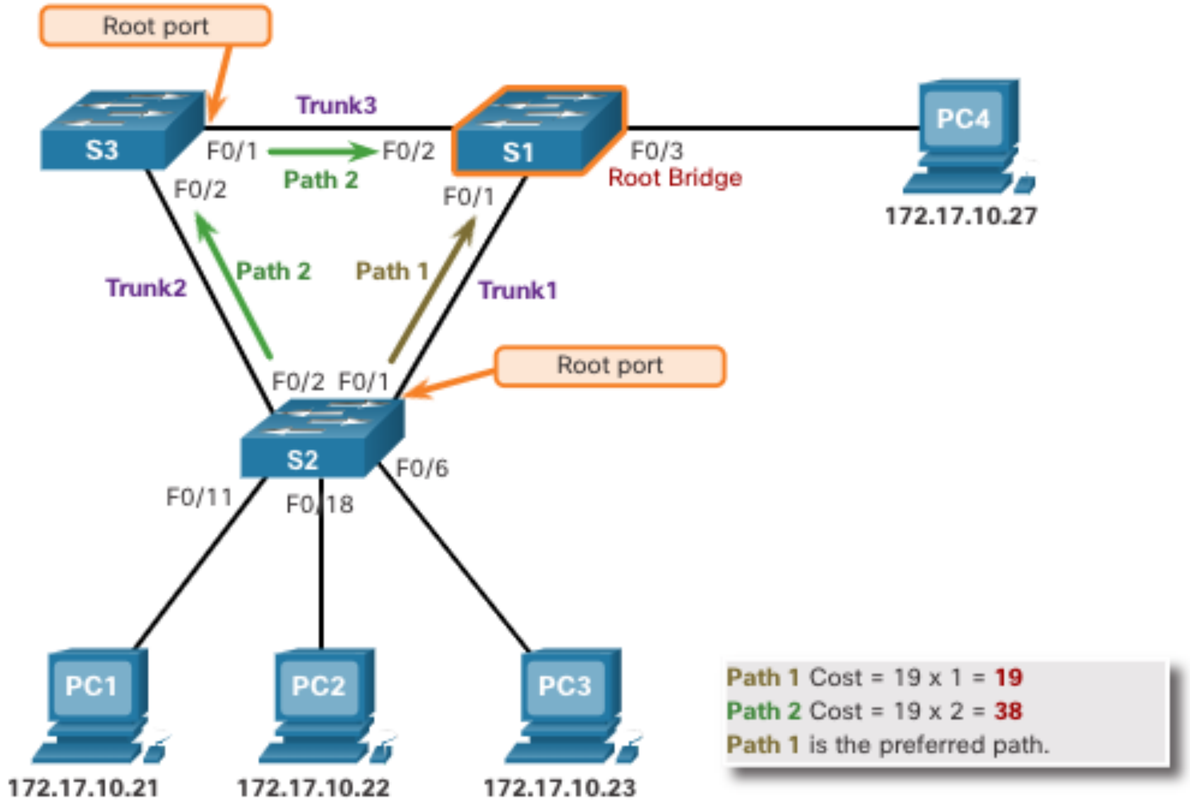
Determine the Root Path Cost

- When the root bridge has been elected for a given spanning tree instance, the STA starts determining the best paths to the root bridge from all destinations in the broadcast domain. The path information, known as the internal root path cost, is determined by the sum of all the individual port costs along the path from the switch to the root bridge.
- When a switch receives the BPDU, it adds the ingress port cost of the segment to determine its internal root path cost.
- The default port costs are defined by the speed at which the port operates. The table shows the default port costs suggested by IEEE. Cisco switches by default use the values as defined by the IEEE 802.1D standard, also known as the short path cost, for both STP and RSTP.
- Although switch ports have a default port cost associated with them, the port cost is configurable. The ability to configure individual port costs gives the administrator the flexibility to manually control the spanning tree paths to the root bridge.

Link Speed	STP Cost: IEEE 802.1D-1998	RSTP Cost: IEEE 802.1w-2004
10 Gbps	2	2,000
1 Gbps	4	20,000
100 Mbps	19	200,000
10 Mbps	100	2,000,000

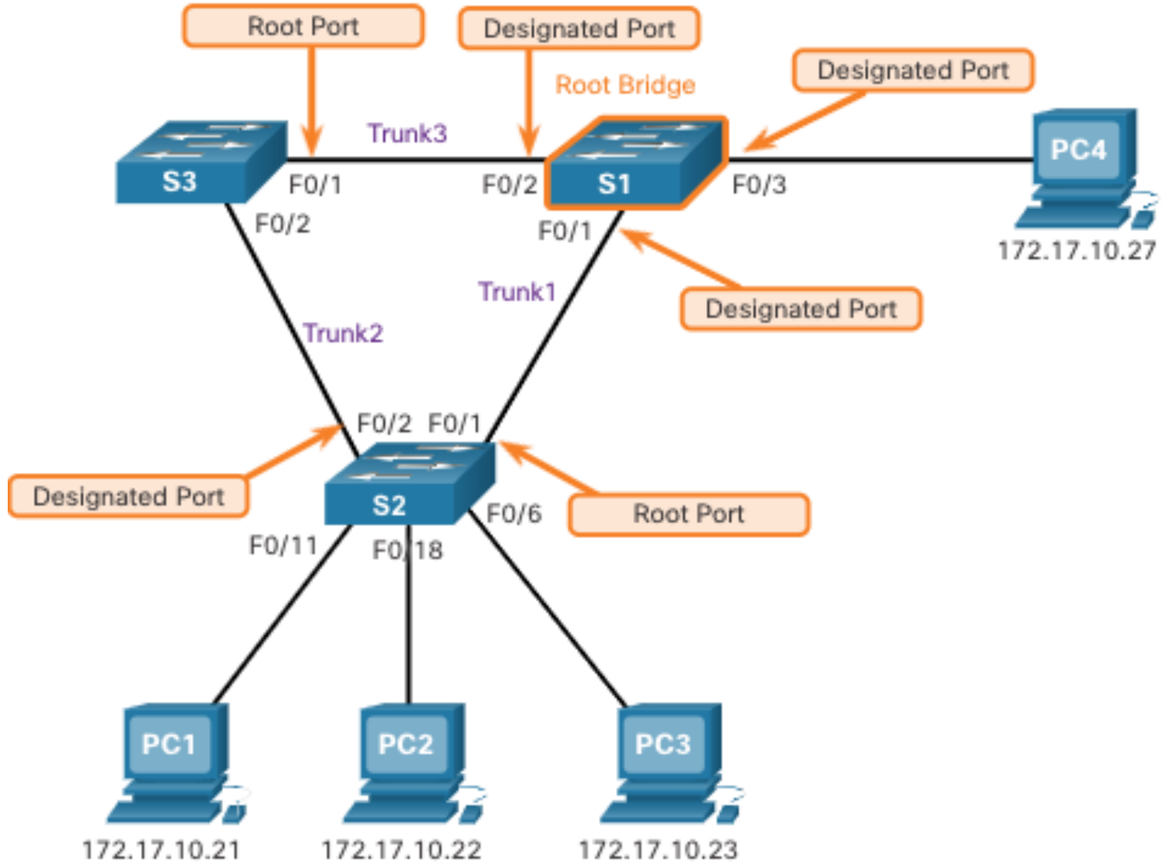
2. Elect the Root Ports

- After the root bridge has been determined, the STA algorithm is used to select the root port. Every non-root switch will select one root port. The root port is the port closest to the root bridge in terms of overall cost to the root bridge. This overall cost is known as the internal root path cost.
- The internal root path cost is equal to the sum of all the port costs along the path to the root bridge, as shown in the figure. Paths with the lowest cost become preferred, and all other redundant paths are blocked. In the example, the internal root path cost from S2 to the root bridge S1 over path 1 is 19 while the internal root path cost over path 2 is 38. Because path 1 has a lower overall path cost to the root bridge, it is the preferred path and F0/1 becomes the root port on S2.



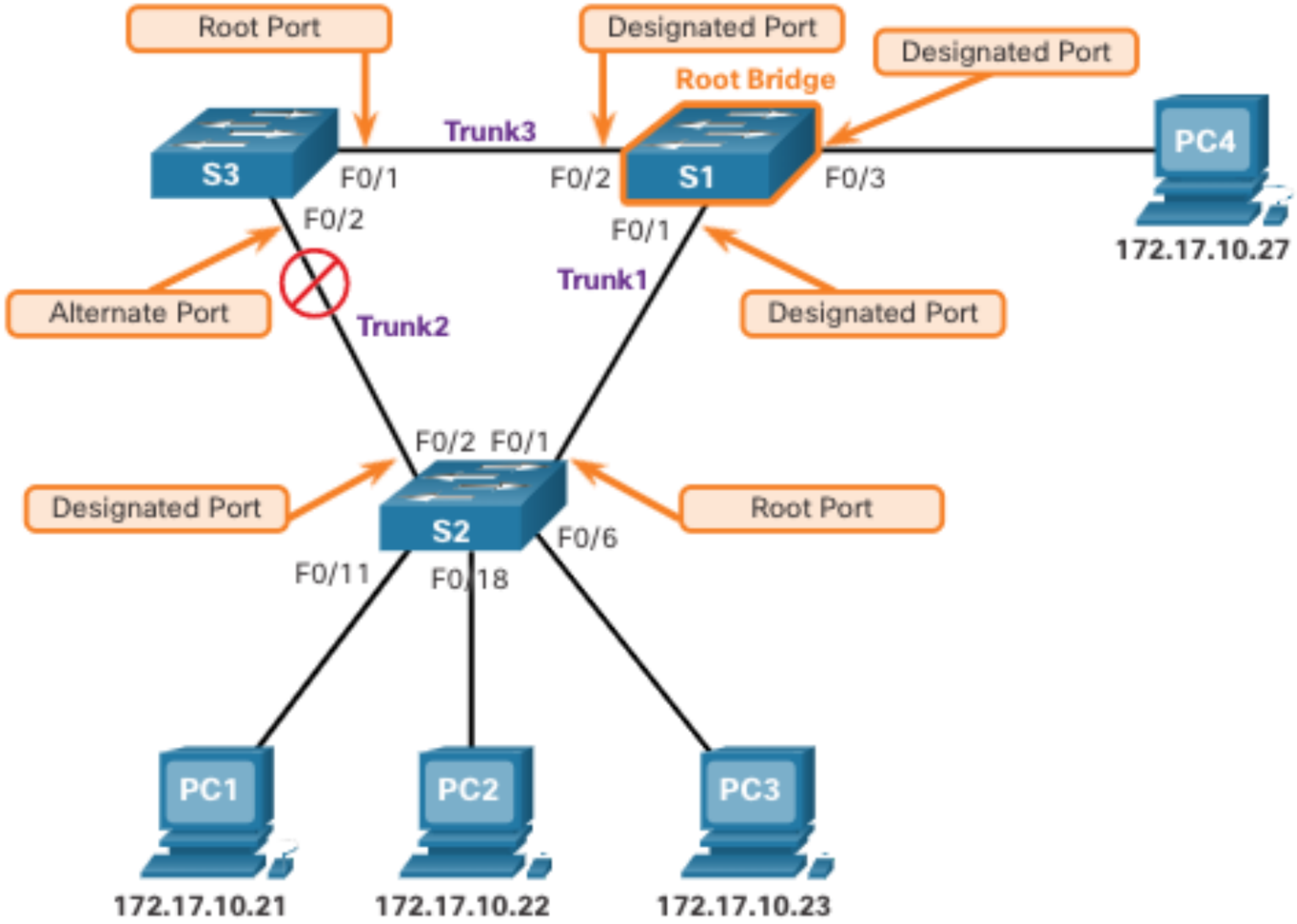
3. Elect Designated Ports

- Every segment between two switches will have one designated port. The designated port is a port on the segment that has the internal root path cost to the root bridge. In other words, the designated port has the best path to receive traffic leading to the root bridge.
- What is not a root port or a designated port becomes an alternate or blocked port.
- All ports on the root bridge are designated ports.
- If one end of a segment is a root port, the other end is a designated port.
- All ports attached to end devices are designated ports.
- On segments between two switches where neither of the switches is the root bridge, the port on the switch with the least-cost path to the root bridge is a designated port.



4. Elect Alternate (Blocked) Ports

If a port is not a root port or a designated port, then it becomes an alternate (or backup) port. Alternate ports are in discarding or blocking state to prevent loops. In the figure, the STA has configured port F0/2 on S3 in the alternate role. Port F0/2 on S3 is in the blocking state and will not forward Ethernet frames. All other inter-switch ports are in forwarding state. This is the loop-prevention part of STP.



Elect a Root Port from Multiple Equal-Cost Paths

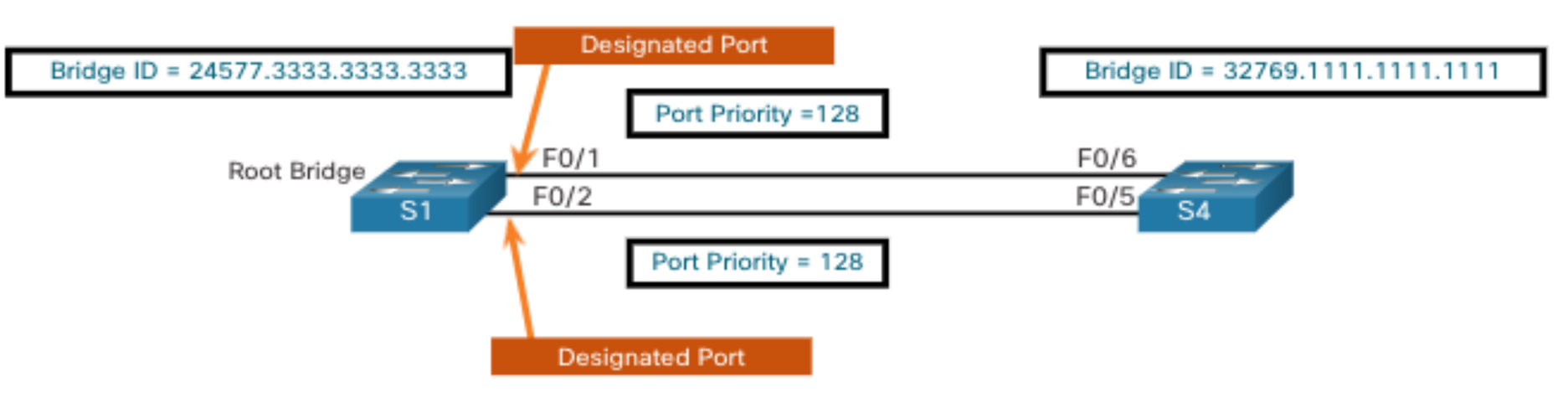
When a switch has multiple equal-cost paths to the root bridge, the switch will determine a port using the following criteria:

- Lowest sender BID
- Lowest sender port priority
- Lowest sender port ID

Elect a Root Port from Multiple Equal-Cost Paths (Cont.)

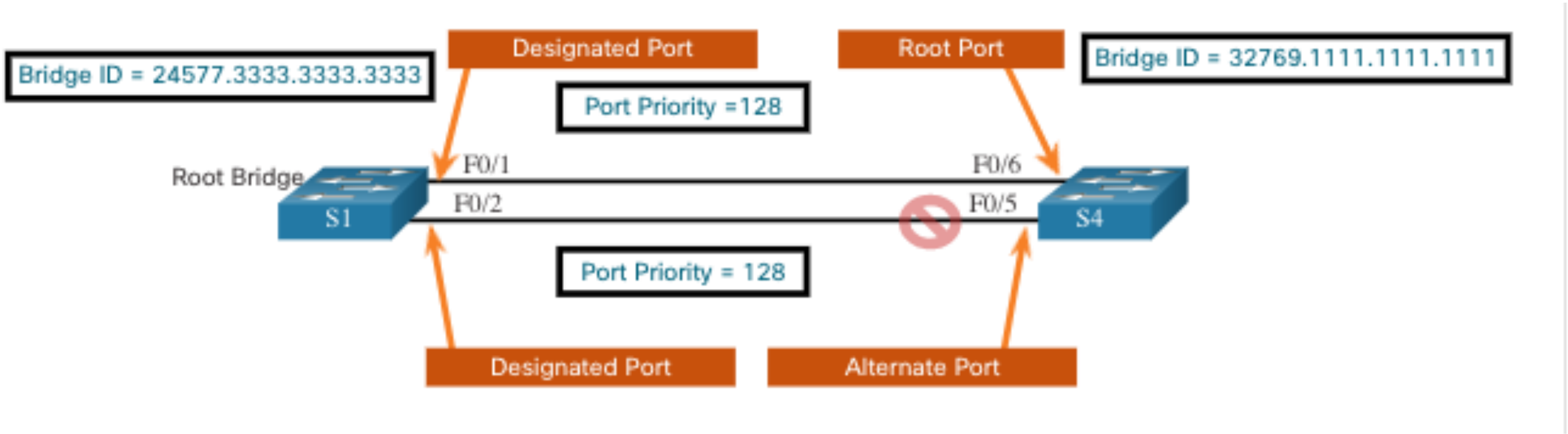
Lowest Sender Port Priority: This topology has two switches which are connected with two equal-cost paths between them. S1 is the root bridge, so both of its ports are designated ports.

- S4 has two ports with equal-cost paths to the root bridge. Because both ports are connected to the same switch, the sender's BID (S1) is equal. So the first step is a tie.
- Next, is the sender's (S1) port priority. The default port priority is 128, so both ports on S1 have the same port priority. This is also a tie. However, if either port on S1 was configured with a lower port priority, S4 would put its adjacent port in forwarding state. The other port on S4 would be a blocking state.



Elect a Root Port from Multiple Equal-Cost Paths (Cont.)

- **Lowest Sender Port ID:** The last tie-breaker is the lowest sender's port ID. Switch S4 has received BPDUs from port F0/1 and port F0/2 on S1. The decision is based on the sender's port ID, not the receiver's port ID. Because the port ID of F0/1 on S1 is lower than port F0/2, the port F0/6 on switch S4 will be the root port. This is the port on S4 that is connected to the F0/1 port on S1.
- Port F0/5 on S4 will become an alternate port and placed in the blocking state.



STP Timers and Port States

STP convergence requires three timers, as follows:

- **Hello Timer** -The hello time is the interval between BPDUs. The default is 2 seconds but can be modified to between 1 and 10 seconds.
- **Forward Delay Timer** -The forward delay is the time that is spent in the listening and learning state. The default is 15 seconds but can be modified to between 4 and 30 seconds.
- **Max Age Timer** -The max age is the maximum length of time that a switch waits before attempting to change the STP topology. The default is 20 seconds but can be modified to between 6 and 40 seconds.

Note: The default times can be changed on the root bridge, which dictates the value of these timers for the STP domain.

Per-VLAN Spanning Tree

STP can be configured to operate in an environment with multiple VLANs. In Per-VLAN Spanning Tree (PVST) versions of STP, there is a root bridge elected for each spanning tree instance. This makes it possible to have different root bridges for different sets of VLANs. STP operates a separate instance of STP for each individual VLAN. If all ports on all switches are members of VLAN 1, then there is only one spanning tree instance.

Evolution of STP

Different Versions of STP

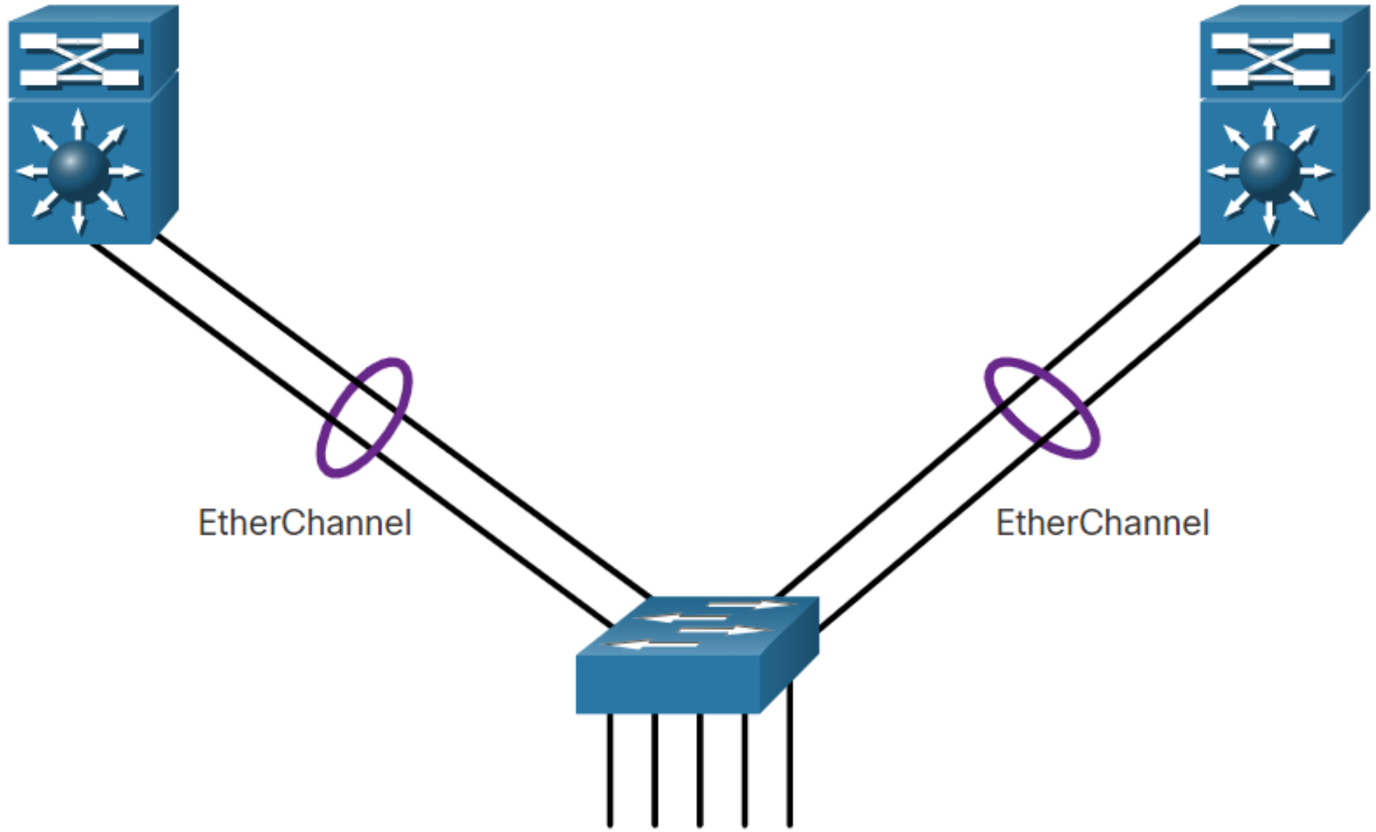
STP Variety	Description
STP	This is the original IEEE 802.1D version (802.1D-1998 and earlier) that provides a loop-free topology in a network with redundant links. Also called Common Spanning Tree (CST), it assumes one spanning tree instance for the entire bridged network, regardless of the number of VLANs.
PVST+	Per-VLAN Spanning Tree (PVST+) is a Cisco enhancement of STP that provides a separate 802.1D spanning tree instance for each VLAN configured in the network. PVST+ supports PortFast, UplinkFast, BackboneFast, BPDU guard, BPDU filter, root guard, and loop guard.
802.1D-2004	This is an updated version of the STP standard, incorporating IEEE 802.1w.
RSTP	Rapid Spanning Tree Protocol (RSTP) or IEEE 802.1w is an evolution of STP that provides faster convergence than STP.
Rapid PVST+	This is a Cisco enhancement of RSTP that uses PVST+ and provides a separate instance of 802.1w per VLAN. Each separate instance supports PortFast, BPDU guard, BPDU filter, root guard, and loop guard.
MSTP	Multiple Spanning Tree Protocol (MSTP) is an IEEE standard inspired by the earlier Cisco proprietary Multiple Instance STP (MISTP) implementation. MSTP maps multiple VLANs into the same spanning tree instance.
MST	Multiple Spanning Tree (MST) is the Cisco implementation of MSTP, which provides up to 16 instances of RSTP and combines many VLANs with the same physical and logical topology into a common RSTP instance. Each instance supports PortFast, BPDU guard, BPDU filter, root guard, and loop guard.

EtherChannel Operation

EtherChannel

EtherChannel technology was originally developed by Cisco as a LAN switch-to-switch technique of grouping several Fast Ethernet or Gigabit Ethernet ports into one logical channel.

When an EtherChannel is configured, the resulting virtual interface is called a port channel. The physical interfaces are bundled together into a port channel interface, as shown in the figure.

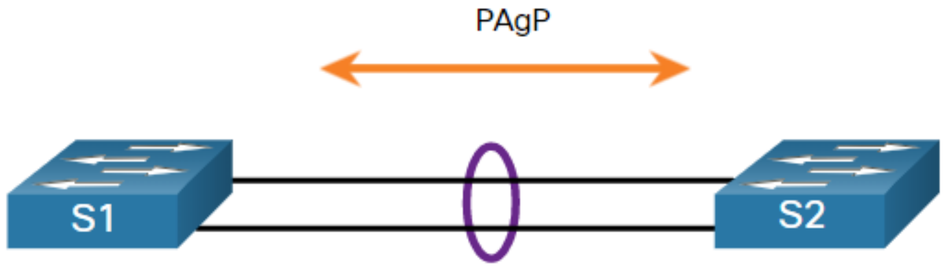


AutoNegotiation Protocols

EtherChannels can be formed through negotiation using one of two protocols, Port Aggregation Protocol (PAgP) or Link Aggregation Control Protocol (LACP). These protocols allow ports with similar characteristics to form a channel through dynamic negotiation with adjoining switches.

Note: It is also possible to configure a static or unconditional EtherChannel without PAgP or LACP.

PAgP Mode Settings Example



The table shows the various combination of PAgP modes on S1 and S2 and the resulting channel establishment

S1	S2	Channel Establishment
On	On	Yes
On	Desirable/Auto	No
Desirable	Desirable	Yes
Desirable	Auto	Yes
Auto	Desirable	Yes
Auto	Auto	No

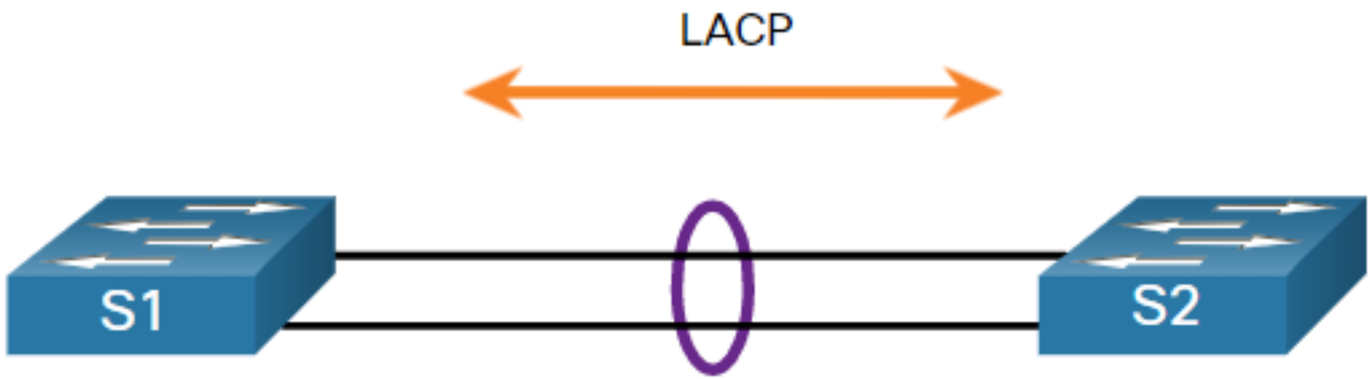
LACP Operation

LACP is part of an IEEE specification (802.3ad) that allows several physical ports to be bundled to form a single logical channel. LACP allows a switch to negotiate an automatic bundle by sending LACP packets to the other switch. It performs a function similar to PAgP with Cisco EtherChannel. Because LACP is an IEEE standard, it can be used to facilitate EtherChannels in multivendor environments. On Cisco devices, both protocols are supported.

LACP provides the same negotiation benefits as PAgP. LACP helps create the EtherChannel link by detecting the configuration of each side and making sure that they are compatible so that the EtherChannel link can be enabled when needed. The modes for LACP are as follows:

- **On** - This mode forces the interface to channel without LACP. Interfaces configured in the on mode do not exchange LACP packets.
- **LACP active** - This LACP mode places a port in an active negotiating state. In this state, the port initiates negotiations with other ports by sending LACP packets.
- **LACP passive** - This LACP mode places a port in a passive negotiating state. In this state, the port responds to the LACP packets that it receives but does not initiate LACP packet negotiation.

LACP Mode Settings Example



The table shows the various combination of LACP modes on S1 and S2 and the resulting channel establishment outcome.

S1	S2	Channel Establishment
On	On	Yes
On	Active/Passive	No
Active	Active	Yes
Active	Passive	Yes
Passive	Active	Yes
Passive	Passive	No

Configure EtherChannel

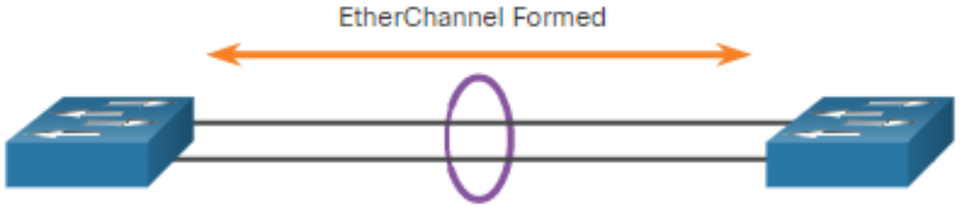
Configuration Guidelines

The following guidelines and restrictions are useful for configuring EtherChannel:

- **EtherChannel support** - All Ethernet interfaces must support EtherChannel with no requirement that interfaces be physically contiguous.
- **Speed and duplex** - Configure all interfaces in an EtherChannel to operate at the same speed and in the same duplex mode.
- **VLAN match** - All interfaces in the EtherChannel bundle must be assigned to the same VLAN or be configured as a trunk (shown in the figure).
- **Range of VLANs** - An EtherChannel supports the same allowed range of VLANs on all the interfaces in a trunking EtherChannel. If the allowed range of VLANs is not the same, the interfaces do not form an EtherChannel, even when they are set to **auto** or **desirable** mode.

Configuration Guidelines (Cont.)

- The figure shows a configuration that would allow an EtherChannel to form between S1 and S2.
- If these settings must be changed, configure them in port channel interface configuration mode. Any configuration that is applied to the port channel interface also affects individual interfaces. However, configurations that are applied to the individual interfaces do not affect the port channel interface. Therefore, making configuration changes to an interface that is part of an EtherChannel link may cause interface compatibility issues.
- The port channel can be configured in access mode, trunk mode (most common), or on a routed port.



S1 Port Configurations	
Speed	1 Gbps
Duplex	Full
VLAN	10

S2 Port Configurations	
Speed	1 Gbps
Duplex	Full
VLAN	10

LACP Configuration Example

Configuring EtherChannel with LACP requires the following three steps:

- **Step 1.** Specify the interfaces that compose the EtherChannel group using the **interface range** *interface* global configuration mode command. The **range** keyword allows you to select several interfaces and configure them all together.
- **Step 2.** Create the port channel interface with the **channel-group** *identifier* **mode active** command in interface range configuration mode. The identifier specifies a channel group number. The **mode active** keywords identify this as an LACP EtherChannel configuration.
- **Step3.** To change Layer 2 settings on the port channel interface, enter port channel interface configuration mode using the **interface port-channel** command, followed by the interface identifier. In the example, S1 is configured with an LACP EtherChannel. The port channel is configured as a trunk interface with the allowed VLANs specified.

```
S1(config)# interface range FastEthernet 0/1 - 2
S1(config-if-range)# channel-group 1 mode active
Creating a port-channel interface Port-channel 1
S1(config-if-range)# exit
S1(config-if)# interface port-channel 1
S1(config-if)# switchport mode trunk
S1(config-if)# switchport trunk allowed vlan 1,2,20
```

Verify and Troubleshoot EtherChannel

Verify EtherChannel

As always, when you configure devices in your network, you must verify your configuration. If there are problems, you will also need to be able to troubleshoot and fix them. There are a number of commands to verify an EtherChannel configuration:

- The **show interfaces port-channel** command displays the general status of the port channel interface.
- The **show etherchannel summary** command displays one line of information per port channel.
- The **show etherchannel port-channel** command displays information about a specific port channel interface.
- The **show interfaces etherchannel** command can provide information about the role of a physical member interface of the EtherChannel.

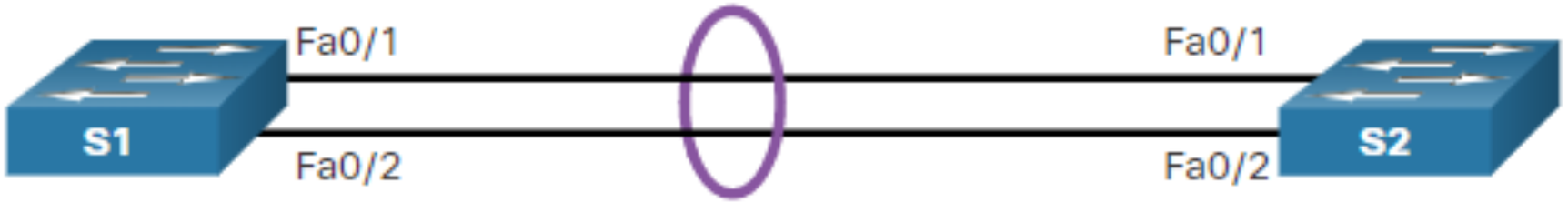
Common Issues with EtherChannel Configurations

All interfaces within an EtherChannel must have the same configuration of speed and duplex mode, native and allowed VLANs on trunks, and access VLAN on access ports. Ensuring these configurations will significantly reduce network problems related to EtherChannel. Common EtherChannel issues include the following:

- Assigned ports in the EtherChannel are not part of the same VLAN, or not configured as trunks. Ports with different native VLANs cannot form an EtherChannel.
- Trunking was configured on some of the ports that make up the EtherChannel, but not all of them. It is not recommended that you configure trunking mode on individual ports that make up the EtherChannel. When configuring a trunk on an EtherChannel, verify the trunking mode on the EtherChannel.
- If the allowed range of VLANs is not the same, the ports do not form an EtherChannel even when PAgP is set to the **auto** or **desirable** mode.
- The dynamic negotiation options for PAgP and LACP are not compatibly configured on both ends of the EtherChannel.

Troubleshoot EtherChannel Example

In the figure, interfaces F0/1 and F0/2 on switches S1 and S2 are connected with an EtherChannel. However, the EtherChannel is not operational.



Troubleshoot EtherChannel Example (Cont.)

Step 1. View the EtherChannel Summary Information: The output of the **show etherchannel summary** command indicates that the EtherChannel is down.

```
S1# show etherchannel summary
Flags:  D - down        P - bundled in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      N - not in use, no aggregation
        f - failed to allocate aggregator
        M - not in use, minimum links not met
        m - not in use, port not aggregated due to minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port
        A - formed by Auto LAG
Number of channel-groups in use: 1
Number of aggregators:           1
Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
1      Po1(SD)         -      Fa0/1(D)    Fa0/2(D)
```

Troubleshoot EtherChannel Example (Cont.)

Step 2. View Port Channel Configuration: In the **show run | begin interface port-channel** output, more detailed output indicates that there are incompatible PAgP modes configured on S1 and S2.

```
S1# show run | begin interface port-channel
interface Port-channel1
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
!
interface FastEthernet0/1
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
 channel-group 1 mode on
!
interface FastEthernet0/2
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
 channel-group 1 mode on
!====================================
S2# show run | begin interface port-channel
interface Port-channel1
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
!
interface FastEthernet0/1
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
 channel-group 1 mode desirable
!
interface FastEthernet0/2
 switchport trunk allowed vlan 1,2,20
 switchport mode trunk
 channel-group 1 mode desirable
```

Troubleshoot EtherChannel Example (Cont.)

Step 3: Correct the Misconfiguration: To correct the issue, the PAgP mode on the EtherChannel is changed to desirable.

Note: EtherChannel and STP must interoperate. For this reason, the order in which EtherChannel-related commands are entered is important, which is why you see interface Port-Channel 1 removed and then re-added with the **channel-group** command, as opposed to directly changed. If one tries to change the configuration directly, STP errors cause the associated ports to go into blocking or errdisabled state.

```
S1(config)# no interface port-channel 1
S1(config)# interface range fa0/1 - 2
S1(config-if-range)# channel-group 1 mode desirable
Creating a port-channel interface Port-channel 1
S1(config-if-range)# no shutdown
S1(config-if-range)# exit
S1(config)# interface range fa0/1 - 2
S1(config-if-range)# channel-group 1 mode desirable
S1(config-if-range)# no shutdown
S1(config-if-range)# interface port-channel 1
S1(config-if)# switchport mode trunk
S1(config-if)# end
S1#
```

Troubleshoot EtherChannel Example (Cont.)

Step 4. Verify EtherChannel is Operational: The EtherChannel is now active as verified by the output of the **show etherchannel summary** command.

```
S1# show etherchannel summary
Flags:  D - down        P - bundled in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      N - not in use, no aggregation
        f - failed to allocate aggregator
        M - not in use, minimum links not met
        m - not in use, port not aggregated due to minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port
        A - formed by Auto LAG
Number of channel-groups in use: 1
Number of aggregators:           1
Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
1      Po1(SU)         PAgP      Fa0/1(P)    Fa0/2(P)
```

Implement Port Security

Secure Unused Ports

Layer 2 attacks are some of the easiest for hackers to deploy but these threats can also be mitigated with some common Layer 2 solutions.

- All switch ports (interfaces) should be secured before the switch is deployed for production use. How a port is secured depends on its function.
- A simple method that many administrators use to help secure the network from unauthorized access is to disable all unused ports on a switch. Navigate to each unused port and issue the Cisco IOS **shutdown** command. If a port must be reactivated at a later time, it can be enabled with the **no shutdown** command.
- To configure a range of ports, use the **interface range** command.

```
Switch(config)# interface range type module/first-number - last-number
```

Mitigate MAC Address Table Attacks

The simplest and most effective method to prevent MAC address table overflow attacks is to enable port security.

- Port security limits the number of valid MAC addresses allowed on a port. It allows an administrator to manually configure MAC addresses for a port or to permit the switch to dynamically learn a limited number of MAC addresses. When a port configured with port security receives a frame, the source MAC address of the frame is compared to the list of secure source MAC addresses that were manually configured or dynamically learned on the port.
- By limiting the number of permitted MAC addresses on a port to one, port security can be used to control unauthorized access to the network.

Enable Port Security (Cont.)

After port security is enabled, other port security specifics can be configured, as shown in the example.

```
S1(config-if)# switchport port-security ?
  aging         Port-security aging commands
  mac-address   Secure mac address
  maximum       Max secure addresses
  violation     Security violation mode
  <cr>
S1(config-if)# switchport port-security
```

Limit and Learn MAC Addresses (Cont.)

The switch can be configured to learn about MAC addresses on a secure port in one of three ways:

1. Manually Configured: The administrator manually configures a static MAC address(es) by using the following command for each secure MAC address on the port:

```
Switch(config-if)# switchport port-security mac-address mac-address
```

2. Dynamically Learned: When the **switchport port-security** command is entered, the current source MAC for the device connected to the port is automatically secured but is not added to the running configuration. If the switch is rebooted, the port will have to re-learn the device's MAC address.

3. Dynamically Learned – Sticky: The administrator can enable the switch to dynamically learn the MAC address and "stick" them to the running configuration by using the following command:

```
Switch(config-if)# switchport port-security mac-address sticky
```

Saving the running configuration will commit the dynamically learned MAC address to NVRAM.

Port Security Violation Modes

If the MAC address of a device attached to a port differs from the list of secure addresses, then a port violation occurs and the port enters the error-disabled state.

- To set the port security violation mode, use the following command:

```
Switch(config-if)# switchport port-security violation {shutdown | restrict | protect}
```

The following table shows how a switch reacts based on the configured violation mode.

Mode	Description
shutdown (default)	The port transitions to the error-disabled state immediately, turns off the port LED, and sends a syslog message. It increments the violation counter. When a secure port is in the error-disabled state, an administrator must re-enable it by entering the **shutdown** and **no shutdown** commands.
restrict	The port drops packets with unknown source addresses until you remove a sufficient number of secure MAC addresses to drop below the maximum value or increase the maximum value. This mode causes the Security Violation counter to increment and generates a syslog message.
protect	This is the least secure of the security violation modes. The port drops packets with unknown MAC source addresses until you remove a sufficient number of secure MAC addresses to drop below the maximum value or increase the maximum value. No syslog message is sent.

Mitigate VLAN Attacks

VLAN Attacks Review

A VLAN hopping attack can be launched in one of three ways:

- Spoofing DTP messages from the attacking host to cause the switch to enter trunking mode. From here, the attacker can send traffic tagged with the target VLAN, and the switch then delivers the packets to the destination.
- Introducing a rogue switch and enabling trunking. The attacker can then access all the VLANs on the victim switch from the rogue switch.
- Another type of VLAN hopping attack is a double-tagging (or double-encapsulated) attack. This attack takes advantage of the way hardware on most switches operate.

Steps to Mitigate VLAN Hopping Attacks

Use the following steps to mitigate VLAN hopping attacks:

Step 1: Disable DTP (auto trunking) negotiations on non-trunking ports by using the **switchport mode access** interface configuration command.

Step 2: Disable unused ports and put them in an unused VLAN.

Step 3: Manually enable the trunk link on a trunking port by using the **switchport mode trunk** command.

Step 4: Disable DTP (auto trunking) negotiations on trunking ports by using the **switchport nonegotiate** command.

Step 5: Set the native VLAN to a VLAN other than VLAN 1 by using the **switchport trunk native vlan** *vlan_number* command.

```
S1(config)# interface range fa0/1 - 16
S1(config-if-range)# switchport mode access
S1(config-if-range)# exit
S1(config)#
S1(config)# interface range fa0/17 - 20
S1(config-if-range)# switchport mode access
S1(config-if-range)# switchport access vlan 1000
S1(config-if-range)# exit
S1(config)#
S1(config)# interface range fa0/21 - 24
S1(config-if-range)# switchport mode trunk
S1(config-if-range)# switchport nonegotiate
S1(config-if-range)# switchport trunk native vlan 999
S1(config-if-range)# end
S1#
```

Mitigate DHCP Attacks

DHCP Attack Review

The goal of a DHCP starvation attack is to an attack tool such as Gobbler to create a Denial of Service (DoS) for connecting clients.

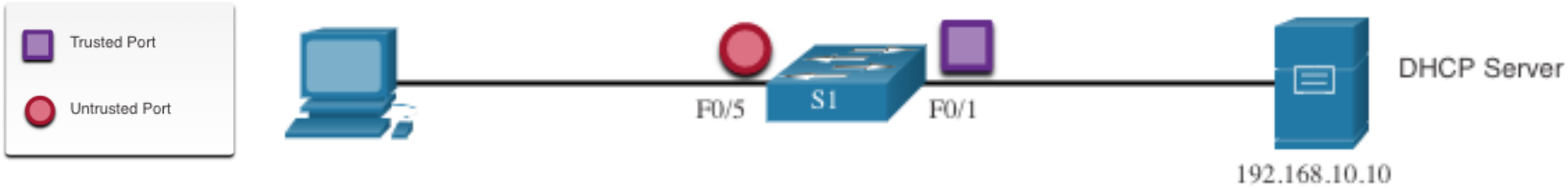
Recall that DHCP starvation attacks can be effectively mitigated by using port security because Gobbler uses a unique source MAC address for each DHCP request sent. However, mitigating DHCP spoofing attacks requires more protection.

Gobbler could be configured to use the actual interface MAC address as the source Ethernet address, but specify a different Ethernet address in the DHCP payload. This would render port security ineffective because the source MAC address would be legitimate.

DHCP spoofing attacks can be mitigated by using DHCP snooping on trusted ports.

DHCP Snooping Configuration Example

Refer to the DHCP snooping sample topology with trusted and untrusted ports.



- DHCP snooping is first enabled on S1.
- The upstream interface to the DHCP server is explicitly trusted.
- F0/5 to F0/24 are untrusted and are, therefore, rate limited to six packets per second.
- Finally, DHCP snooping is enabled on VLANS 5, 10, 50, 51, and 52.

```
S1(config)# ip dhcp snooping
S1(config)# interface f0/1
S1(config-if)# ip dhcp snooping trust
S1(config-if)# exit
S1(config)# interface range f0/5 - 24
S1(config-if-range)# ip dhcp snooping limit rate 6
S1(config-if)# exit
S1(config)# ip dhcp snooping vlan 5,10,50-52
S1(config)# end
S1#
```

Mitigate ARP Attacks

Dynamic ARP Inspection

In a typical ARP attack, a threat actor can send unsolicited ARP replies to other hosts on the subnet with the MAC Address of the threat actor and the IP address of the default gateway. To prevent ARP spoofing and the resulting ARP poisoning, a switch must ensure that only valid ARP Requests and Replies are relayed.

Dynamic ARP inspection (DAI) requires DHCP snooping and helps prevent ARP attacks by:

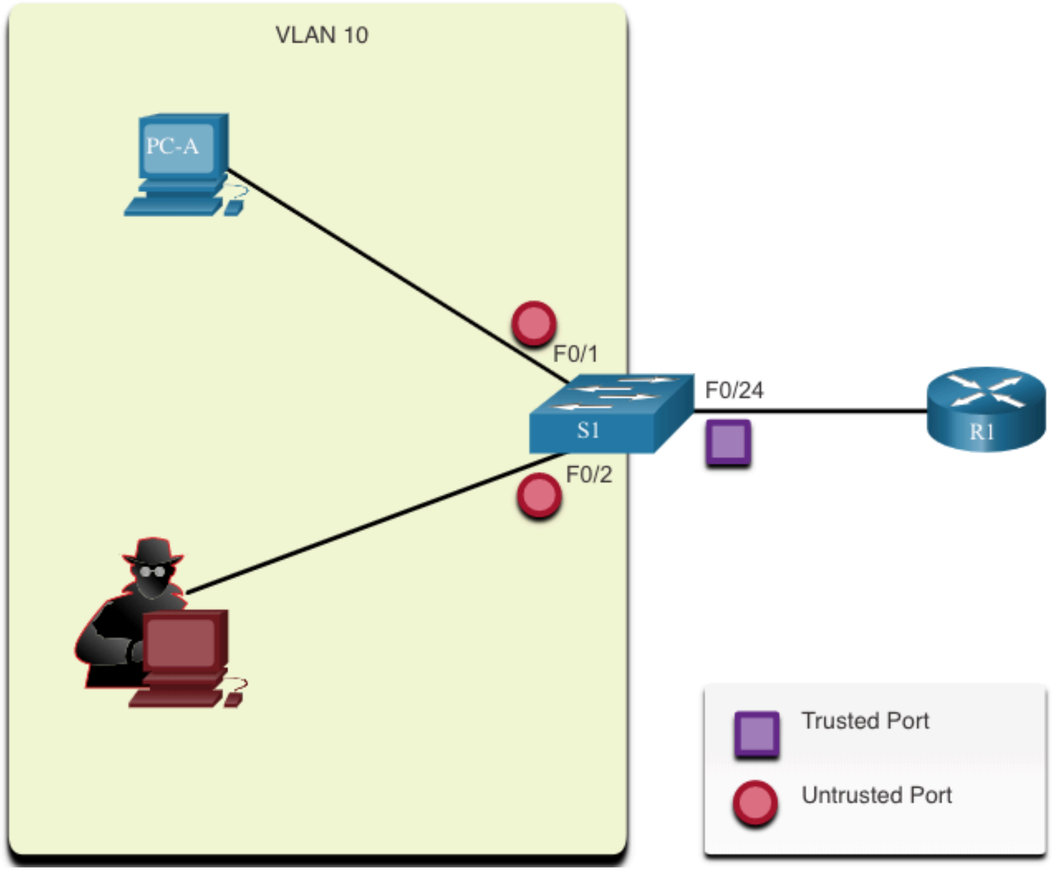
- Not relaying invalid or gratuitous ARP Replies out to other ports in the same VLAN.
- Intercepting all ARP Requests and Replies on untrusted ports.
- Verifying each intercepted packet for a valid IP-to-MAC binding.
- Dropping and logging ARP Replies coming from invalid to prevent ARP poisoning.
- Error-disabling the interface if the configured DAI number of ARP packets is exceeded.

DAI Implementation Guidelines

To mitigate the chances of ARP spoofing and ARP poisoning, follow these DAI implementation guidelines:

- Enable DHCP snooping globally.
- Enable DHCP snooping on selected VLANs.
- Enable DAI on selected VLANs.
- Configure trusted interfaces for DHCP snooping and ARP inspection.

It is generally advisable to configure all access switch ports as untrusted and to configure all uplink ports that are connected to other switches as trusted.



Mitigate STP Attacks

PortFast and BPDU Guard

Recall that network attackers can manipulate the Spanning Tree Protocol (STP) to conduct an attack by spoofing the root bridge and changing the topology of a network.

To mitigate STP attacks, use PortFast and Bridge Protocol Data Unit (BPDU) Guard:

PortFast

- PortFast immediately brings a port to the forwarding state from a blocking state, bypassing the listening and learning states.
- Apply to all end-user access ports.

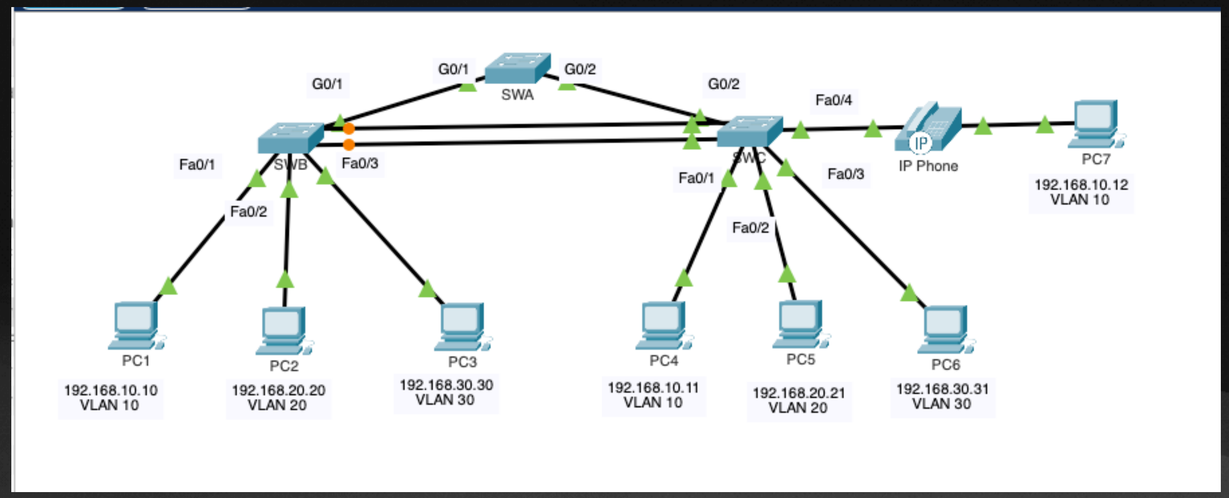
BPDU Guard

- BPDU guard immediately error disables a port that receives a BPDU.
- Like PortFast, BPDU guard should only be configured on interfaces attached to end devices.

Lab: Switch Configure

Objective:

- **VLANs**
- **Trunking**
- **LACP IEEE 802.1Q**



https://ipv9.me/rmutp_lab2

Q&A

Thank you for your attention. Enjoy the rest of your evening.