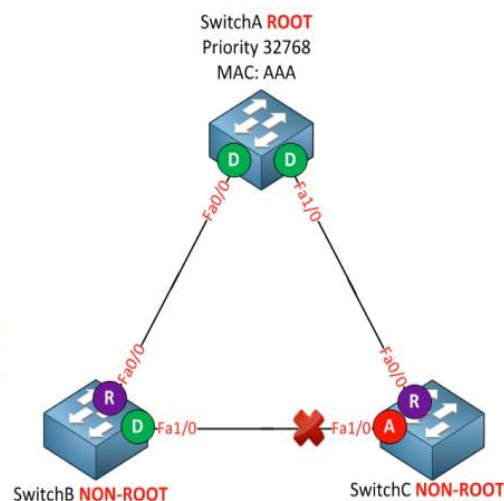
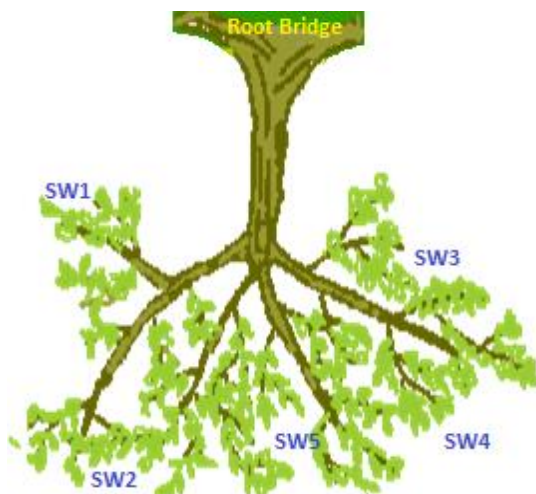


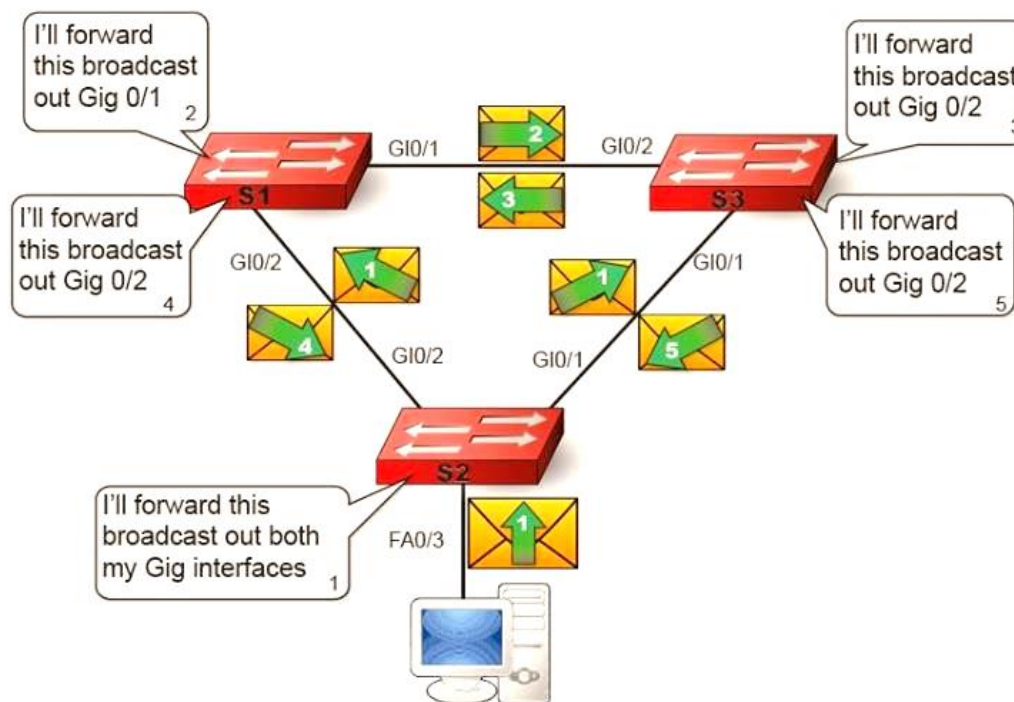
## STP (Spanning Tree Protocols):

- 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 create 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 are any redundant links available in the network that can cause Layer 2 loops.
- o Layer 2 loops in the network can cause unnecessary resource utilization.
- o Multiple frame transmission, unstable MAC table & unnecessary frame lookup by host.
- o To find a redundant link, it uses an algorithm, known as STA (spanning-tree algorithm).
- o Spanning Tree Protocols use STA (Spanning Tree Algorithm) to prevent Layer 2 loops.
- o STA detecting layer 2 loops and blocks it until the 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 seconds for preventing Layer 2 loops.
- o Bridge Priority increment uses 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 change timers of Spanning Tree Protocols (STP) and advertise to all.
- o Root Bridge Switch is also responsible for propagating topology change notification.
- o Root Bridge Switch all ports are always designated ports and always in forwarding state.
- o Terms bridge, switch are used interchangeably when discussing Spanning Tree Protocols.



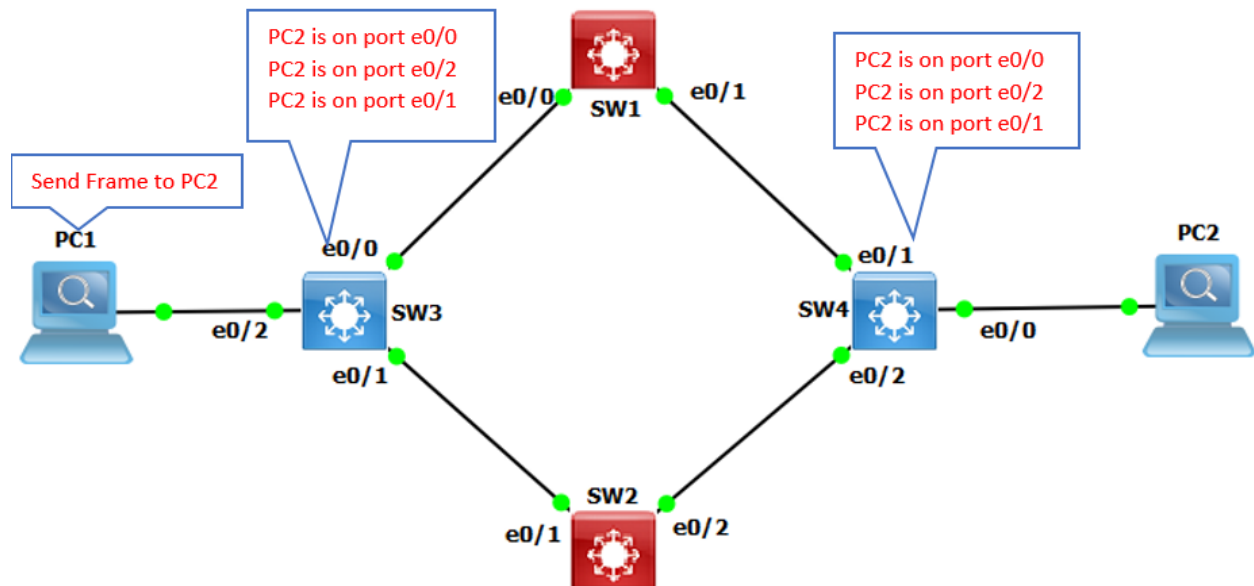
### Broadcast Storm:

- 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.



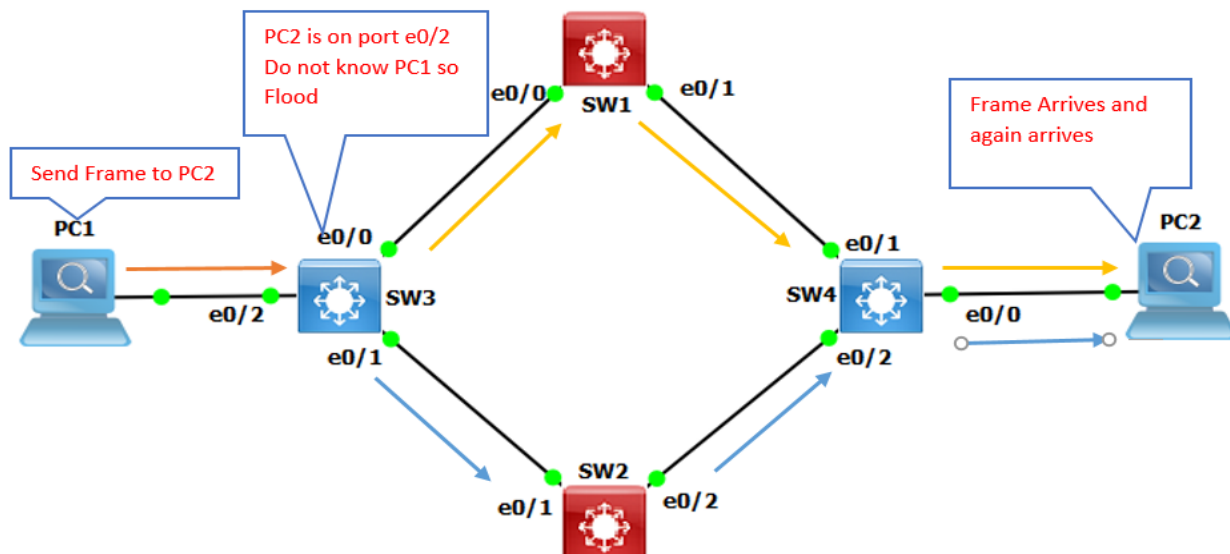
### MAC Database Instability:

- 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:

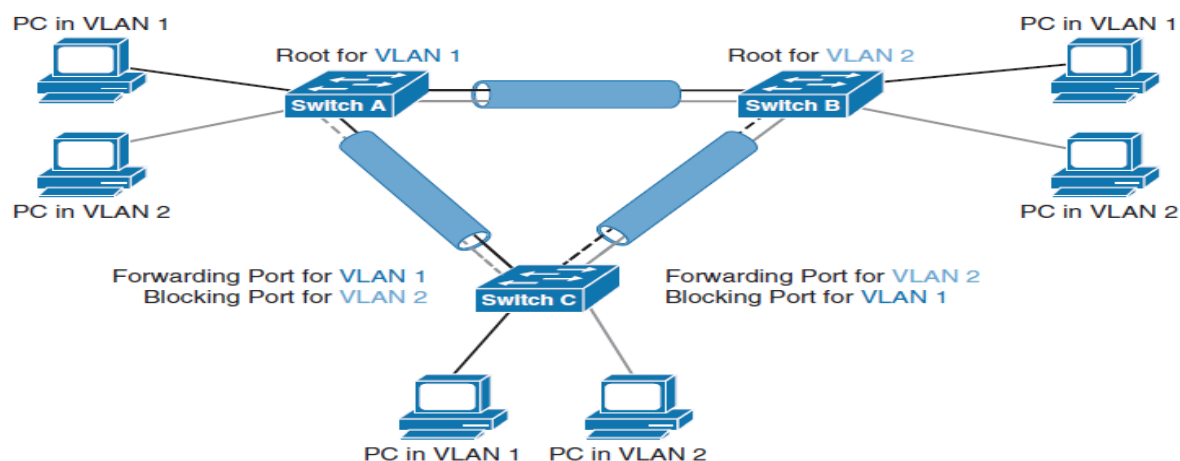
- o Multiple copies of unicast frames may be delivered to destination host.
- o Multiple copies of the same frame can cause unrecoverable errors & issue.



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  
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
Et0/2	Desg	FWD	100	128.3	P2p
Et0/3	Desg	FWD	100	128.4	P2p
Et1/0	Desa	FWD	100	128.5	P2b

Default Switch Priority

Default Port Priority





## 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
<b>Disabled</b> (Shutdown by Admin)	<b>Discarding</b> (Blocking data frame)
<b>Blocking</b> (Blocked redundant link)	
<b>Listening</b> (Listing the data frame)	<b>Learning</b> (Building CAM table)
<b>Learning</b> (Creating CAM table)	
<b>Forwarding</b> (Converged, Data flow allowed)	<b>Forwarding</b> (Converged, Data flow allowed)

State	Type	Forwards STP Frames (BPDUs)	Forwards User Data Frames	Learns MAC Addresses	LED Color on Switch
<b>Blocking</b>	Stable	YES	NO	NO	
<b>Listening</b>	Transitional	YES	NO	NO	
<b>Learning</b>	Transitional	YES	NO	YES	
<b>Forwarding</b>	Stable	YES	YES	YES	
<b>Disabled</b>	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 BPDUs**, Topology Change Notification (TCN) BPDUs.
- o The last one BPDUs 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 BPDUs 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 BPDUs to all switches.

### Spanning Tree Protocol

Protocol Identifier: Spanning Tree Protocol (0x0000)

Protocol Version Identifier: Spanning Tree (0)

**BPDUs 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:

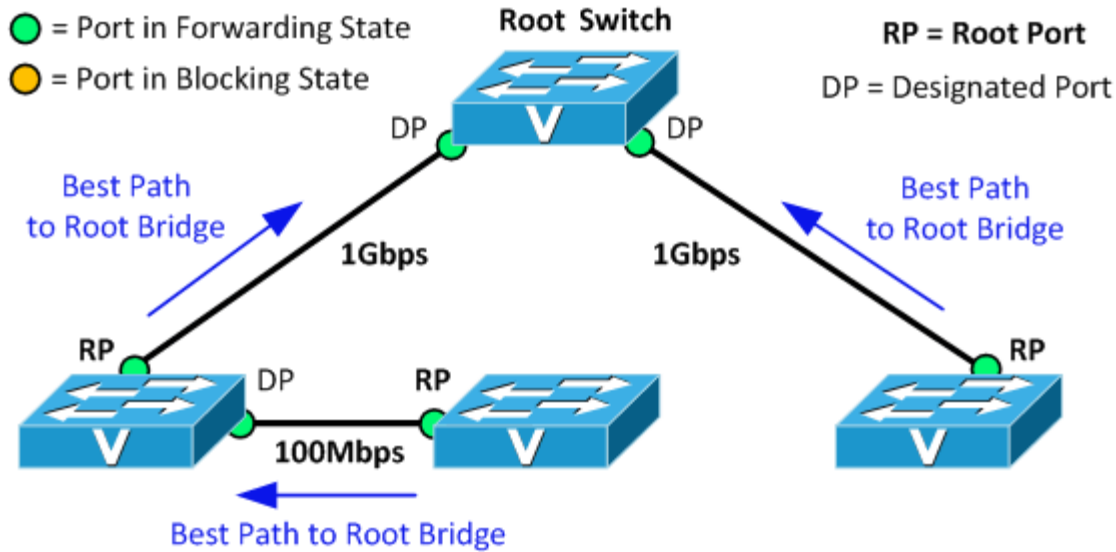
- o A non – root port, which is forwarding away from the root switch.
- o Designated Port has the lowest cost in that Ethernet segment.
- o Switch can have multiple designated ports & marked as forwarding port.
- o Designated Port has the lowest Path Cost on particular LAN segment.
- o In Cisco Switches 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.

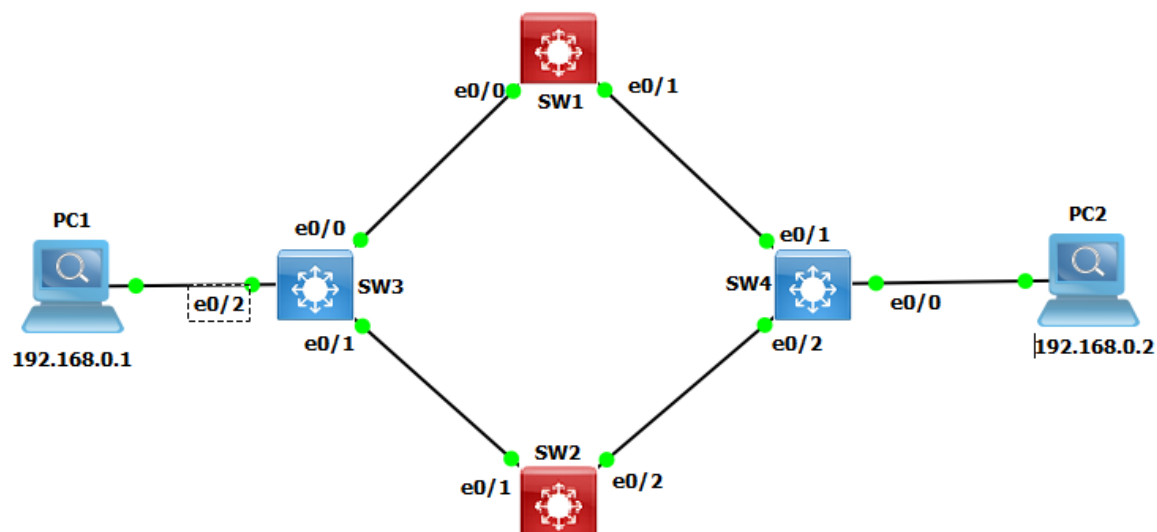
### Forwarding State:

- 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

If both information same it means Root Bridge

VLAN0001

Spanning tree enabled protocol ieee

Root ID	Priority	32769	
	Address	aabb.cc00.0100	Root Bridge Information
	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	Desg	FWD	100	128.3	P2p
Et0/3	Desg	FWD	100	128.4	P2p
Et1/0	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

Root Bridge all ports  
are Designated &  
Forwarding State

S2#show spanning-tree vlan 1

VLAN0001

Spanning tree enabled protocol ieee

Root ID	Priority	32769	
	Address	aabb.cc00.0100	Priority= VLAN ID + Default Priority Value
	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	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

Non-Root Bridge  
one Root Port