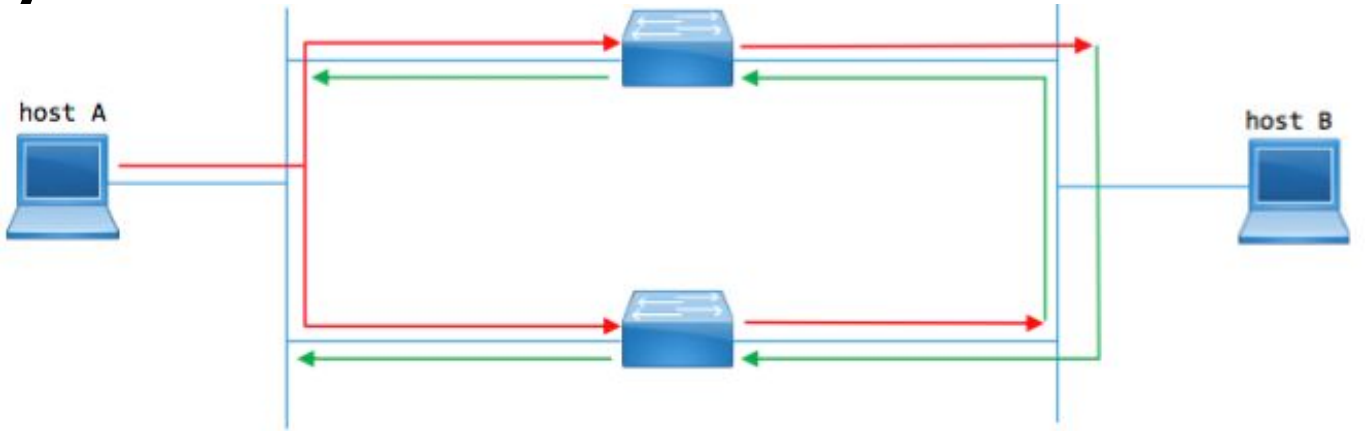
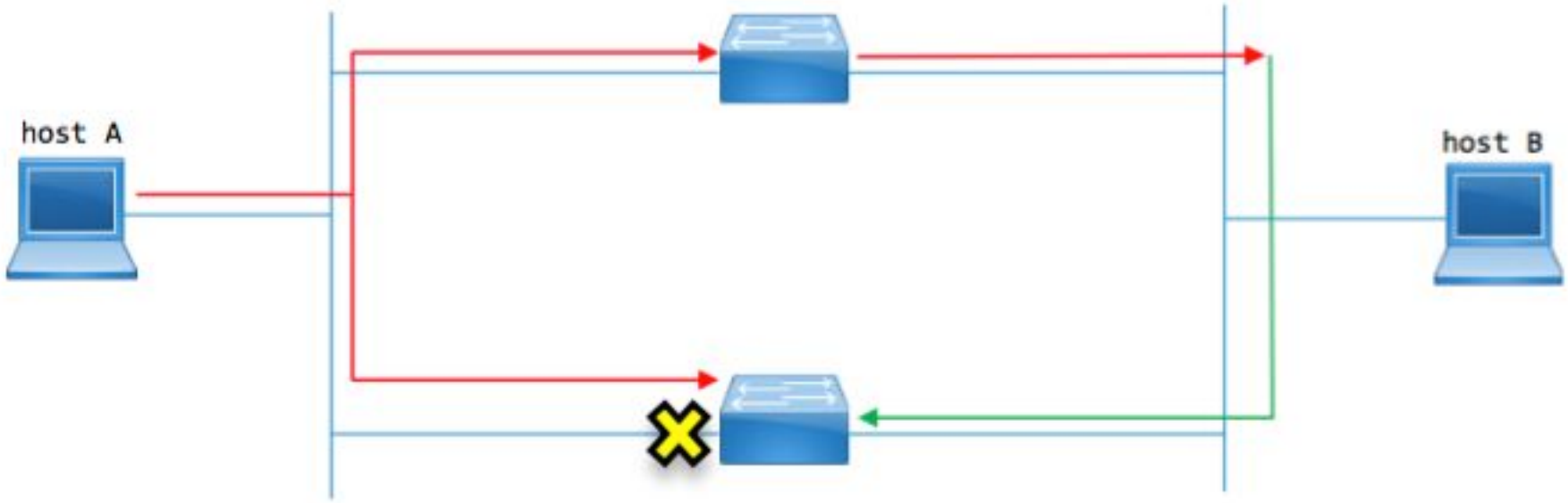
What is Spanning-Tree ?
Why would we need it ?



- Switches do not learn broadcast MAC FFFF.FFFF.FFFF
- Frames sent with broadcast MAC destination are flooded out every port within the VLAN
- Without Spanning Tree a broadcast packet from host A would loop endlessly in the network

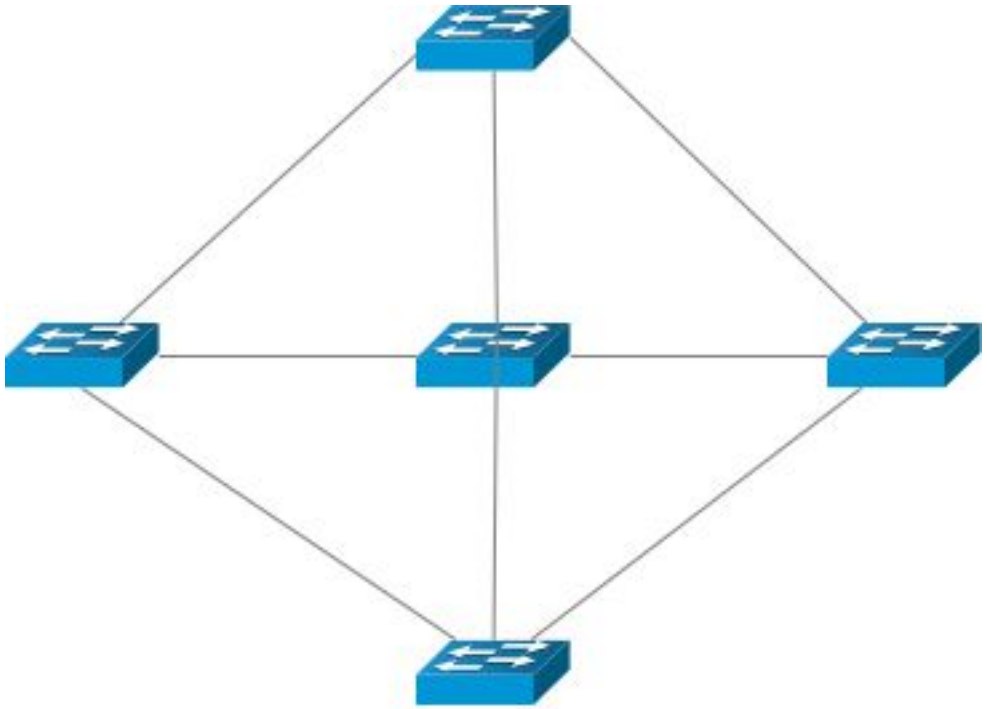
What will STP achieve ?



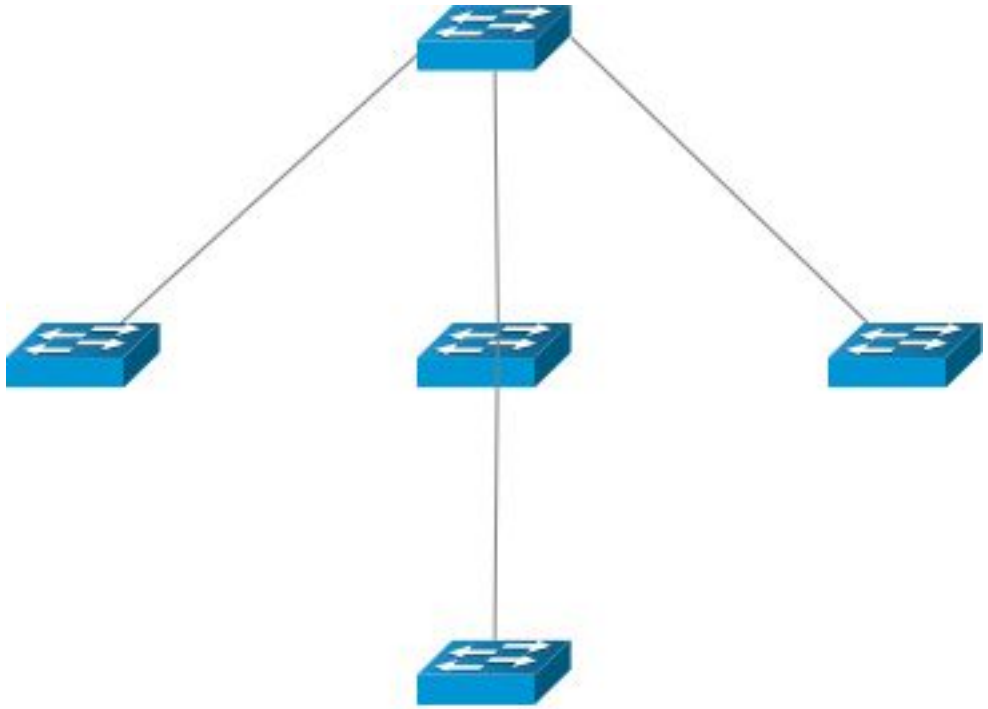
- Spanning Tree Protocol will block redundant links to prevent L2 frames from looping in the network.
- Any data frame received on a blocked port will be dropped and no data frames are transmitted on this port
- Some L2 control traffic is permitted (CDP, VTP for instance)

Why do they call it spanning tree

- Prune redundant paths to get tree like structure



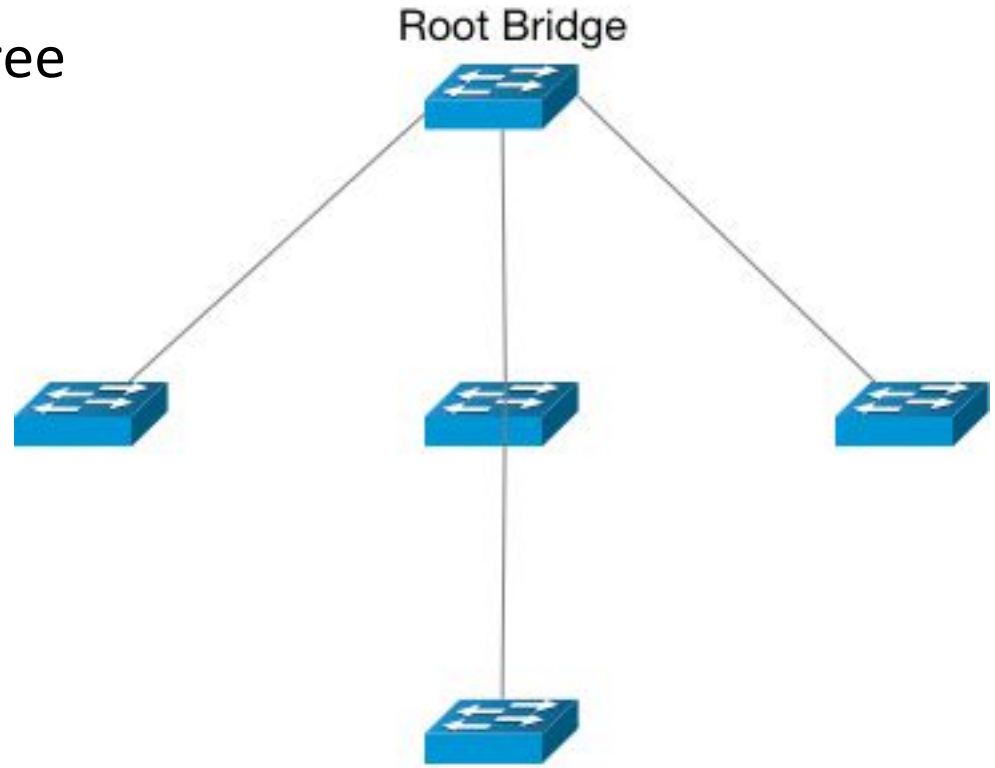
This



Becomes this

Understanding Bridge ID

- One switch has to be elected Root of the tree
- Bridge ID is used to determine who is root.



Understanding Bridge ID Cont.

Each bridge has a Bridge ID (BID):

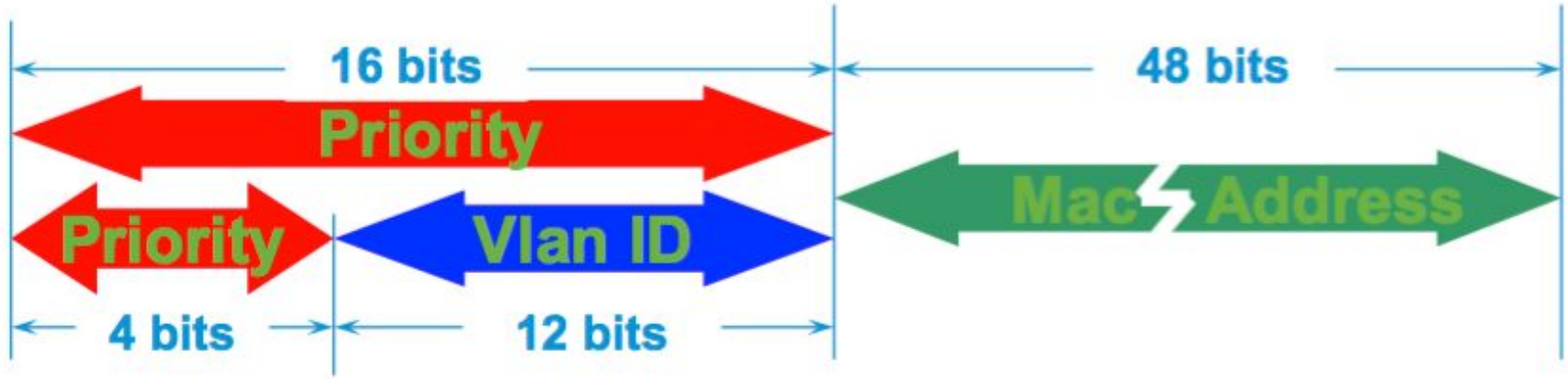
Bridge ID: 8 bytes	
Bridge Priority	**Mac Address**
16 bits	**48 bits**

The bridge with the lowest BID becomes Root

- All bridges have a different BID
  (because a Mac address is part of the BID=> deterministic)
- The bridge priority can be modified
  (allowing the user to select the Root)

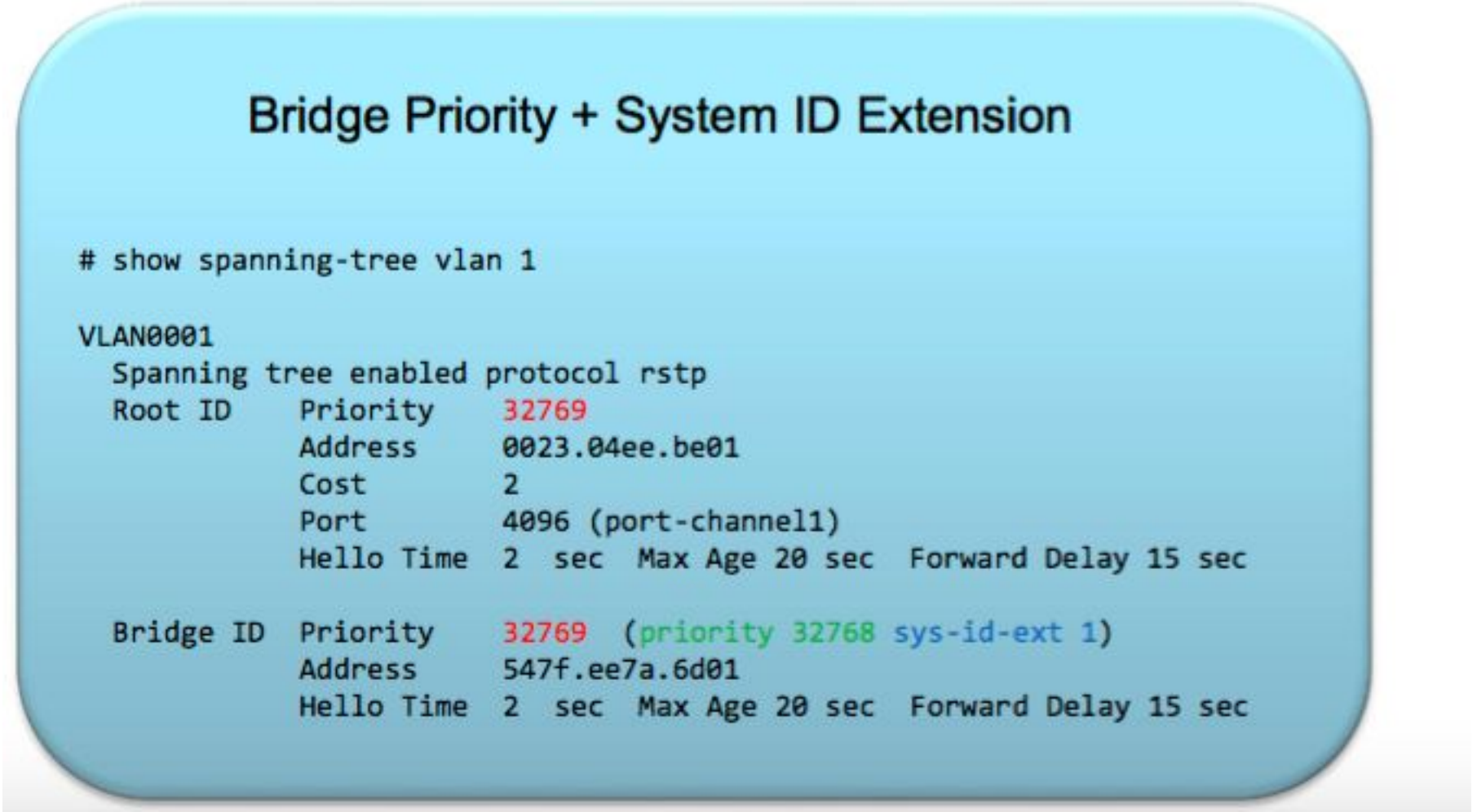
Extended System ID

- Bridge ID = bridge priority + mac address
- So far, one mac address was used per vlan
- 802.1t steals 12 bits from the bridge priority to code the vlan number



- **Bridge priority can now only take 16 values, by increments of 4096**
- **Only one mac address is needed per bridge**

Bridge Priority + Extended System ID



Bridge Priority Configuration

- Using Bridge Priority to control Root switch election

1. It is always recommended to control who is elected root
2. The easiest way to do this is to configure the bridge priority on the switch that you want to be root
3. The command to do this is:

spanning-tree vlan x priority y x is the VLAN number and y is the priority

```
Router1(config)#spanning-tree vlan 1 priority ?
  <0-61440>  bridge priority in increments of 4096
Router1(config)#spanning-tree vlan 1 priority 4096

show spanning-tree vlan 1
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    4097   Remember the priority is the configured value plus the VLAN number
             Address     000C.85C9.A510
             This bridge is the root
             Hello Time  2 sec  Max Age 20 sec
```

Bridge Priority Configuration

- Using Bridge Priority to control Root switch election

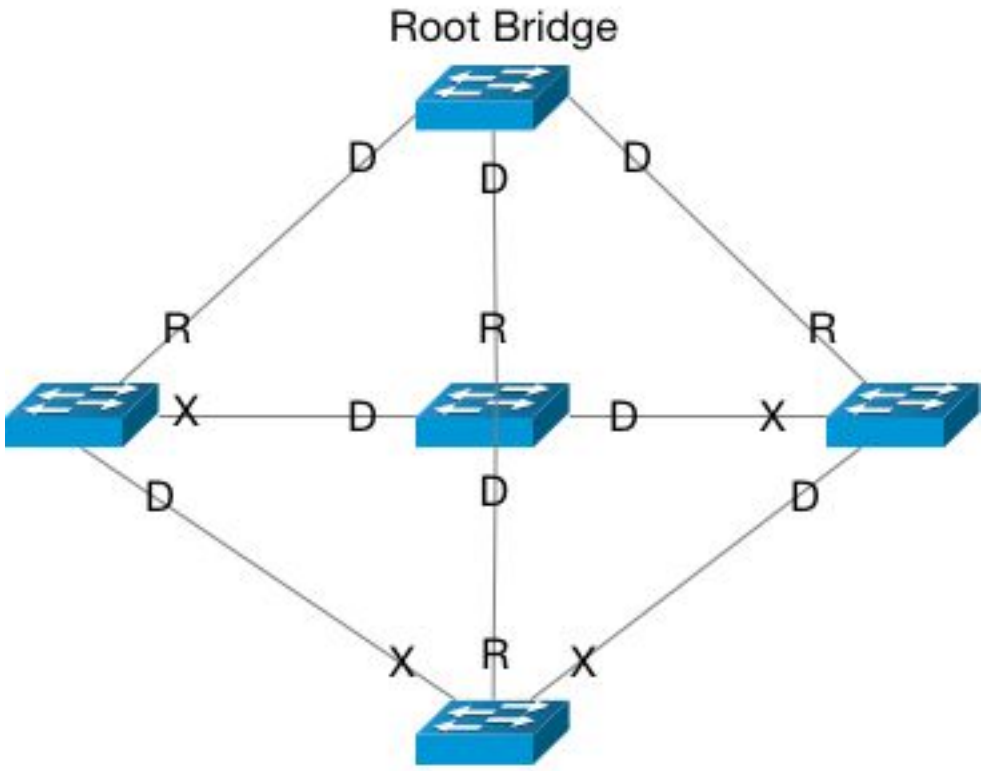
1. It is also a good idea to control who is the backup in case the root bridge fails
2. The way to do this is to configure the priority at a higher value than the root but less than the default
3. In the example below we have configured a second router priority at 8192.

```
Router2(config)#spanning-tree vlan 1 priority 8192

Router2#show spanning-tree vlan 1
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    4097
             Address     000C.85C9.A510
             Cost        4
             Port        1(GigabitEthernet1/0/1)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    8193  (priority 8192 sys-id-ext 1)
```

STP Terminology



Root Bridge
- Switch with lowest BID.
- Only one Root in the network

Root ports
- Port with lowest cost to the Root Bridge
- Marked by R in the diagram

Designated ports
- Providing connectivity to a LAN segment
- Marked by D in the diagram

Blocked ports
- Providing redundant connectivity
- Marked by X in the diagram

Root Bridge Election

- The Root Bridge election process uses several STP messages sent between switches.
- The messages are called Bridge Protocol Data Units (BPDU)
- Each BPDU carries several fields:

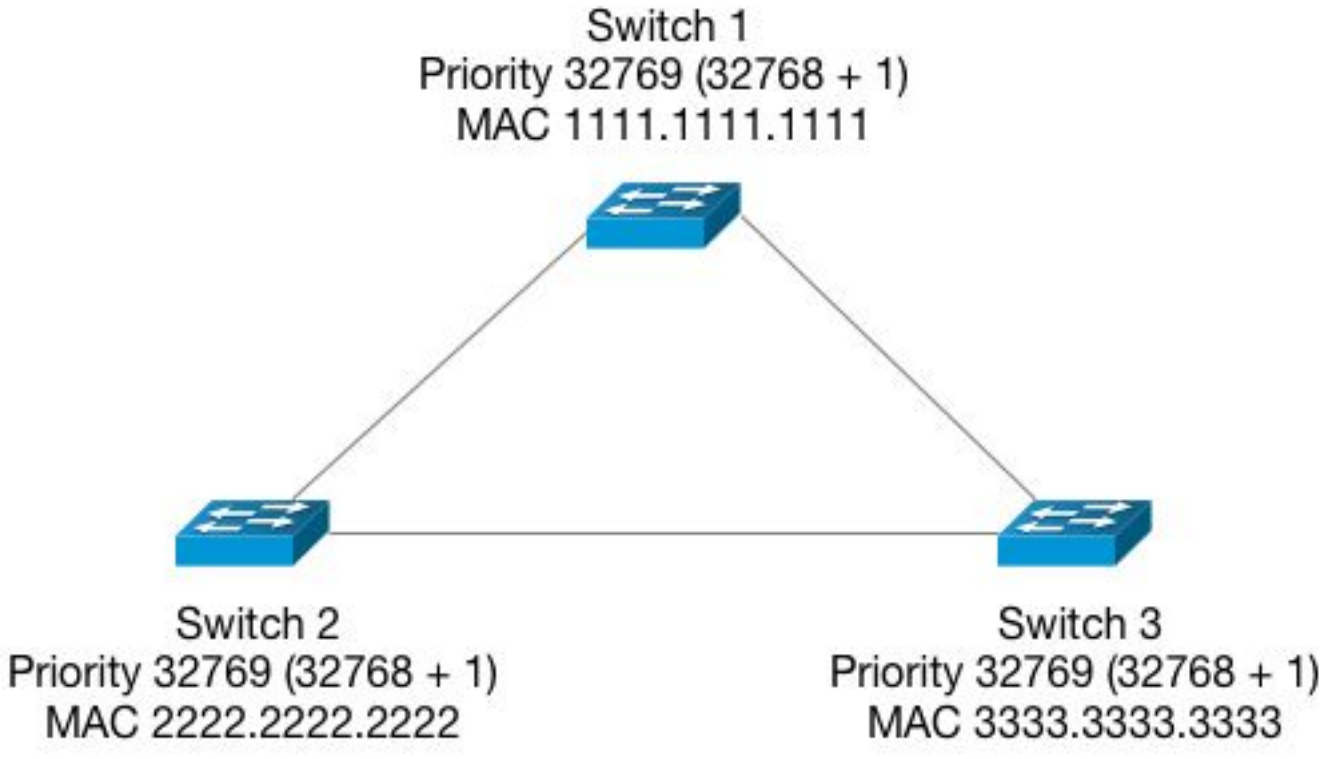
Field	Description
Root Bridge ID	BID of the switch that the sender of this BPDU believes to be the root switch
Sender's Bridge ID	BID of the switch sending this Hello BPDU
Cost to the Root Bridge	The STP cost between this switch and the current root
Timer values on Root Bridge	Hello Timer, Max Age Timer, Forward Delay Timer

Root Bridge Election Cont.

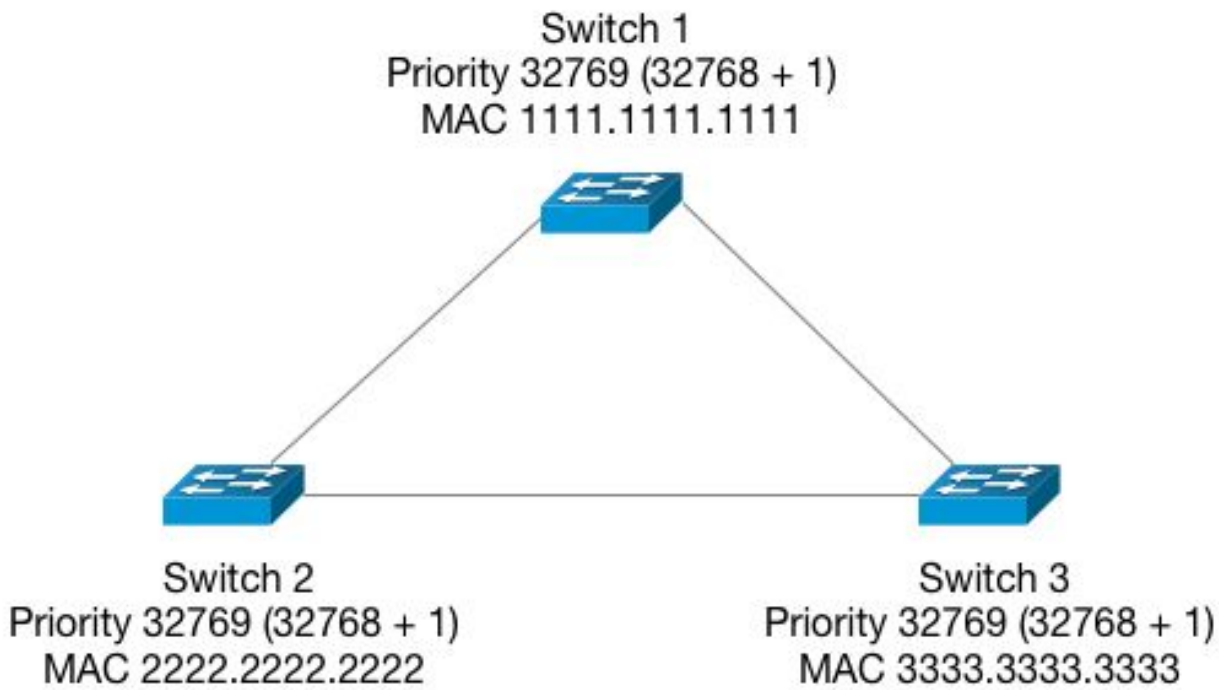
- When a switch comes online it will send a BPDU with its information.
- If it receives a BPDU from another device, it will compare BID between itself and the other device.
- The BID field begins with the Bridge Priority. The switch with the lowest Bridge Priority will be elected root.
- If there is a Bridge Priority tie between the switches then the switch with the lowest MAC address will be elected root

Root Bridge Election and convergence

- The Root Bridge election process starts with each switch advertising themselves as root by sending a Hello BPDU
- Each switch lists its own BID as Root BID
- The Cost field is set to 0 because there is no path cost to itself



Root Bridge Election and Convergence Cont.



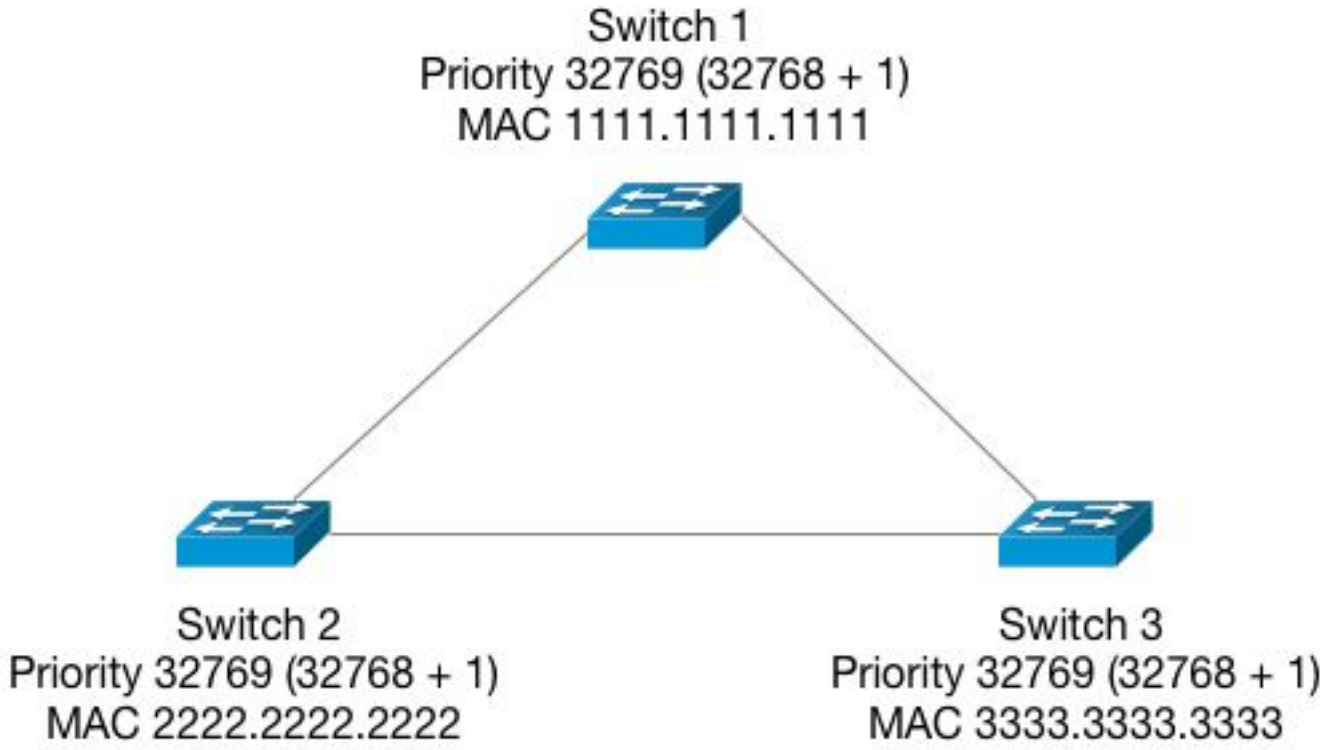
Switch 2 BPDU Hello Packet
BID = sw2 Priority + MAC
Root BID = sw2 Priority + MAC
Root Path Cost = 0

Switch 1 BPDU Hello Packet
BID = sw1 Priority + MAC
Root BID = sw1 Priority + MAC
Root Path Cost = 0

Switch 3 BPDU Hello Packet
BID = sw3 Priority + MAC
Root BID = sw3 Priority + MAC
Root Path Cost = 0

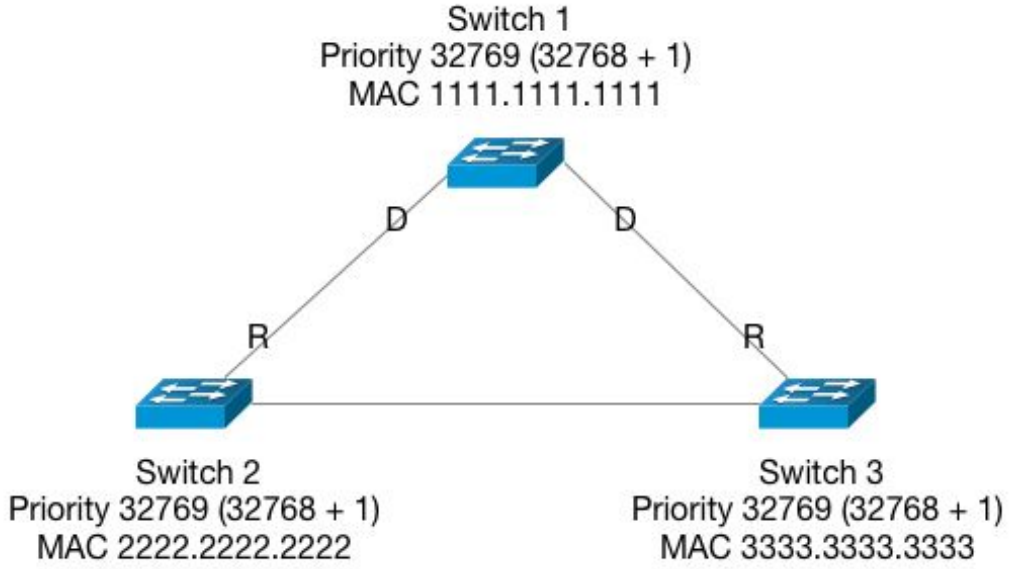
Root Bridge Election and Convergence Cntd.

- They will keep their status as Root Bridge until they receive a Hello BPDU which carries a lower (BID)
- This Hello BPDU then becomes a superior BPDU.
- This process continues until every switch agrees on which device has the lower BID and should be root



Root Bridge and Convergence Cont.

- The switch receiving the superior BPDU makes changes to the Hello BPDU it has been sending out.
- It changes the value of the Root BID to reflect the Root BID from the superior Hello BPDU and adds path cost to root.
- It will also mark the port with the lowest path cost to Root as the Root Port.
- Root switch marks all its ports as designated.



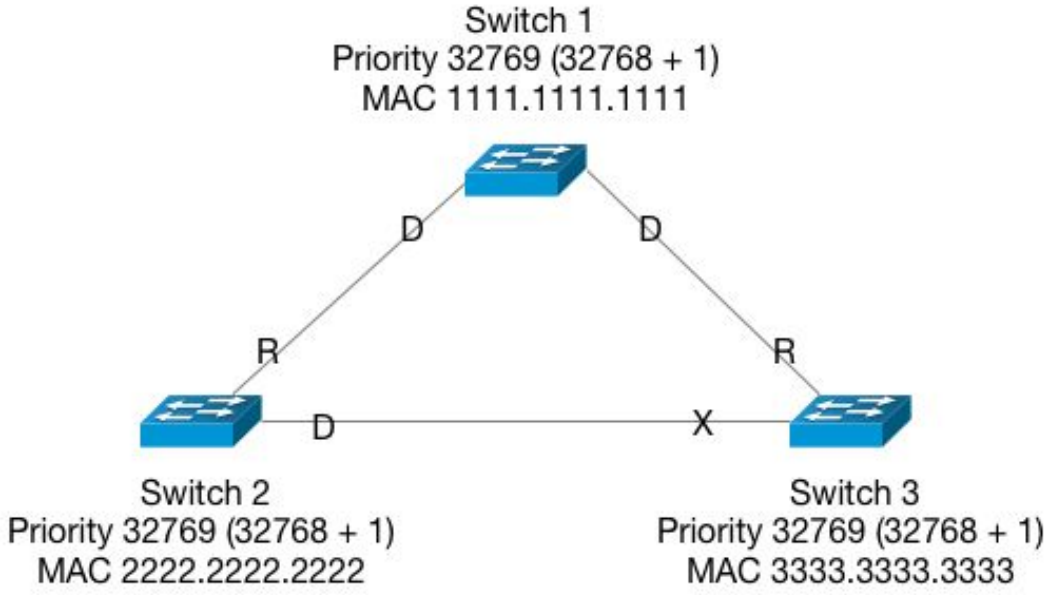
Switch 2 BPDU Hello Packet
BID = sw2 Priority + MAC
Root BID = sw1 Priority + MAC
Root Path Cost = 2

Switch 1 BPDU Hello Packet
BID = sw1 Priority + MAC
Root BID = sw1 Priority + MAC
Root Path Cost = 0

Switch 3 BPDU Hello Packet
BID = sw3 Priority + MAC
Root BID = sw1 Priority + MAC
Root Path Cost = 2

Root Bridge Election and Convergence Cont.

- Switch 2 and Three will then determine who should be the designated bridge for the LAN segment between them.
- Path Cost is equal so superior BID will win.
- Switch 2 has the superior BID so it will place its port as designated and switch 3 will block



Switch 2 BPDU Hello Packet
BID = sw2 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

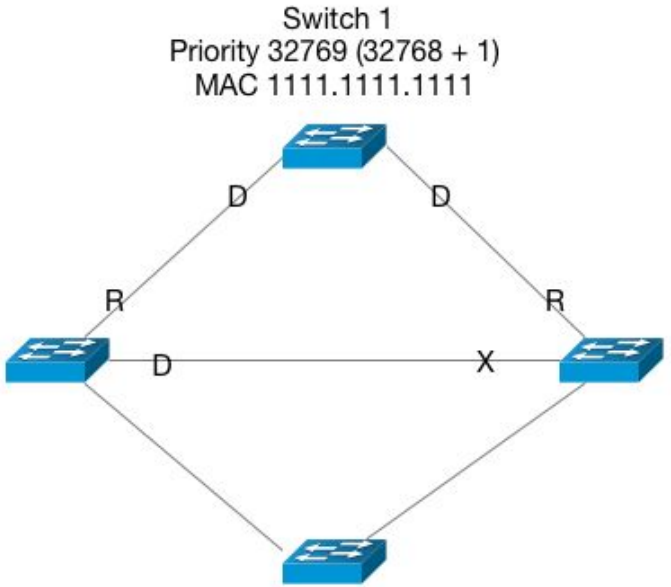
Switch 1 BPDU Hello Packet
BID = sw1 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 0

Switch 3 BPDU Hello Packet
BID = sw3 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

Root Bridge Election and Convergence Cont.

- We have now added a 4th switch with connections to switch 2 and 3.
- It will determine that Switch 1 is root in the same method described before
- The BPDU advertised by Switches 2 and 3 have identical path costs
- Root port is determined by lower BID on the BPDU. In this case 2

Root Bridge Election and Convergence Cont.



Switch 2 BPDU Hello Packet
BID = sw2 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

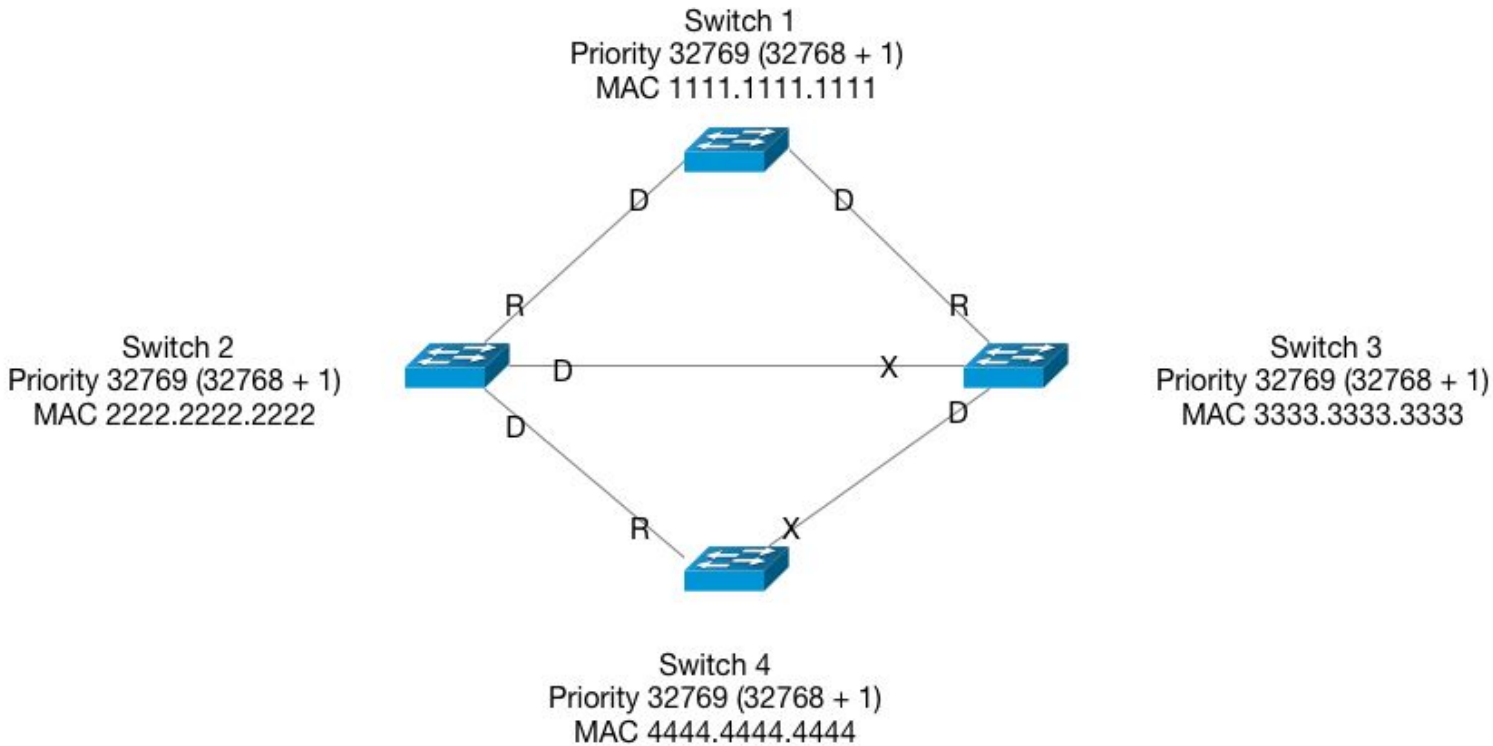
Switch 1 BPDU Hello Packet
BID = sw1 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 0

Switch 3 BPDU Hello Packet
BID = sw3 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

Root Bridge Election and Convergence Cont.

- Once Switch 4 has determined its Root Port, a negotiation takes place on the link to Switch 3 to determine who will be Designated Port for that segment.
- Switch 3 has the superior BPDU so it puts its port as Designated and Switch 4 blocks

Root Bridge Election and Convergence Cont.



Switch 2 BPDU Hello Packet
BID = sw2 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

Switch 1 BPDU Hello Packet
BID = sw1 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 0

Switch 3 BPDU Hello Packet
BID = sw3 Priority + MAC
Root BID = switch1 Priority + MAC
Root Path Cost = 2

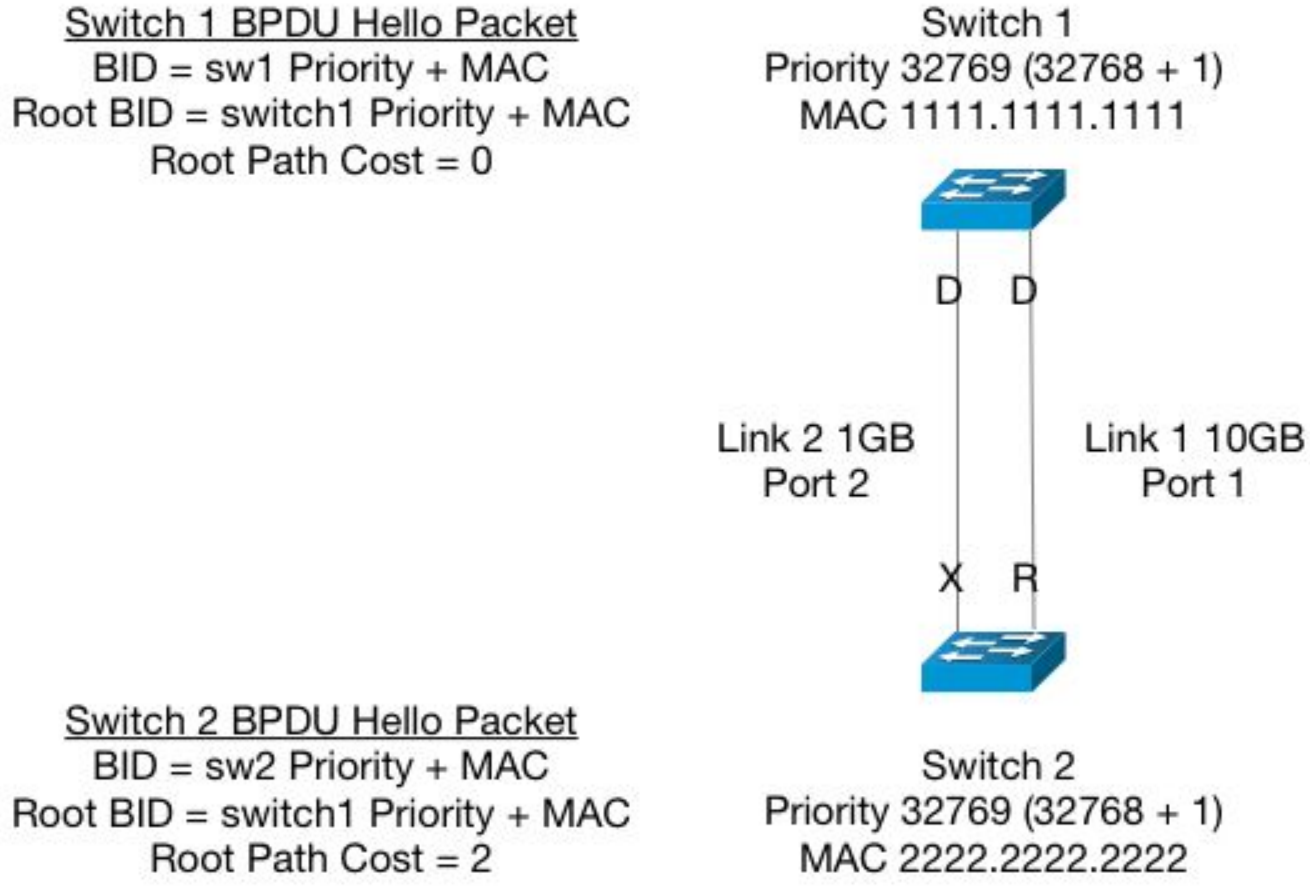
Root Bridge Election and Convergence Cont.

- In the next diagram we have added a second link between Switches 1 and 2.
- In this case the BID that is received on both ports of Switch 2 is identical.
- One port is 10GB and the other is 1GB.
- Root Port is determined by the lowest Path Cost to Root. This is determined by the bandwidth.
- Each bandwidth link is assigned a Value depending of if you are using original (short) or Long values
- The Value is assigned inbound based on port type or manual configuration.

Bandwidth (Mbits/sec)	New Value (802.1t)	Original value
10	2,000,000	100
100	200,000	19
1000	20,000	4
10,000	2,000	2

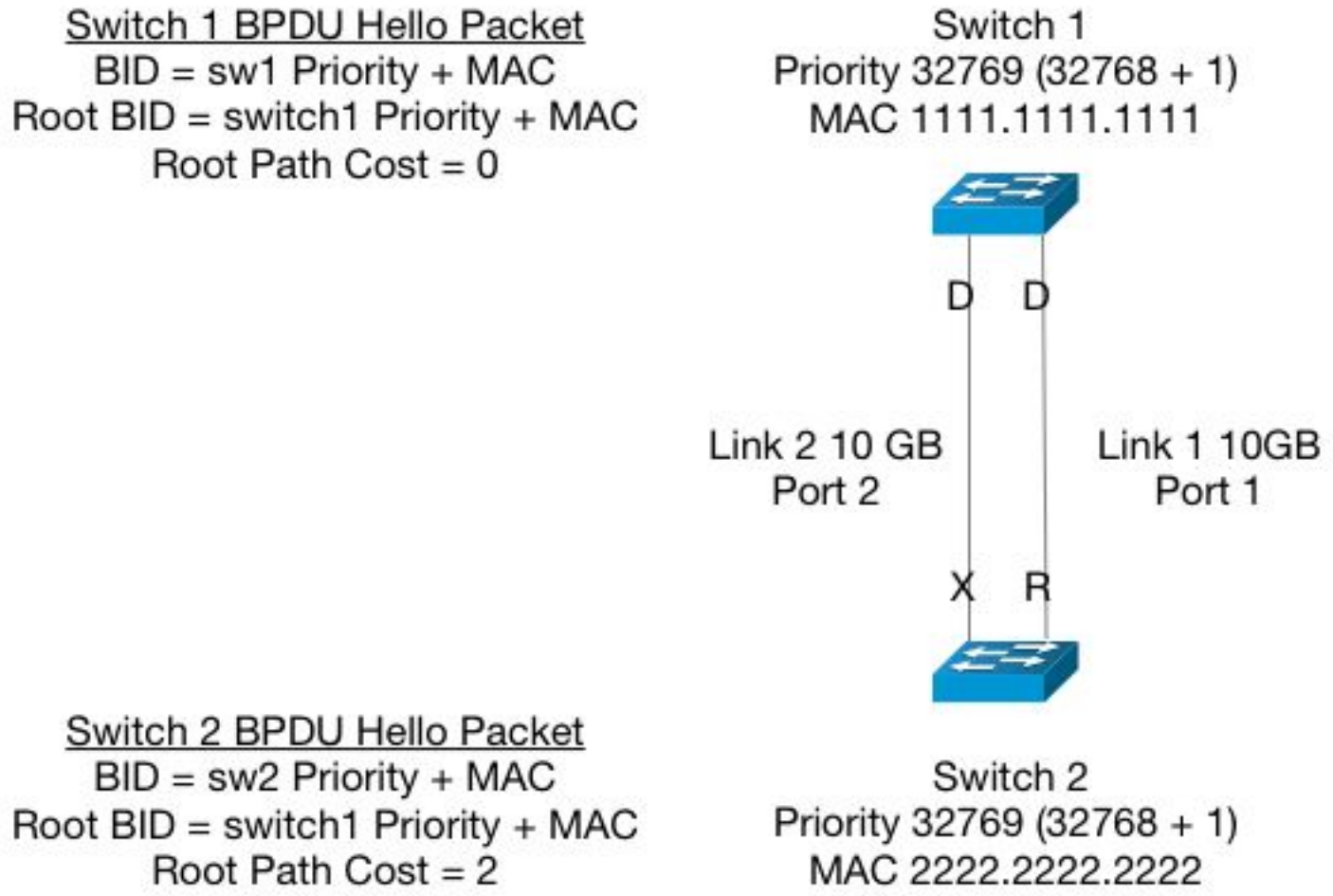
Root Bridge Election and Convergence Cont.

- Port 1 is 10GB and thus has a lower path cost to root. It will become the Root Port
- The Port 2 link goes through the normal process to determine who is Designated and who is blocking. In this case ports on the root switch are always Designated.



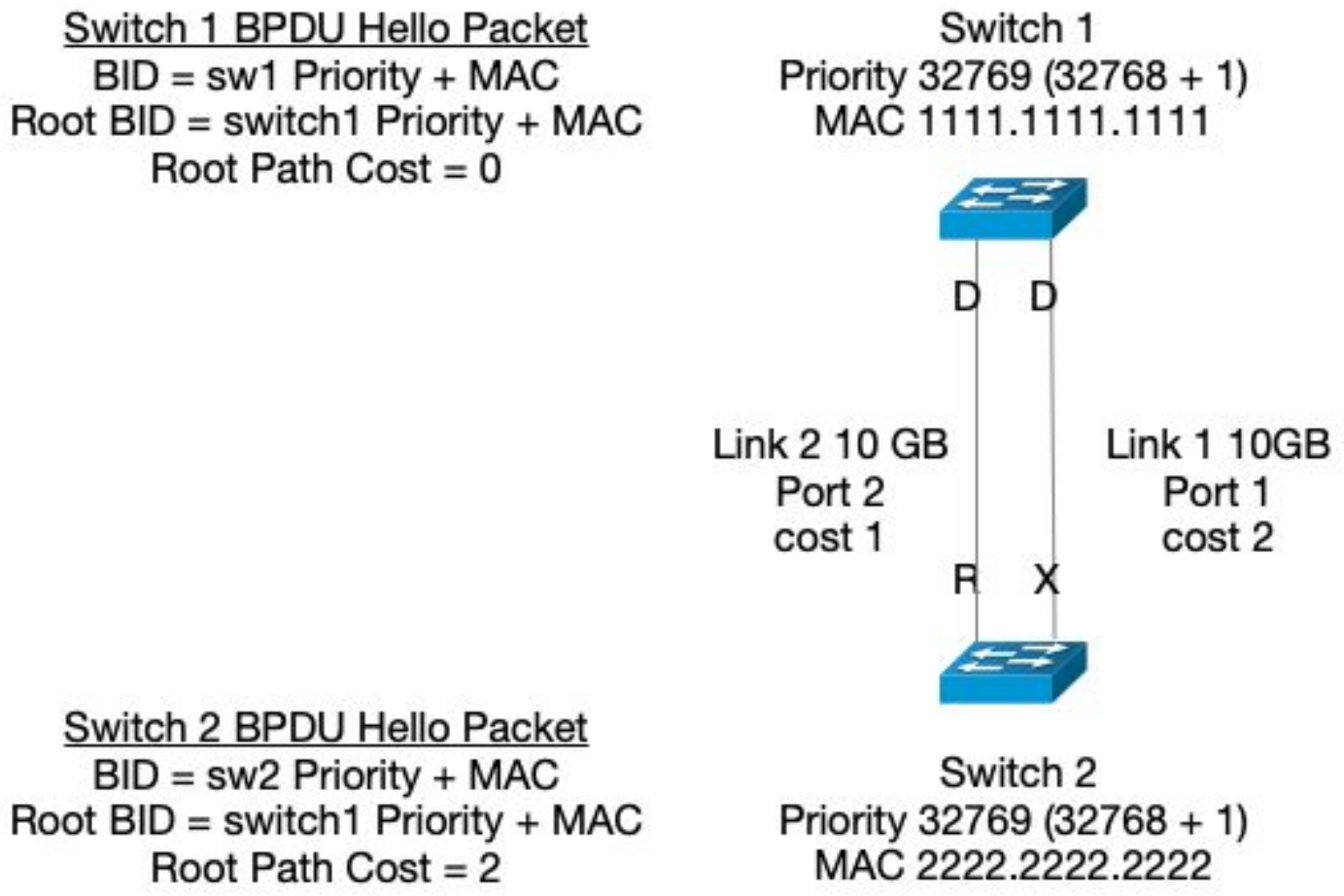
Root Bridge Election and Convergence Cont.

- In this diagram the bandwidth is the same on both links.
- BID is same
- Path Cost is the same
- To determine who should be root port STP used a Port-ID field in the BPDU to make the final deciscion.
- Lower number port wins out.
- In this case port 1 would be the root port.



Root Bridge Election and Convergence Cont.

- Path cost can be configured to control root port
- Command is “spanning-tree cost x”
- We can force port 2 to be root port by lowering the path cost to 1



Root Bridge Election and Convergence Cont.

- When a port is brought up it will go through three spanning tree states

1. Listening – This is the state the port is in while the root election is occurring. It is listening for STP BPDU this takes 15 seconds.
2. Learning – After the election process the port then learns MAC addresses that will forward on that port. This takes 15 seconds.
3. Forwarding/Blocking – Traffic either begins forwarding in the port or is blocked based on the election.

- Because of this process it can take 30 seconds for a port to being forwarding traffic after being brought into service.
- This can cause issues with protocols such as DHCP or workstations that download their image upon boot

Root Bridge Election and Convergence Cont.

- To remedy the problem from the previous slide there is a spanning tree enhancement that allows a port to go immediately forwarding when brought up.
- The enhancement is called spanning tree portfast.
- This is configured on an interface level with the command:

Switch(config-if)#spanning-tree portfast

- This feature should never be configured on a connection to a bridge device (switch, hub etc)
- Because it bypasses the regular spanning tree process it can cause loops
- Only configure this on ports connected to end workstations

Root Bridge Election and Convergence Summary

- Root Bridge is the bridge with the lowest Bridge ID, which consists of Bridge priority and MAC address.

- After the Root Bridge is Elected ports will transition into one of three roles:

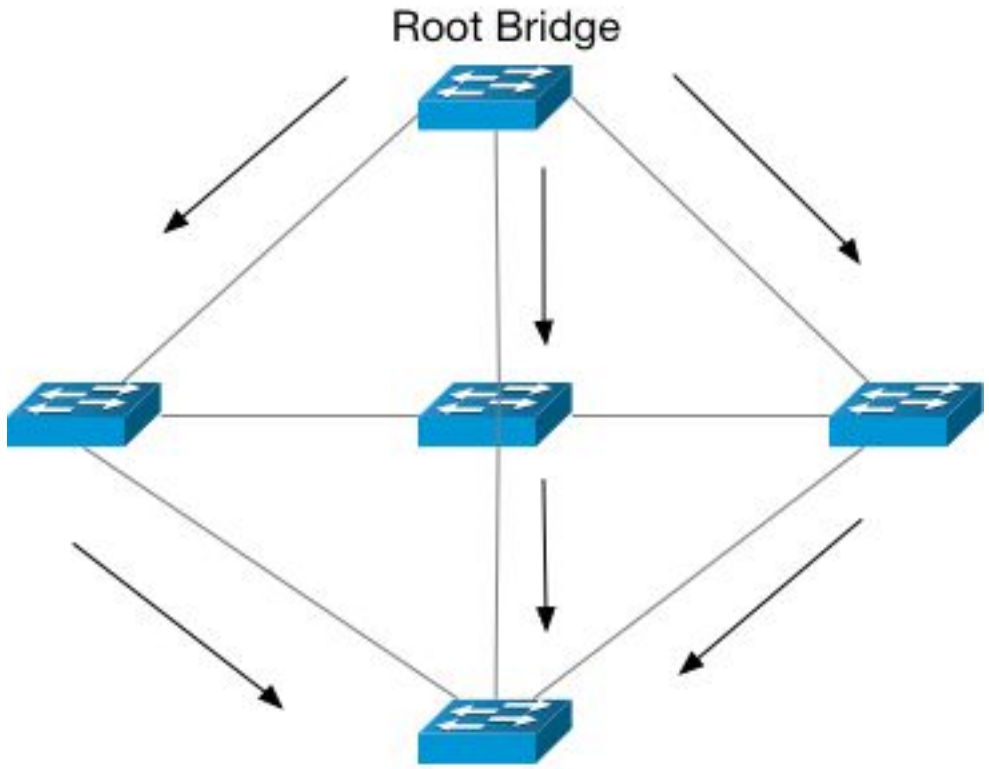
1. Root Port – Lowest path cost to the root bridge
2. Designated Port – Access to the root for a LAN segment
3. Blocked Port – Redundant path

- Bridge ID being the same the path to root is determined by

1. Lowest path cost to root
2. Lowest Port-ID

BPDU flow steady state

- Root Bridge generates all BPDU
- Each bridge as it receives the BPDU will adjust the Cost and forward it out all Designated ports
- The Bridge will not forward out Root Ports or Blocking ports i.e. any port where it expects to receive BPDU



Spanning Tree Summary

- These slides show the basics of spanning tree operations and spanning tree configuration.
- To learn more go to:

https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst2960/software/release/12-2_53_se/configuration/guide/2960scg/swstp.html#93510