STP - Spanning Tree Protool

SDC CNW (CSE 4541)

CSE, FET, ITER
SOA University, BBSR-30

References

Glen E. Clarke & Richard Deal

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Todd Lammle

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Discussion Flow

- Introduction
- Redundancy in Network
- STP Terms
- Bridge Port Roles
- STP States
- Types of STP
- STP Examples
- Exercise on STP

Review Questions

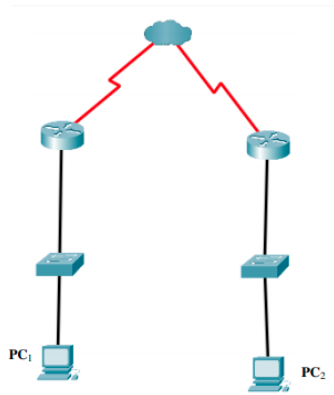
Introduction

- Spanning Tree Protocol (STP) is a Layer 2 network protocol used to prevent looping and the broadcast storms within a network topology.
- STP was invented by **Radia Perlman** from **Digital Equipment Corporation(DEC)**.
- Next development/variations:
  - IEEE 802.1d - Common Spanning Tree (CST)
  - Cisco default version - Per-VLAN Spanning Tree+ (PVST+)
  - IEEE802.1w - Rapid Spanning Tree Protocol (RSTP)
  - IEEE 802.1s - multiple spanning tree (MSTP)
  - Cisco version - Rapid PVST+
- Spanning tree also allows a network design to include backup links providing fault tolerance if an active link fails.
- STP creates a spanning tree that characterizes the relationship of nodes within a network of connected layer-2 bridges, and disables those links that are not part of the spanning tree, leaving a single active path between any two network nodes.

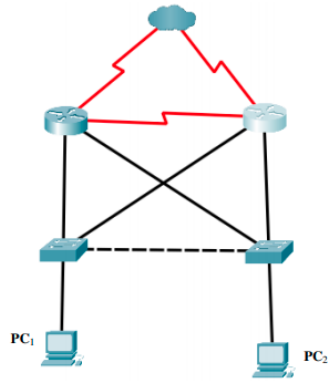
Redundancy in Network

- Redundancy in a network refers to the inclusion of backup or duplicate components, connections, or paths within the network infrastructure.

Network without redundancy



Network with redundancy



Advantages of redundancy

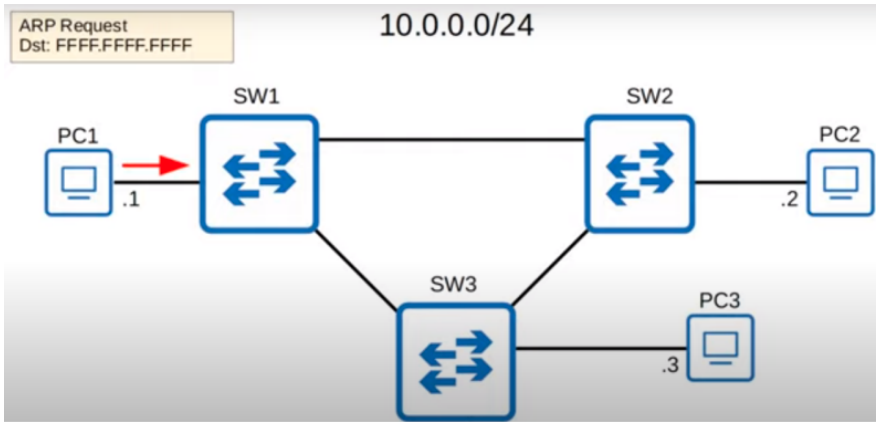
- ☆ **Fault tolerance:** It helps to ensure network reliability and availability by minimizing the impact of failures.
- ☆ **Load balancing:** It allows for distributing network traffic across multiple components or paths, which helps to balance the load and optimize performance. This can prevent bottlenecks and congestion in the network.
- ☆ **Scalability:** It supports network scalability by providing additional capacity and resources.
- ☆ **Maintenance and upgrades:** It enables organizations to perform maintenance and upgrades without disrupting network operations.

Disadvantages of redundancy

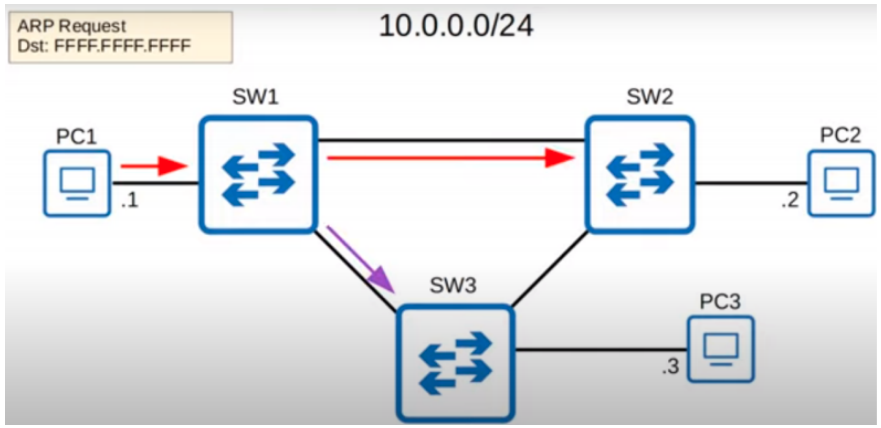
- ☆ **Loop Formation:** Redundant connections can create loops. Because of loop broadcast frames circulate endlessly to generate broadcast storms.
- ☆ **MAC Address Instability:** In the presence of loops, the MAC address tables can become unstable. Switches may continuously update their MAC address tables due to changing paths and varying port associations.
- ☆ **Traffic Congestion:** If all paths are active simultaneously, traffic may overload certain links while others remain underutilized.
- ☆ **Inefficient Resource Utilization:** Will happen, If redundant connections are not properly managed.

Broadcast Storm

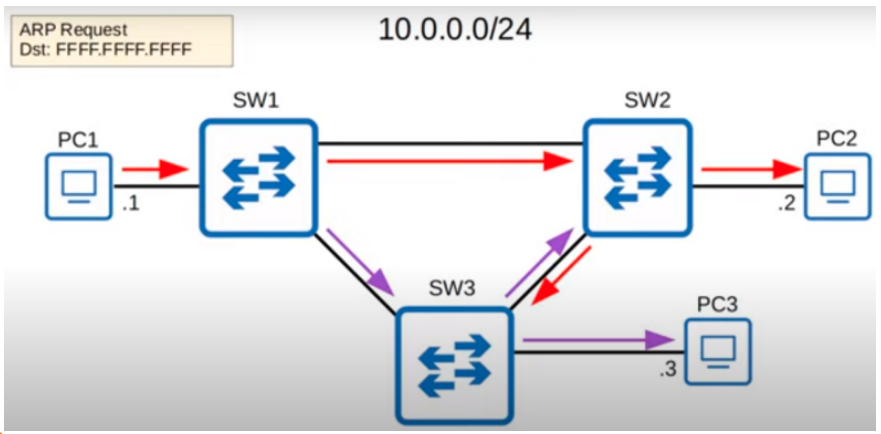
1. PC1 broadcast an ARP packet



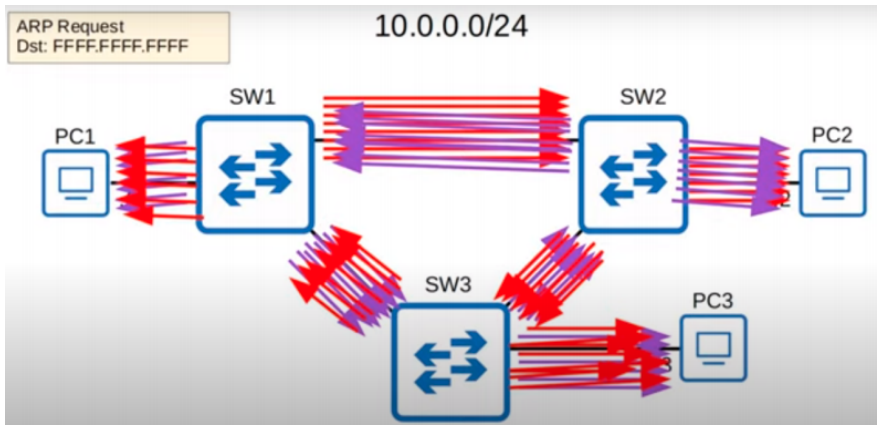
2. SW1 forwards the packet



3. SW2 and SW3 forwards the packet



4. All switches forward packets



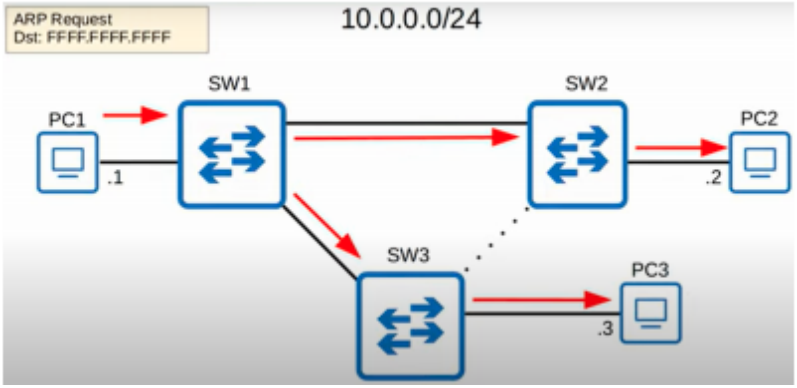
(1) As there is a cycle the same will occur for each broadcast received from the other switch.

(2) As switch works in layer 2 so there wont be any TTL in header. Which gradually will lead to flood of packets.

Solution: Spanning Tree Protocol (STP)

- Blocking the alternative path temporarily.
- STP helps to decide which ports to block keeping the network connected.
- STP uses the spanning-tree algorithm (STA) to first create a topology database and then search out and disable redundant links.

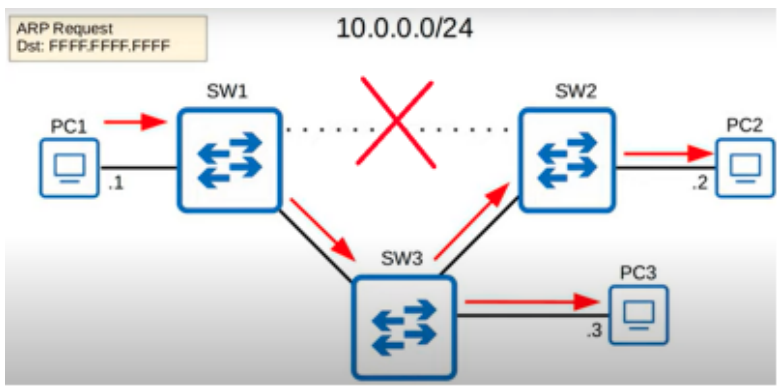
To avoid loop



Blocking the alternative path temporarily

- If the loop is avoided then broadcast-storm will not be formed.
- STP achieves its primary objective of preventing network loops on layer 2 network bridges or switches by monitoring the network to track all links and shut down the redundant ones.

A link failure case

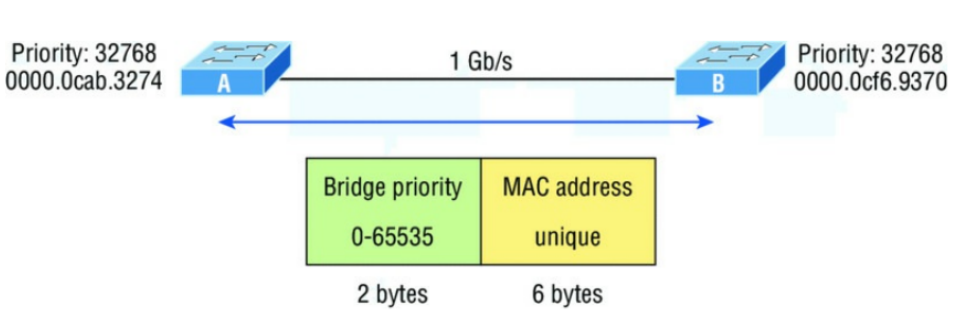


Alternate link under used

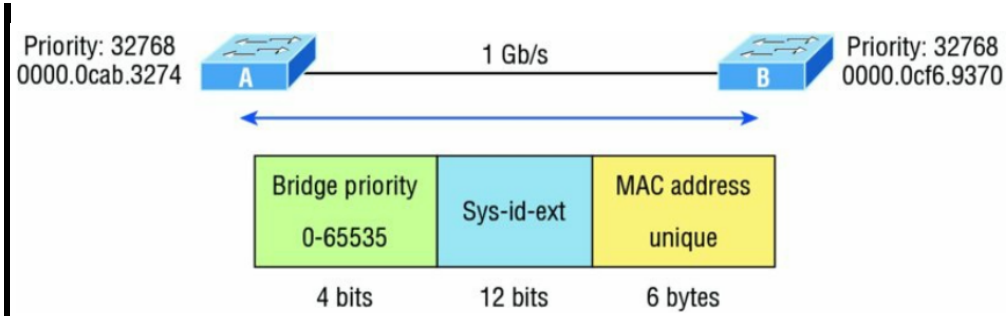
- If a selected path is discarded then the temporarily closed ports will be used to form new spanning tree protocol.

Spanning-Tree Terms

Bridge ID: It is an 8-byte field that is a combination of bridge priority (2 bytes) and Base Mac address (6 bytes) of a device. If there is a **tie** on bridge priority then the Base Mac address is considered.



(a) IEEE 802.1D STP bridge ID



(b) PVST+ unique bridge ID

Bridge Priority: It is a priority, which is assigned to every switch, 32768 by default.

Root bridge: It is the bridge with the lowest Bridge ID. All the decisions like which ports are the root ports (the port with the best path to the root bridge) are made from the perspective of the root bridge.

Non-root bridge: These are all bridges that aren't the root bridge. Non-root bridges exchange BPDUs with all the other bridges and update the STP topology database on all switches. This prevents loops and helps defend against link failures.

Spanning-Tree Terms Contd...

BPDU: For STP to function, the switches need to share information, *Bridge Protocol Data Units (BPDUs)*, about themselves and their connections. BDPUs are sent out as multicast frames to which only other layer 2 switches or bridges are listening. Switches will use BPDUs to learn the topology of the network: what switch is connected to other switches, and whether any layer 2 loops are based on this topology. It contains sender's bridge ID, cost to the root bridge, timer values on root bridge. All switches exchange BPDU in order to elect root bridge. By default, BPDUs are sent out every two seconds.

Port cost: Port cost determines the best path when multiple links are used between two switches. The cost of a link is determined by the bandwidth of a link, and this path cost is the deciding factor used by every bridge to find the most efficient path to the root bridge.

Path cost: A switch may encounter one or more switches on its path to the root bridge, and there may be more than one possible path. All unique paths are analyzed individually, and a path cost is calculated for each unique path by adding the individual port costs encountered on the way to the root bridge. The path with the lowest cost will be selected.

Speed	Link Cost
10 Mbps	100
100 Mbps	19
1 Gbps	4
10 Gbps	2

Note: You can override the default value on the per-interface basis using the following command: `S(config)#interface <int-name>` `S(config-if)#spanning-tree cost VALUE`

Bridge Port Roles

STP uses roles to determine how a port on a switch will act within the spanning-tree algorithm.

Root port: The root port is the link with the lowest path cost to the root bridge. If more than one link connects to the root bridge, then a port cost is found by checking the bandwidth of each link.The lowest-cost port becomes the root port. **When multiple links connect to the same device, the port connected to the lowest port number on the upstream switch will be the one that's used**. The root bridge can never have a root port designation, while every other switch in a network must have one and only one root port.

Designated port: A designated port is one that's been determined to have the best (lowest) cost to get to on a given network segment, compared to other ports on that segment. A designated port will be marked as a forwarding port, and you can have only one forwarding port per network segment.

Non-designated port: A non-designated port is one with a higher cost than the designated port. These are basically the ones left over after the root ports and designated ports have been determined. Non-designated ports are put in blocking or discarding mode-they are not forwarding ports.

Forwarding port: A forwarding port forwards frames and will be either a root port or a designated port.

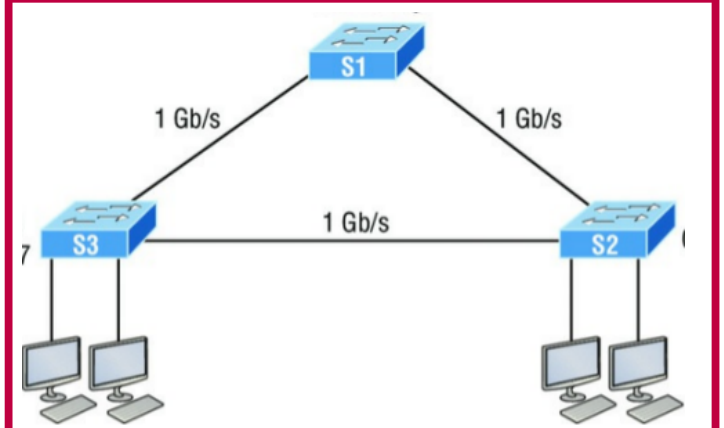
Bridge Port Roles Contd...

Blocked port: A blocked port won't forward frames in order to prevent loops. A blocked port will still always listen to BPDU frames from neighbor switches, but it will drop any and all other frames received and will never transmit a frame. It is in 2 flavors as per IEEE 802.1w: Alternate and Backup port.

Alternate port: This corresponds to the blocking state of 802.1d and is a term used with the newer 802.1w (Rapid Spanning Tree Protocol). An alternative port is located on a switch connected to a LAN segment with two or more switches connected, and one of the other switches holds the designated port.

Backup port: This corresponds to the blocking state of 802.1d and is a term now used with the newer 802.1w. A backup port is connected to a LAN segment where another port on that switch is acting as the designated port.

STP operations



`show spanning-tree` commands

- `S1#show spanning-tree ?`
- `S1#show spanning-tree`
- `S1#show spanning-tree summary`
- `S1#show spanning-tree detail`
- `S1#show spanning-tree active`
- `S1#show spanning-tree interface ?`
- `S1#show spanning-tree vlan ?`

Spanning-Tree Port States

The ports on a bridge or switch running IEEE 802.1d STP can transition through five different states:

Disabled (technically, not a transition state): A port in the administratively disabled state doesnt participate in frame forwarding or STP. A port in the disabled state is virtually nonoperational.

Blocking(BLK): A blocked port won't forward frames; it just listens to BPDUs. The purpose of the blocking state is to prevent the use of looped paths. All ports are in blocking state by **default** when the switch is powered up.

Listening(LSN): This port listens to BPDUs to make sure no loops occur on the network before passing data frames. A port in listening state prepares to forward data frames without populating the MAC address table.

Learning(LRN): The switch port listens to BPDUs and learns all the paths in the switched network. A port in learning state populates the MAC address table but still doesn't forward data frames. **Forward delay** refers to the time it takes to transition a port from listening to learning mode, or from learning to forwarding mode, which is set to **15 seconds by default** and can be seen in the **`show spanning-tree`** output.

Forwarding(FWD): This port sends and receives all data frames on the bridged port. If the port is still a designated or root port at the end of the learning state, it will enter the forwarding state.

Switches populate the MAC address table in learning and forwarding modes only.

STP Convergence

- Convergence occurs when all ports on bridges and switches have transitioned to either forwarding or blocking modes.
- No data will be forwarded until convergence is complete. All host data stops transmitting through the when STP is converging.
- Convergence is vital because it ensures that all devices have a coherent database.
- **Blocking state:** A port in a blocking state will remain there for **20 seconds by default** (the maximum age timer).
- **Listening state:** A port will stay in this state for the length of the forward delay timer. The **default** for this value is **15 seconds**.
- **Learning state:** A port will stay in this state for the length of the forward delay timer. The **default** for this value is **15 seconds**.
- **Forwarding state:** Finally, after the forward delay timer expires, ports that were in a learning state are placed in a forwarding state. In a forwarding state, the port will process BPDUs, update its MAC address table with frames that it receives, and forward user traffic through the port.
- If a port has to go through all four states, convergence takes 50 seconds: 20 seconds in blocking, 15 seconds in listening, and 15 seconds in learning.
- The original STP (802.1d) takes **50** seconds to go from blocking to forwarding mode by **default**.

Types of Spanning-tree Protocols

There are several varieties of spanning-tree protocols in use today:

- **IEEE 802.1d:** The original standard for bridging and STP, which is really slow but requires very little bridge resources. Its also referred to as Common Spanning Tree (CST).
- **PVST+:** Per-VLAN Spanning Tree+ is the Cisco proprietary enhancement for STP that provides a separate 802.1d spanning-tree instance for each VLAN. It is just as slow as the CST protocol, but with it, we get to have **multiple root bridges**. This creates more efficiency of the links in the network, but it does use more bridge resources than CST does.
- **IEEE 802.1w - Rapid Spanning Tree Protocol (RSTP):**, It enhanced the BPDU exchange and paved the way for much faster network convergence, but it still only allows for one root bridge per network like CST. The bridge resources used with RSTP are higher than CST's but less than PVST+.
- **IEEE 802.1s (MSTP):** Maps multiple VLANs into the same spanning-tree instance to save processing on the switch. It's basically a spanning-tree protocol that rides on top of another spanning-tree protocol.
- **Rapid PVST+:** Ciscos version of RSTP that also uses PVST+ and provides a separate instance of 802.1w per VLAN. It gives us really fast convergence times and optimal traffic flow but predictably requires the most CPU and memory of all.

STP Election Process- Root Switch/Bridge

- **Bridge ID =** priority (4 bits) + system ID extension (12 bits) + MAC address (48 bits); the default bridge priority is 32,768.
- **Port ID =** priority (4 bits) + ID (Interface number) (12 bits); the default port priority is 128.
- **Select the root switch/bridge:**
  - ✍ Switches elect a root switch based on the bridge ID(BID) in the BPDUs.
  - ✍ The switch with the smallest (lowest) bridge ID.
  - ✍ Rest switches are non-root switch/bridge.
  - ✍ Two-part are in BID: Priority and MAC address.
  - ✍ Lowest priority becomes the root switch/bridge. If **Tie** in priority
  - ✍ The lowest MAC address portion of the BID is the root.
- Mark the ports of the root bridge as designated forwarding port (FWD). The root bridge can never have a root port (RP) designation.
- **Port across the root port (RP) is always designated forwarding port (FWD).**

STP Election Process-Root Port

- **Select root port on non-root bridge:** The best path from the switch to the root bridge. Every non-root bridge has one and only one root port.
  - A switch's root port (RP) is its interface through which it has the least STP/RSTP cost to reach the root switch (least root cost). **If best root cost ties for two or more paths**.
  - Choose based on the lowest neighbor bridge ID.
  - Choose based on the lowest neighbor port priority.
  - Choose based on the lowest neighbor internal port number.
- **Select Forwarding port on non-root bridge:** Each LAN segment has one designated forwarding port.
- **Select Blocking port:** The remaining ports on non-root bridge(s).

Forwarding Port in Non-Root Switch

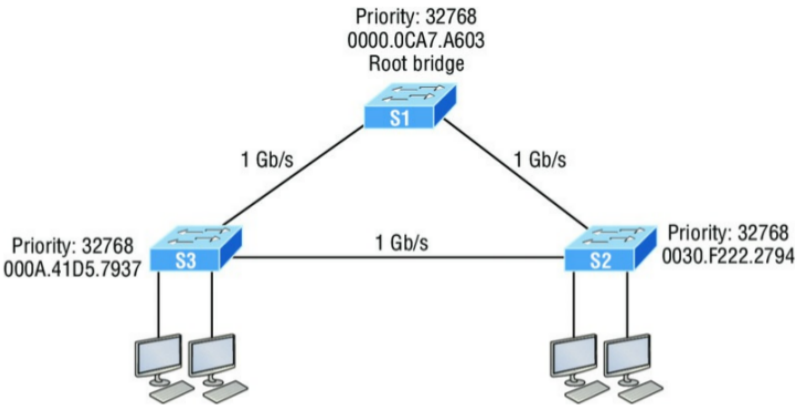
- Each switch has a single root port that it uses to reach the root switch.
- **Designated port:** In addition to each switch having a **root port**, each segment also has a single port that it uses to reach the root, and this port is called a designated port.
- The switch (and its port) that is chosen should have the best path to the root switch.

Steps taken by switches in determining which port on which switch will be chosen as the designated port for a particular LAN segment:

- ✍ The connected switch on the segment with the lowest accumulated path cost to the root switch will be used.
- ✍ If there is a tie in accumulated path costs between two switches, the switch with the lowest switch ID will be chosen.
- ✍ If it happens that it is the same switch, but with two separate connections to the LAN segment, the switch port with the lowest priority is chosen.
- ✍ If there is still a tie (the priorities of the ports on this switch are the same), the physically lowest numbered port on the switch is chosen.

Example: STP Election Process

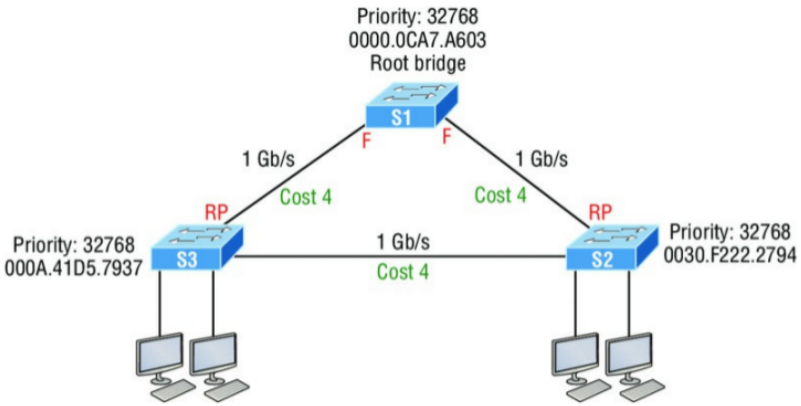
STP for three-switch network



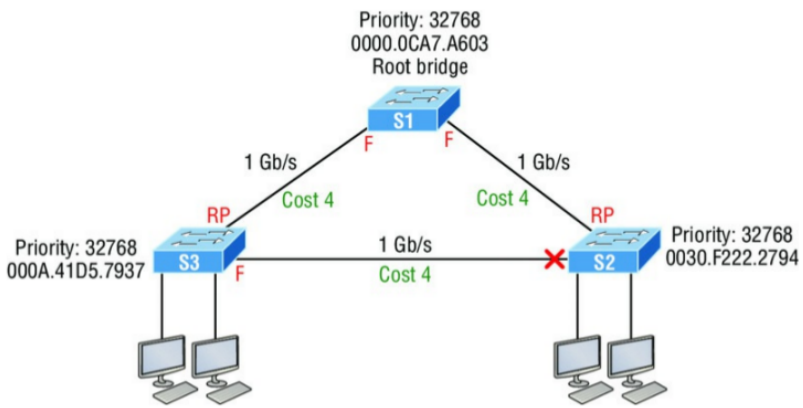
STP Operation

- ☆ Root bridge selected: **S1**.
- ☆ S1 ports: desginated Forwarding (F).
- ☆ Root ports selected on S2 and S3; Lowest cost to root bridge.
- ☆ Forwarding port on **S2** towards S3 as Lowest BID than S3.
- ☆ Blocking port on **S3** towards S2..

1. STP operation

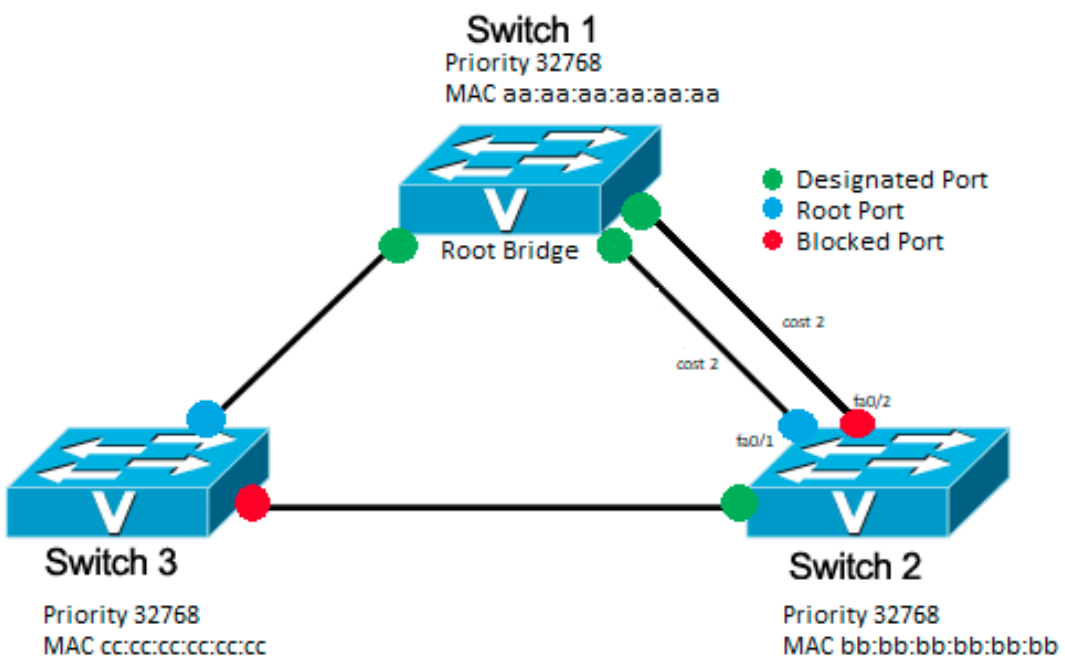


2. STP Operation



Example 1: STP Election Process

Verify the ports



STP Operation

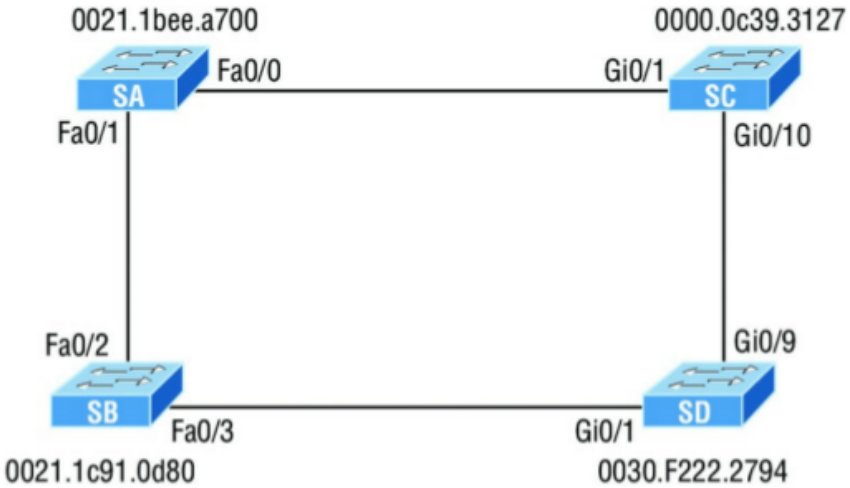
- ☆ Find root bridges.
- ☆ Find the root port.
- ☆ Find non-root bridges.
- ☆ Find the forward ports.
- ☆ Find block ports.

- ☆ The below given points determine root port on switch 2;

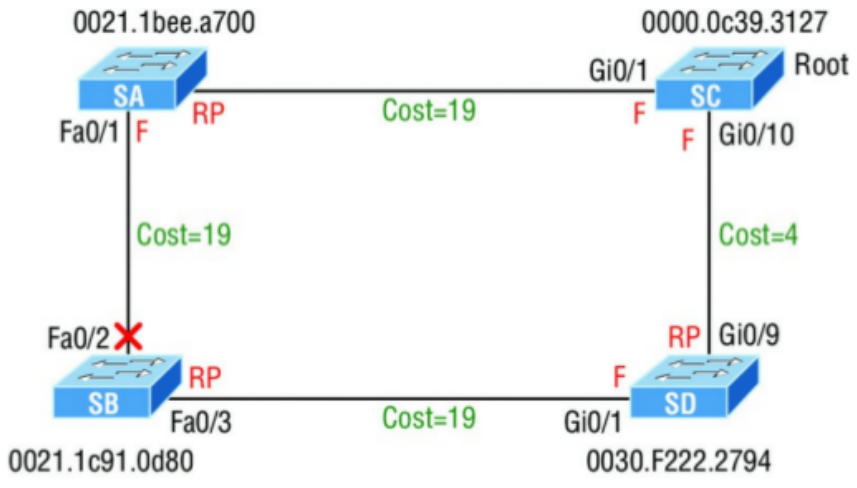
- ☆ **A switch port receiving superior BPDUs.** Ports fa0/1 and fa0/2 receive the same superior BPDU, therefore, further steps are needed to determine the root port. Port Fa0/3 on Switch 2 does not qualify because its receiving BPDUs from Switch 3.
- ☆ **The port with the lowest root path cost.** We can see ports fa0/1 and fa0/2 have equal path costs, so we still have a tie.
- ☆ **The port with the lowest sender BID.** Again, fa0/1 and fa0/2 have the same BID (that of Switch 2), and therefore the final step will be used to determine the root port.
- ☆ **The lowest port number of the sending switch.** fa0/1 is the lowest port number and is therefore elected the root port for this switch.

Example 2: STP Operation

Verify the ports



STP Operation

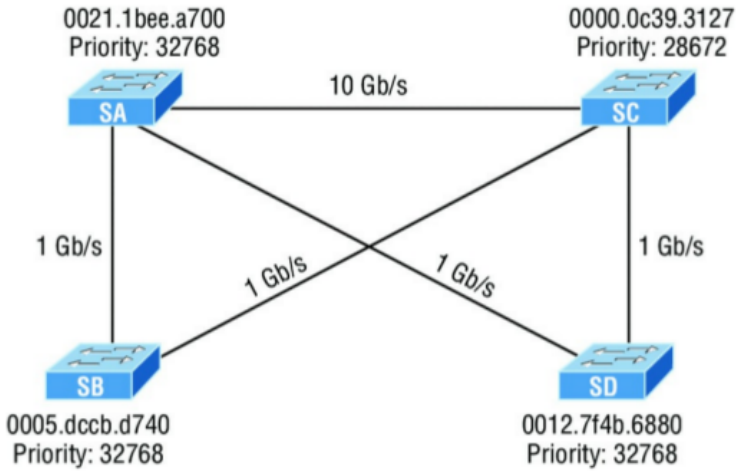


STP working procedure

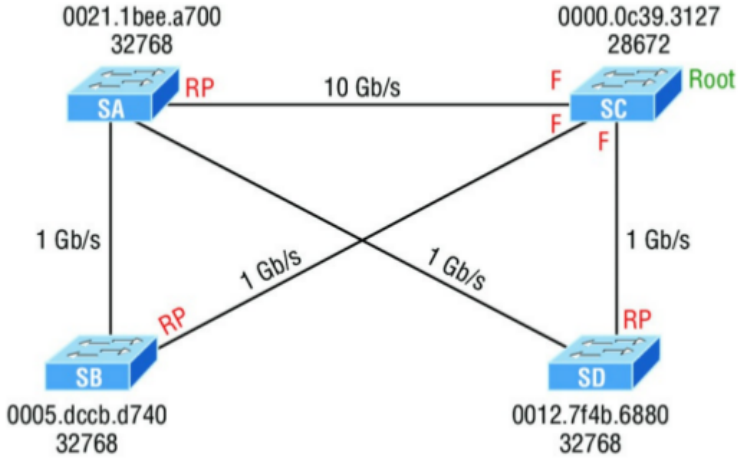
- ☆ Find th root bridge by looking at bridge IDs. Set ports of root bridge are **F**.
- ☆ Determine the root port by finding the lowest path cost to the root bridge.
- ☆ Find the designated ports on non-root bridge. How are the designated ports chosen over a link connecting the switches?
  1. ❶ Select the switch with the lowest accumulated path cost to the root bridge. We want the fast path to the root bridge.
  2. ❷ If there is a tie on the accumulated path cost from both switches to the root bridge, then select port of the switch with lowest bridge ID.
- ☆ Anything left over goes into a discarding role (blocking ports).

Example 3: STP Operation

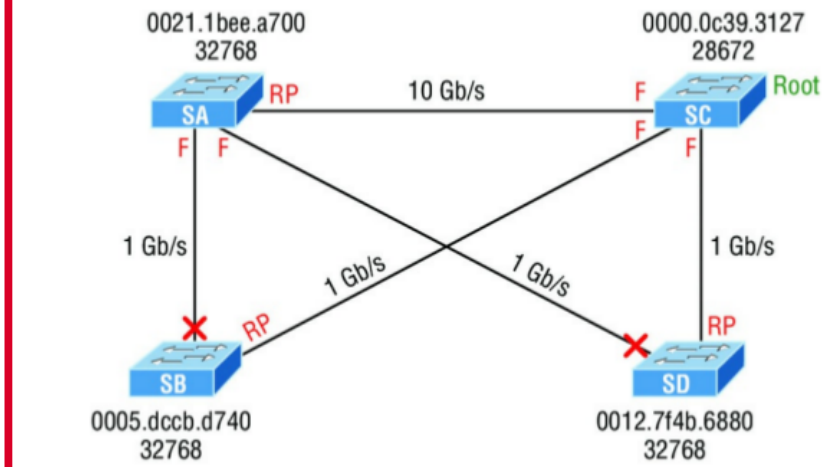
Find root bridge and designated ports



1. Root bridge & root port selection



2. All ports marked

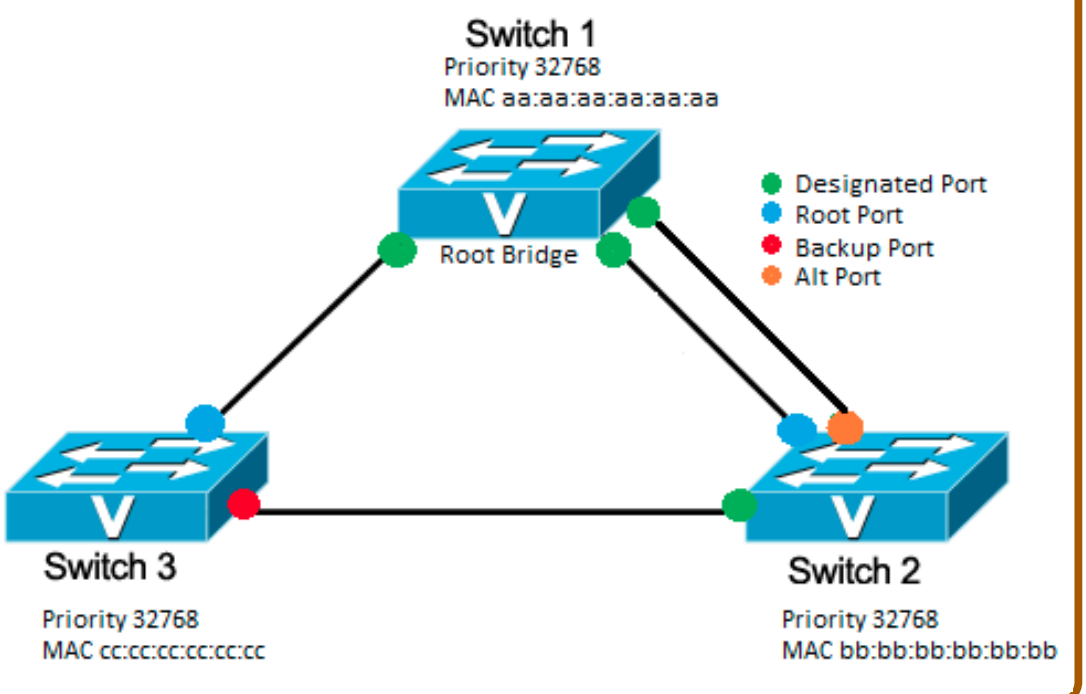


Alternate and Backup Ports

In IEEE 802.1W-RSTP, the election process is the same as STP, except the blocked port is split into two new port roles: **alternate** and **backup**.

- ☆ **Alternate:** An alternate port receives BPDUs from another switch but remains in a blocked state. For example, lets say a switch has two paths to the root bridge. It will elect one of the two ports as a root port and the other will become an alternate port. If at any time the root port fails, this redundant path, *the alternate port*, will become the new root port.
- ☆ **Backup:** A backup port receives BPDUs from its own switch but remains in a blocked state. For example, If a switch has two ports connecting to different switches, then one port will be elected as a root port and the other will become the backup port.

Verify the ports



RSTP Operation

Rapid Spanning Tree Protocol (RSTP): RSTP is as its name suggests, a faster transition to a port-forwarding state. Unlike STP, which has five switchport states, RSTP has only three: discarding, learning, and forwarding.

- ☆ Find root bridges.
- ☆ Find the root port.
- ☆ Find non-root bridges.
- ☆ Find the forward ports.
- ☆ Find block ports.

STP Commands

GCM spanning-tree commands

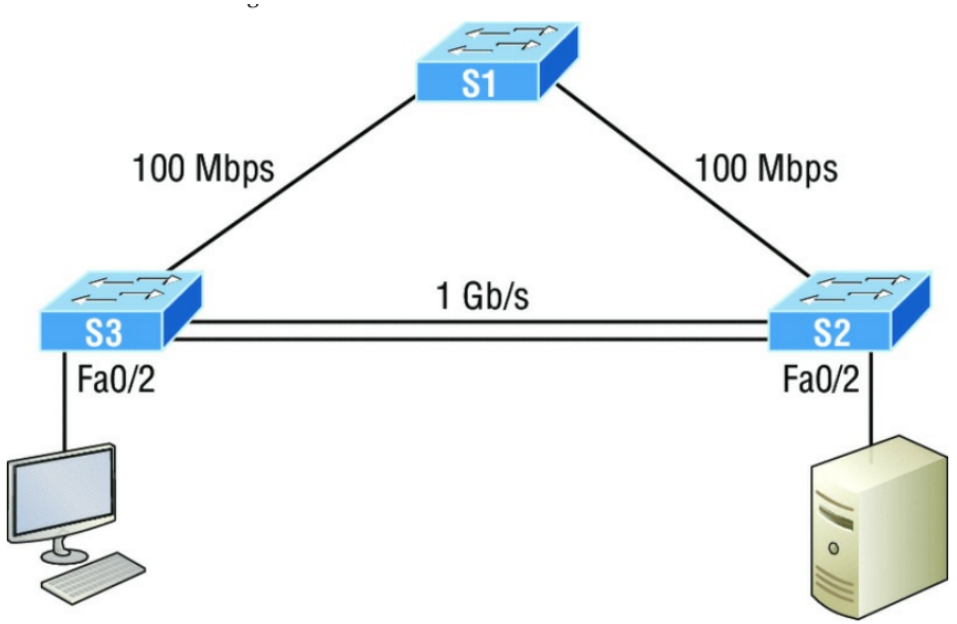
- `Switch(config)#spanning-tree ?`
- `Switch(config)#spanning-tree mode ?`
- `Switch(config)#spanning-tree mode {pvst | rapid-pvst }`
- `Switch(config)#spanning-tree vlan <vlan-num> ?`
- `Switch(config)#spanning-tree vlan <vlan-num> {priority | root | cr}`
- `Switch(config)#spanning-tree vlan <vlan-num> priority ?`
- `Switch(config)#spanning-tree vlan <vlan-num> root ?`

Interface spanning-tree commands

- `Switch(config)#interface <intface-name>`
- `Switch(config-if)#spanning-tree ?`
- `Switch(config-if)#spanning-tree cost ?` /* port path cost */
- `Switch(config-if)#spanning-tree vlan <vlan-num> ?`
- `Switch(config-if)#spanning-tree vlan 1 cost` /* change an interface's ST port path cost */
- `Switch(config-if)#spanning-tree vlan 1 port-priority ?`
  /* change an interface's spanning tree (ST) port priority */

Exercise on STP

Identify the ports



Data

- ☆ Bridge priority for all switches: 32769
- ☆ MAC S1: 0001.C9A5.A748
- ☆ MAC S2: 0501.C9A5.8240
- ☆ MAC S3: 0004.9A04.ED97
- ☆ Default bridge priority: 32769
- ☆ Default port priority: 128

Review Questions

1. Which of the following is a layer 2 protocol used to maintain a loop-free network? discovery?

   (A) VTP
   (B) STP
   (C) RIP
   (D) CDP

2. Which statement describes a spanning-tree network that has converged?

   (A) All switch and bridge ports are in the forwarding state.
   (B) All switch and bridge ports are assigned as either root or designated ports.
   (C) All switch and bridge ports are in either the forwarding or blocking state.
   (D) All switch and bridge ports are either blocking or looping.

3. How many bits is the sys-id-ext field in a BPDU?

   (A) 4
   (B) 8
   (C) 12
   (D) 16

4. Which are states in 802.1d? (Choose all that apply.)

   (A) Blocking
   (B) Discarding
   (C) Listening
   (D) Learning
   (E) Forwarding
   (F) Alternate

5. You have configured your switches with the **`spanning-tree vlan x root primary`** and **`spanning-tree vlan x root secondary`** commands. Which of the following tertiary switch will take over if both switches fail?

   (A) A switch with priority 4096
   (B) A switch with priority 8192
   (C) A switch with priority 12288
   (D) A switch with priority 20480

6. Which of the following are roles in STP? (Choose all that apply.)

   (A) Blocking
   (B) Discarding
   (C) Listening
   (D) Learning
   (E) Forwarding
   (F) Alternate

THANK YOU