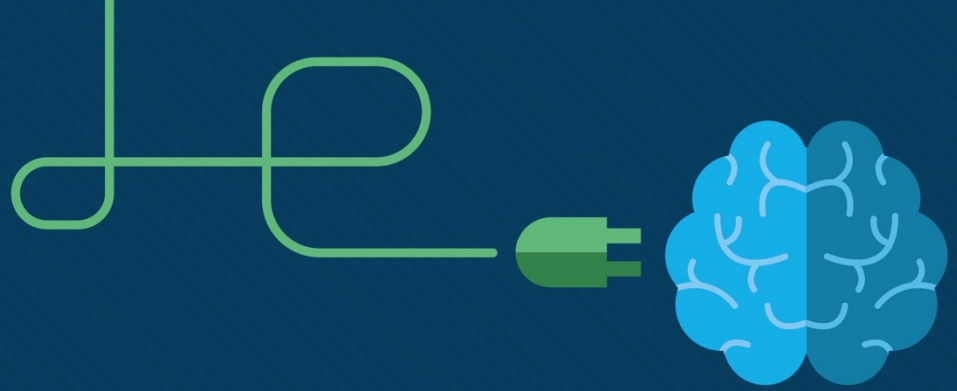


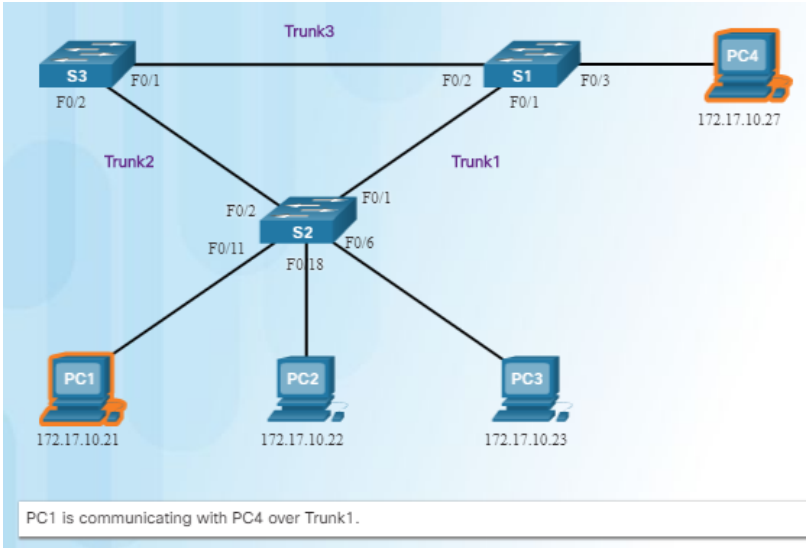
# Chapter 3: STP

CCNA Routing and Switching

Scaling Networks v6.0

# Spanning Tree Protocol

- Switched networks commonly have redundant paths and even redundant links between the same two devices.
  - Redundant paths eliminate a single point of failure in order to improve reliability and availability.
  - Redundant paths can cause physical and logical Layer 2 loops.
- Spanning Tree Protocol (STP) is a Layer 2 protocol that helps especially when there are redundant links.
- Layer 2 loop issues
  - Mac database instability – copies of the same frame being received on different ports.
  - Broadcast storms – broadcasts are flooded endlessly causing network disruption.
  - Multiple frame transmission – multiple copies of unicast frames delivered to the same destination.

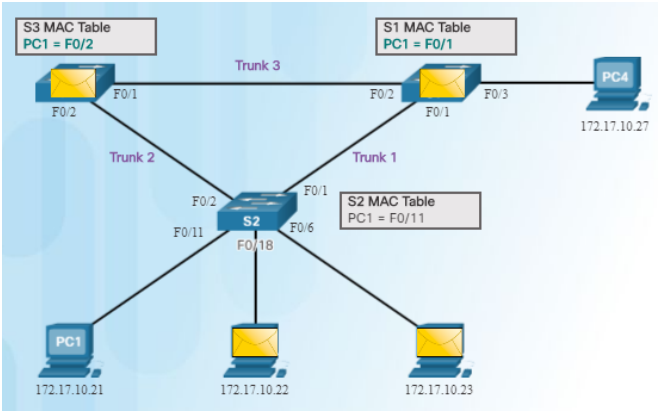


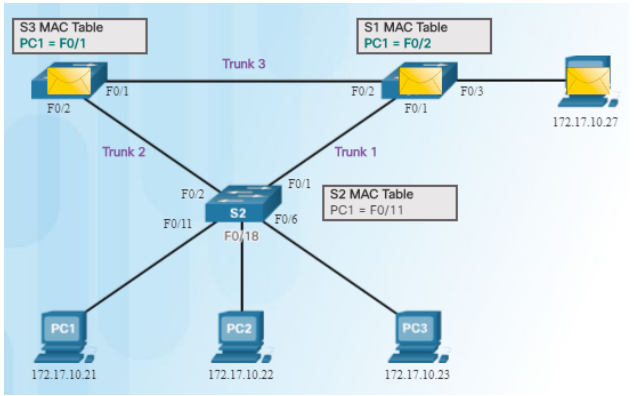
# Issues with Layer 1 Redundancy: MAC Database Instability

- Ethernet frames do not have a time to live (TTL) field like the Layer 3 IP header has. This means that Ethernet has no mechanism to drop frames that propagate endlessly. This can result in MAC database instability.

  1. PC1 sends a broadcast frame to S2.
  2. S2 updates the MAC address table for PC1's MAC address on port 11.
  3. S2 forwards the frame out all ports except the port the frame came in on. S1 and S3 receive the frame on a trunk and update their own MAC address tables that PC1 is reachable through the trunk port.
  4. S1 and S3 send the frame out all ports except the port it came in on.
  5. When S1 sends the frame out port 2 (Trunk 3), S3 updates the MAC address table to reflect that PC1 is now reachable through port 1.

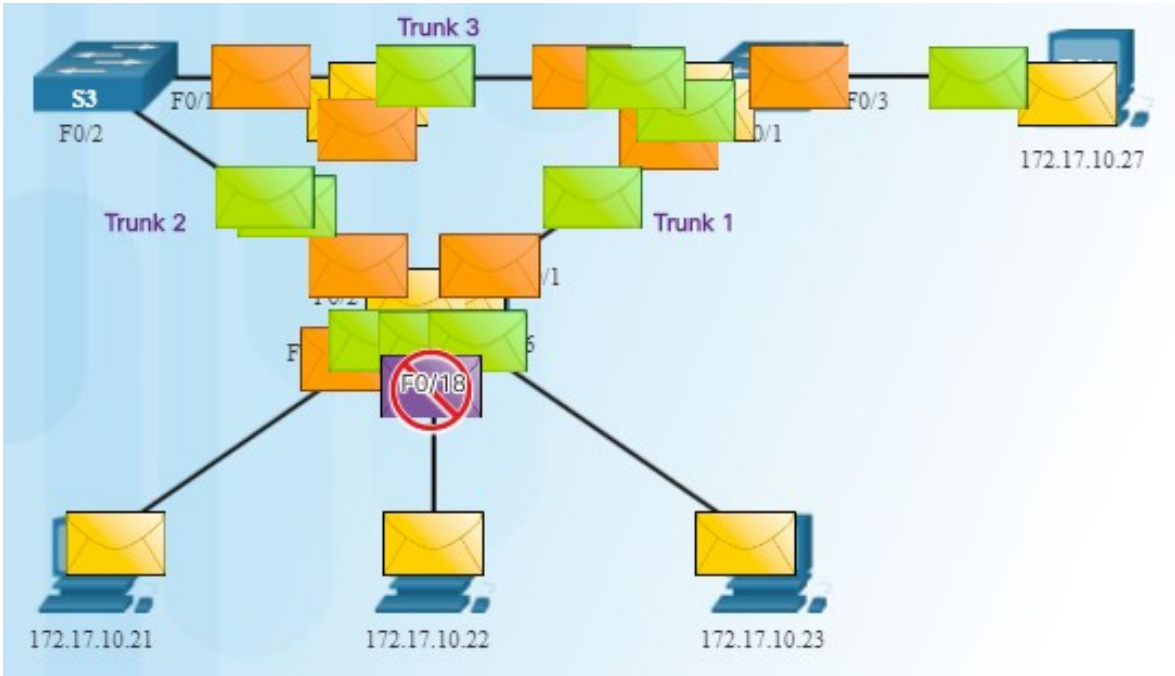
  - A host caught in a network loop is not accessible to other hosts.
  - Due to constant changes in the MAC address table, Switches S3 and S1 do not know which port to forward frames.



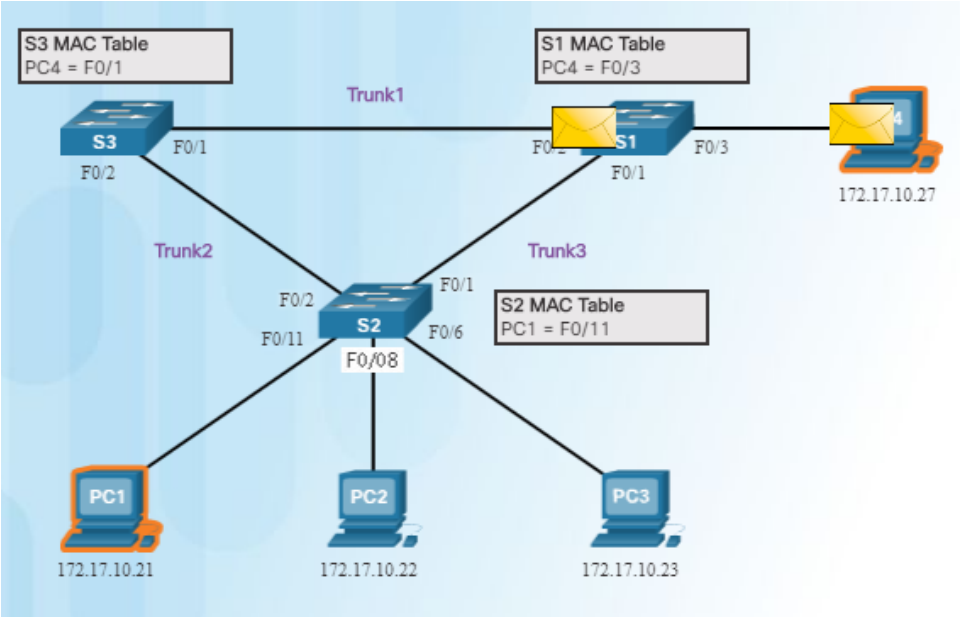
# Issues with Layer 1 Redundancy: Broadcast Storms

- Broadcast storm – so many broadcast frames in a Layer 2 loop that use all available bandwidth and make the network unreachable for legitimate network traffic.
  - Causes a denial of service (DoS)
  - Can develop in seconds and bring the network down



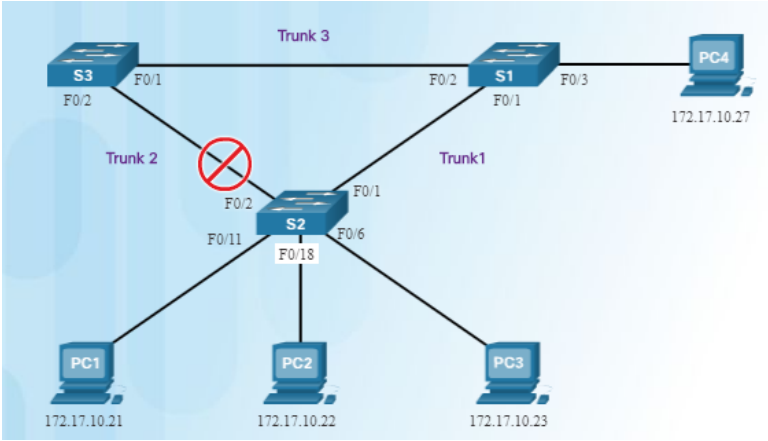
# Issues with Layer 1 Redundancy: Duplicate Unicast Frames

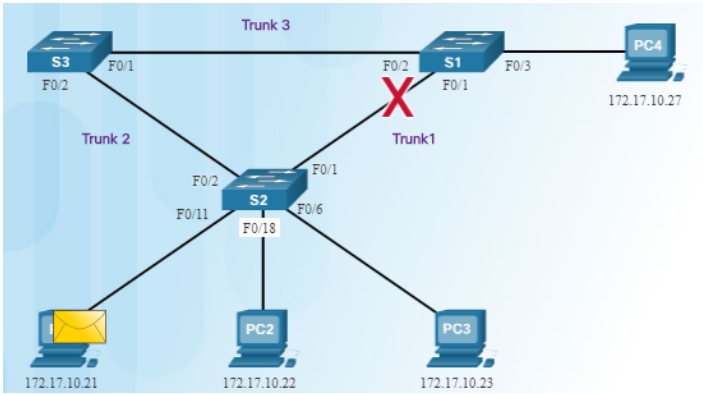
- An unknown unicast frame is when the switch does not have the destination MAC address in its MAC address table and has to broadcast the frame out all ports except the port the frame was received on (the ingress port).
- Unknown unicast frames sent onto a looped network can result in duplicate frames arriving at the destination device.
  1. PC1 sends a frame destined for PC4.
  2. S2 does not have PC4's MAC address in the MAC address table so it forwards the frame out all ports including the trunks that lead to S1 and S3. S1 sends the frame to PC4. S3 also sends a copy of the frame over to S1 which delivers the same frame again to PC4.



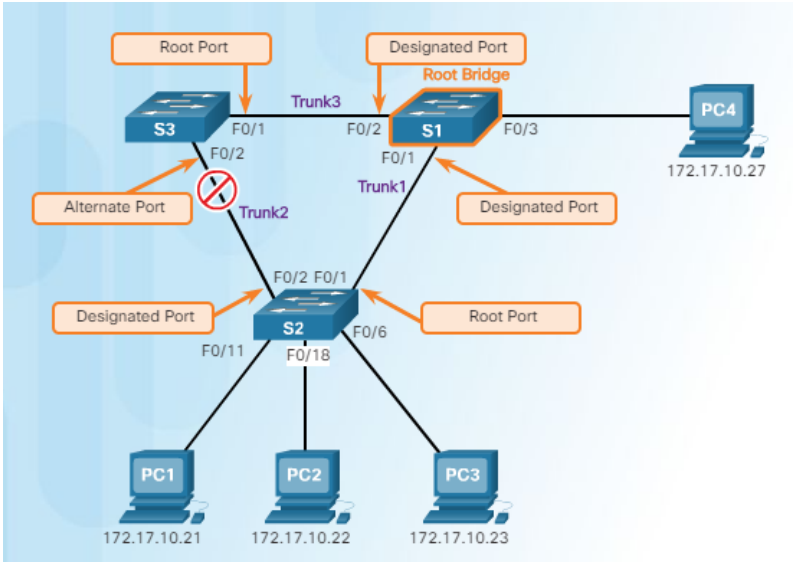
# Spanning Tree Algorithm: Introduction

- The Spanning Tree Protocol (STP) creates one logical path through the switch network (all destinations on the network).
  - Blocks redundant paths that could cause a loop.
  - STP sends bridge protocol data units (BPDUs) between Layer 2 devices in order to create the one logical path.
- A port on S2 is blocked so traffic can only flow one way between any two devices.
- When Trunk1 fails, the blocked port on S2 is unblocked and traffic can flow between S2 and S3.



# Spanning Tree Algorithm: Port Roles

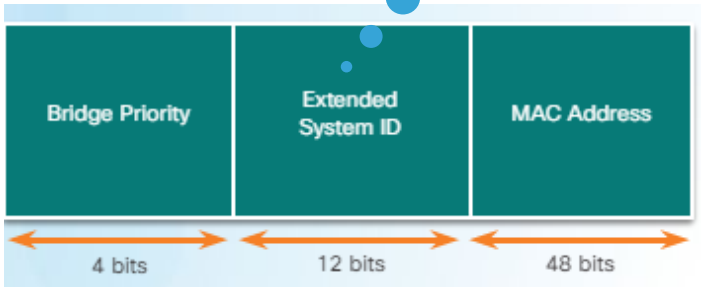


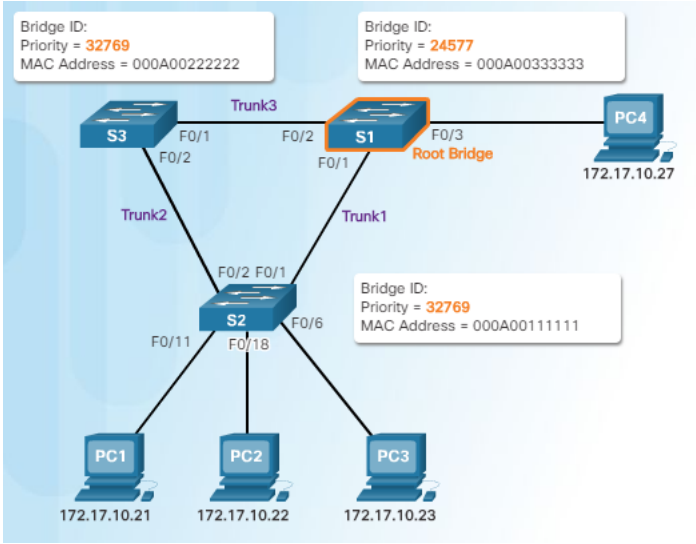

- Root bridge
  - one Layer 2 device in a switched network.
- Root port
  - one port on a switch that has the lowest cost to reach the root bridge.
- Designated port
  - selected on a per-segment (each link) basis, based on the cost to get back to root bridge for either side of the link.
- Alternate port
  - (RSTP only) backup port for the designated port when the other side is not a root port.
- Backup port
  - (RSTP only) backup port for the root port.

# Spanning Tree Algorithm: Root Bridge

Supports per-VLAN STP operations

- Lowest bridge ID (BID) becomes root bridge
  - Originally BID had two fields: bridge priority and MAC address
  - Bridge priority default is 32,768 (can change)
  - Lowest MAC address (if bridge priority is not changed) becomes determinant for root bridge.



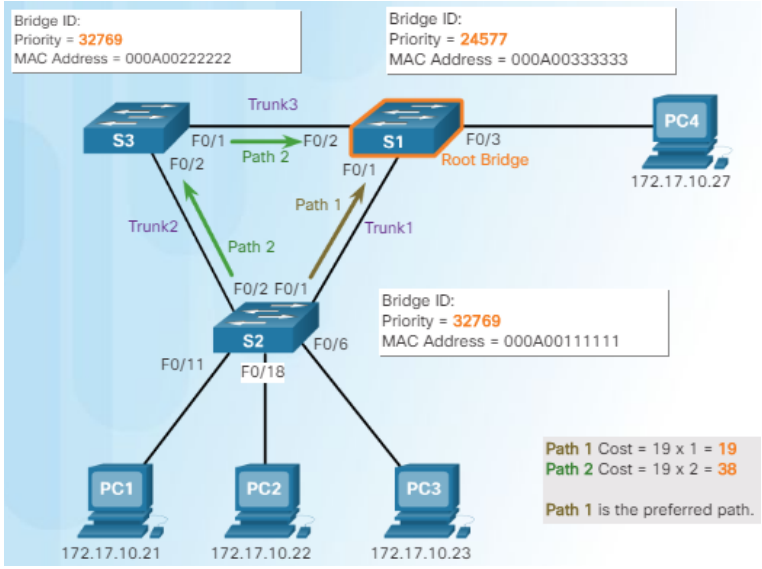



# Spanning Tree Algorithm: Root Path Cost

- Root path cost is used to determine the role of the port and whether or not traffic is blocked.
- Can be modified with the **spanning-tree cost** interface command.

```
S2# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
S2(config)# interface f0/1
S2(config-if)# spanning-tree cost 25
S2(config)# interface f0/1
S2(config-if)# no spanning-tree cost
```

```
S2# show spanning-tree

VLAN001
   Spanning tree enabled protocol ieee
   Root ID     Priority  24577
               Address      000A.0033.3333
               Cost         19
               Port         1
               Hello Time   2 sec Max Age 20 sec Forward Delay 15 sec

   Bridge ID   Priority     32769  (priority 32768 sys-id-ext 1)
               Address 000A.0011.1111
               Hello time 2 sec Max Age 20 sec Forward Delay 15 sec
               Aging Time 300

Interface    Role   Sts  Cost    Prio.Nbr  Type
-----------  -----  ---- -----   --------- ----------------
F0/1         Root   FWD  19       128.1    Edge P2p
F0/2         Desg   FWD  19       128.2    Edge P2p
```



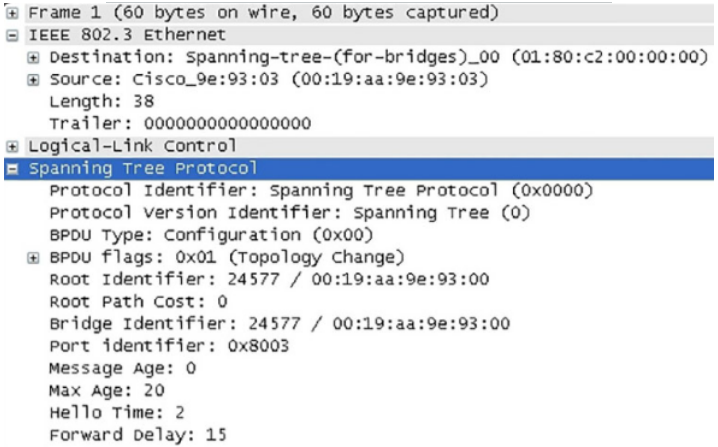

| Link Speed | Cost (Revised IEEE Specification) | Cost (Previous IEEE Specification) |
|---|---|---|
| 10 Gb/s | 2 | 1 |
| 1 Gb/s | 4 | 1 |
| 100 Mb/s | 19 | 10 |
| 10 Mb/s | 100 | 100 |

## STP Operation

# 802.1D Bridge Protocol Data Unit (BPDU) Frame Format

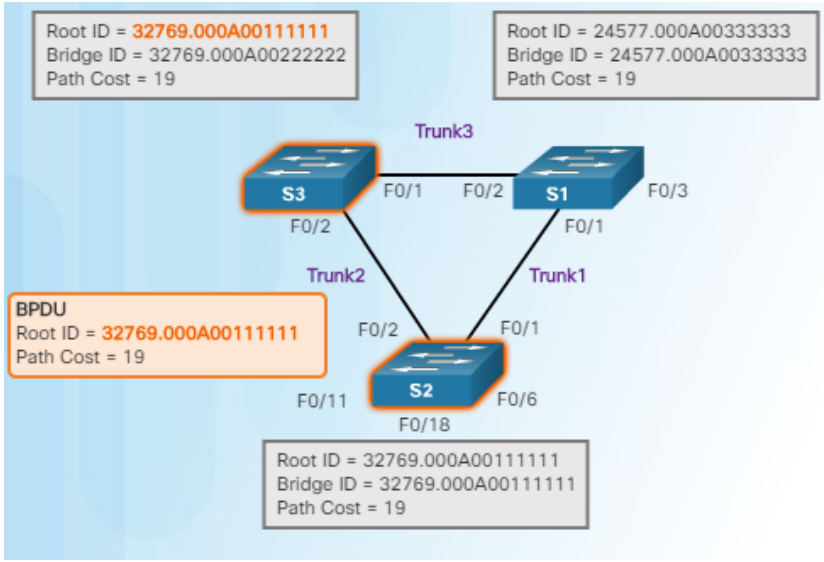
| Field | Description |
|---|---|
| Protocol ID | Type of protocol being used; set to 0 |
| Version | Protocol version; set to 0 |
| Message type | Type of message; set to 0 |
| Flags | Topology change (TC) bit signals a topology a change; topology change acknowldgment (TCA) bit used when a configuration message with the TC bit set has been received |
| Root ID | Root bridge information |
| Root path cost | Cost of the path from the switch sending the configuration message to the root bridge |
| Bridge ID | Includes priority, extended system ID, and MAC address ID of the bridge sending the message |
| Port ID | Port number from which the BPDU was sent |
| Message age | Amount of time since the root bridge sent the configuration message |
| Max age | When the current configuration message will be deleted |
| Hello time | Time between root bridge messages |
| Forward delay | Time the bridges should wait before going to a new state |

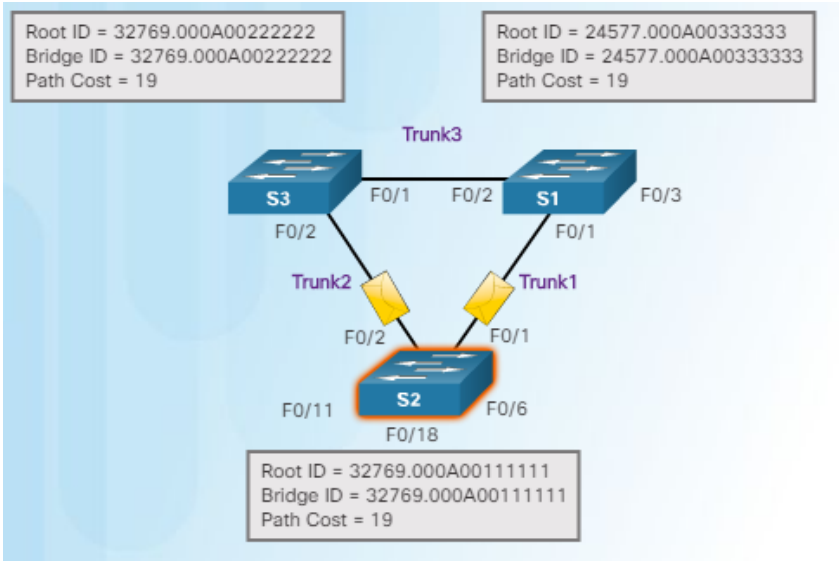
| Field Number | Bytes | Field |
|---|---|---|
| 1-4 | 2 | Protocol ID |
| | 1 | Version |
| | 1 | Message Type |
| | 1 | Flags |
| 5-8 | 8 | Root ID |
| | 4 | Root Path Cost |
| | 8 | Bridge ID |
| | 2 | Port ID |
| 9-12 | 2 | Message Age |
| | 2 | Max Age |
| | 2 | Hello Time |
| | 2 | Forward Delay |



# 802.1D BPDU Propagation and Process

1. When a switch is powered on, it assumes it is the root bridge until BPDUs are sent and STP calculations are performed. S2 sends out BPDUs.
2. S3 compares its root ID with the BPDU from S2. S2 is lower so S3 updates its root ID.

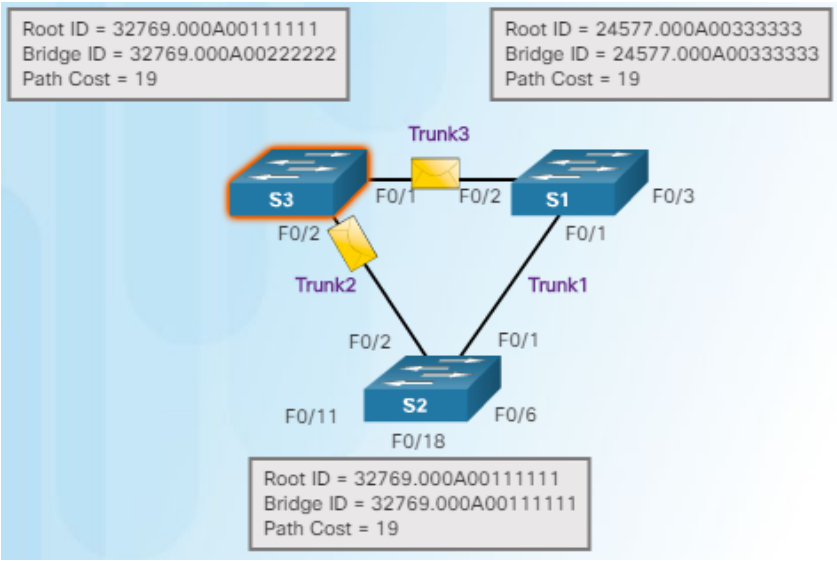


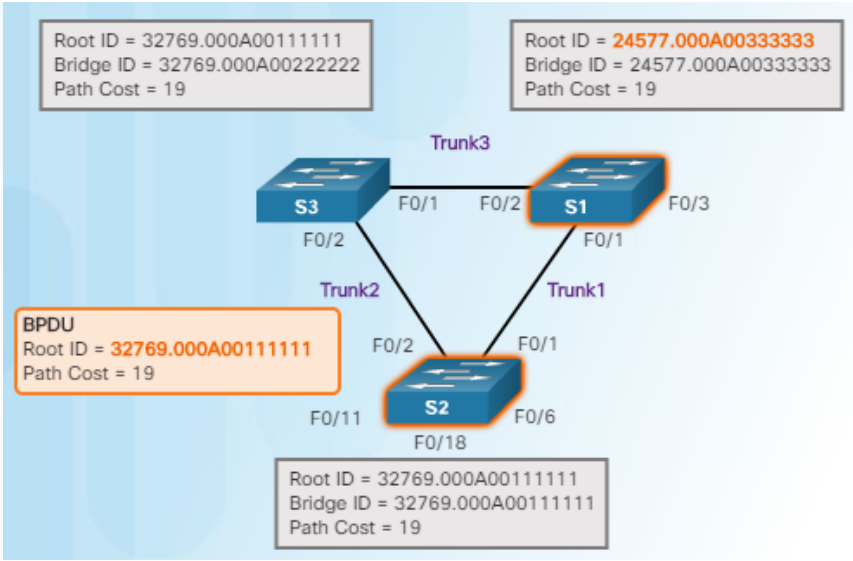



# 802.1D BPDU Propagation and Process (Cont.)

3. S1 receives the same information from S2 and because S1 has a lower BID, it ignores the information from S2.

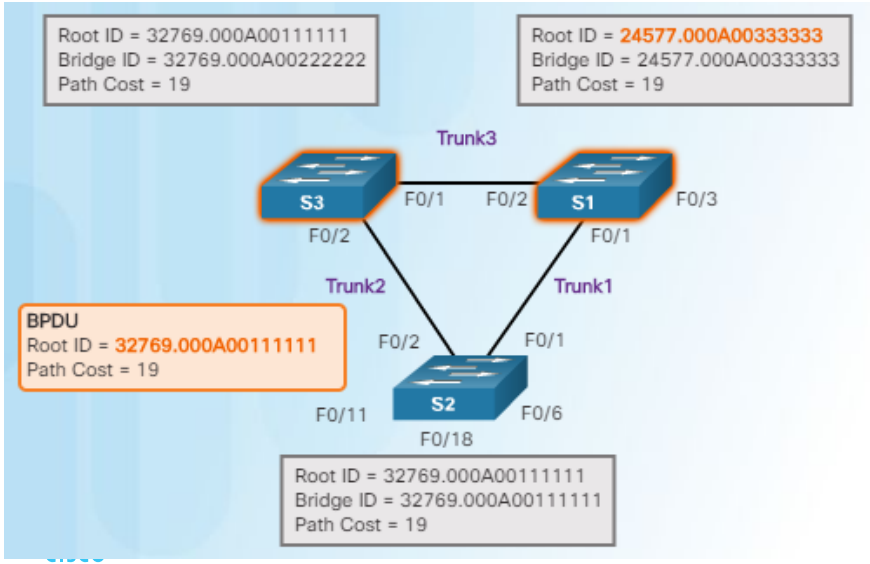
4. S3 sends BPDUs out all ports indicating that S2 is root bridge.

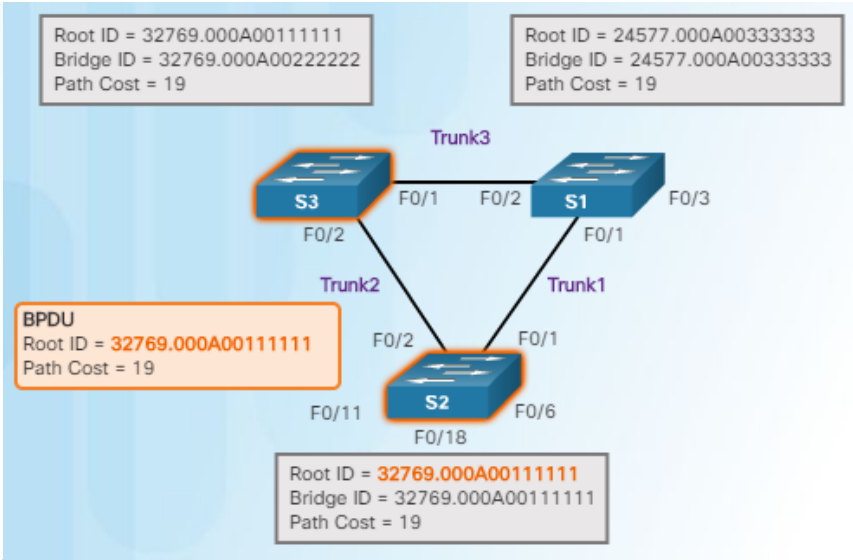


# 802.1D BPDU Propagation and Process (Cont.)

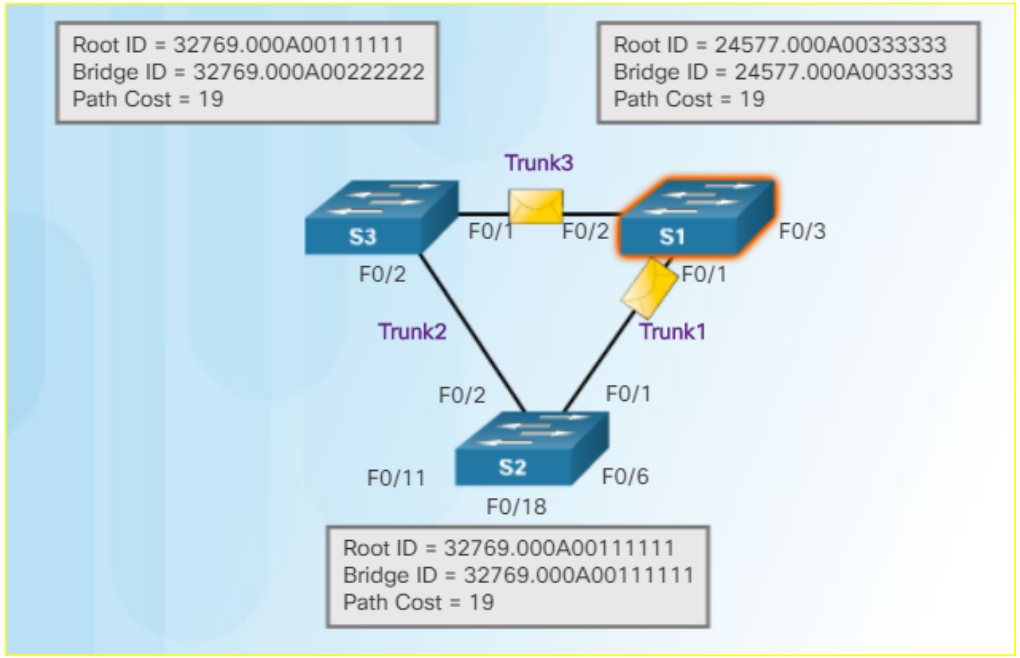
5. S2 compares the info from S3 so S2 still thinks it is root bridge.
6. S1 gets the same information from S3 (that S2 is root bridge), but because S1 has a lower BID, the switch ignores the information in the BPDU.



# 802.1D BPDU Propagation and Process (Cont.)

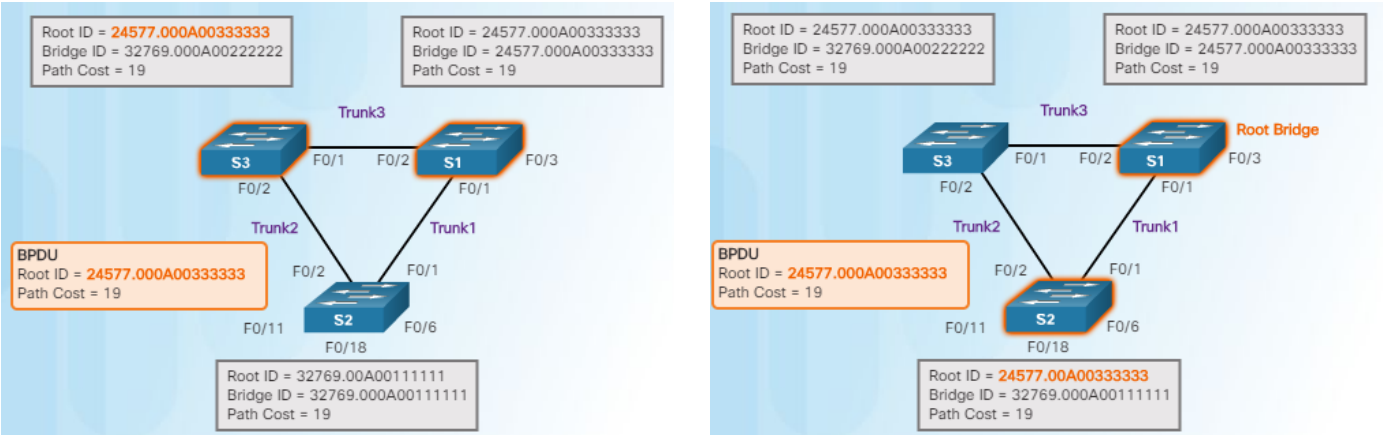
7. S1 now sends out BPDUs out all ports. The BPDU contains information designated S1 as root bridge.



# 802.1D BPDU Propagation and Process (Cont.)

8. S3 compares the info from S1 so S3 now sees that the BID from S1 is lower than its stored root bridge information which is currently showing that S2 is root bridge. S3 changes the root ID to the information received from S1.

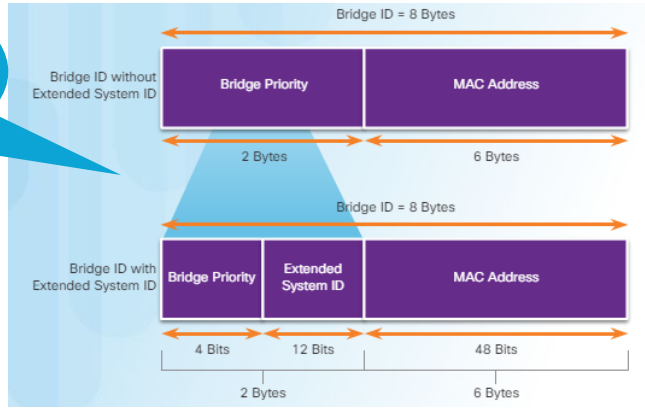
9. S2 compares the info from S1 so S2 now sees the BID from S1 is lower than its own BID. S2 now updates its own information showing S1 as root bridge.



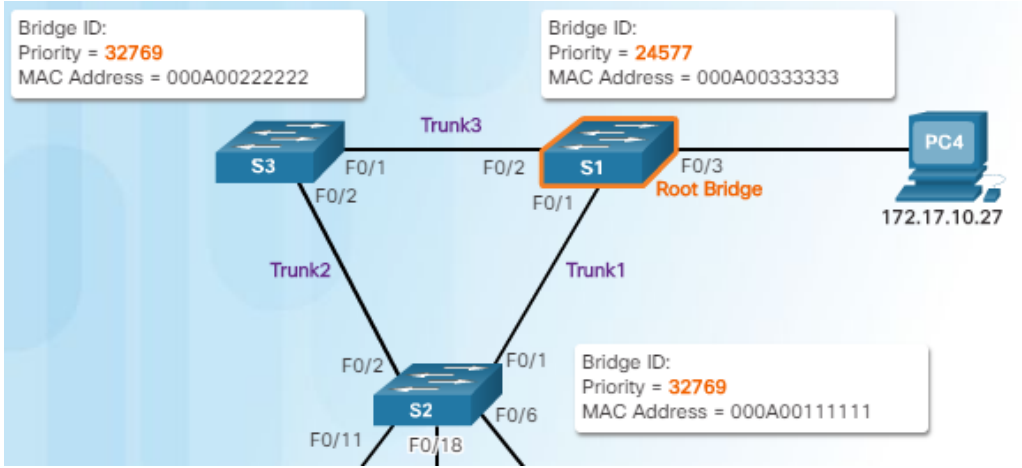

Remember that after root bridge has been determined,
the other port roles can be determined because those roles are determined by total path cost back to root bridge.

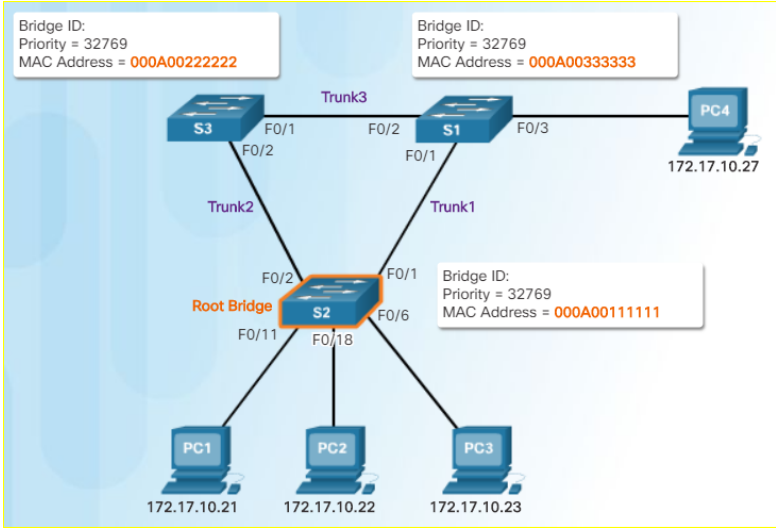
# Extended System ID

Remember - lowest BID becomes root




- If priorities are all set to the default, lowest MAC address is the determining factor in lowest BID.
- The priority value can be modified to influence root bridge elections.



# Types of Spanning Tree Protocols

# Types of Spanning Tree Protocols

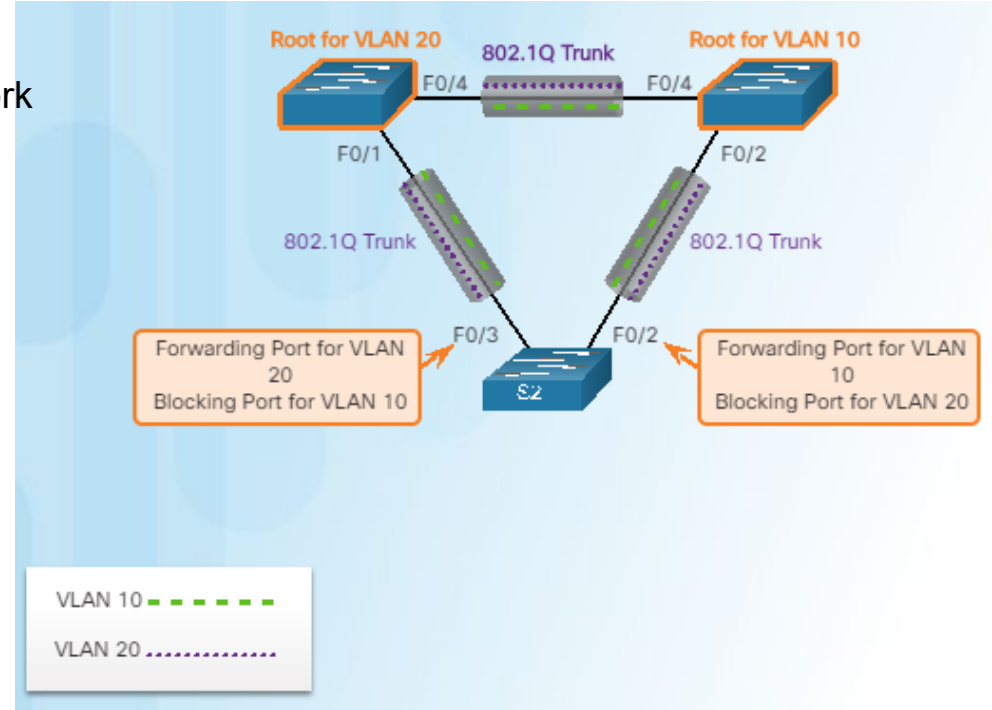
| STP Type | Description |
|---|---|
| 802.1D | 1998 - Original STP standard |
| CST | One spanning-tree instance |
| PVST+ | Cisco update to 802.1D; each VLAN has its own spanning-tree instance |
| 802.1D | 2004 – Updated bridging and STP standard |
| 802.1w (RSTP) | Improves convergence by adding new roles to ports and enhancing BPDU exchange |
| Rapid PVST+ | Cisco enhancement of RSTP using PVST+ |
| 802.1s (MSTP) | Multiple VLANs can have the same spanning-tree instance |

# Characteristics of Spanning Tree Protocols

| STP Type | Standard | Resources Needed | Convergence | Tree Calculation |
|---|---|---|---|---|
| STP | 802.1D | Low | Slow | All VLANs |
| PVST+ | Cisco | High | Slow | Per VLAN |
| RSTP | 802.1w | Medium | Fast | All VLANs |
| Rapid PVST+ | Cisco | Very high | Fast | Per VLAN |
| MSTP | 802.1s | Medium or high | Fast | Per instance |

# PVST+

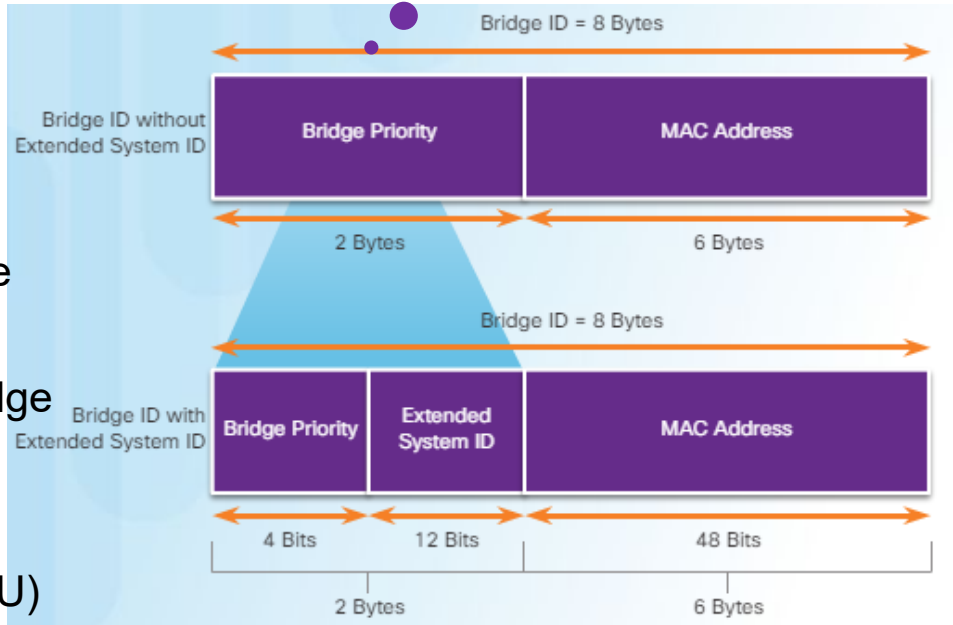
- Original 802.1D defines a common spanning tree
  - One spanning tree instance for the switched network (no matter how many VLANs)
  - No load sharing
  - One uplink must block for all VLANs
  - Low CPU utilization because only one instance of STP is used/calculated
- Cisco PVST+ - each VLAN has its own spanning tree instance
  - One port can be blocking for one VLAN and forwarding for another VLAN
  - Can load balance
  - Can stress the CPU if a large number of VLANs are used



# Extended System ID and PVST+ Operation

Remember that the BID is a unique ID

- The extended system ID field ensures each switch has a unique BID for each VLAN.
- The VLAN number is added to the priority value.
  - Example – VLAN 2 priority is 32770 (default value of 32768 plus the VLAN number of 2 equals 32770)
  - Can modify the priority number to influence the root bridge decision process
- Reasons to select a particular switch as root bridge
  - Switch is positioned such that most traffic patterns flow toward this particular switch
  - Switch has more processing power (better CPU)
  - Switch is easier to access and manage remotely

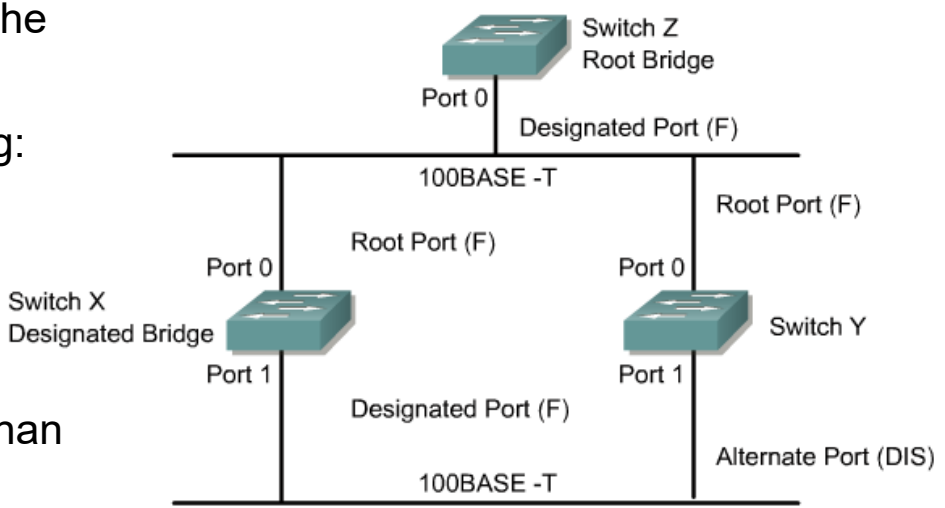


# Rapid Spanning Tree Protocol (RSTP)

- A key hindrance of STP is convergence.
- Ordinary STP takes 30 – 50 seconds to converge, with default settings
- RSTP helps with convergence issues that plague legacy STP.
- In RSTP, all bridges send BPDUs automatically
  - While in STP, the root triggers BPDUs
- In RSTP, bridges act to bring the network to convergence
  - While in STP, bridges passively wait for time-outs before changing port states
- RSTP has two more port designations
  - Alternate Port—backup for Root Port
  - Backup port—backup for Designated Port on the segment

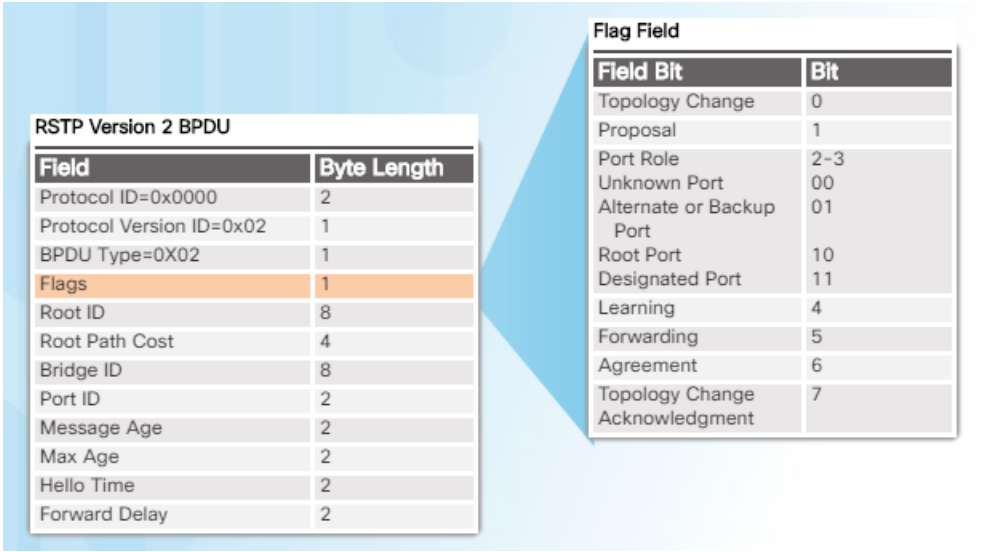
# Rapid Spanning Tree Protocol (RSTP)

- The Rapid Spanning-Tree Protocol is defined in the **IEEE 802.1w** LAN standard.
- The standard and protocol introduce the following:
  - Clarification of port states and roles
  - Definition of a set of link types that can go to forwarding state rapidly
  - Concept of allowing switches, in a converged network, to generate their own BPDUs rather than relaying root bridge BPDUs
- The “blocked” state of a port has been renamed as the “discarding” state.



# Rapid Spanning Tree Protocol (RSTP)

- RSTP uses type 2, version 2 BPDUs
  - Original version was type 0, version 0
- A switch using RSTP can work with and communicate with a switch running the original 802.1D version
- BPDUs are used as a keepalive mechanism
  - 3 missed BPDUs indicates lost connectivity



RSTP Version 2 BPDU

| Field | Byte Length |
|---|---|
| Protocol ID=0x0000 | 2 |
| Protocol Version ID=0x02 | 1 |
| BPDU Type=0X02 | 1 |
| Flags | 1 |
| Root ID | 8 |
| Root Path Cost | 4 |
| Bridge ID | 8 |
| Port ID | 2 |
| Message Age | 2 |
| Max Age | 2 |
| Hello Time | 2 |
| Forward Delay | 2 |

Flag Field

| Field Bit | Bit |
|---|---|
| Topology Change | 0 |
| Proposal | 1 |
| Port Role<br>Unknown Port<br>Alternate or Backup Port<br>Root Port<br>Designated Port | 2-3<br>00<br>01<br><br>10<br>11 |
| Learning | 4 |
| Forwarding | 5 |
| Agreement | 6 |
| Topology Change Acknowledgment | 7 |

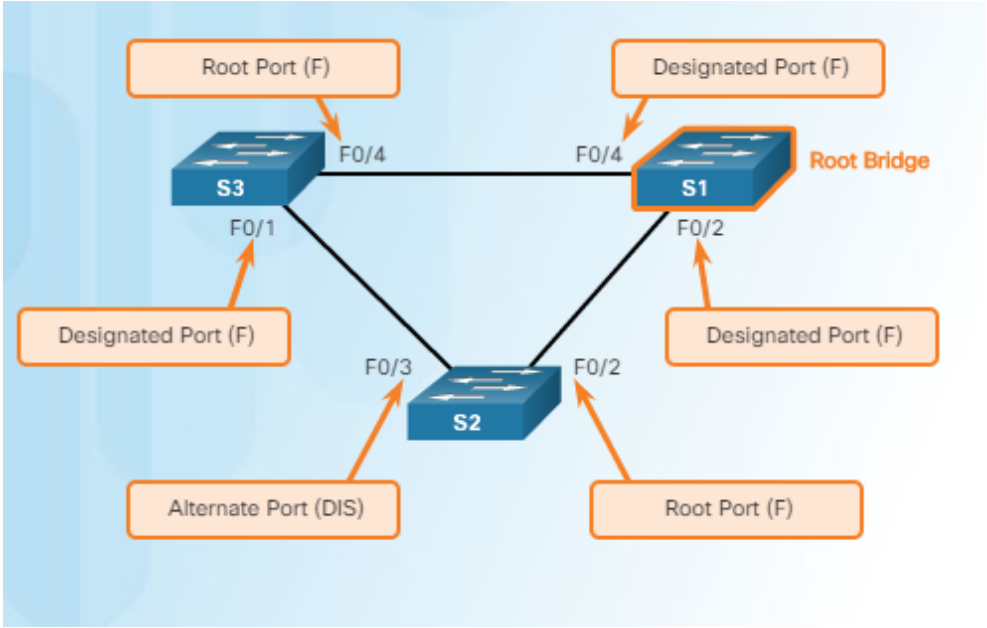
# Rapid Spanning Tree Protocol (RSTP)

- RSTP Port States

| STP (802.1D) Port State | RSTP (802.1w) Port State | Is Port Included in Active Topology? | Is Port Learning Mac Addresses? |
|---|---|---|---|
| Disabled | Discarding | No | No |
| Blocking | Discarding | No | No |
| Listening | Discarding | No | No |
| Learning | Learning | No | Yes |
| Forwarding | Forwarding | Yes | Yes |

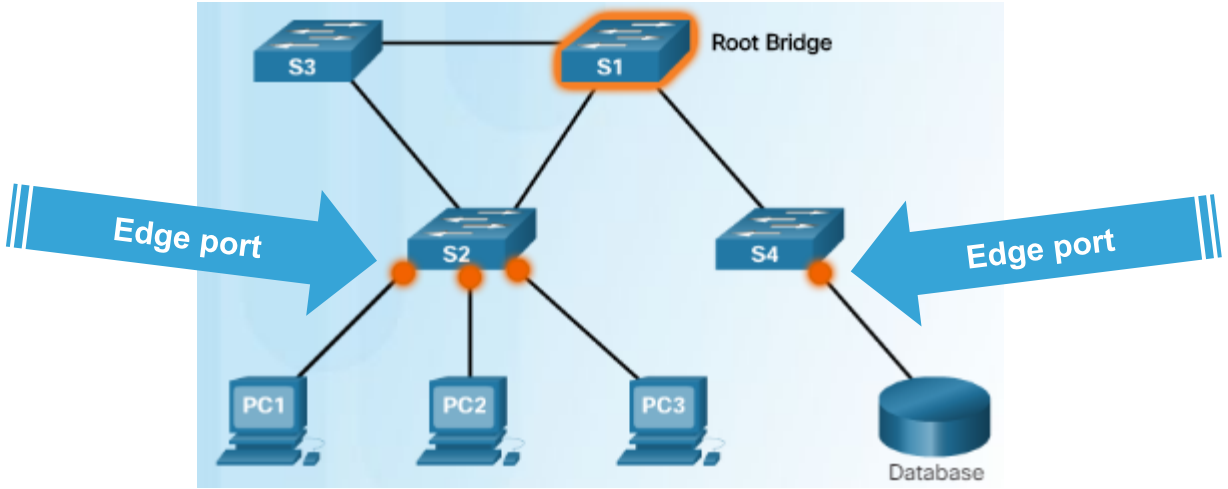
# Rapid PVST+

- Rapid PVST+ speeds up STP recalculations and converges quicker
  - Cisco version of RSTP
- Two new port types
  - Alternate port (DIS)
  - Backup port
- Independent instance of RSTP runs for each VLAN
- Cisco features such as UplinkFast and BackboneFast are not compatible with switches that run RSTP



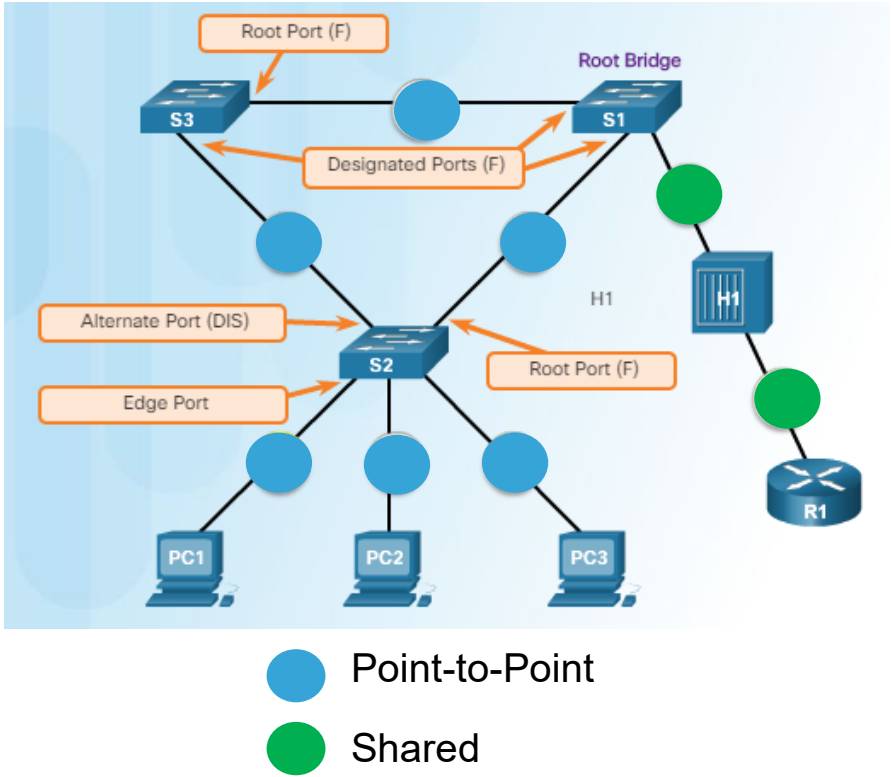
# Edge Ports

- Has an end device connected – NEVER another switch
- Immediately goes to the forwarding state
- Functions similar to a port configured with Cisco PortFast
- Use the **spanning-tree portfast** command



# Link Types

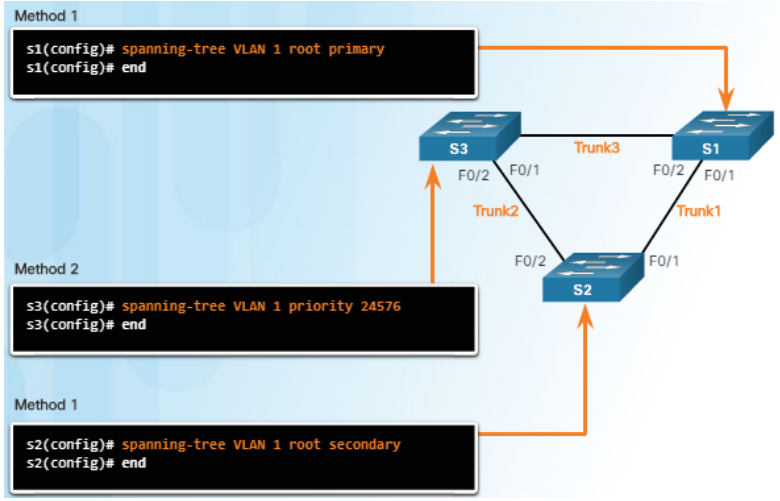
- Point-to-Point – a port in full-duplex mode connecting from one switch to another switch or from a device to a switch
- Shared – a port in half-duplex mode connecting a hub to a switch



# Spanning Tree Configuration

# Configuring and Verifying the Bridge ID

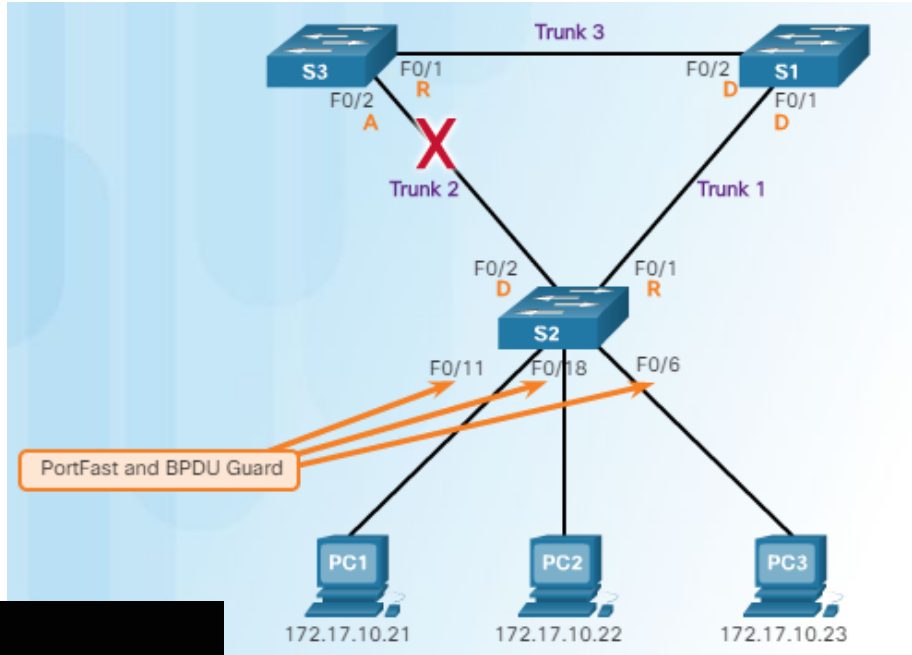
- Two ways to influence the root bridge election process
  - Use the **spanning-tree vlan *x* root primary** or **secondary** command.
  - Change the priority value by using the **spanning-tree vlan *x* priority *x*** command.
- Verify the bridge ID and root bridge election by using the **show spanning-tree** command.




```
S3# show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     00A.0033.3333
              This bridge is the root
              Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
  Bridge ID   Priority    24577  (priority  24576  sys-id-ext  1)
              Address     000A.0033.3333
              Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
              Aging Time  300

Interface     Role    Sts    Cost     Prio.Nbr   Type
------------  -----   ----   -----    ----------  ------
Fa0/1         Desg    FWD    4        128.1       p2p
Fa0/2         Desg    FWD    4        128.2       p2p
```

# PortFast and BPDU Guard

- PortFast is used on ports that have end devices attached.
  - Puts a port in the forwarding state
  - Allows DHCP to work properly
- BPDU Guard disables a port that has PortFast configured on it if a BPDU is received




```
S2(config)# interface FastEthernet 0/11
S2(config-if)# spanning-tree portfast
%Warning: portfast should only be enabled on ports connected to a single host.
Connecting hubs, concentrators, switches, bridges, etc... to this interface
when portfast is enabled, can cause temporary bridging loops.
 Use with CAUTION

%Portfast has been configured on FastEthernet0/11 but will only
 have effect when the interface is in a non-trunking mode.
S2(config-if)# spanning-tree bpduguard enable
```

```
S2# show running-config interface f0/11
Building configuration...

Current configuration : 90 bytes
!
interface FastEthernet0/11
 spanning-tree portfast
 spanning-tree bpduguard enable
```

## PVST+ Configuration

# PVST+ Load Balancing

```
S3(config)# spanning-tree vlan 20 root primary
S3(config)# spanning-tree vlan 10 root secondary
```

or

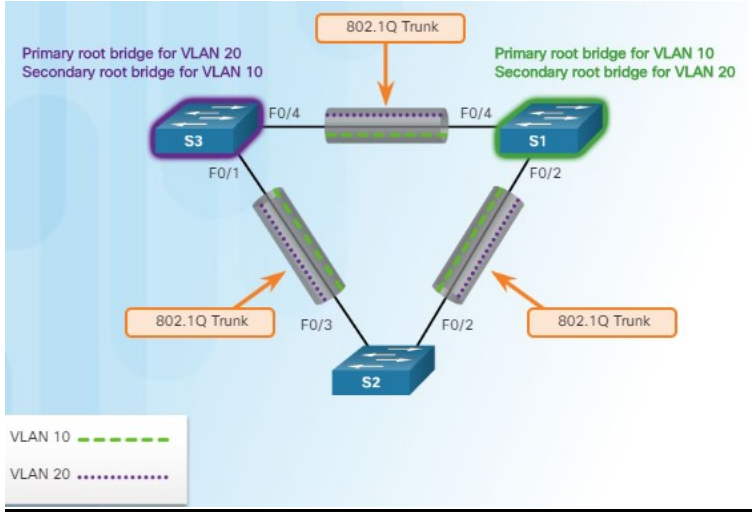
```
S3(config)# spanning-tree vlan 20 priority 4096
```

```
S1(config)# spanning-tree vlan 10 root primary
S1(config)# spanning-tree vlan 20 root secondary
```

or

```
S1(config)# spanning-tree vlan 10 priority 4096
```

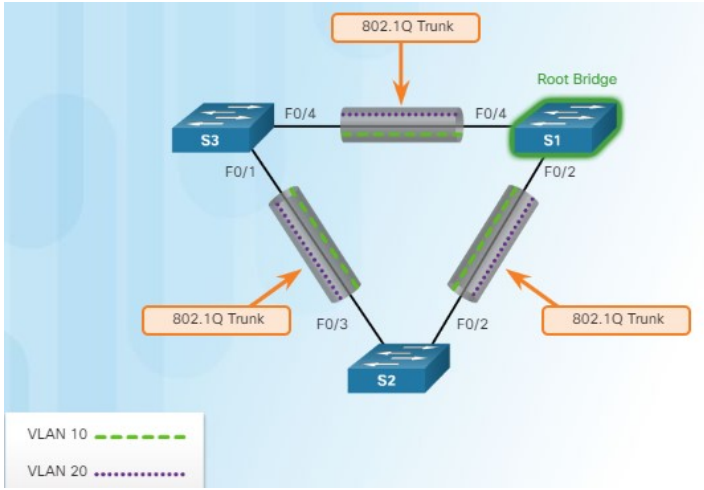
```
S1# show running-config
Building configuration...

Current configuration : 1595 bytes
!
version 12.2
<output omitted>
!
spanning-tree mode pvst
spanning-tree extend system-id
spanning-tree vlan 1 priority 24576
spanning-tree vlan 10 priority 4096
spanning-tree vlan 20 priority 28672
```




```
S1# show spanning-tree active
<output omitted>

VLAN0010
   Spanning tree enabled protocol ieee
   Root ID     Priority    4106
               Address     0019.aa9e.b000
               This bridge is the root
               Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
   Bridge ID   Priority    4106  (priority  4096  sys-id-ext  10)
               Address     0019.aa9e.b000
               Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
               Aging Time  300

Interface       Role    Sts    Cost      Prio.Nbr      Type
------------    -----   ----   -----     ----------    ------
Fa0/2           Desg    FWD    19         128.2         p2p
Fa0/4           Desg    FWD    19         128.4         p2p
```

# Spanning Tree Mode

- Rapid PVST+ supports RSTP on a per-VLAN basis.
  - Default on a 2960 is PVST+.
  - The **spanning-tree mode rapid-pvst** puts a switch into Rapid PVST+ mode.
  - The **spanning-tree link-type point-to-point** interface command designates a particular port as a point-to-point link (does not have a hub attached).
  - The **clear spanning-tree detected-protocols** privileged mode command is used to clear STP.




```
S1# configure terminal
S1(config)# spanning-tree mode rapid-pvst
S1(config)# interface f0/2
S1(config-if)# spanning-tree link-type point-to-point
S1(config-if)# end
S1# clear spanning-tree detected-protocols
```

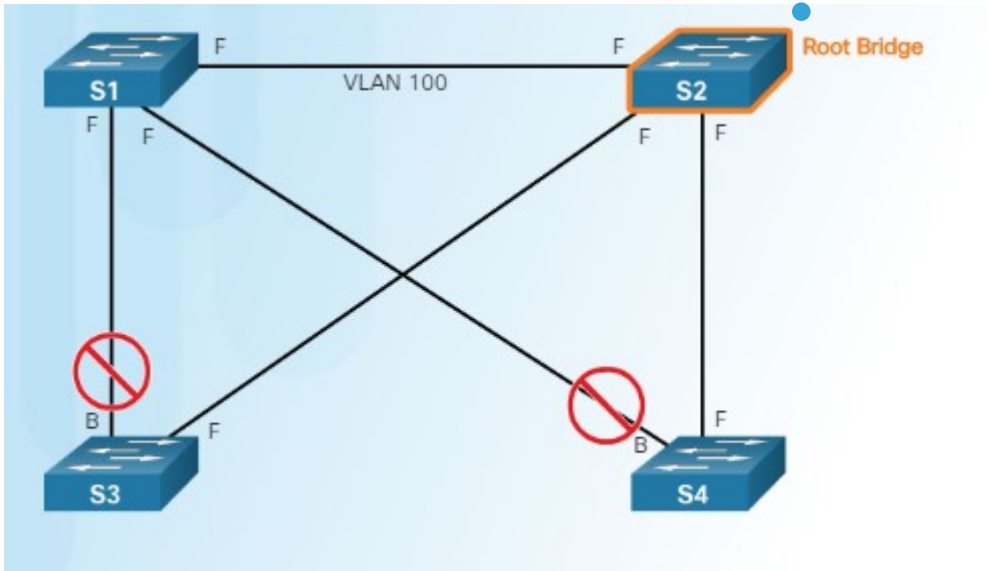
```
S1# show run

<output omitted>

spanning-tree mode rapid-pvst
spanning-tree extend system-id
spanning-tree vlan 1 priority 24576
spanning-tree vlan 10 priority 4096
spanning-tree vlan 20 priority 28672
```

```
S1# show spanning-tree vlan 10

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID     Priority    4106
              Address     0019.aa9e.b000
              This bridge is the root
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    4106   (priority 4096 sys-id-ext 10)
              Address     0019.aa9e.b000
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/2            Desg LRN 19        128.2    P2p
Fa0/4            Desg LRN 19        128.4    P2p
```

# Expected Topology Versus Actual Topology

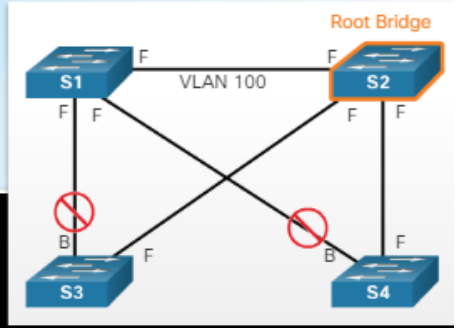
- Ensure that the spanning-tree topology matches what is expected.

Use **show** commands to verify STP. Do not forget to verify load balancing.



# Overview of STP Status

- Use the **show spanning-tree** and **show spanning-tree vlan *x*** commands to verify the STP status.

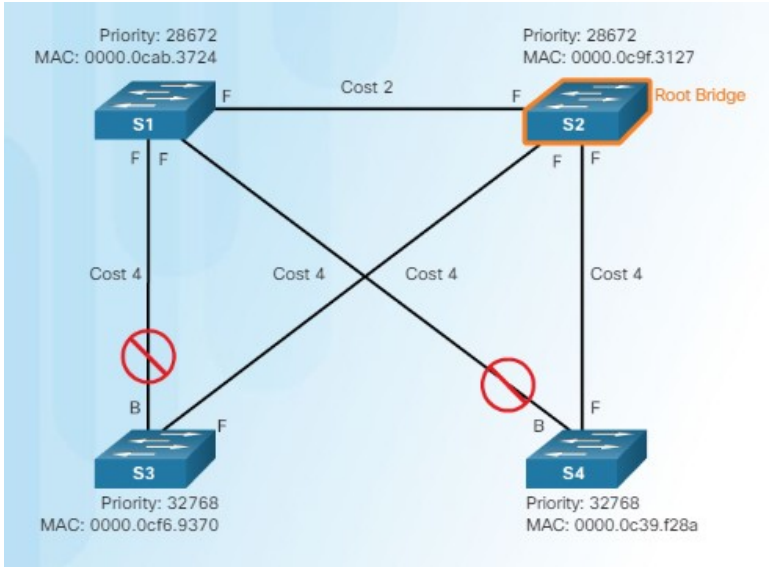


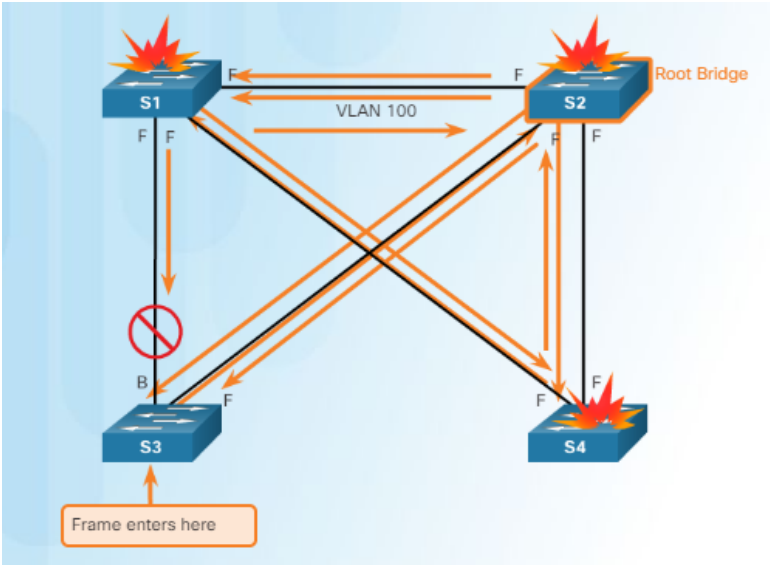

```
S1# show spanning-tree vlan 100

VLAN0100
 Spanning tree enabled protocol rstp
 Root ID     Priority    28772
             Address     0000.0c9f.3127
             Cost        2
             Port        88 (TenGigabit9/1)
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
 Bridge ID   Priority    28772 (priority 28672 sys-id-ext 100)
             Address     0000.0cab.3724
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec
             Aging Time  300

Interface        Role Sts Cost      Prio.Nbr Type
---------        ---------------    --------------------------------
Gi3/1            Desg FWD 4         128.72   P2p
Gi3/2            Desg FWD 4         128.80   P2p
Te9/1            Root FWD 2         128.88   P2p
```

**Ten gigabit Ethernet interface**

# Spanning Tree Failure Consequences

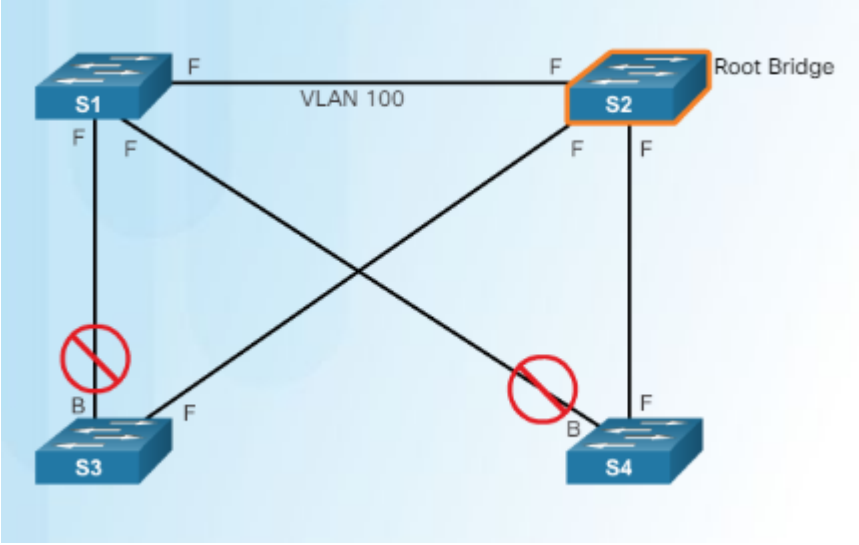
- NEVER turn STP off; this can cause a switched network to be unusable – Remember that there is not a TTL mechanism at Layer 2.



# Repairing a Spanning Tree Problem

- Manually remove redundant links (physically remove the cable OR through configuration, if possible).
  - Determine and repair the cause of the spanning tree failure.
  - If unable to determine the problem, reinstall cables one at a time (or re-enable the ports) to locate the issue.



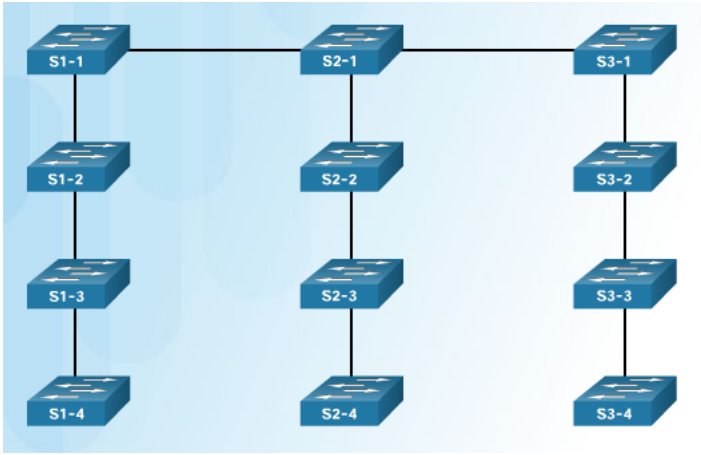
# Switch Stacking Concepts

- Can connect up to nine 3750 switches
- One switch (the stack master) controls the operation of the stack
  - If this switch goes down, a new stack master is elected
- Appears as one entity to the network
  - Stack is assigned one IP address
- Each switch has a unique stack member number
  - Can configure a priority value to determine which switch is stack master
  - Highest stack member priority value is stack master
- The stack master has the saved and running configuration files for the entire stack.
  - Only one configuration file to manage and maintain

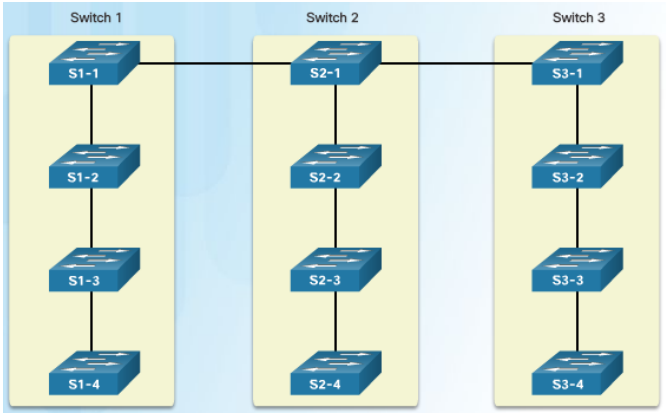
```
Switch# show running-config | begin interface
interface GigabitEthernet1/0/1
!
interface GigabitEthernet1/0/2
!
interface GigabitEthernet1/0/3
!
<output omitted>
!
interface GigabitEthernet1/0/52
!
interface GigabitEthernet2/0/1
!
interface GigabitEthernet2/0/2
!
<output omitted>
!
interface GigabitEthernet2/0/52
!
interface GigabitEthernet3/0/1
!
interface GigabitEthernet3/0/2
!
<output omitted>
!
interface GigabitEthernet3/0/52
```

# Spanning Tree and Switch Stacks

- Each stack appears as one spanning tree instance
- Can add switches without affecting the STP diameter (the maximum number of switches data must cross to connect between any two switches)
  - IEEE recommends a maximum diameter of 7 switches for default STP timers
    - Default STP timers are hello – 2 seconds, max age – 20 seconds, forward delay timer – 15 seconds




Diameter of 9 from S1-4 to S3-4




With stacked switches, the diameter is now 3

# Chapter 3: STP

- Build a simple switched network with redundant links.
- Explain how different varieties of spanning tree protocols operate
- Implement PVST+ and Rapid PVST+ in a switched LAN environment.

**Spanning Tree Protocol Explained**

https://www.youtube.com/watch?v=japdEY1UKe4