# STP (Spanning Tree Protocols):

o   For backup purpose and fault tolerance, we usually create redundant links.
o   Redundant link preventing entire network down situation from single link failure.
o   Redundant link can creates network loops that flood down frames in the network.
o   STP automatically removes layer 2 switching loops by shutting down redundant links.
o   Spanning Tree Protocols (STP) is a protocol, it actively monitors all links of the network.
o   Cisco Switch flooding frame unknown unicasting, multicasting and broadcasting.
o   If there any redundant link available in the network that can cause Layer 2 loop.
o   Layer 2 loops in the network can cause problem unnecessary resources utilization.
o   Multiple frame transmission, unstable MAC table & unnecessary frame lookup by host.
o   To finds a redundant link, it uses an algorithm, known as STA (spanning-tree algorithm).
o   Spanning Tree Protocols used STA (Spanning Tree Algorithm) to prevent Layer 2 loop.
o   STA detecting layer 2 loops and block it until first one link goes down or disconnected.
o   Spanning Tree Protocols is a link management protocol that provides path redundancy.
o   Spanning Tree Protocols (STP) preventing undesirable loops in the whole network.
o   Spanning Tree Protocols is a protocol that runs on switches that helps to solve loops.
o   Spanning Tree Protocols use BPDU in every 2 second for preventing Layer 2 loop.
o   Bridge Priority increment use 4096 because no of VLAN can exist in cisco Switches.
o   Bridge & system ID tie by default so Lower MAC address switch selected as Root Bridge.
o   Root Bridge can changed timers of Spanning Tree Protocols (STP) and advertised to all.
o   Root Bridge Switch is also responsible for propagating topology changes notification.
o   Root Bridge Switch all port is always designated port and always in forwarding state.
o   Terms bridge, switch are used interchangeably when discussing Spanning Tree Protocols.
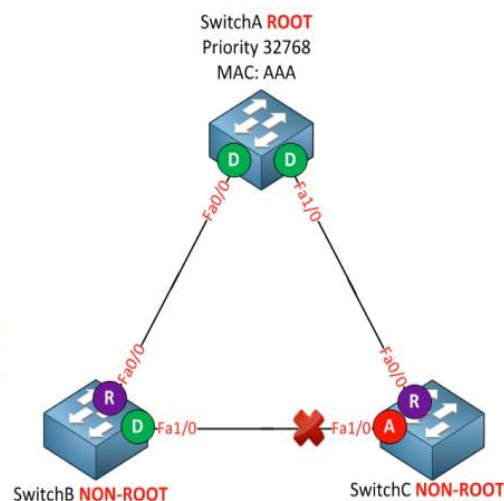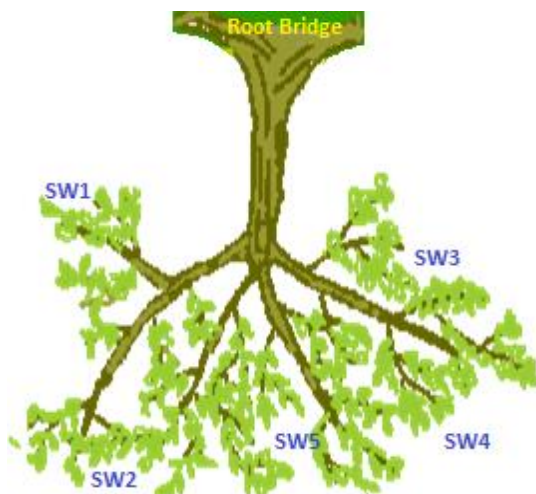
Broadcast Storm:
o   When Switch receives broadcast frames, it continues broadcasting them.
o   The Switches broadcasting them again to its other interfaces or ports.
o   Broadcasting will keep going on forever until you shutdown the network.
o   This phenomenon or situation is called a broadcast storm of Switches.
o   The Broadcast storm consumes the entire bandwidth of the network.
o   The Broadcast storm denies bandwidth for normal network traffic.
o   The Broadcast storm can shut down entire network in seconds or less.
o   The Broadcast storms start small but like snowball end up being very big.
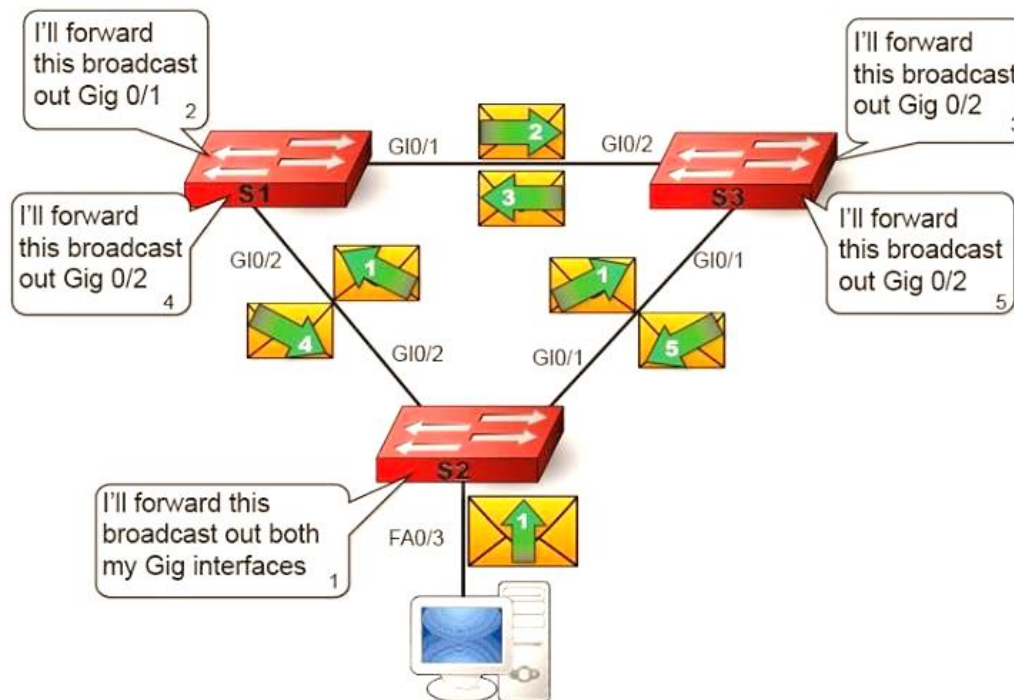
MAC Database Instability:
o   MAC tables are built by examining the source MAC address on a packet received.
o   The source MAC address is tied to the interface or port it was received on.
o   If loop occurs, then same source MAC address could be seen on multiple interfaces.
o   Looped in the network can make MAC Address Table or CAM table unstable.
o   Instability of MAC table causes copies of same frame to be delivered to multiple ports.
o   MAC instability results multiple copies of a frame arrive on different ports of a switch.
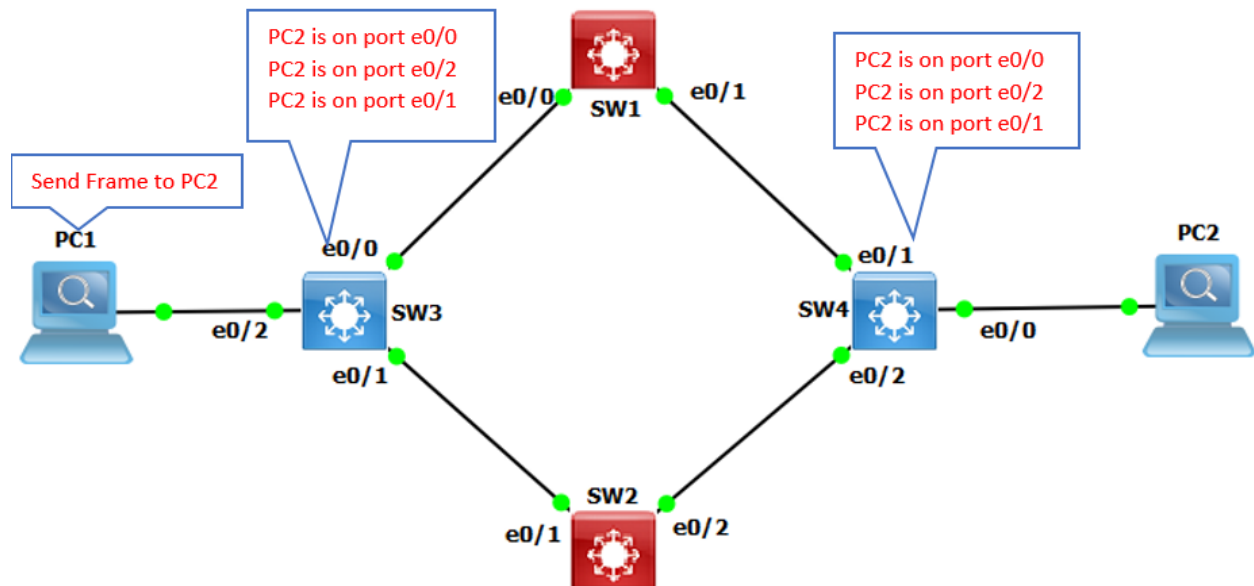
Multiple Frame Transmission:

o Multiple copies of unicast frames may be delivered to destination host.

o Multiple copies of the same frame can cause unrecoverable errors & issue.
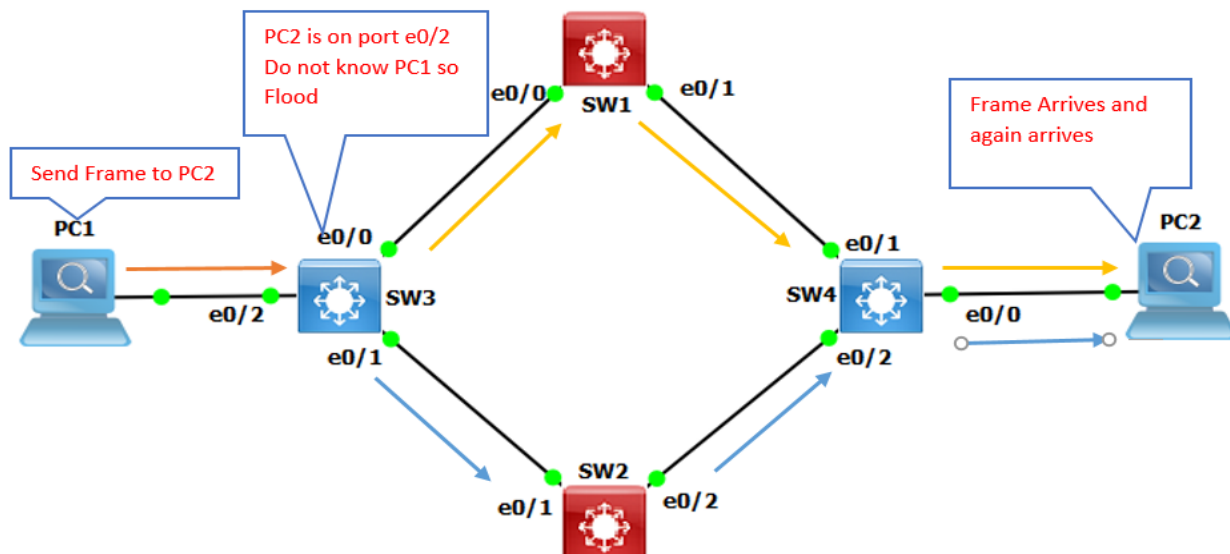
Different Version or Type of Spanning Tree				
Protocol	**Standard**	**Resources Needed**	**Convergence**	**Numbers of Trees**
STP	802.1D	Low	Slow	One
PVST+	Cisco	High	Slow	One for every VLAN
RSTP	802.1w	Medium	Fast	One
Rapid PVST+	Cisco	Very high	Fast	One for every VLAN
MST	802.1S	Medium or High	Fast	One for multiple VLANs

PVST+:

o   PVST+ is term which stands for Per-VLAN Spanning Tree Plus (PVST+).

o   PVST+ is a Cisco implementation of Spanning Tree Protocols (STP).

o   Per-VLAN Spanning Tree+ (PVST+) is an extension of the PVST standard.

o   PVST+ supports Dot1Q trunking encapsulation while PVST not support.

o   PVST+ provides separate Spanning-Tree instance for each VLAN in network.

o   PVST+ run a Spanning-Tree instance per VLAN (Virtual Local Area Network).

o   PVST+ provide each VLAN have its own Spanning Tree Protocol topology.

o   PVST is usually the default Spanning Tree Protocol (STP) on Cisco Switches.

o   PVSTP+ take 30 to 50 seconds to transit from blocking state to forwarding state.
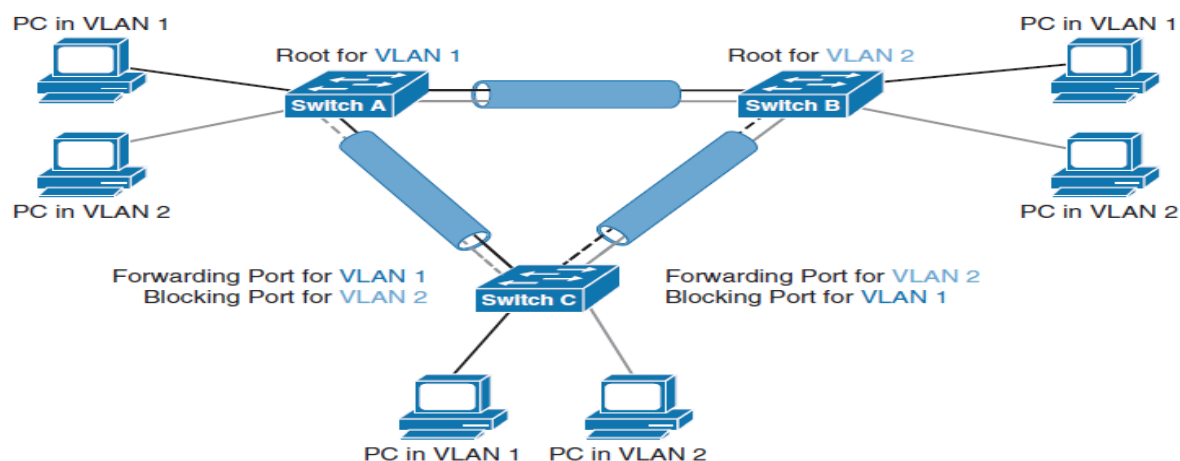
RPVST+:

o   RPVST+ is term which is stands for Rapid Per-VLAN Spanning Tree Plus.

o   Rapid PVST+ (IEEE 802.1w) is an enhanced version of the PVST+ version.

o   Rapid PVST+ allows for faster Spanning-Tree calculations and convergence.

o   RSTP is typically able to respond less than 10 seconds of a physical link failure.

o   Rapid PVST+ defines three port states Discarding, Learning, and Forwarding.

o   RSTP works by adding an alternative port and a backup port compared to STP.

o   Rapid PVST+ provides multiple enhancements to optimize network performance.

o   UplinkFast and BackboneFast are not required for Rapid Spanning Tree (RPVST+).

o   Rapid PVSTP already have the functionality of UplinkFast and BackboneFast.

o   Activate RSTP get UplinkFast-like and BackboneFast-like functionality & feature.

o   The backbone & UplinkFast feature is not needed when RSTP is enabled on Switch.

```
SW1#show spanning-tree summary
Switch is in rapid-pvst mode

UplinkFast                              is enabled but inactive in rapid-pvst mode
BackboneFast                            is enabled but inactive in rapid-pvst mode
```

Switch Priority:

o   By default, all Cisco Switches has a Bridge Priority or Switch Priority value of 32,768.

o   Bridge Priority value decides which Switch can become Root Bridge (Root Switch).

o   Switch with lowest Bridge Priority (Switch Priority) Value will become the Root Switch.

Root Bridge:

o   Root Bridge is the starting point of the Spanning Tree Protocol STP network topology.

o   STP uses two parameters, bridge priority and MAC addresses of participating switches.

o   A Cisco Switch that has the lowest bridge priority value, is elected as the root bridge.

o   If bridge priority is same in all switches, switch which has lowest MAC address is elected.

o   By default, the bridge priority or switch priority value is set to 32768 in all Cisco Switches.

o   Unless change this value, Switch that has lowest MAC address is elected as Root Bridge.

o   If want specific switch to be elected as Root Bridge, can set bridge priority value less than.

o   Selection process of the Root Bridge happens each time when a network change occurs.

o   Like new switch is added in network topology, or existing switch is removed, or Root failed.

Non-Root Bridge:

o   Except Root Bridge, all remaining switches of network are considered as Non-Root Bridges.

o   Non-Root Bridges receive updates from Root Bridge & update their STP databases relatively.

Port Priority:

o   Each port of a Switch has a Port Priority value associated with it, **128** by default.

o   **Gi0/1 128.25 P2P**: Gi0/1 is the interface 128 is default value and 25 is port number.

o   P2P means Point-to-point (Full Duplex) and Shr means Shared (Half Duplex) like hub.

```
SW1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee          Default Switch Priority
  Root ID    Priority    32769
             Address     aabb.cc00.0100
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     aabb.cc00.0100
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------
Et0/0               Desg FWD 100       128.1    P2p
Et0/1               Desg FWD 100       128.2    P2p    Default Port Priority
Et0/2               Desg FWD 100       128.3    P2p
Et0/3               Desg FWD 100       128.4    P2p
Et1/0               Desg FWD 100       128.5    P2p
```

Path Cost:

o Based on connected media link, STP assigns a value to each port of the network.

o This assign value to connected media link or port is known as the port cost value.

o STP uses this value to choose the single best path available between two switches.

o The Root Port is calculated by using the lowest accumulated Path Cost Value.

o The Root Port is lowest accumulated path cost value to reach the Root Switch.

o The Spanning Tree cost value is inversely proportional to the associated bandwidth.

o Therefore, a path with low-cost value is more preferable than path with high cost value.

Bandwidth	Short Old Cost	Long New Cost
10 Mbps	100	2,000,000
100 Mbps	19	200,000
1 Gbps	4	20,000
10 Gbps	2	2,000
20 Gbps	1	1,000
100 Gbps	1	200
1 Tbps	1	20
10 Tbps	1	2

```
Interface          Role Sts Cost          Prio.Nbr Type
----------------   ---- --- ----------    -------- ----
Gi5/1              Desg LRN 4              128.5    P2p
Fa6/1              Desg FWD 19             128.4    P2p
Fa8/1              Desg FWD 19             128.2    P2p
Et9/1              Desg FWD 100            128.1    P2p
```

STP	RSTP
Disabled (Shutdown by Admin)	**Discarding** (Blocking data frame)
Blocking (Blocked redundant link)	
Listing (Listing the data frame)	**Learning** (Building CAM table)
Learning (Creating CAM table)	
Forwarding (Converged, Data flow allowed)	**Forwarding** (Converged, Data flow allowed)

State	Type	Forwards STP Frames (BPDUs)	Forwards User Data Frames	Learns MAC Addresses	LED Color on Switch.
Blocking	Stable	YES	NO	NO	
Listening	Transitional	YES	NO	NO	
Learning	Transitional	YES	NO	YES	
Forwarding	Stable	YES	YES	YES	
Disabled	Stable	NO	NO	NO	OFF

BPDU (Bridge Protocol Data Units):

o   Bridge Protocol Data Units (BPDUs) are messages exchanged between the switches.

o   BPDUs frames contain info about switch ID, originating switch port & MAC address.

o   BPDUS frames also contain info regarding switch port priority, switch port cost etc.

o   Bridge Protocol Data Units (BPDUs) frames are sent out as multicast messages regularly.

o   BPDUS frames use the multicast destination MAC address which is 01:80:c2:00:00:00.

o   When BPDUs are received, the Switch uses a mathematical formula called the STA.

o   Spanning Tree Algorithm (STA) know when there is a Layer 2 Switch loop in network.

o   Spanning Tree Algorithm determines which of redundant ports needs to be shut down.

o   Three types of BPDUs are Configuration BPDU, Topology Change Notification (TCN) BPDU.

o   The last one BPDU type is the Topology Change Notification Acknowledgment (TCA).

o   Basic purpose of BPDUs & Spanning Tree Algorithm is to avoid Layer 2 Switching loops.

o   Basic purpose of BPDUs and Spanning Tree Algorithm to avoid Layer 2 Broadcast storms.

o   Configuration BPDUs are used to elect the Root Bridges, root ports, and designated ports.

o   When topology change occurs, Switch send TCN BPDU out its root port, destined for Root.

o   TCN contains no information about the change – it only indicates that a change occurred.

o   By responding with a TCN with the Topology Change Acknowledgement (TCA) flag set.

o   Once Root Bridge receives the TCN, it will send out a configuration BPDU to all switches.

```
∨ Spanning Tree Protocol
      Protocol Identifier: Spanning Tree Protocol (0x0000)
      Protocol Version Identifier: Spanning Tree (0)
      BPDU Type: Configuration (0x00)
    ∨ BPDU flags: 0x01, Topology Change
          0... .... = Topology Change Acknowledgment: No
          .... ...1 = Topology Change: Yes
    ∨ Root Identifier: 32768 / 1 / aa:bb:cc:00:01:00
          Root Bridge Priority: 32768
          Root Bridge System ID Extension: 1
          Root Bridge System ID: aa:bb:cc:00:01:00 (aa:bb:cc:00:01:00)
      Root Path Cost: 0
    ∨ Bridge Identifier: 32768 / 1 / aa:bb:cc:00:01:00
          Bridge Priority: 32768
          Bridge System ID Extension: 1
          Bridge System ID: aa:bb:cc:00:01:00 (aa:bb:cc:00:01:00)
      Port identifier: 0x8001
      Message Age: 0
      Max Age: 20
      Hello Time: 2
      Forward Delay: 15
```

Spanning Tree Port Roles:

Root Port:

o   For non–root switch, port that connects this switch to the root switch.
o   The Root port is the port that directly connects to the Root Bridge
o   The Root Port is the port which has least cost to reach root switch.
o   The Root port is the port that is closest to the root bridge or root switch.
o   Every non-root bridge must have a root port connect to root switch.
o   Only one Root Port on non-root Switch and no Root Port in root bridge.
o   A Root Port has the least cost from the "Switch" to the Root Bridge.
o   The Root ports forward traffic toward the root bridge or Root switch.

Alternate Port:

o   Alternate port is a best alternate path to the root bridge or Switch.
o   Alternative port moves to the forwarding state if any change in topology.

Designated Port:

o   A non – root port, which is forwarding away from the root switch.
o   Designated Port has the lowest cost in that Ethernet segment.
o   Switch can have multiple designated ports & marked as forwarding port.
o   Designated Port has the lowest Path Cost on particular LAN segment.
o   In Cisco Switches a Root Port can never be a designated port.
o   For root bridges or switch, all switch ports are designated ports.

Non-Designated Port:

o   Non-designated port having higher port cost than the designated port.
o   Spanning Tree Protocol marks non-designated port as the blocking port.
o   Non-designated port not forward any frames and used to remove loops.
o   If any change in topology, the same port may become a designated port.
o   The non-designated port of is a Cisco switch port that is blocked.
o   A non-designated port of switch is not a root port or a designated port.

```
Interface            Role Sts Cost        Prio.Nbr Type
-------------------- ---- --- --------- -------- -----
Et0/0                Desg FWD 100        128.1    P2p
Et0/1                Root FWD 100        128.2    P2p
Et0/2                Altn BLK 100        128.3    P2p
Et0/3                Desg FWD 100        128.4    P2p
```
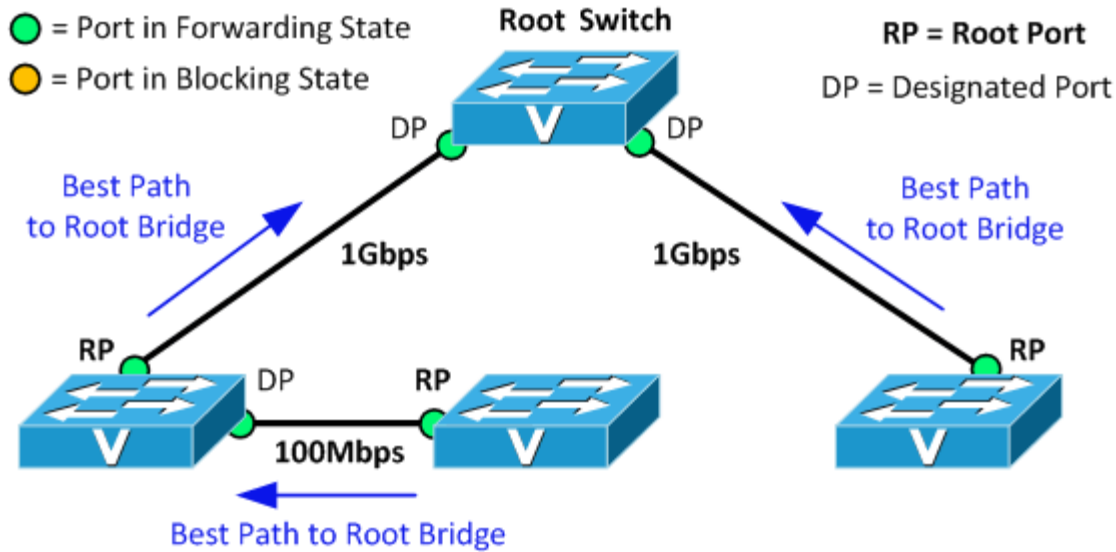
Spanning Tree Port States:

o Ports on a switch with enabled STP are in one of these five port states.
o Blocking state, listening state, learning state, Forwarding and Disabled.
o Switch does not enter any of these port states immediately except blocking state.
o When the STP is enabled, every switch in the network starts in the blocking state.
o Spanning Tree Protocol later changes to the listening state and learning states.

Blocking State:

o When we power on a Switch, the switch puts all of its ports in this state.
o The Switch Ports will go into a blocking state at the time of election process.
o In Blocking state, the switch only listens and processes the BPDUs only.
o Switch port in blocking state does not participate in frame forwarding.
o Port in blocking state discards frames received from attached network segment.
o During blocking state, port only listening & processing BPDUs on its interfaces.
o After 20 seconds, Switch port changes from the blocking state to listening state.

Listening State:

o After blocking state, Root Port or Designated Port will move to listening state.
o All other ports besides root and designated ports will remain in a blocked state.
o During listening state, port discards frames received from attached network segment.
o During listening state port discards frames switched from another port for forwarding.
o After 15 seconds, the switch port moves from the listening state to the learning state.

Learning State:
o   Only root port & designated ports enter into learning state from listening.
o   A Cisco Switch port change to learning state after the listening state.
o   During the learning state, the port is listening for and processing BPDUs.
o   In the learning state, the port begins to process the user frames.
o   In the learning state, the port start updating the MAC address table.
o   Data or user frames are not forwarded to the destination port of switch.
o   After 15 seconds, switch port moves from learning state to forwarding state.

Forwarding State:
o   In this state, the switch listens and processes both BPDUs and user frames.
o   Port in forwarding state forwards frames across attached network segment.
o   In forwarding state, port will process BPDUs & update its MAC Address table.
o   Data frames are forwarded to destination, Forwarding State is normal state.
o   The Data and configuration messages are passed through the port or link.

Disabled State:
o   A port in the disabled state does not participate in frame forwarding.
o   A port in the disabled state does not participate in operation of STP.
o   A port in the disabled state is considered non-operational.
o   This state applies to all ports which are either manually shut down.
o   All unplugged ports or interface also remain in Disabled state.

Interface	Role	Sts	Cost	Prio.Nbr	Type
Et0/0	Desg	FWD	100	128.1	P2p
Et0/1	Root	LIS	100	128.2	P2p
Et0/2	Altn	BLK	100	128.3	P2p
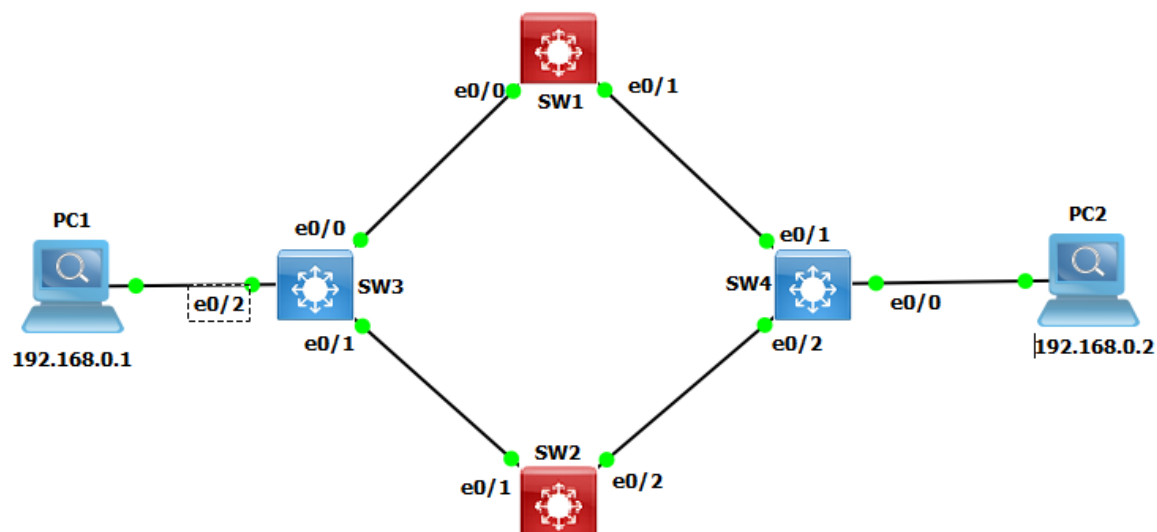
Spanning Tree Configuration
SW1(config)# spanning-tree mode pvst
SW1(config)# spanning-tree mode rapid-pvst
SW1(config)# spanning-tree vlan 1 root primary
SW1(config)# spanning-tree vlan 1 root secondary
SW1(config)# spanning-tree vlan 1 priority <0-61440>
SW1(config-if) #spanning-tree cost 10
SW1(config-if) #spanning-tree vlan 1 cost 10
SW1(config-if) #spanning-tree vlan 1 port-priority 64
SW1(config)# spanning-tree pathcost method long
SW1# show spanning-tree vlan 1
SW1# show spanning-tree summary
SW1# Show spanning-tree vlan 1 detail

Spanning Tree Timers:

STP timers are hello timer, forward delay timer and max age timer.

Hello Time:

o   Hello Time, defines interval Root Bridge send out configuration BPDUs.
o   The Default Spanning Tree Protocol (STP) hello timer is 2 seconds.
o   STP hello timer can be adjust to any value between 1 and 10 seconds.

Forward Delay:

o   Forward delay timer is time interval spent in listening & learning state.
o   The Forward Delay is the length of the Listening and the Learning states.
o   Default Spanning Tree Protocol (STP) forward delay timer is 15 seconds.
o   STP forward delay timer can be adjust to any value between 4 & 30 seconds.

Maximum Age:

o   The Spanning Tree Maximum Age timer often referenced as MaxAge.
o   The time interval that a Cisco Switch stores a BPDU before discarding it.
o   Length of time each Switch save superior BPDU's info before discarding it.
o   Each port of Cisco Switch keeps a copy of the best BPDU it has learned.
o   If the port no longer receives the BPDUs after the Max Age time has elapsed.
o   Switch assumes that topology change must have occurred & BPDU is aged out.
o   By default, Spanning Tree Protocol Maximum Age timer is set to 20 seconds.
o   The STP max age timer can be tune to any value between 6 and 40 seconds.

Commands	Description
SW1# show spanning-tree vlan 1	Display STP details
SW1(config)#spanning-tree vlan 1 hello-time 5	Changing STP Hello time
SW1(config)#spanning-tree vlan 1 forward-time 20	Changing STP Forward Delay time
SW1(config)#spanning-tree vlan 1 max-age 40	Changing STP Maximum Age time

Message Age:

Unlike the three Spanning Tree Protocol timers, Message Age is not a fixed value.

This field contains time that has passed since root switch initially originated BPDU.

Root switch sends all its BPDUs with Message Age of 0 & all subsequent switches add 1.

Effectively, the Message Age tells the switch how far the switch is from the root switch.

Remaining lifetime of a BPDU after being received by a switch is MaxAge-MessageAge.

STP Operation:

o   All the Cisco Switches of the Spanning Tree domain first elect a Root Bridge.

o   The root bridge acts as a point of reference for all other switches in the network.

o   All ports of the root bridge or root Switch remain in the forwarding mode.

o   Once the root bridge is elected, all remaining switches select a single port.

o   That has the shortest path cost to reach the root bridge and marked it as root port.

o   After selecting root port, switches determine single designated port for each connection.

o   If multiple ports or interfaces are connected with the same switch or LAN segment.

o   Switch select only one port that has lowest path cost & marks it as the designated port.

o   Once the root port & designated ports are selected, the Switch blocks all remaining ports.

o   The Switches block all other ports to remove any possible or existing loop from network.

Root Ports Selection:

o   First of all, the interface that associated to lowest path cost is more preferred.

o   Interface associated to lowest system priority of advertising switch is preferred next.

o   Port associated to lowest system MAC address of advertising switch is preferred next.

o   When multiple links are associated to same switch, lowest port priority is preferred.

o   When multiple links are associated to same switch, lower port number is preferred

```
S1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769                      Root Bridge Information
             Address     aabb.cc00.0100
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

   Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     aabb.cc00.0100
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec
                                                    Switch's Own information

Interface         Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Et0/0             Desg FWD 100       128.1    P2p
Et0/1             Desg FWD 100       128.2    P2p
Et0/2   Root Bridge all ports  Desg FWD 100  128.3    P2p
Et0/3   are Designated &       Desg FWD 100  128.4    P2p
Et1/0   Forwarding State       Desg FWD 100  128.5    P2p
Et1/1             Desg FWD 100       128.6    P2p
Et1/2             Desg FWD 100       128.7    P2p
Et1/3             Desg FWD 100       128.8    P2p
```

If both information, same it means Root Bridge

```
S2#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     aabb.cc00.0100
             Cost        100
             Port        1 (Ethernet0/0)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

   Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     aabb.cc00.0200
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec

Interface         Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Et0/0             Root FWD 100       128.1    P2p
Et0/1             Altn BLK 100       128.2    P2p
Et0/2             Desg FWD 100       128.3    P2p
Et0/3             Desg FWD 100       128.4    P2p
Et1/0   Non-Root Bridge   Desg FWD 100  128.5    P2p
Et1/1   one Root Port     Desg FWD 100  128.6    P2p
Et1/2             Desg FWD 100       128.7    P2p
Et1/3             Desg FWD 100       128.8    P2p
```

Priority= VLAN ID + Default Priority Value