

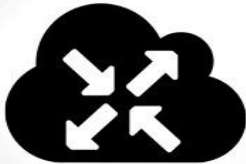


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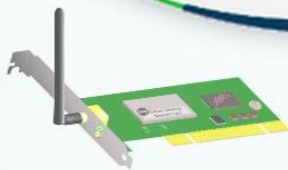
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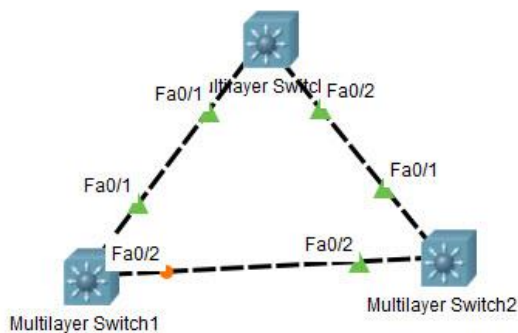
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## Spanning Tree Protocol:

- STP Stand for Spanning Tree Protocol.
- STP is work in Switch to avoid loop in switch's or in other words we can say the spanning Tree protocol is a network protocol that builds a loop-free logical topology for Ethernet networks.
- STP is Open Standard.
- STP works when multiple switches are used with redundant links.
- By default it is enable in CISCO Switches.
- STP will help us to create a loop free topology by blocking certain interfaces.
- Redundant link can creates network loops that flood down frames in the network.
- STP automatically removes layer 2 switching loops by shutting down redundant links.
- To finds a redundant link, it uses an algorithm, known as **Spanning-tree algorithm (STA)**.
- STP used STA to prevent layer 2 loops.
- Spanning Tree Algorithm detecting layer 2 loops and blocks it until first one link goes down or disconnected.
- **Spanning Tree Protocols use BPDU (bridge protocol data unit) in every 2 second for preventing layer 2 loops.**

## Let see with Example:



## Without STP we have the following issues.

1. Broadcast Storm
2. MAC Database Instability
3. Multiple Frame Transmission

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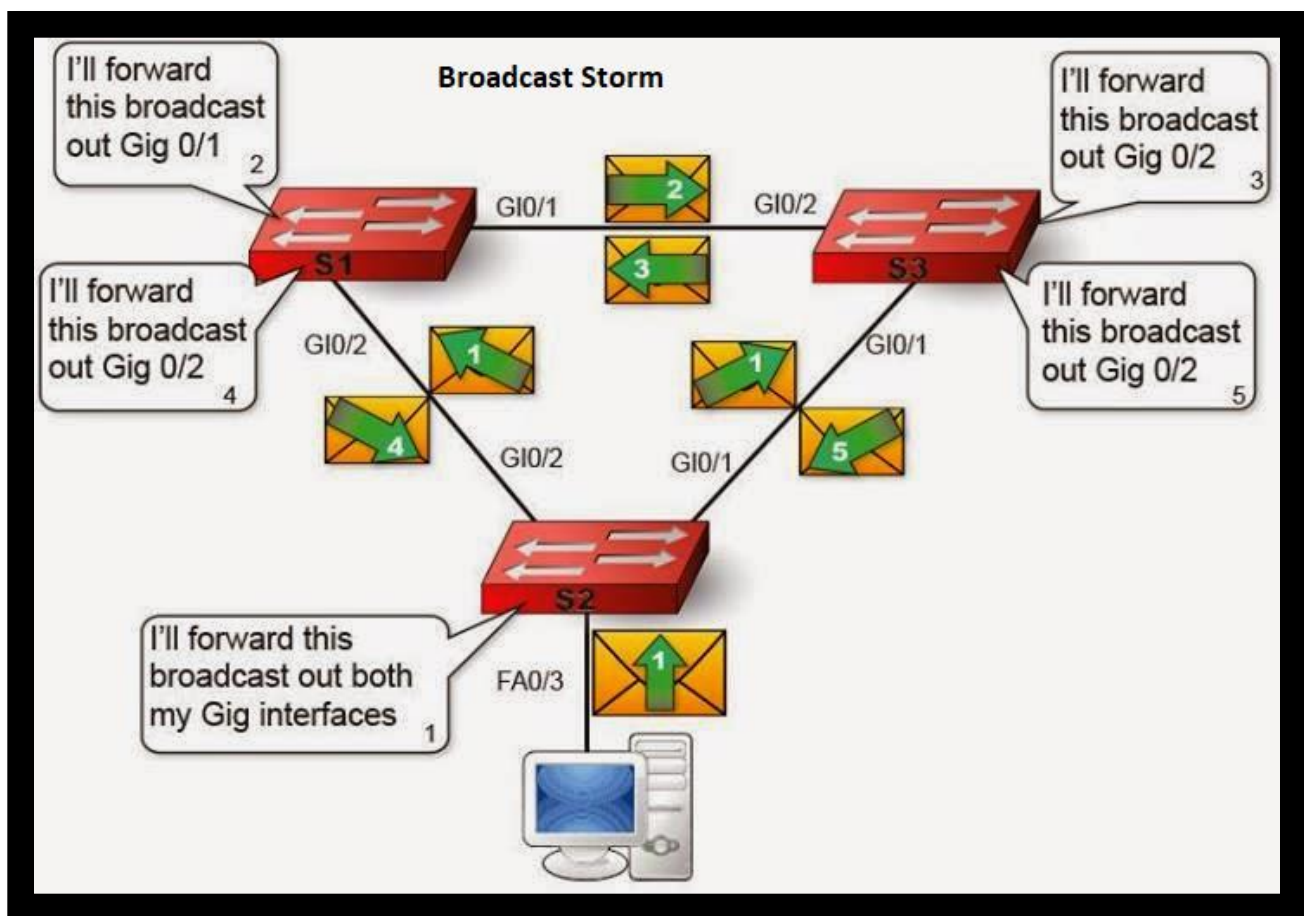
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## Broadcast Storm:

- When switch receives broadcast frame, it continues broadcasting them.
- The Switches broadcasting them again to its other interfaces.
- Broadcasting will keep going on forever until we shut down the network.
- This Process is known as Broadcast storm of switches.
- Broadcast storm consumes the entire bandwidth of the network.
- Broadcast storm denies bandwidth for normal network traffic.



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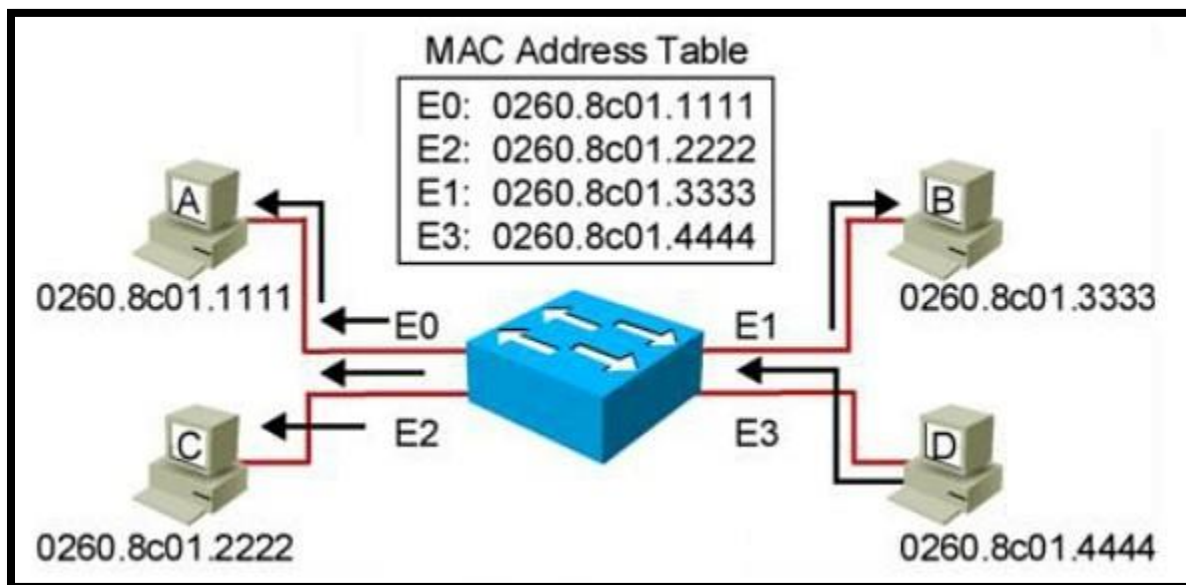
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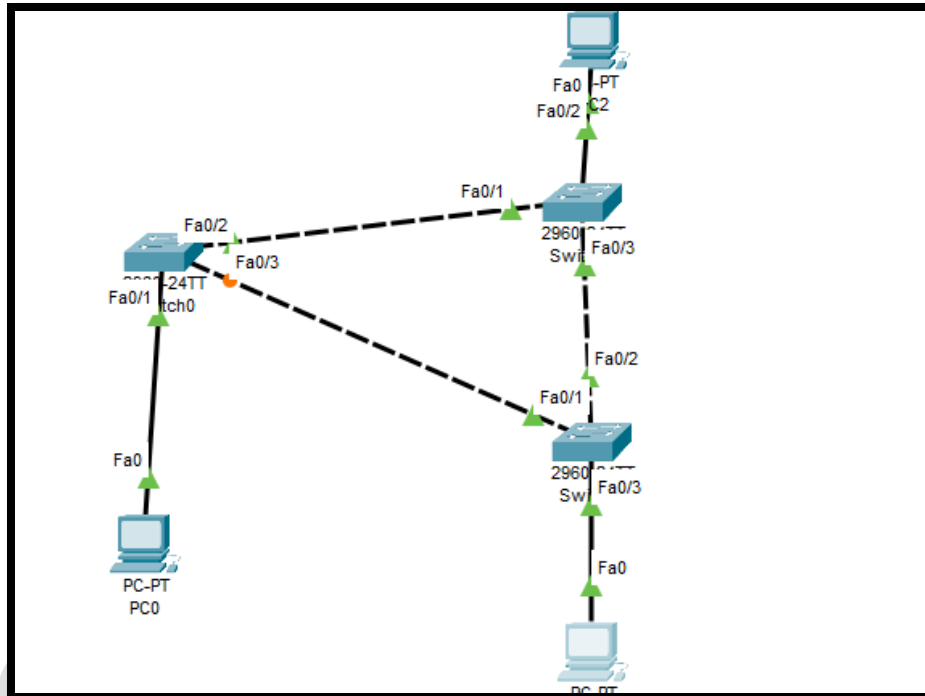
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## MAC Database Instability:

- MAC tables are built by examining the source MAC address on a packet received.
- The source MAC address is tied to the interface it was received on.
- If loop occurs in the network then same source MAC address could be seen on more than one Interface.
- So MAC table will be unstable that is instability of MAC table causes copies of same frame to be delivered to multiple interfaces.
- MAC Instability results multiple copies of a frame arrive on different interface of switch.





### Multiple Frame Transmission:

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

### Switch Priority:

- By default, all Cisco Switches has a **Bridge Priority or Switch Priority** value of 32,768.
- Bridge Priority value decides which Switch can become Root Bridge (Root Switch).
- **Switch with lowest Bridge Priority (Switch Priority) Value will become the Root Switch.**

### Let see How STP is working.

- STP Selecting Root Bridge.
- STP Selecting Root Port.
- STP Selecting Designated port and non-Designated port.

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## Selecting the Root Bridge:

- The bridge with the lowest Bridge ID.
- Bridge ID = Priority + MAC address of the switch.
- All Switches priority is 32768+1 = 32769
- All Switches have same priority then they will compare MAC address.
- All Switches exchange information that is called BPDU (Bridge Protocol Data Units).
- Switches Send BPDU every 2 second.
- To Check we will use command : `sh spanning-tree`
- From the all switches in the network one is elected as Root Bridge. And all the remaining switches will be considered as Non root Bridge.

```
SW1#sh spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
            Address    0060.2F97.B2E3
            Cost      19
            Port      2(FastEthernet0/2)
            Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
            Address    00D0.5882.71C6
            Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec
            Aging Time 20

Interface    Role Sts Cost      Prio.Nbr Type
-----
Fa0/1        Desg FWD 19        128.1   P2p
Fa0/2        Root FWD 19        128.2   P2p
Fa0/3        Altn BLK 19        128.3   P2p
```

## Non-Root Bridge:

- Except Root Bridge, all remaining switches of network are considered as Non-Root Bridges.
- Non-Root Bridges receive updates from Root Bridge & update their STP databases relatively.

## Port Priority:

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

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- Gi0/1 128.20 P2P: Gi0/1 is the interface 128 is default value and 20 is port number.
- P2P means Point-to-point (Full Duplex) and Shr means Shared (Half Duplex) like hub.

## **Spanning Tree Port Roles:**

### **Designated Port:**

- A non – root port, which is forwarding away from the root switch.
- Switch can have multiple designated ports & marked as forwarding port.
- For root bridges all switch ports are designated ports.
- In Cisco Switches a Root Port can never be a designated port.

### **Non-Designated Port:**

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

### **Root Port:**

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

### **Alternate Port:**

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

### **Forwarding Ports:**

- It also has two type designated ports and Root ports.



### Blocking Ports:

- It is also called Non-Forwarding ports

### Selecting the Root Port:

- Shortest path to the root bridge (Every non root bridge looks the best way to go root bridge) Least cost (speed).
- Typical Costs of different Ethernet networks.

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

### STP Port states

1. Listening 15 sec.
2. Learning 15 sec.
3. Blocking 20 sec.
4. Forwarding No limits
5. Disable No limits

### Listening State:

- After blocking state, Root Port or Designated Port will move to listening state.
- During listening state, port discards frames received from attached network segment.
- During listening state port discards frames switched from another port for forwarding.
- After 15 seconds, the switch port moves from the listening state to the learning state.

### Learning State:

- Only root port & designated ports enter into learning state from listening.
- A Cisco Switch port change to learning state after the listening state.
- During the learning state, the port is listening for and processing BPDUs.
- In the learning state, the port begins to process the user frames.

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- In the learning state, the port start updating the MAC address table.
- Data or user frames are not forwarded to the destination port of switch.
- After 15 seconds, switch port moves from learning state to forwarding state.

### Forwarding State:

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

### Blocking State:

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

### Disabled State:

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

### Type of STP:

Type of STP				
Protocol	Standard	Resources Need	Convergence	Numbers of Trees
STP	802.1D	Low	Slow	One
PVST+	CISCO	High	Slow	One for Every VLAN
RSTP	802.1W	Medium	Fast	One

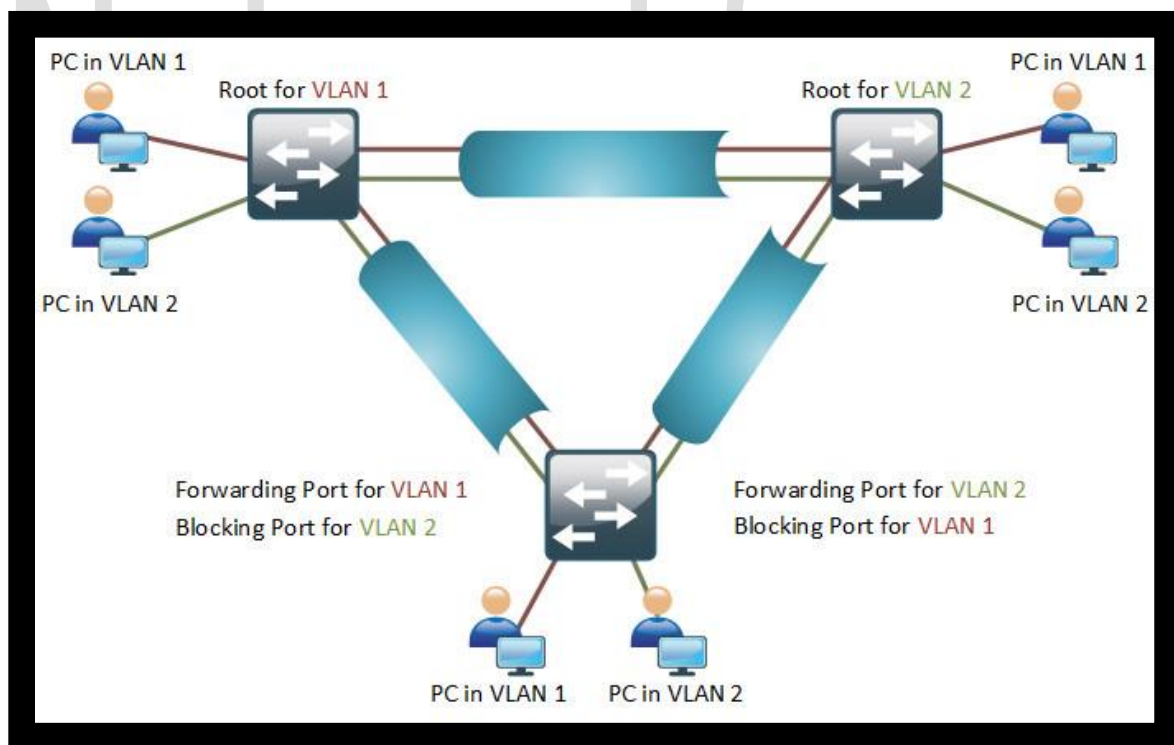
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Rapid PVST+	CISCO	Very High	Fast	One for Every VLAN
MST	802.1S	Medium or High	Fast	One for Multiple Vlan

### PVST+:

- PVST+ stands for Per VLAN Spanning Tree Plus (PVST+).
- PVST+ is a CISCO Implementation of STP.
- Per-VLAN Spanning Tree+ (PVST+) is an extension of the PVST standard.
- PVST+ supports **DOT1Q trucking** encapsulation while PVST not support.
- PVST+ Provide each VLAN have its own Spanning Tree Protocol topology.
- PVST is usually the default spanning tree protocol on CISCO Switches.
- **PVST+ takes 30 to 50 seconds to transit from blocking state to forwarding state.**



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## RPVST+:

- RPVST+ stands for Rapid Per-VLAN Spanning Tree Plus.
- Rapid PVST+ is an enhanced version of the PVST+ version.
- Rapid PVST+ allows for faster spanning Tree calculations and convergence.
- RSTP is typically able to respond less than 10 seconds of a physical link failure.
- Rapid PVST+ defines three port states Discarding, Learning and Forwarding.
- We can enable RSTP by using command: **spanning-tree mode rapid-pvst**

STP	RSTP
Disabled	Discarding
Blocking	Discarding
Listening	Discarding
Learning	Learning
Forwarding	Forwarding

```
Switch#sh spanning-tree
VLAN0001
Spanning tree enabled protocol rstp
Root ID    Priority    32769
Address    0001.64B9.1217
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    0001.64B9.1217
Hello Time 2 sec    Max Age 20 sec    Forward Delay 15 sec
Aging Time 20

Interface      Role Sts Cost      Prio.Nbr Type
-----
Fa0/1          Desg FWD 19        128.1    P2p
```



```
Switch#sh spanning-tree summary
Switch is in rapid-pvst mode
Root bridge for: default
Extended system ID      is enabled
Portfast Default        is disabled
PortFast BPDU Guard Default is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default       is disabled
EtherChannel misconfig guard is disabled
UplinkFast              is disabled
BackboneFast            is disabled
Configured Pathcost method used is short

Name                    Blocking Listening Learning Forwarding STP Active
-----
VLAN0001                1          0          0          0          1
-----
1 vlans                  1          0          0          0          1
```

## BPDU (Bridge Protocol Data Units):

- Bridge Protocol Data Units (BPDUs) are messages exchanged between the switches.
- BPDUs frames contain info about switch ID, originating switch port & MAC address.
- BPDUS frames also contain info regarding switch port priority, switch port cost etc.
- Bridge Protocol Data Units (BPDUs) frames are sent out as multicast messages regularly.
- BPDUS frames use the multicast destination MAC address which is 01:80:c2:00:00:00.
- When BPDUs are received, the Switch uses a mathematical formula called the STA.
- Spanning Tree Algorithm (STA) know when there is a Layer 2 Switch loop in network.
- Spanning Tree Algorithm determines which of redundant ports needs to be shut down.
- Three types of BPDUs are Configuration BPDU, Topology Change Notification (TCN) BPDU and Topology Change Notification Acknowledgment (TCA).
- Basic purpose of BPDUs & Spanning Tree Algorithm is to avoid Layer 2 Switching loops.
- Basic purpose of BPDUs and Spanning Tree Algorithm to avoid Layer 2 Broadcast storms.
- Configuration BPDUs are used to elect the Root Bridges, root ports, and designated ports.

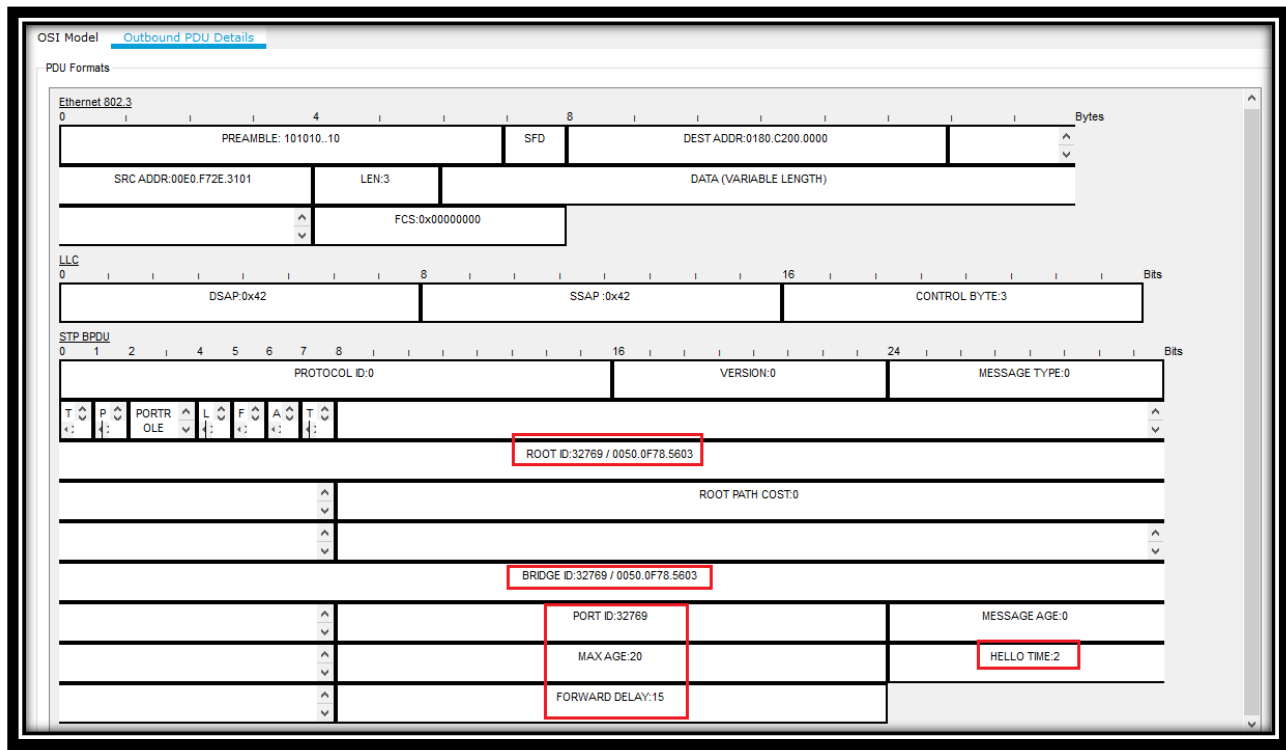
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- When topology change occurs, Switch send TCN BPDUs out its root port, destined for Root.
- TCN contains no information about the change – it only indicates that a change occurred.
- By responding with a TCN with the Topology Change Acknowledgement (TCA) flag set.
- Once Root Bridge receives the TCN, it will send out a configuration BPDUs to all switches.



### Spanning Tree Timers:

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

### Hello Time:

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

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## Forward Delay:

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

## Maximum Age:

- The Spanning Tree Maximum Age timer often referenced as MaxAge.
- If the port no longer receives the BPDUs after the Max Age time has elapsed.
- Switch assumes that topology change must have occurred & BPDU is aged out.
- By default, Spanning Tree Protocol Maximum Age timer is set to 20 seconds.
- The STP max age timer can be tune to any value between 6 and 40 seconds.

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

## Port Fast:

- By passing the listening & learning states, go to forwarding mode.
- STP PortFast feature causes a port to enter forwarding state immediately.
- Port Fast port normally connect to end devices such as server, printer or PC.
- Do not enable portfast on an interface to another device which is hub/switch.
- If Port Fast feature port connect to a cisco switches, it may cause a loop.
- PVST+, Rapid PVST+, or MSTP Spanning tree all support Port Fast feature.
- Port Fast can be enable on interface level or globally on Cisco switch.
- When running globally it enable Portfast on interface that is edge port.

Enable Portfast Feature	We can check by debug
interface e0/0 spanning-tree portfast no shutdown	debug spanning-tree events

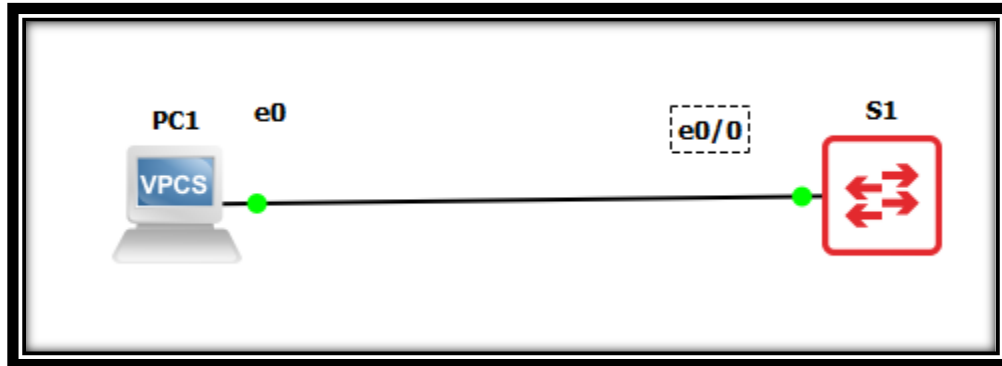
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### Lab Time:



PC Configuraition:	Switch Configuration:
<pre>PC1&gt; sh ip  NAME      : PC1[1] IP/MASK   : 0.0.0.0/0 GATEWAY   : 0.0.0.0 DNS       : MAC       : 00:50:79:66:68:00 LPORT     : 10001 RHOST:PORT : 127.0.0.1:10002 MTU       : 1500  PC1&gt; ip 192.168.1.2/24 192.168.1.1 Checking for duplicate address... PC1 : 192.168.1.2 255.255.255.0 gateway 192.168.1.1  PC1&gt; sh ip  NAME      : PC1[1] IP/MASK   : 192.168.1.2/24 GATEWAY   : 192.168.1.1 DNS       : MAC       : 00:50:79:66:68:00 LPORT     : 10001</pre>	<pre>interface e0/0 spanning-tree portfast no shutdown</pre>

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```
RHOST:PORT : 127.0.0.1:10002
MTU:      : 1500

PC1> save
Saving startup configuration to startup.vpc
. done
```

### Without Port Fast:

```
S1#debug spanning-tree events
Spanning Tree event debugging is on
S1#config t
Enter configuration commands, one per line. End with CNTL/Z.
S1(config)#int e0/0
S1(config-if)#sh
S1(config-if)#
*Sep 25 16:54:33.795: STP: VLAN0001 we are the spanning tree root
*Sep 25 16:54:33.795: STP[1]: Generating TC trap for port Ethernet0/0
S1(config-if)#
*Sep 25 16:54:35.799: %LINK-5-CHANGED: Interface Ethernet0/0, changed state to administratively down
*Sep 25 16:54:36.806: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to down
S1(config-if)#no sh
S1(config-if)#
*Sep 25 16:54:42.356: set portid: VLAN0001 Et0/0: new port id 8001
*Sep 25 16:54:42.356: STP: VLAN0001 Et0/0 -> listening
S1(config-if)#
*Sep 25 16:54:44.353: %LINK-3-UPDOWN: Interface Ethernet0/0, changed state to up
*Sep 25 16:54:45.353: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to up
S1(config-if)#
*Sep 25 16:54:57.362: STP: VLAN0001 Et0/0 -> learning
S1(config-if)#
*Sep 25 16:55:12.362: STP[1]: Generating TC trap for port Ethernet0/0
*Sep 25 16:55:12.362: STP: VLAN0001 Et0/0 -> forwarding
S1(config-if)#
```

### With Port Fast:

```
S1(config)#int e0/0
S1(config-if)#sp
S1(config-if)#spanning-tree por
S1(config-if)#spanning-tree portfa
S1(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 Ethernet0/0 but will only
have effect when the interface is in a non-trunking mode.
S1(config-if)#sh
S1(config-if)#n
*Sep 25 17:02:20.779: STP: VLAN0001 we are the spanning tree root
S1(config-if)#no
S1(config-if)#
*Sep 25 17:02:22.785: %LINK-5-CHANGED: Interface Ethernet0/0, changed state to administratively down
*Sep 25 17:02:25.148: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to down
S1(config-if)#no sh
S1(config-if)#
*Sep 25 17:02:34.970: set portid: VLAN0001 Et0/0: new port id 8001
*Sep 25 17:02:34.970: STP: VLAN0001 Et0/0 -> jump to forwarding from blocking
S1(config-if)#
*Sep 25 17:02:36.975: %LINK-3-UPDOWN: Interface Ethernet0/0, changed state to up
*Sep 25 17:02:37.979: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to up
```

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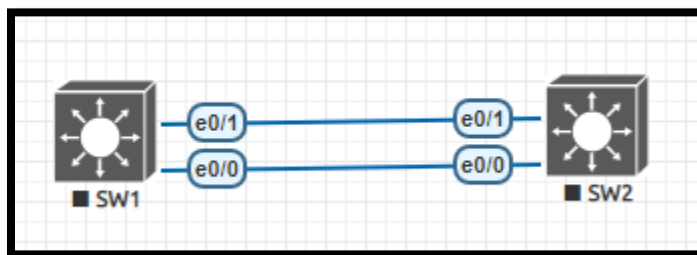


## MST:

- MST stands for Multiple Spanning Tree.
- IEEE 802.1s define multiple Spanning Tree implementations.
- Common Spanning Tree has a single instance for all VLANs.
- It is concept of mapping one or more VLANs to single STP instance.
- For Example, the 2000 VLANs can be mapped to two MST instances.
- Rather than to maintaining and running 2000 separate Spanning Trees.
- Each Cisco Switch needs to maintain only two Spanning Trees only.
- Reducing need for switch resources also converges faster than PVRST+.
- Multiple Spanning Tree (MST) works with the concept of the regions.
- A region is defined by the name given in MST configuration mode.
- Region is group of devices configured together to form logical region.
- It is similar to administration domain collection of VLANs have same config.
- Collection of VLANs managed under the same MST umbrella is regions.
- It has same attributes Configuration Name, Revision Number and Instance.
- MST configuration name identify MST region & revision number any number.
- MST revision number is locally significant number signify the MST configuration.
- MST name, instance and revision number must match to build MST topology.

Lab time MST:

**((L2-ADVIPSERVICESK9-MS.HIGH\_IRON\_20160628.bin) -Switch Image which use in this Lab)**



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### SW1 Configuration

```
SW1(config)#interface range e0/0-1
SW1(config-if-range)#switchport trunk encapsulation dot1q
SW1(config-if-range)#switchport mode trunk
SW1(config-if-range)#no shutdown
SW1(config)#vlan 10,20,30,40,50,60
```

### SW2 Configuration

```
SW2(config)#interface range e0/0-1
SW2(config-if-range)#switchport trunk encapsulation dot1q
SW2(config-if-range)#switchport mode trunk
SW2(config-if-range)#no shutdown
SW2(config-if-range)#vlan 10,20,30,40,50,60
```

### SW1 MST Configuration

```
SW1(config)#spanning-tree mode mst
SW1(config)#spanning-tree mst configuration
SW1(config-mst)#name test
SW1(config-mst)#revision 1
SW1(config-mst)#instance 1 vlan 10,20,30
SW1(config-mst)#instance 2 vlan 40,50,60
SW1#show spanning-tree mst
SW1#show spanning-tree mst configuration
SW1# show spanning-tree bridge
SW1#show spanning-tree root
SW1(config)#spanning-tree mst 1 priority 4096
SW1(config)#spanning-tree mst 2 priority 0
```

### SW2 MST Configuration

```
SW2(config)#spanning-tree mode mst
SW2(config)#spanning-tree mst configuration
SW2(config-mst)#name test
SW2(config-mst)#revision 1
SW2(config-mst)#instance 1 vlan 10,20,30
```

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```
SW2(config-mst)#instance 2 vlan 40,50,60
```

```
SW2#show spanning-tree mst
```

```
SW2#show spanning-tree mst configuration
```

```
SW2# show spanning-tree bridge
```

```
SW2#show spanning-tree root
```

```
SW2(config)#spanning-tree mst 1 priority 0
```

```
SW2(config)#spanning-tree mst 2 priority 4096
```

```
S1#sh spanning-tree mst configuration
```

```
Name [test]
```

```
Revision 1 Instances configured 3
```

```
Instance Vlans mapped
```

```
-----  
0 1-9,11-19,21-29,31-39,41-49,51-59,61-4094
```

```
1 10,20,30
```

```
2 40,50,60  
-----
```

```
S1#show spanning-tree bridge
```

MST Instance	Bridge ID	Hello Time	Max Age	Fwd Dly	Protocol
MST0	32768 (32768, 0) aabb.cc00.0100	2	20	15	mstp
MST1	1 ( 0, 1) aabb.cc00.0100	2	20	15	mstp
MST2	4098 ( 4096, 2) aabb.cc00.0100	2	20	15	mstp

```
S1#sh spanning-tree root
```

MST Instance	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
MST0	32768 aabb.cc00.0100	0	2	20	15	
MST1	1 aabb.cc00.0100	0	2	20	15	
MST2	2 aabb.cc00.0200	2000000	2	20	15	Et0/0

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