Module 5: STP Concepts

Introduction

Welcome to STP Concepts!

A well-designed Layer 2 network will have redundant switches and paths to ensure that if one switch goes down, another path to a different switch is available to forward data. Users of the network would not experience any disruption of service. Redundancy in a hierarchical network design fixes the problem of a single point of failure, yet it can create a different kind of problem called Layer 2 loops.

What is a loop? Imagine that you are at a concert. The singer's microphone and the amplified loudspeaker can, for a variety of reasons, create a feedback loop. What you hear is an amplified signal from the microphone that comes out of the loudspeaker which is then picked up again by the microphone, amplified further, and passed again through the loudspeaker. The sound quickly becomes very loud, unpleasant, and makes it impossible to hear any actual music. This continues until the connection between the microphone and the loudspeaker is cut.

A Layer 2 loop creates similar chaos in a network. It can happen very quickly and make it impossible to use the network. There are a few common ways that a Layer 2 loop can be created and propagated. Spanning Tree Protocol (STP) is designed specifically to eliminate Layer 2 loops in your network. This module discusses causes of loops and the various types of spanning tree protocols. It includes a video and a Packet Tracer activity to help you understand STP concepts.

Module Objectives

Module Title: STP Concepts

Module Objective: Explain how STP enables redundancy in a Layer 2 network.

Topic Title	Topic Objective
Purpose of STP	Explain common problems in a redundant, L2 switched network.
STP Operations	Explain how STP operates in a simple switched network.
Evolution of STP	Explain how Rapid PVST+ operates.

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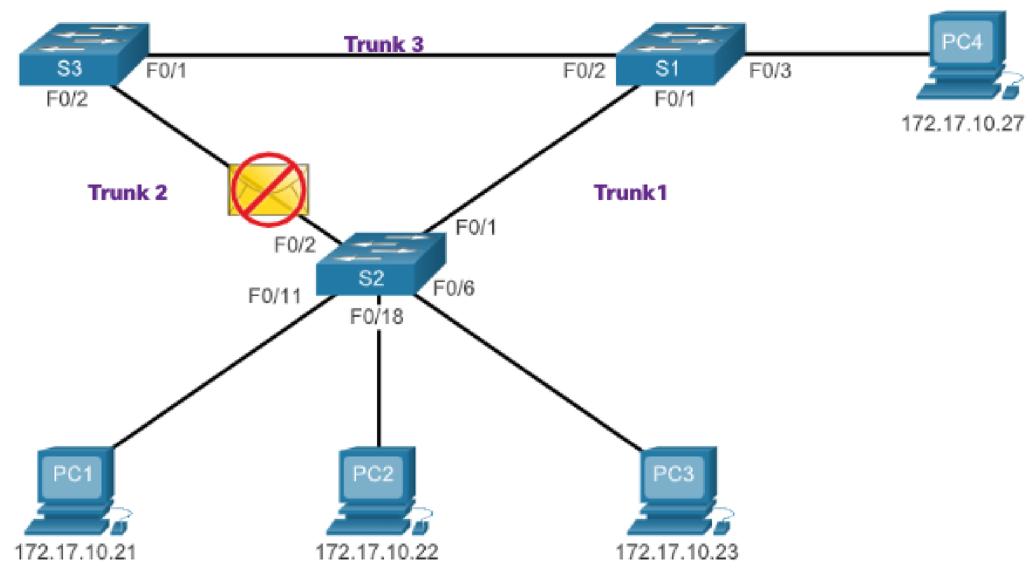
Module 5: STP Concepts

TOPIC 5.1: Purpose of STP
5.1.1 Redundancy in Layer 2 Switched Networks

- This topic covers the causes of loops in a Layer 2 network and briefly explains how spanning tree protocol works. Redundancy is an important part of the hierarchical design for eliminating single points of failure and preventing disruption of network services to users. Redundant networks require the addition of physical paths, but logical redundancy must also be part of the design. Having alternate physical paths for data to traverse the network makes it possible for users to access network resources, despite path disruption. However, redundant paths in a switched Ethernet network may cause both physical and logical Layer 2 loops.
- Ethernet LANs require a loop-free topology with a single path between any two devices. A loop in an Ethernet LAN can cause continued propagation of Ethernet frames until a link is disrupted and breaks the loop.

5.1 Purpose of STP
5.1.2 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.

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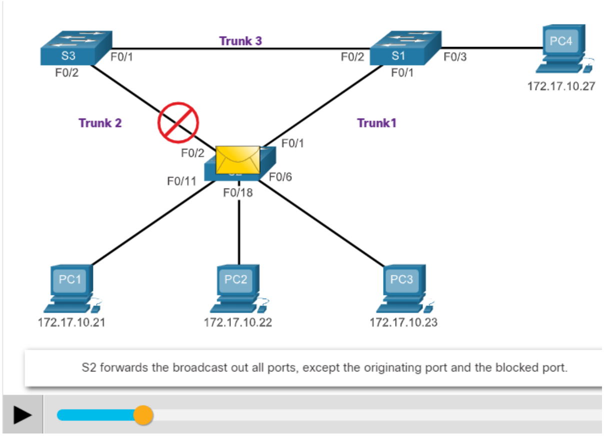
Video Presentation Captured

STP Normal Operation



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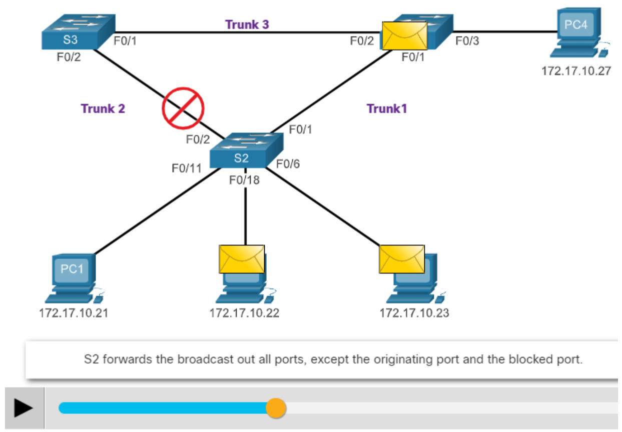

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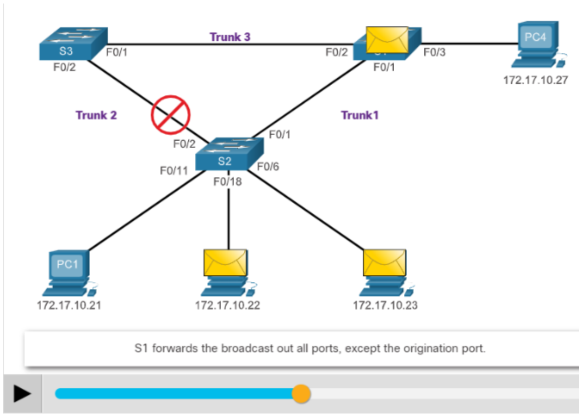

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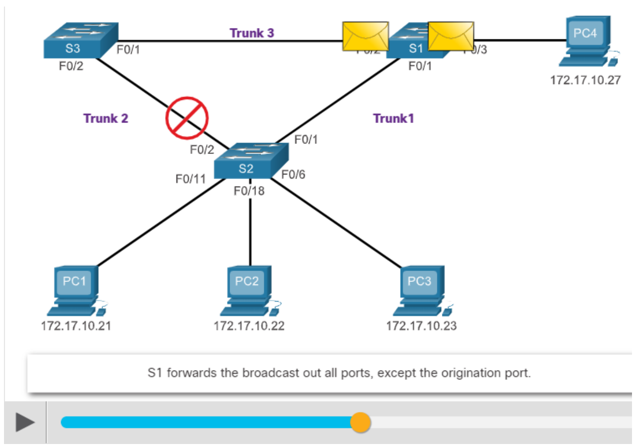

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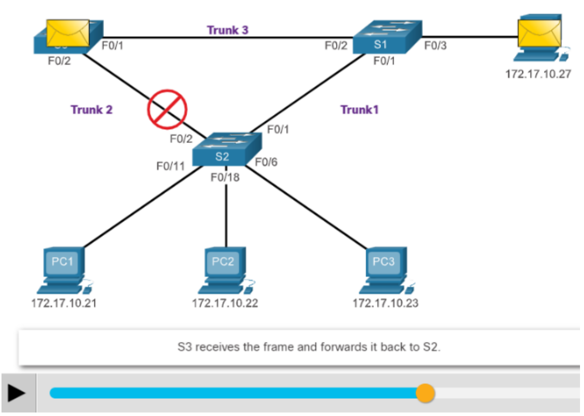

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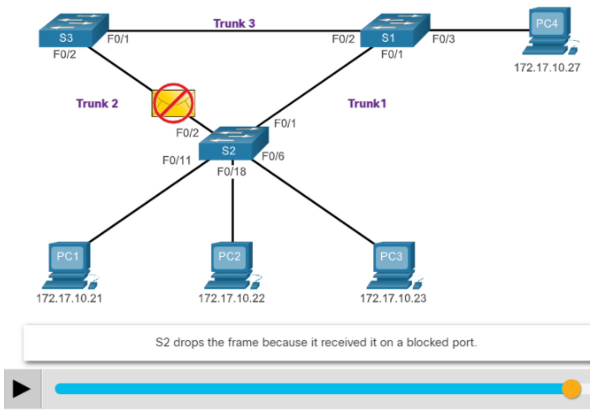

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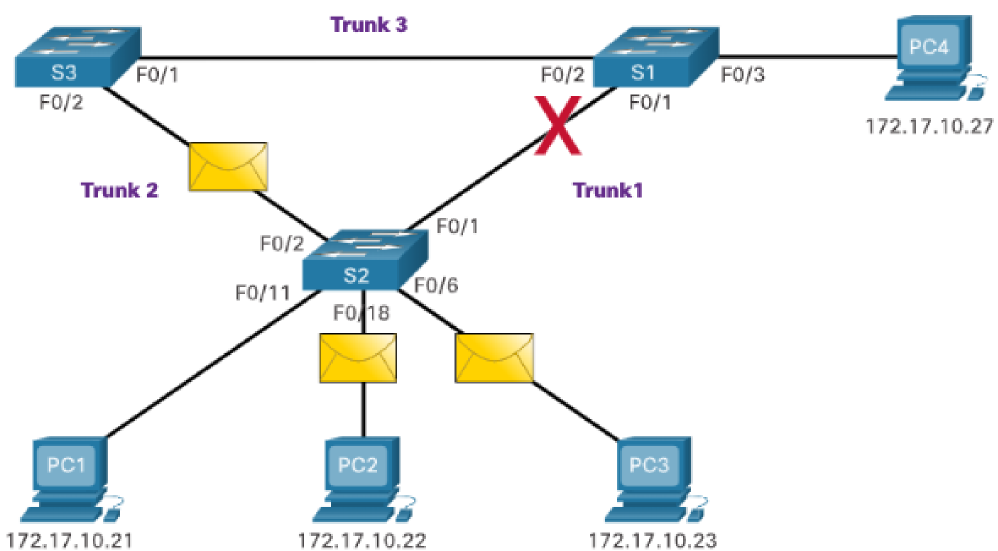
5.1.3 STP Recalculation

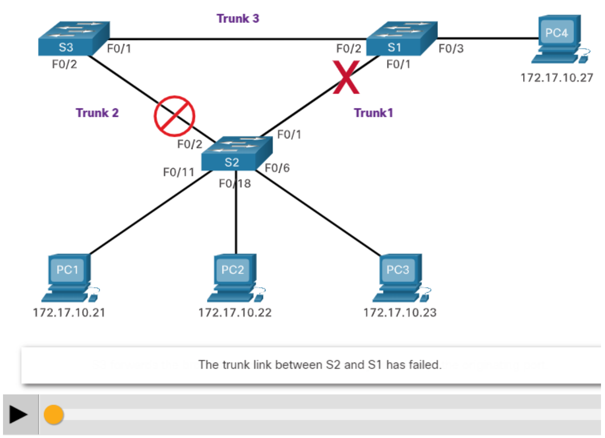
STP compensates for a failure in the network by recalculating and opening up previously blocked ports.



5.1.4 Issues with Redundant Switch Links

- Path redundancy provides multiple network services by eliminating the possibility of a single point of failure. When multiple paths exist between two devices on an Ethernet network, and there is no spanning tree implementation on the switches, a Layer 2 loop occurs. A Layer 2 loop can result in MAC address table instability, link saturation, and high CPU utilization on switches and end-devices, resulting in the network becoming unusable.
- Layer 2 Ethernet does not include a mechanism to recognize and eliminate endlessly looping frames. Both IPv4 and IPv6 include a mechanism that limits the number of times a Layer 3 networking device can retransmit a packet. A router will decrement the TTL (Time to Live) in every IPv4 packet, and the Hop Limit field in every IPv6 packet. When these fields are decremented to 0, a router will drop the packet. Ethernet and Ethernet switches have no comparable mechanism for limiting the number of times a switch retransmits a Layer 2 frame. STP was developed specifically as a loop prevention mechanism for Layer 2 Ethernet.

Video Presentation Captured
STP Compensates with Network Failure



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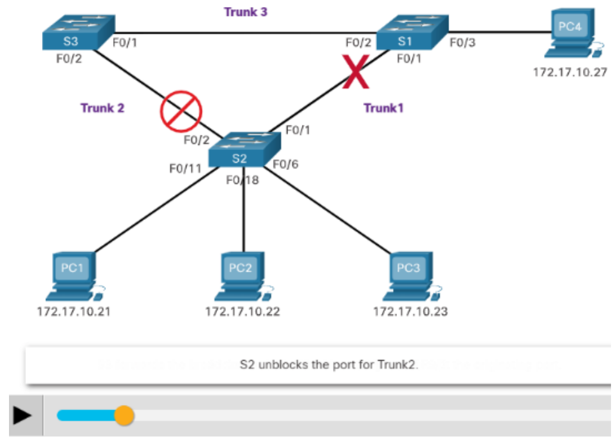

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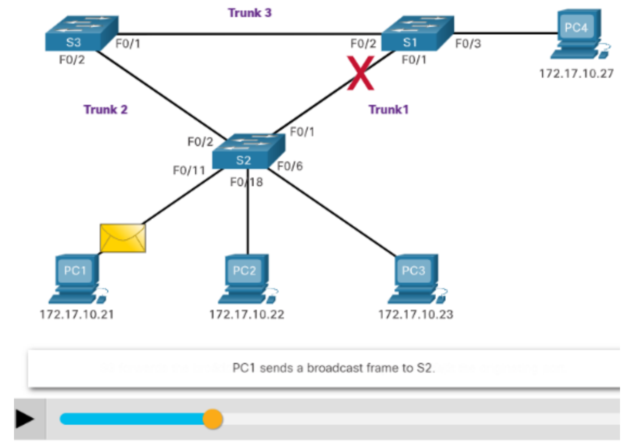

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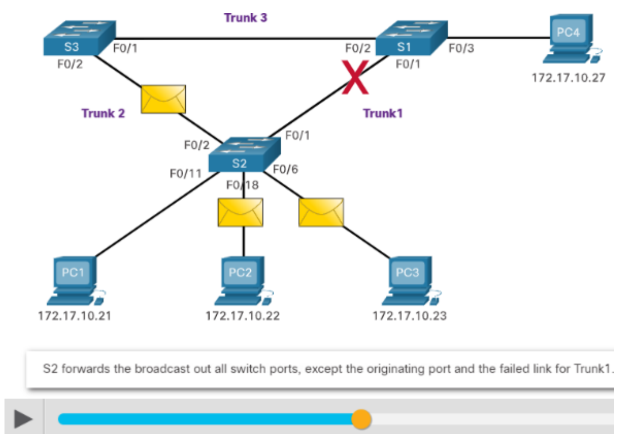

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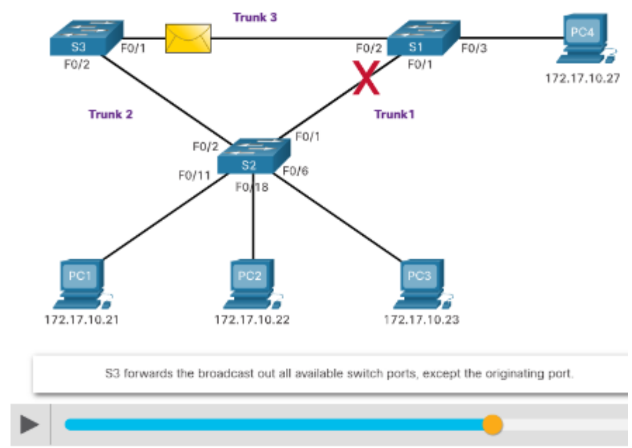

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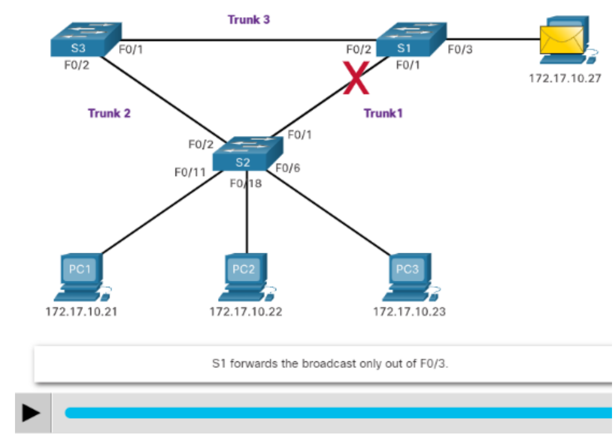

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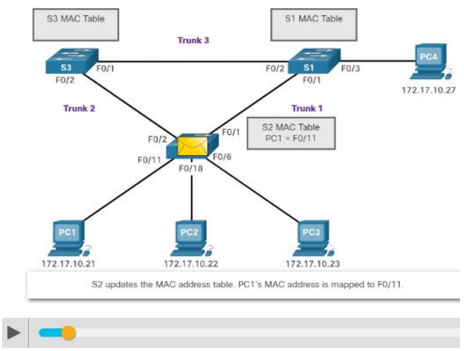
Layer 2 Loops



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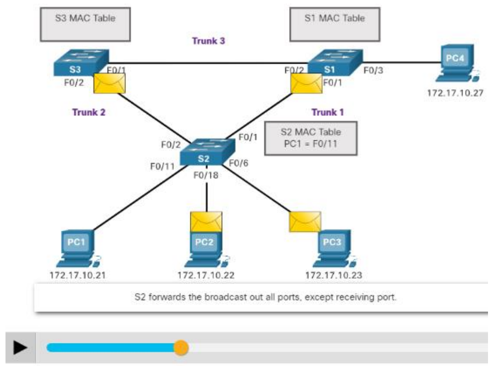

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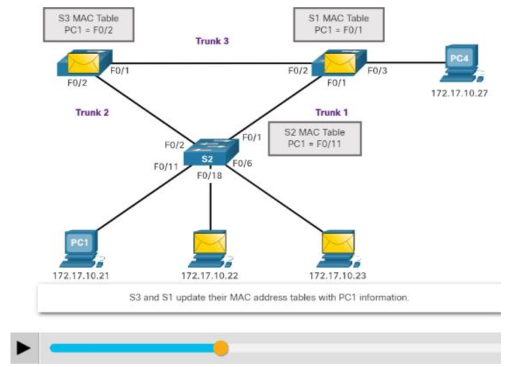

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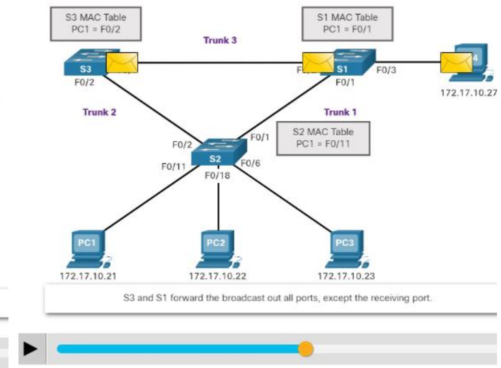

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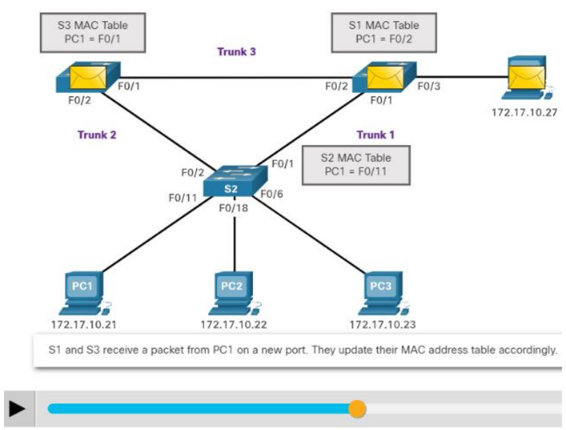

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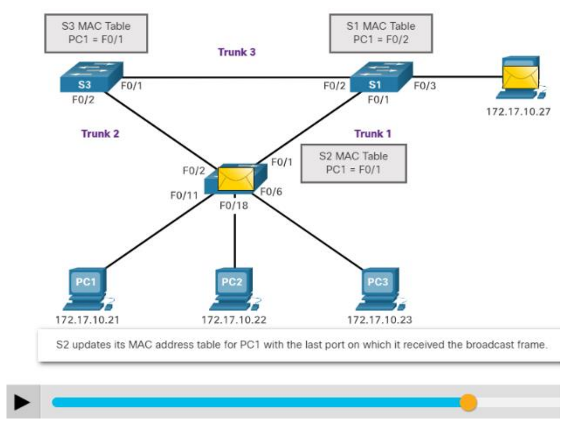

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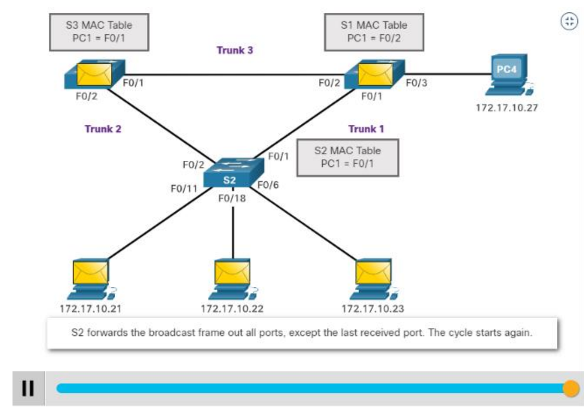

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5.1.5 Layer 2 Loops

- Without STP enabled, Layer 2 loops can form, causing broadcast, multicast and unknown unicast frames to loop endlessly. This can bring down a network quickly.
- When a loop occurs, the MAC address table on a switch will constantly change with the updates from the broadcast frames, which results in MAC database instability. This can cause high CPU utilization, which makes the switch unable to forward frames.
- An unknown unicast frame is when the switch does not have the destination MAC address in its MAC address table and must forward the frame out all ports, except the ingress port.

5.1.6 Broadcast Storm

- A broadcast storm is an abnormally high number of broadcasts overwhelming the network during a specific amount of time. Broadcast storms can disable a network within seconds by overwhelming switches and end devices. Broadcast storms can be caused by a hardware problem such as a faulty NIC or from a Layer 2 loop in the network.
- Layer 2 broadcasts in a network, such as ARP Requests are very common. Layer 2 multicasts are typically forwarded the same way as a broadcast by the switch. IPv6 packets are never forwarded as a Layer 2 broadcast, ICMPv6 Neighbor Discovery uses Layer 2 multicasts.
- A host caught in a Layer 2 loop is not accessible to other hosts on the network. Additionally, due to the constant changes in its MAC address table, the switch does not know out of which port to forward unicast frames.
- To prevent these issues from occurring in a redundant network, some type of spanning tree must be enabled on the switches. Spanning tree is enabled, by default, on Cisco switches to prevent Layer 2 loops from occurring.

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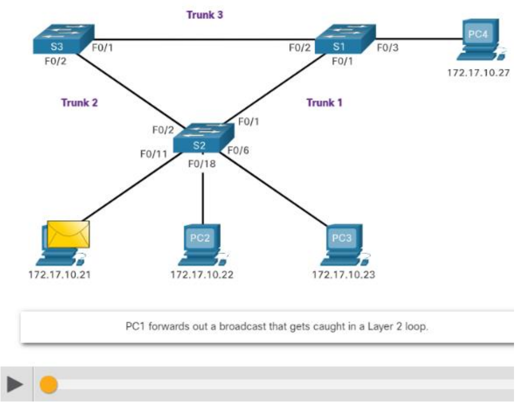
Broadcast Storm



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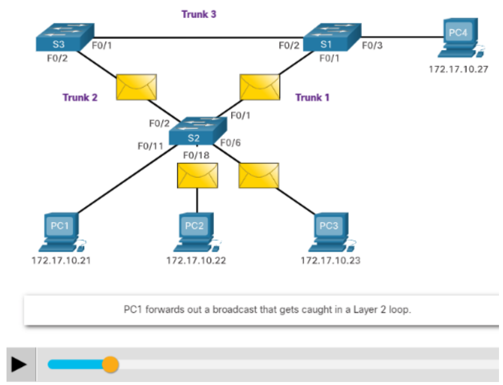

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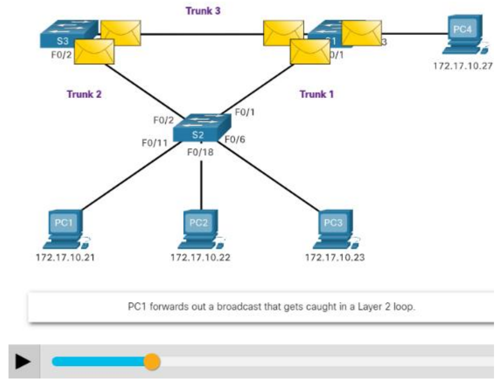

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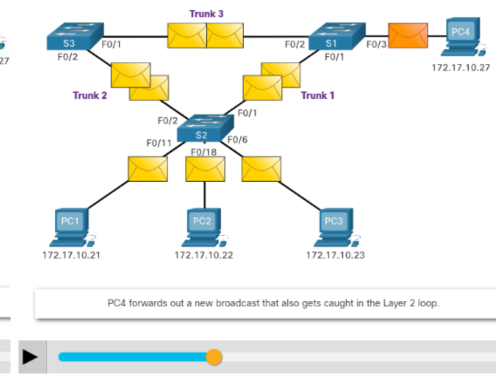

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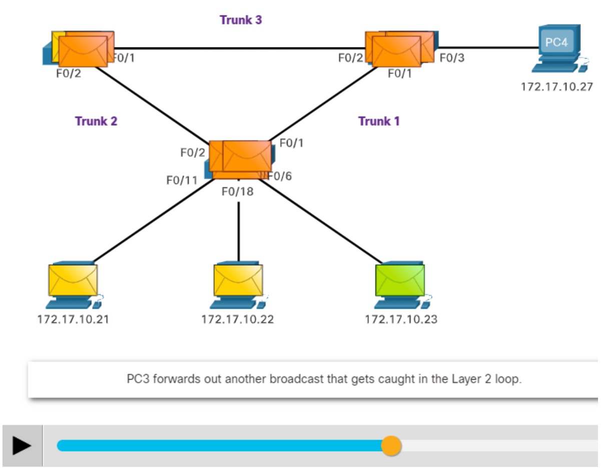

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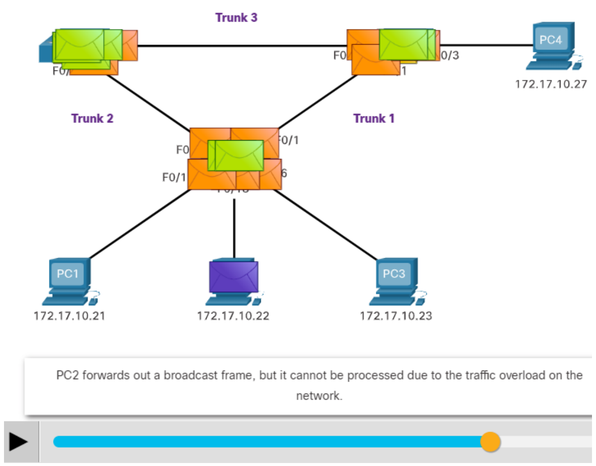

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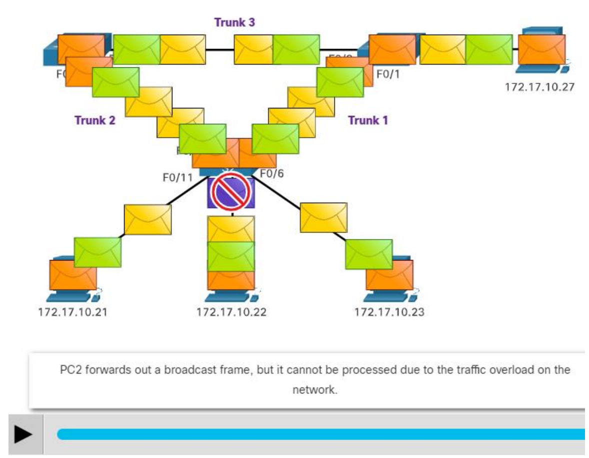

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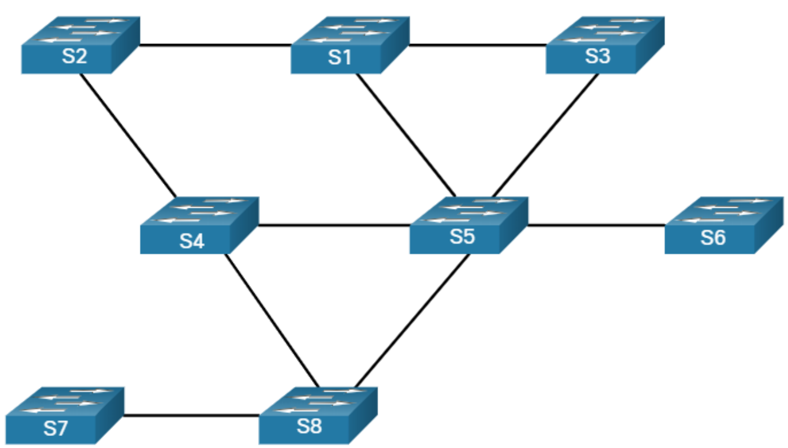
5.1.7 The Spanning Tree Algorithm

- STP is based on an algorithm invented by Radia Perlman while working for Digital Equipment Corporation, and published in the 1985 paper "An Algorithm for Distributed Computation of a Spanning Tree in an Extended LAN." Her spanning tree algorithm (STA) creates a loop-free topology by selecting a single root bridge where all other switches determine a single least-cost path.
- STP prevents loops from occurring by configuring a loop-free path through the network using strategically placed "blocking-state" ports. The switches running STP are able to compensate for failures by dynamically unblocking the previously blocked ports and permitting traffic to traverse the alternate paths.

STA Scenario Topology

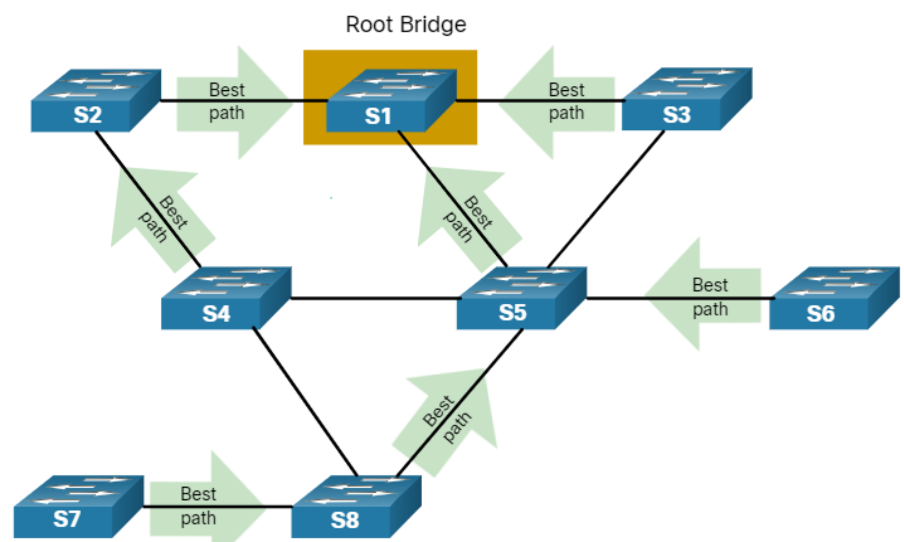
This STA scenario uses an Ethernet LAN with redundant connections between multiple switches.



Select the Root Bridge

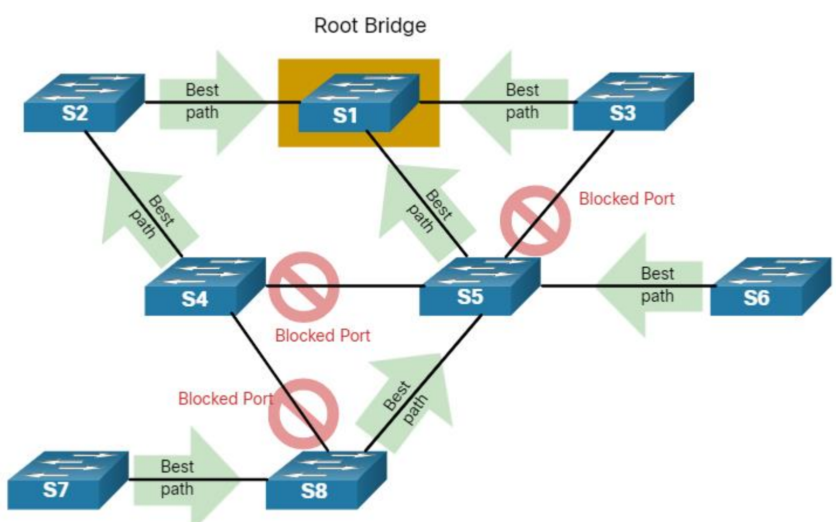
The spanning tree algorithm begins by selecting a single root bridge. The figure shows that switch S1 has been selected as the root bridge. In this topology, all links are equal cost (same bandwidth). Each switch will determine a single, least cost path from itself to the root bridge.

Note: The STA and STP refers to switches as bridges. This is because in the early days of Ethernet, switches were referred to as bridges.



Block Redundant Paths

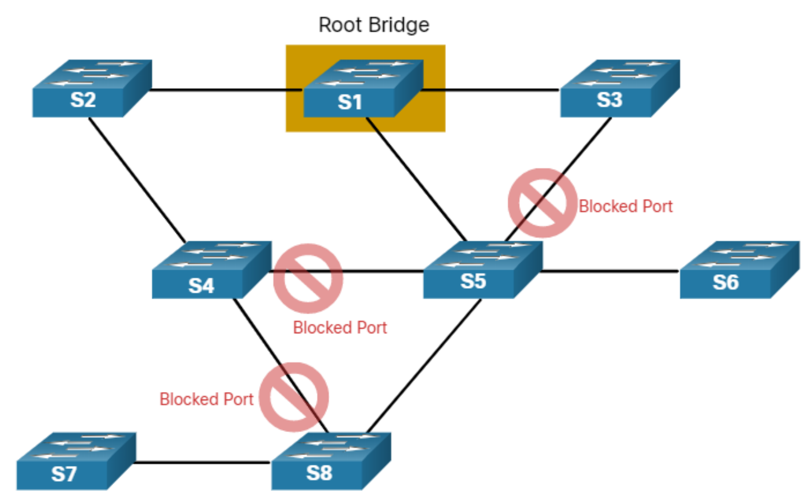
STP ensures that there is only one logical path between all destinations on the network by intentionally blocking redundant paths that could cause a loop, as shown in the figure. When a port is blocked, user data is prevented from entering or leaving that port. Blocking the redundant paths is critical to preventing loops on the network.



Switches S4, S5, and S8 have blocked redundant paths to the root bridge.

Loop – Free Topology

A blocked port has the effect of making that link a non-forwarding link between the two switches, as shown in the figure. Notice that this creates a topology where each switch has only a single path to the root bridge, similar to branches on a tree that connect to the root of the tree.

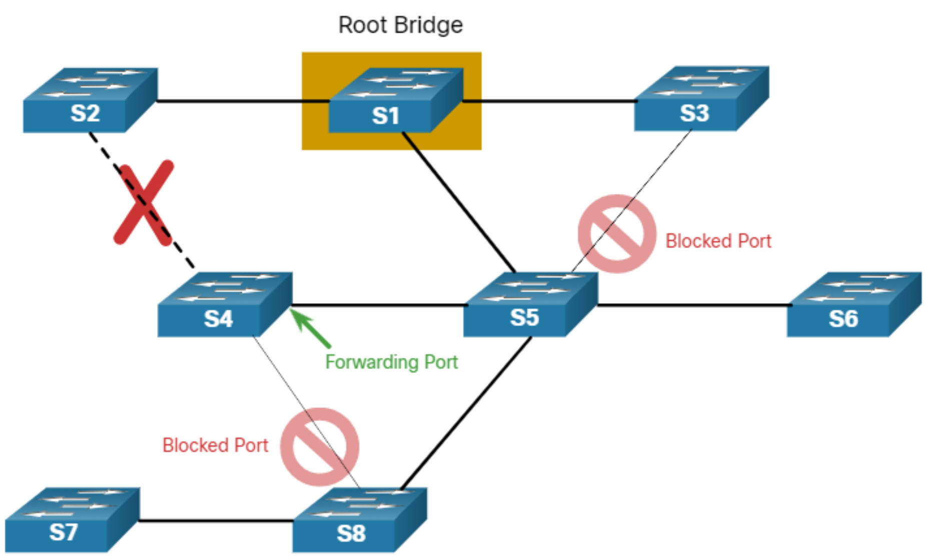


Each switch now has just one forwarding path to the root bridge.

Link – Failure Causes Recalculation

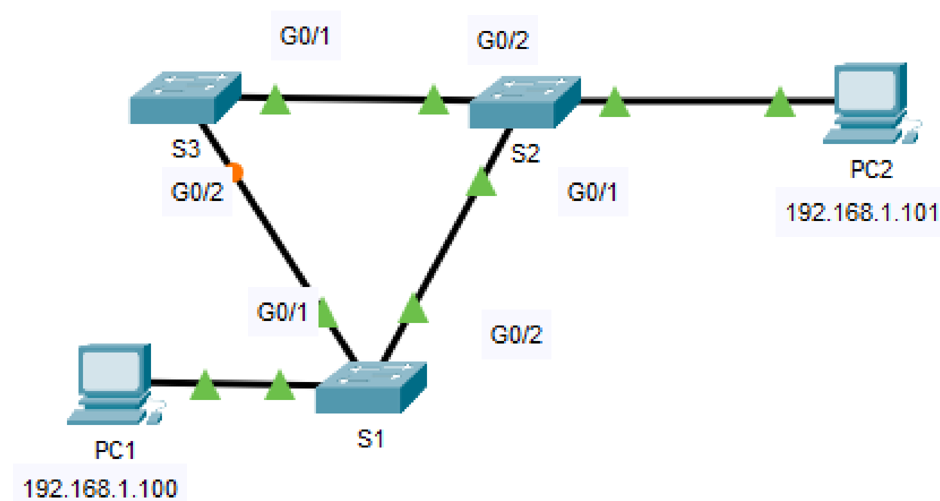
The physical paths still exist to provide redundancy, but these paths are disabled to prevent the loops from occurring. If the path is ever needed to compensate for a network cable or switch failure, STP recalculates the paths and unblocks the necessary ports to allow the redundant path to become active. STP recalculations can also occur any time a new switch or new inter-switch link is added to the network.

The figure shows a link failure between switches S2 and S4 causing STP to recalculate. Notice that the previously redundant link between S4 and S5 is now forwarding to compensate for this failure. There is still only one path between every switch and the root bridge.



Packet Tracer Activity 5.1.9 – Investigate STP Loop Prevention

Topology



Packet Tracer Activity 5.1.9 – Investigate STP Loop Prevention

Packet Tracer - Investigate STP Loop Prevention

Objectives

In this lab, you will observe spanning-tree port states and watch the spanning-tree convergence process.

- Describe the operation of Spanning Tree Protocol.
- Explain how Spanning Tree Protocol prevents switching loops while allowing redundancy in switched networks.

Background / Scenario

In this activity you will use Packet Tracer to observe the operation of Spanning Tree Protocol in a simple switched network that has redundant paths.

Instructions

Part 1: Observe a Converged Spanning-Tree Instance

Step 1: Verify Connectivity.

Ping from PC1 to PC2 to verify connectivity between the hosts. Your ping should be successful.

Step 2: View spanning-tree status on each switch.

Use the **show spanning-tree vlan 1** command to gather information about the spanning tree status of each switch. Complete the table. For the purposes of the activity, only consider information about the Gigabit trunk ports. The Fast Ethernet ports are access ports that have end devices connected and are not part of the inter-switch trunk-based spanning tree.

NOTE: You need to install the latest packet tracer 7.3 simulation to run this packet tracer activity and you need to log in your **NETACAD Account** before doing the PT activity. Please refer to the reading resources and packet tracer resources.

Switch	Port	Status (FWD, BLK...)	Root Bridge?
S1	G0/1		
	G0/2		
S2	G0/1		
	G0/2		
S3	G0/1		
	G0/2		

Packet Tracer uses a different link light on one of the connections between the switches.

What do you think this this link light means?

What path will frames take from PC1 to PC2?

Why do the frames not travel through S3?

Why has spanning tree placed a port in blocking state?

Part 2: Observe spanning-tree convergence

Step 1: Remove the connection between S1 and S2.

a. Open a CLI window on switch S3 and issue the command **show spanning-tree vlan 1**. Leave the CLI window open.

b. Select the delete tool from the menu bar and click the cable that connects S1 and S2.

Step 2: Observe spanning-tree convergence.

a. Quickly return to the CLI prompt on switch S3 and issue the **show spanning-tree vlan 1** command.

b. Use the up-arrow key to recall the **show spanning-tree vlan 1** command and issue it repeatedly until the orange link light on the cable turns green. Observe the status of port G0/2.

What do you see happen to the status of the G0/2 port during this process?

You have observed the transition in port status that occurs as a spanning-tree port moves from blocking to forwarding state.

c. Verify Connectivity by pinging from PC1 to PC2. Your ping should be successful.

Are any ports showing an orange link light that indicates that the port is in a spanning-tree state other than forwarding? Why or why not?

TOPIC 5.1: Purpose of STP
Written Activity 5.1.9 – Check your Understanding

1. Which statement best describes STP?

- ◯ STP is a Layer 2 routing protocol.
- ◯ STP is a Layer 3 routing protocol for Ethernet LANs.
- ◯ STP is a Layer 2 loop prevention protocol for Ethernet LANs.
- ◯ STP is a Layer 3 loop prevention protocol for IP networks.

2. Without STP on the Ethernet LAN, which three types of frames could cause a catastrophic loop in the network? (Choose three.)

- ☐ Unicast
- ☐ Unknown unicast
- ☐ Multicast
- ☐ Broadcast

3. What device is elected by the Spanning Tree Algorithm to which all other switches determine a single least-cost path?

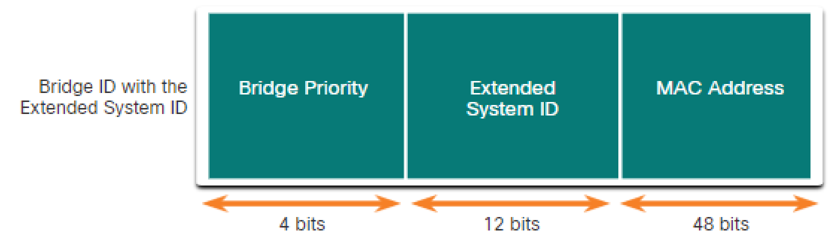
- ◯ Root bridge
- ◯ Dedicated bridge
- ◯ Default gateway
- ◯ Core switch

TOPIC 2: STP Operations
5.2.1 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.



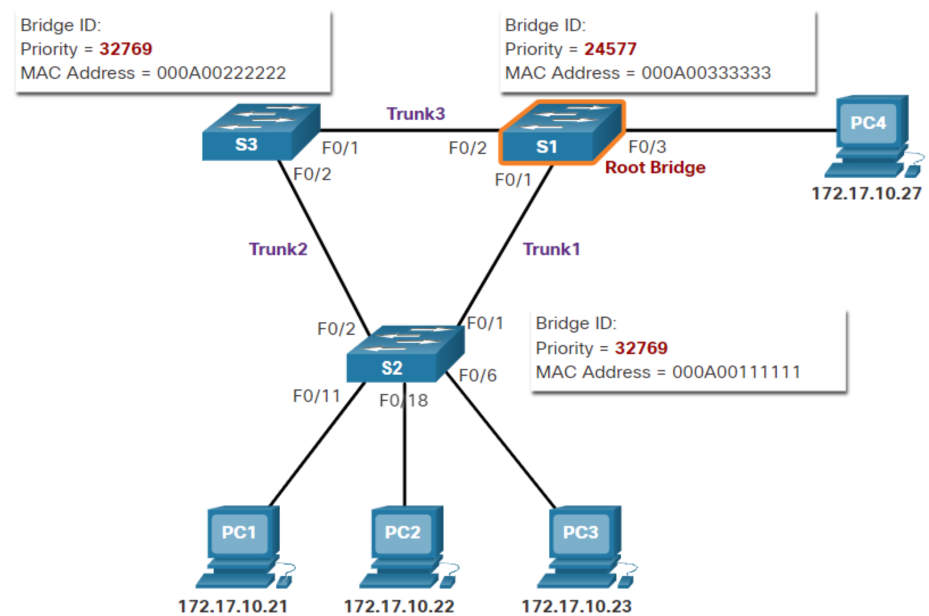
The BID includes the Bridge Priority, the Extended System ID, and the MAC Address of the switch.

5.2 STP Operations
Steps to a Loop-Free Topology

- **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.

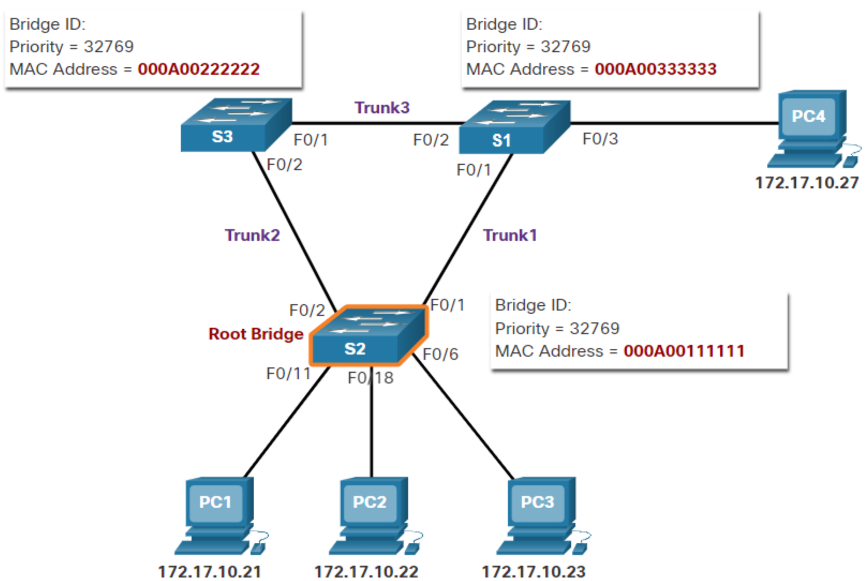
5.2 STP Operations
5.2.1. Elect the Root Bridge

- 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.



5.2 STP Operations
5.2.3 Impact of Default BIDs

- Because the default BID is 32768, it is possible for two or more switches to have the same priority. In this scenario, where the priorities are the same, the switch with the lowest MAC address will become the root bridge. The administrator should configure the desired root bridge switch with a lower priority.
- In the figure, all switches are configured with the same priority of 32769. Here the MAC address becomes the deciding factor as to which switch becomes the root bridge. The switch with the lowest hexadecimal MAC address value is the preferred root bridge. In this example, S2 has the lowest value for its MAC address and is elected as the root bridge for that spanning tree instance.
- **Note**: The priority of all the switches is 32769. The value is based on the 32768 default bridge priority and the extended system ID (VLAN 1 assignment) associated with each switch (32768+1).



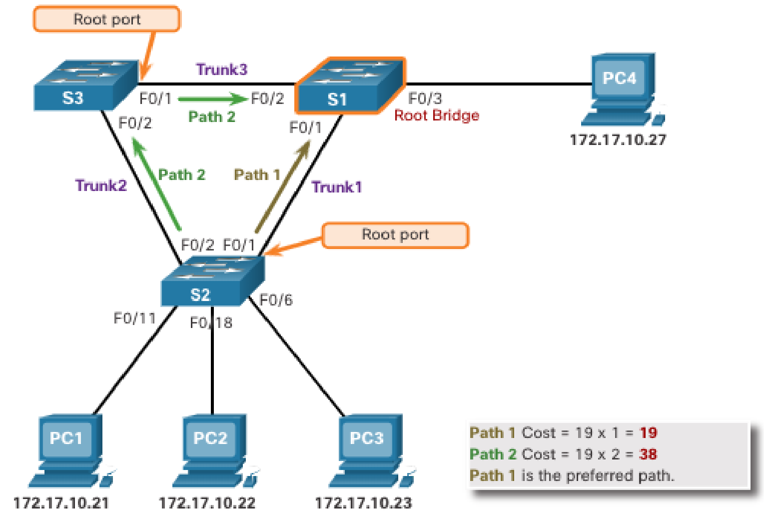
5.2 STP Operations
5.2.4 Determine the Root Path Cost

- 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

5.2 STP Operations
5.2.5 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.



5.2 STP Operations
3.5.6 Elect Designated Ports

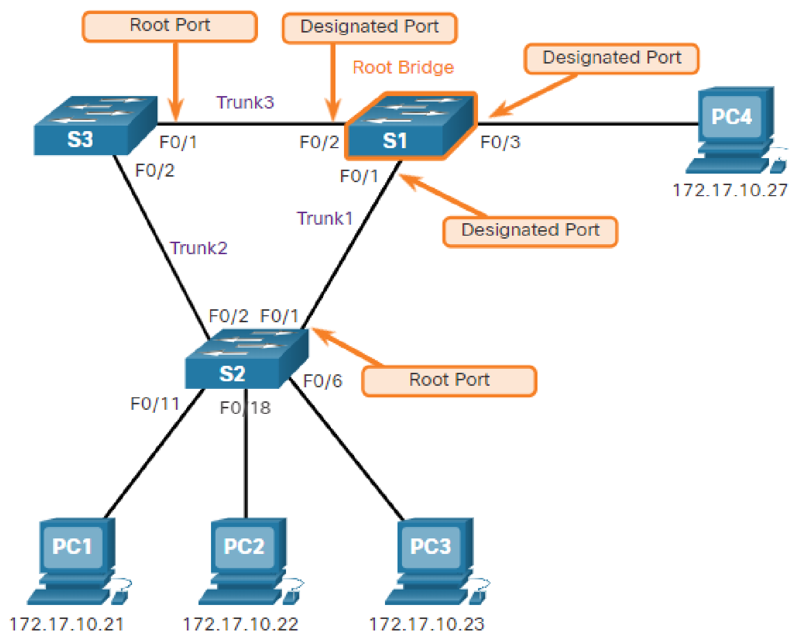
The loop prevention part of spanning tree becomes evident during these next two steps. After each switch selects a root port, the switches will then select designated ports.

Every segment between two switches will have one designated port. The designated port is a port on the segment (with two switches) 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. The end result is a single path from every switch to the root bridge.

Designated Ports on Root Bridge

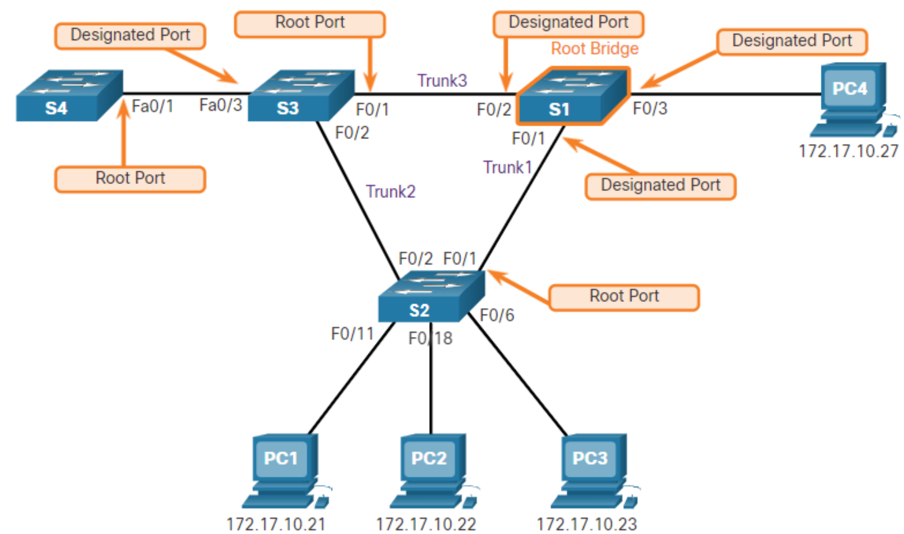
All ports on the root bridge are designated ports, as shown in the figure. This is because the root bridge has the lowest cost to itself.



Designated Ports When There is a Root Port

If one end of a segment is a root port, then the other end is a designated port. To demonstrate this, the figure shows that switch S4 is connected to S3. The Fa0/1 interface on S4 is its root port because it has the best and only path to the root bridge. The Fa0/3 interface on S3 at the other end of the segment would therefore, be the designated port.

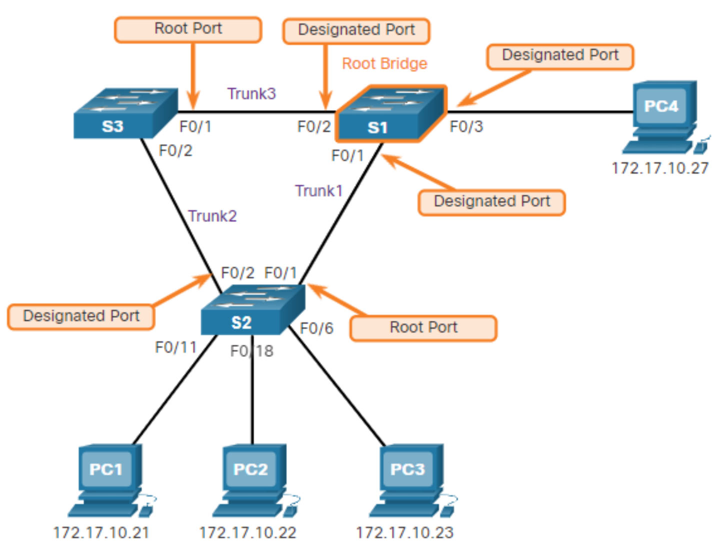
Note: All switch ports with end devices (hosts) attached are designated ports.



Fa0/1 interface on S4 is a designated port because the Fa0/3 interface of S3 is a root port.

Designated Ports When There is No Root Port

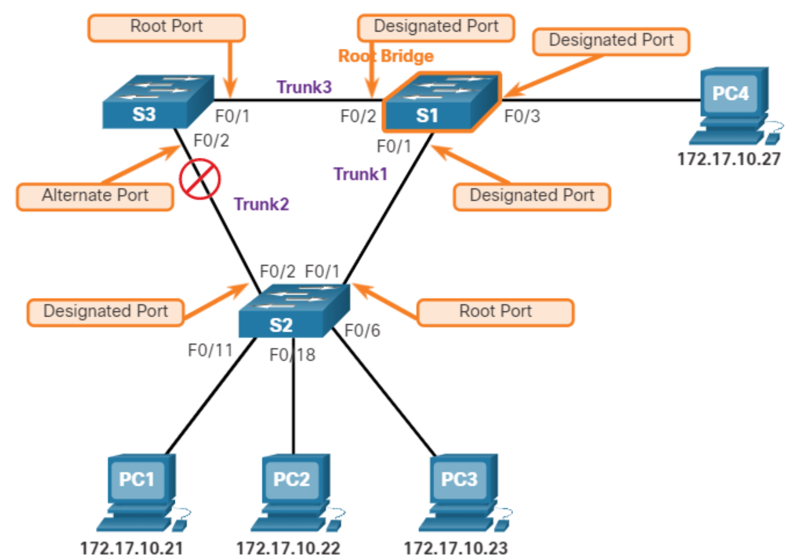
This leaves only segments between two switches where neither of the switches is the root bridge. In this case, the port on the switch with the least-cost path to the root bridge is the designated port for the segment. For example, in the figure, the last segment is the one between S2 and S3. Both S2 and S3 have the same path cost to the root bridge. The spanning tree algorithm will use the bridge ID as a tie breaker. Although not shown in the figure, S2 has a lower BID. Therefore, the F0/2 port of S2 will be chosen as the designated port. Designated ports are in forwarding state.



The Fa0/2 interface of S2 is the designated port on the segment with S3.

STP Operations
5.2.7. 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 and backup 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.



The Fa0/2 interface of S3 is not a root port or a designated port, so it becomes an alternate or blocked port.

5.2 STP Operations

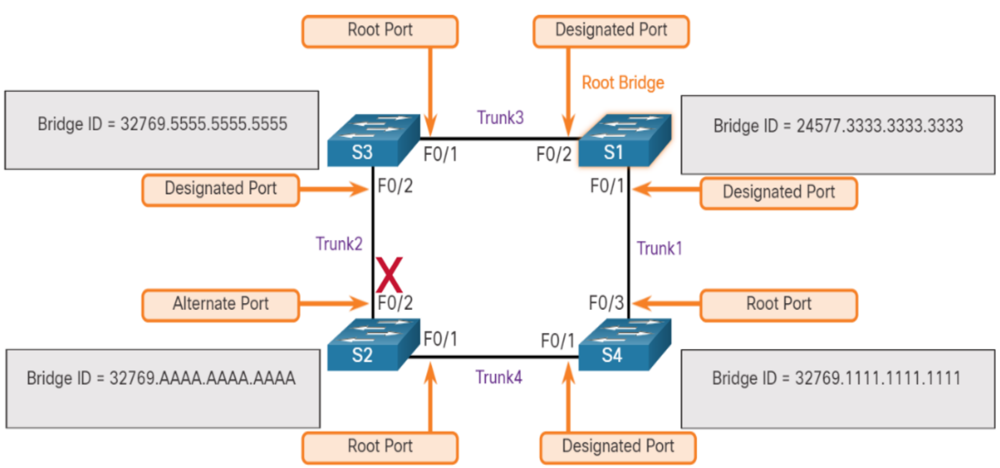
5.2.8 Elect a Root Port from a Multiple Equal – Cost Paths

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

1. Lowest sender BID
2. Lowest sender port priority
3. Lowest sender port ID

Lowest Sender SID

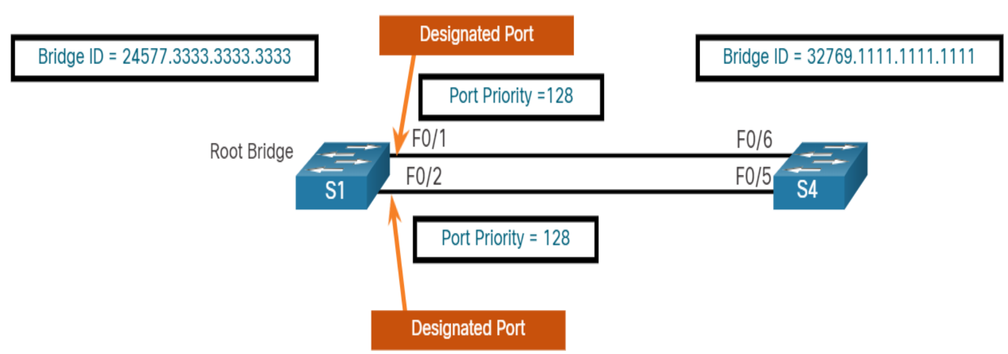
Lowest Sender BID: This topology has four switches with switch S1 as the root bridge. Port F0/1 on switch S3 and port F0/3 on switch S4 have been selected as root ports because they have the root path cost to the root bridge for their respective switches. S2 has two ports, F0/1 and F0/2 with equal cost paths to the root bridge. The bridge IDs of S3 and S4, will be used to break the tie. This is known as the sender's BID. S3 has a BID of 32769.5555.5555.5555 and S4 has a BID of 32769.1111.1111.1111. Because S4 has a lower BID, the F0/1 port of S2, which is the port connected to S4, will be the root port.



Lowest Sender Port Priority

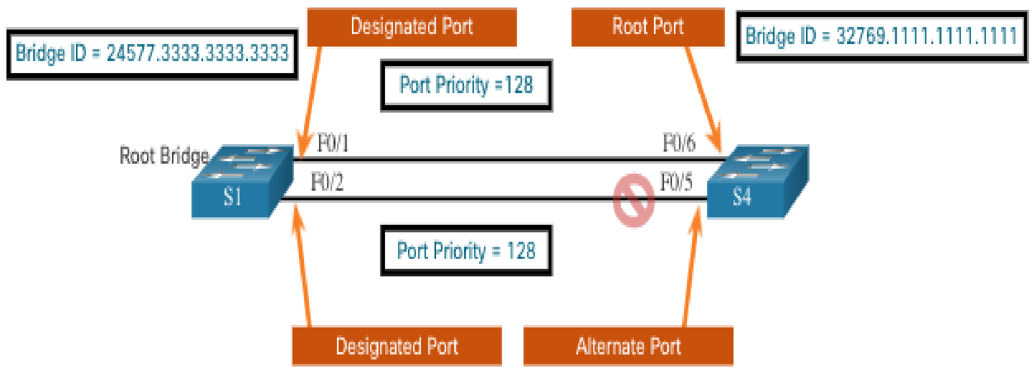
Lowest Sender Port Priority: This topology has two switches which are connected with two equal-cost paths between them. S1 is the root bridge, so both of its ports are designated ports.

- 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.



Lowest Sender Port ID

- **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

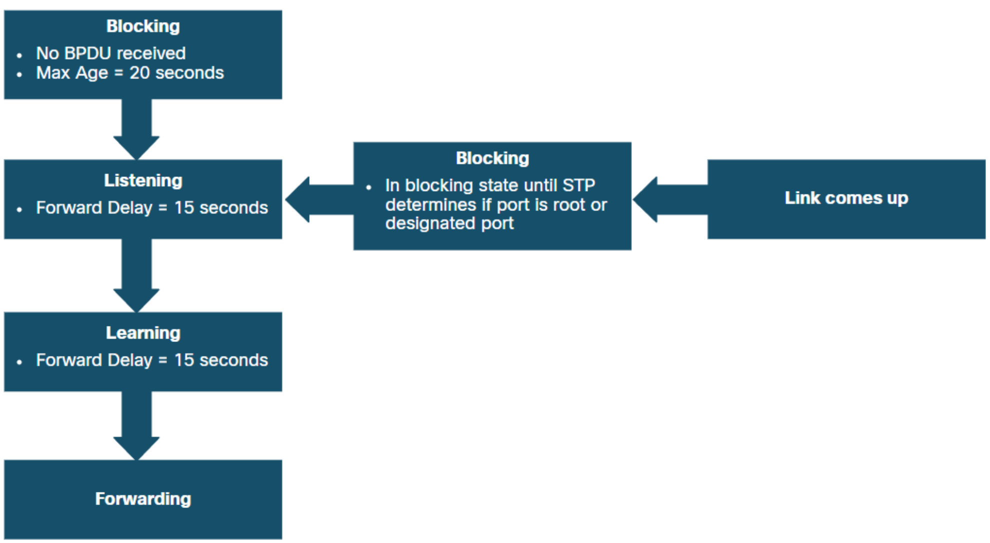
STP convergence requires three timers, as follows:

- **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.

5.2.9 STP Timers and Port States

STP facilitates the logical loop-free path throughout the broadcast domain. The spanning tree is determined through the information learned by the exchange of the BPDU frames between the interconnected switches. If a switch port transitions directly from the blocking state to the forwarding state without information about the full topology during the transition, the port can temporarily create a data loop. For this reason, STP has five ports states, four of which are operational port states as shown in the figure. The disabled state is considered non-operational.



Port State	Description
Blocking	The port is an alternate port and does not participate in frame forwarding. The port receives BPDU frames to determine the location and root ID of the root bridge. BPDU frames also determine which port roles each switch port should assume in the final active STP topology. With a Max Age timer of 20 seconds, a switch port that has not received an expected BPDU from a neighbor switch will go into the blocking state.
Listening	After the blocking state, a port will move to the listening state. The port receives BPDUs to determine the path to the root. The switch port also transmits its own BPDU frames and informs adjacent switches that the switch port is preparing to participate in the active topology.
Learning	A switch port transitions to the learning state after the listening state. During the learning state, the switch port receives and processes BPDUs and prepares to participate in frame forwarding. It also begins to populate the MAC address table. However, in the learning state, user frames are not forwarded to the destination.
Forwarding	In the forwarding state, a switch port is considered part of the active topology. The switch port forwards user traffic and sends and receives BPDU frames.
Disabled	A switch port in the disabled state does not participate in spanning tree and does not forward frames. The disabled state is set when the switch port is administratively disabled.

5.2 STP Operations
5.2.10 Operational Details of Each Port State

The table summarizes the operational details of each port state

Port State	BPDU	MAC Address Table	Forwarding Data Frames
Blocking	Receive only	No update	No
Listening	Receive and send	No update	No
Learning	Receive and send	Updating table	No
Forwarding	Receive and send	Updating table	Yes
Disabled	None sent or received	No update	No

5.2 STP Operations
5.2.11 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.

TOPIC 5.2 STP Operations
Written Activity 5.2.12 – Check your Understanding

1. By default (without any configuration on a switch), what will determine which switch is the root bridge?

   - ◯ The bridge priority
   - ◯ The extended system ID
   - ◯ The MAC address of the switch
   - ◯ The bridge ID

2. The root bridge will be the switch with the:

   - ◯ Lowest bridge ID
   - ◯ Highest bridge ID
   - ◯ Lowest port priority
   - ◯ Highest port priority

3. The port closest to the root bridge in terms of least overall cost (best path) to the root bridge is the:

   - ◯ Designated port
   - ◯ Blocked port or non-dedicated port
   - ◯ Root port
   - ◯ Routed Port

TOPIC 5.2 STP Operations
Written Activity 5.2.12 – Check your Understanding

4. The port on the segment (with two switches) that has the lowest path cost to the root bridge is the:

- ◯ Designated port
- ◯ Blocked port or non-dedicated port
- ◯ Root port
- ◯ Routed Port

5. Which of the following ports will forward Ethernet frames? (Choose two.)

- ☐ Designated port
- ☐ Blocked port or non-dedicated port
- ☐ Root port

6. The sum of individual port costs along the path from the switch to the root bridge is known as the:

- ◯ Least cost path
- ◯ Shortest path cost
- ◯ Best path cost
- ◯ Root path cost

7. How often does a switch send a BPDU?

- ◯ Every 2 seconds
- ◯ Every 15 seconds
- ◯ Every 20 seconds
- ◯ Only when there is a change in the topology

TOPIC 5.3 Evolution of STP
5.3.1 Different Versions of STP

- Many professionals generically use spanning tree and STP to refer to the various implementations of spanning tree, such as Rapid Spanning Tree Protocol (RSTP) and Multiple Spanning Tree Protocol (MSTP). In order to communicate spanning tree concepts correctly, it is important to refer to the implementation or standard of spanning tree in context.
- The latest IEEE documentation on spanning tree (IEEE-802-1D-2004) says, "STP has now been superseded by the Rapid Spanning Tree Protocol (RSTP)."The IEEE uses "STP" to refer to the original implementation of spanning tree and "RSTP" to describe the version of spanning tree specified in IEEE-802.1D-2004.
- Because the two protocols share much of the same terminology and methods for the loop-free path, the primary focus will be on the current standard and the Cisco proprietary implementations of STP and RSTP.
- Cisco switches running IOS 15.0 or later, run PVST+ by default. This version incorporates many of the specifications of IEEE 802.1D-2004, such as alternate ports in place of the former non-designated ports. Switches must be explicitly configured for rapid spanning tree mode in order to run the rapid spanning tree protocol.

5.3.1 Different Versions of STP

Several varieties of spanning tree protocols have emerged since the original IEEE 802.1D specification, as shown in the table.

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.

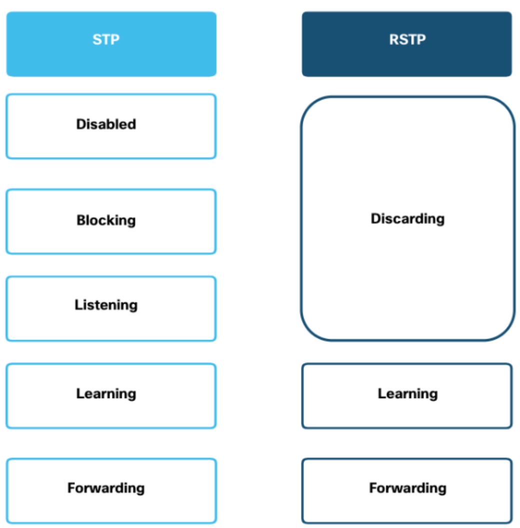
5.3 Evolution of STP
5.3.2 RSTP Concepts

- RSTP (IEEE 802.1w) supersedes the original 802.1D while retaining backward compatibility. The 802.1w STP terminology remains primarily the same as the original IEEE 802.1D STP terminology. Most parameters have been left unchanged. Users that are familiar with the original STP standard can easily configure RSTP. The same spanning tree algorithm is used for both STP and RSTP to determine port roles and topology.
- RSTP increases the speed of the recalculation of the spanning tree when the Layer 2 network topology changes. RSTP can achieve much faster convergence in a properly configured network, sometimes in as little as a few hundred milliseconds. If a port is configured to be an alternate port it can immediately change to a forwarding state without waiting for the network to converge.

Note: Rapid PVST+ is the Cisco implementation of RSTP on a per-VLAN basis. With Rapid PVST+ an independent instance of RSTP runs for each VLAN.

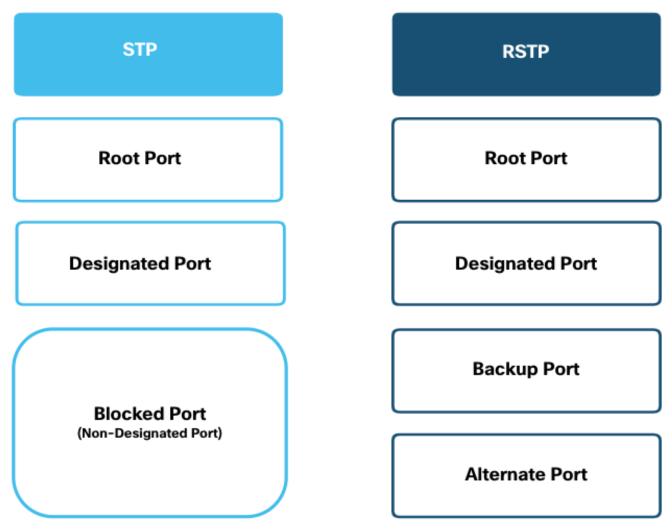
5.3 Evolution of STP
5.3.3 STP and RSTP Port States

There are only three port states in RSTP that correspond to the three possible operational states in STP. The 802.1D disabled, blocking, and listening states are merged into a unique 802.1w discarding state.



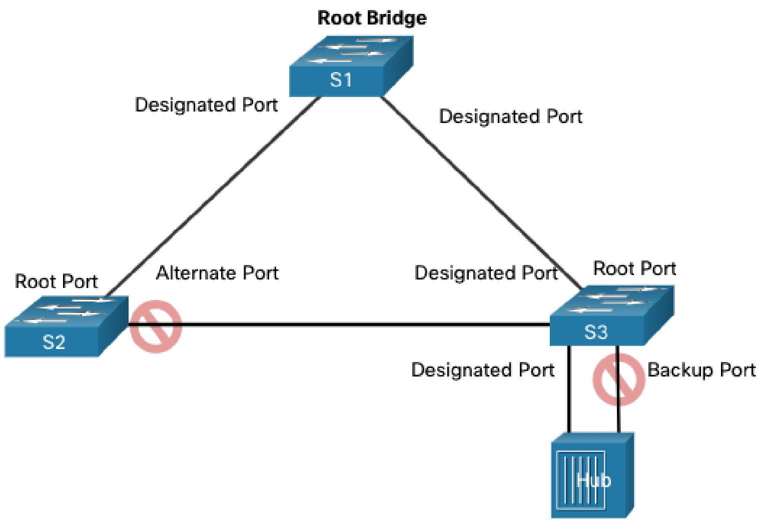
5.3 Evolution of STP
5.3.3 STP and RSTP Port Roles

Root ports and designated ports are the same for both STP and RSTP. However, there are two RSTP port roles that correspond to the blocking state of STP. In STP, a blocked port is defined as not being the designated or root port. RSTP has two port roles for this purpose.



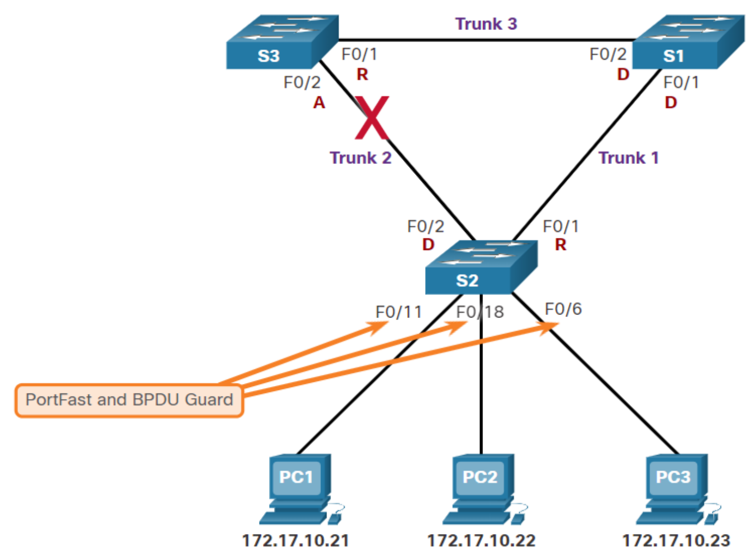
5.3 Evolution of STP
5.3.3 RSTP Alternate and Backup Ports

The alternate port has an alternate path to the root bridge. The backup port is a backup to a shared medium, such as a hub. A backup port is less common because hubs are now considered legacy devices.



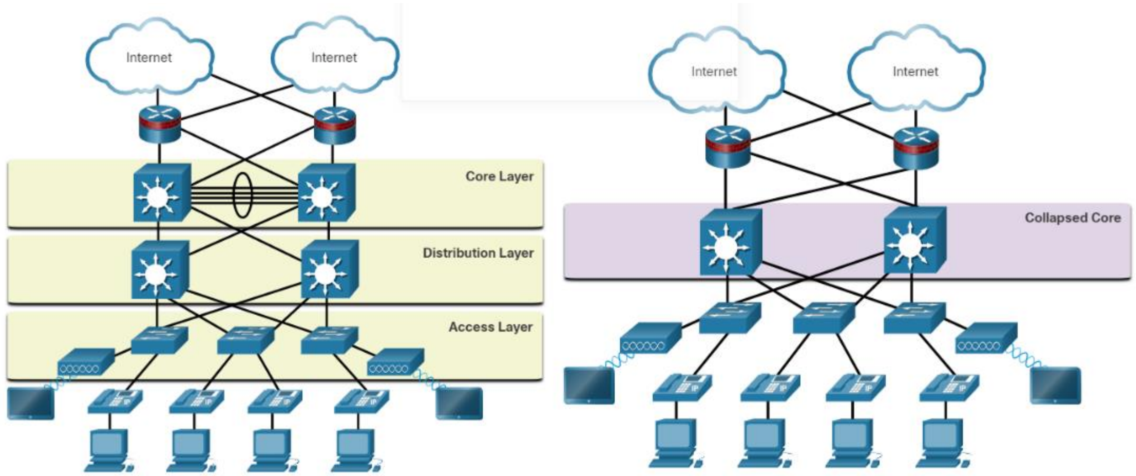
5.3 Evolution of STP
5.3.4 PortFast and BPDU Guard

- When a device is connected to a switch port or when a switch powers up, the switch port goes through both the listening and learning states, each time waiting for the Forward Delay timer to expire. This delay is 15 seconds for each state for a total of 30 seconds. This can present a problem for DHCP clients trying to discover a DHCP server because the DHCP process may timeout. The result is that an IPv4 client will not receive a valid IPv4 address.
- When a switch port is configured with PortFast, that port transitions from blocking to forwarding state immediately, avoiding the 30 second delay. You can use PortFast on access ports to allow devices connected to these ports to access the network immediately. PortFast should only be used on access ports. If you enable PortFast on a port connecting to another switch, you risk creating a spanning tree loop.
- A PortFast-enabled switch port should never receive BPDUs because that would indicate that switch is connected to the port, potentially causing a spanning tree loop. Cisco switches support a feature called BPDU guard. When enabled, it immediately puts the switch port in an errdisabled (error-disabled) state upon receipt of any BPDU. This protects against potential loops by effectively shutting down the port. The administrator must manually put the interface back into service.

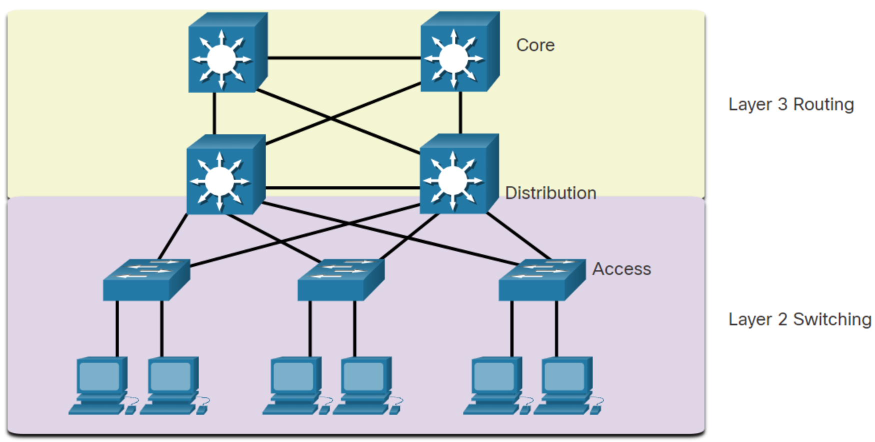


5.3 Evolution of STP
5.3.5 Alternatives to STP

- Over the years, organizations required greater resiliency and availability in the LAN. Ethernet LANs went from a few interconnected switches connected to a single router, to a sophisticated hierarchical network design including access, distribution and core layer switches as shown in the figure:

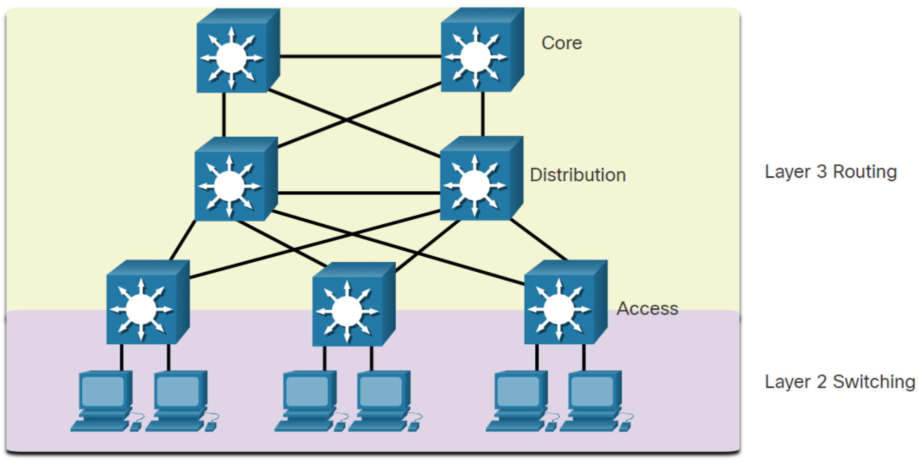


- Depending on the implementation, Layer 2 may include not only the access layer, but also the distribution or even the core layers. These designs may include hundreds of switches, with hundreds or even thousands of VLANs. STP has adapted to the added redundancy and complexity with enhancements, as part of RSTP and MSTP.
- An important aspect to network design is fast and predictable convergence when there is a failure or change in the topology. Spanning tree does not offer the same efficiencies and predictabilities provided by routing protocols at Layer 3.



5.3 Evolution of STP
5.3.5 Alternatives to STP

- Layer 3 routing allows for redundant paths and loops in the topology, without blocking ports. For this reason, some environments are transitioning to Layer 3 everywhere except where devices connect to the access layer switch. In other words, the connections between access layer switches and distribution switches would be Layer 3 instead of Layer 2.



Although STP will most likely continue to be used as a loop prevention mechanism in the enterprise, on access layer switches, other technologies are also being used, including the following:

Multi System Link Aggregation (MLAG)
Shortest Path Bridging (SPB)
Transparent Interconnect of Lots of Links (TRILL)

Note: These technologies are beyond the scope of this course.

TOPIC 5.3 Evolution of STP
Written Activity 5.3.6 – Check your Understanding

1. Which three STP port states are merged into the RSTP discarding port state? (Choose three.)

- ☐ disabled
- ☐ blocking
- ☐ listening
- ☐ learning
- ☐ forwarding

2. Which protocol was designed to bring faster convergence to STP?

- ○ PortFast
- ○ RSTP
- ○ PVST
- ○ MSTP

3. Which technology solves the problem of a device being unable to get an IPv4 address from a DHCP server due to STP forwarding delay timers?

- ○ PortFast
- ○ BPUD guard
- ○ PVST
- ○ MSTP

MODULE 5: STP CONCEPTS
5.4.1 What Did I Learn In this Module?

Purpose of STP

- Redundant paths in a switched Ethernet network may cause both physical and logical Layer 2 loops.
- A Layer 2 loop can result in MAC address table instability, link saturation, and high CPU utilization on switches and end-devices.
- This results in the network becoming unusable. Unlike the Layer 3 protocols, IPv4 and IPv6, Layer 2 Ethernet does not include a mechanism to recognize and eliminate endlessly looping frames.
- Ethernet LANs require a loop-free topology with a single path between any two devices.
- STP is a loop-prevention network protocol that allows for redundancy while creating a loop-free Layer 2 topology.
- Without STP, Layer 2 loops can form, causing broadcast, multicast and unknown unicast frames to loop endlessly, bringing down a network.
- A broadcast storm is an abnormally high number of broadcasts overwhelming the network during a specific amount of time.
- Broadcast storms can disable a network within seconds by overwhelming switches and end devices.
- STP is based on an algorithm invented by Radia Perlman. Her spanning tree algorithm (STA) creates a loop-free topology by selecting a single root bridge where all other switches determine a single least-cost path.

STP Operations

- Using the STA, STP builds a loop-free topology in a four-step process: elect the root bridge, elect the root ports, elect designated ports, and elect alternate (blocked) ports.
- During STA and STP functions, switches use BPDUs to share information about themselves and their connections. BPDUs are used to elect the root bridge, root ports, designated ports, and alternate ports.
- When the root bridge has been elected for a given spanning tree instance, the STA determines 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.
- After the root bridge has been determined the STA algorithm selects the root port. The root port is the port closest to the root bridge in terms of overall cost, which is called the internal root path cost.
- After each switch selects a root port, switches will select designated ports. The designated port is a port on the segment (with two switches) that has the internal root path cost to the root bridge.
- If a port is not a root port or a designated port, then it becomes an alternate (or backup) port. Alternate ports and backup ports are in discarding or blocking state to prevent loops.
- 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, then the lowest sender port priority, and finally the lowest sender port ID.
- STP convergence requires three timers: the hello timer, the forward delay timer, and the max age timer.
- Port states are blocking, listening, learning, forwarding, and disabled.
- In 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.

MODULE 5: STP CONCEPTS
5.4.1 What Did I Learn In this Module?

Evolution of STP

- STP is often used to refer to the various implementations of spanning tree, such as RSTP and MSTP.
- RSTP is an evolution of STP that provides faster convergence than STP.
- RSTP port states are learning, forwarding and discarding.
- PVST+ is a Cisco enhancement of STP that provides a separate spanning tree instance for each VLAN configured in the network. PVST+ supports PortFast, UplinkFast, BackboneFast, BPDU guard, BPDU filter, root guard, and loop guard.
- Cisco switches running IOS 15.0 or later, run PVST+ by default.
- Rapid PVST+ is a Cisco enhancement of RSTP that uses PVST+ and provides a separate instance of 802.1w per VLAN.
- When a switch port is configured with PortFast, that port transitions from blocking to forwarding state immediately, bypassing the STP listening and learning states and avoiding a 30 second delay.
- Use PortFast on access ports to allow devices connected to these ports, such as DHCP clients, to access the network immediately, rather than waiting for STP to converge on each VLAN.
- Cisco switches support a feature called BPDU guard which immediately puts the switch port in an error-disabled state upon receipt of any BPDU to protect against potential loops.
- Over the years, Ethernet LANs went from a few interconnected switches that were connected to a single router, to a sophisticated hierarchical network design. Depending on the implementation, Layer 2 may include not only the access layer, but also the distribution or even the core layers. These designs may include hundreds of switches, with hundreds or even thousands of VLANs. STP has adapted to the added redundancy and complexity with enhancements as part of RSTP and MSTP.
- Layer 3 routing allows for redundant paths and loops in the topology, without blocking ports. For this reason, some environments are transitioning to Layer 3 everywhere except where devices connect to the access layer switch.

MODULE 5: STP CONCEPTS
5.4.2 Module Quiz

1. What additional information is contained in the 12-bit extended system ID of a BPDU?

   - MAC address
   - VLAN ID
   - IP address
   - port ID

2. During the implementation of Spanning Tree Protocol, all switches are rebooted by the network administrator. What is the first step of the spanning-tree election process?

   - Each switch with a lower root ID than its neighbor will not send BPDUs.
   - All the switches send out BPDUs advertising themselves as the root bridge.
   - Each switch determines the best path to forward traffic.
   - Each switch determines what port to block to prevent a loop from occurring.

3. Which STP port role is adopted by a switch port if there is no other port with a lower cost to the root bridge?

   - designated port
   - root port
   - alternate
   - disabled port

4. Which two concepts relate to a switch port that is intended to have only end devices attached and intended never to be used to connect to another switch? (Choose two.)

   - bridge ID
   - edge port
   - extended system ID
   - PortFast
   - PVST+

5. Which two statements describe a switch port that is configured with PortFast? (Choose two.)

   - The switch port immediately transitions from the listening to the forwarding state.
   - The switch port immediately transitions from blocking to the forwarding state.
   - The switch port should never receive BPDUs.
   - The switch port immediately processes any BPDUs before transitioning to the forwarding state.
   - The switch port sends DHCP requests before transitioning to the forwarding state.

6. Which port state will switch ports immediately transition to when configured for PortFast?

   - listening
   - learning
   - forwarding
   - blocking

7. After the election of the root bridge has been completed, how will switches find the best paths to the root bridge?

   - Each switch will analyze the sum of the hops to reach the root and use the path with the fewest hops.
   - Each switch will analyze the BID of all neighbors to reach the root and use the path through the lowest BID neighbors.
   - Each switch will analyze the port states of all neighbors and use the designated ports to forward traffic to the root.
   - Each switch will analyze the sum of all port costs to reach the root and use the path with the lowest cost.

MODULE 5: STP CONCEPTS
Module Quiz

8. What value determines the root bridge when all switches connected by trunk links have default STP configurations?

- ◯ VLAN ID
- ◯ MAC address
- ◯ extended system ID
- ◯ bridge priority

9. Which RSTP ports are connected to end devices?

- ◯ trunk ports
- ◯ designated ports
- ◯ root ports
- ◯ edge ports

10. Which three port states are used by Rapid PVST+? (Choose three.)

- ☐ discarding
- ☐ blocking
- ☐ trunking
- ☐ listening
- ☐ learning
- ☐ forwarding

11. When PVST is running over a switched network, which port state can participate in BPDU frame forwarding based on BPDUs received, but does not forward data frames?

- ◯ blocking
- ◯ listening
- ◯ forwarding
- ◯ disabled

12. An administrator is troubleshooting a switch and wants to verify if it is a root bridge. What command can be used to do this?

- ◯ **show spanning-tree**
- ◯ **show running-config**
- ◯ **show startup-config**
- ◯ **show vlan**

13. What is an accurate description of redundancy?

- ◯ configuring a router with a complete MAC address database to ensure that all frames can be forwarded to the correct destination
- ◯ configuring a switch with proper security to ensure that all traffic forwarded through an interface is filtered
- ◯ designing a network to use multiple virtual devices to ensure that all traffic uses the best path through the internetwork
- ◯ designing a network to use multiple paths between switches to ensure there is no single point of failure

Reference:

CCNAv7 Switching, Routing and Wireless Essentials

https://www.netacad.com

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