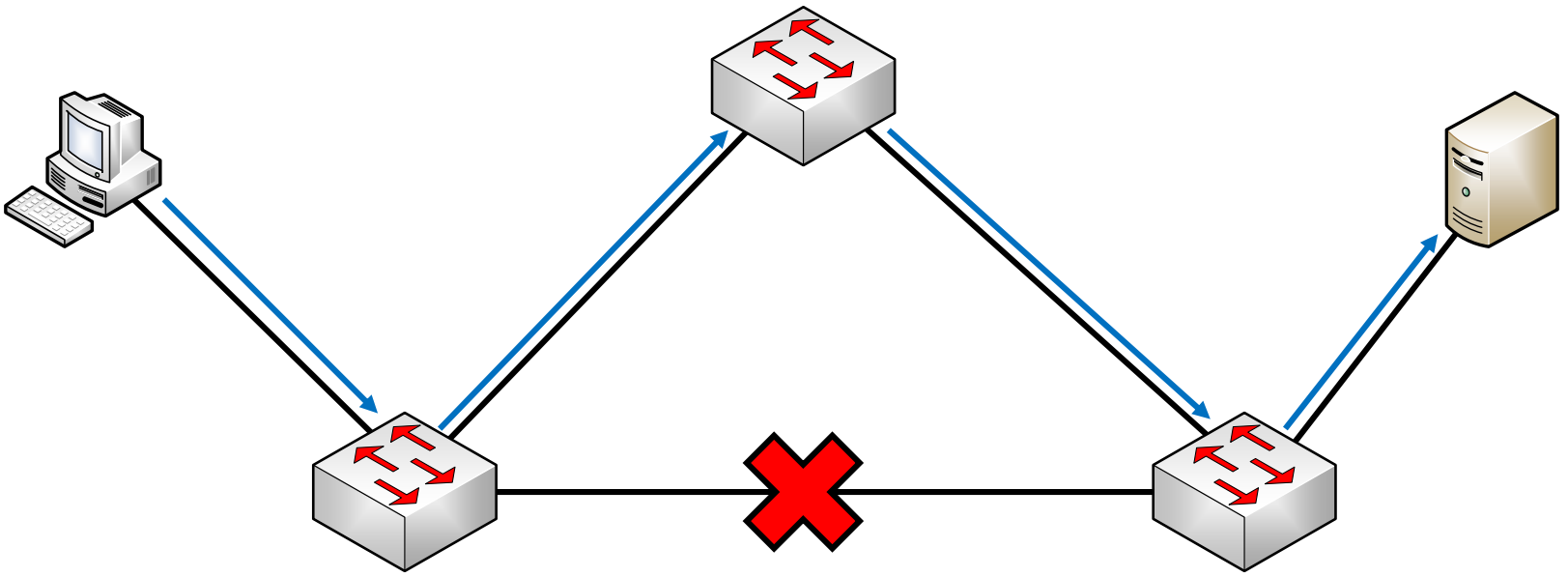
Medium-Sized Switched Network Construction

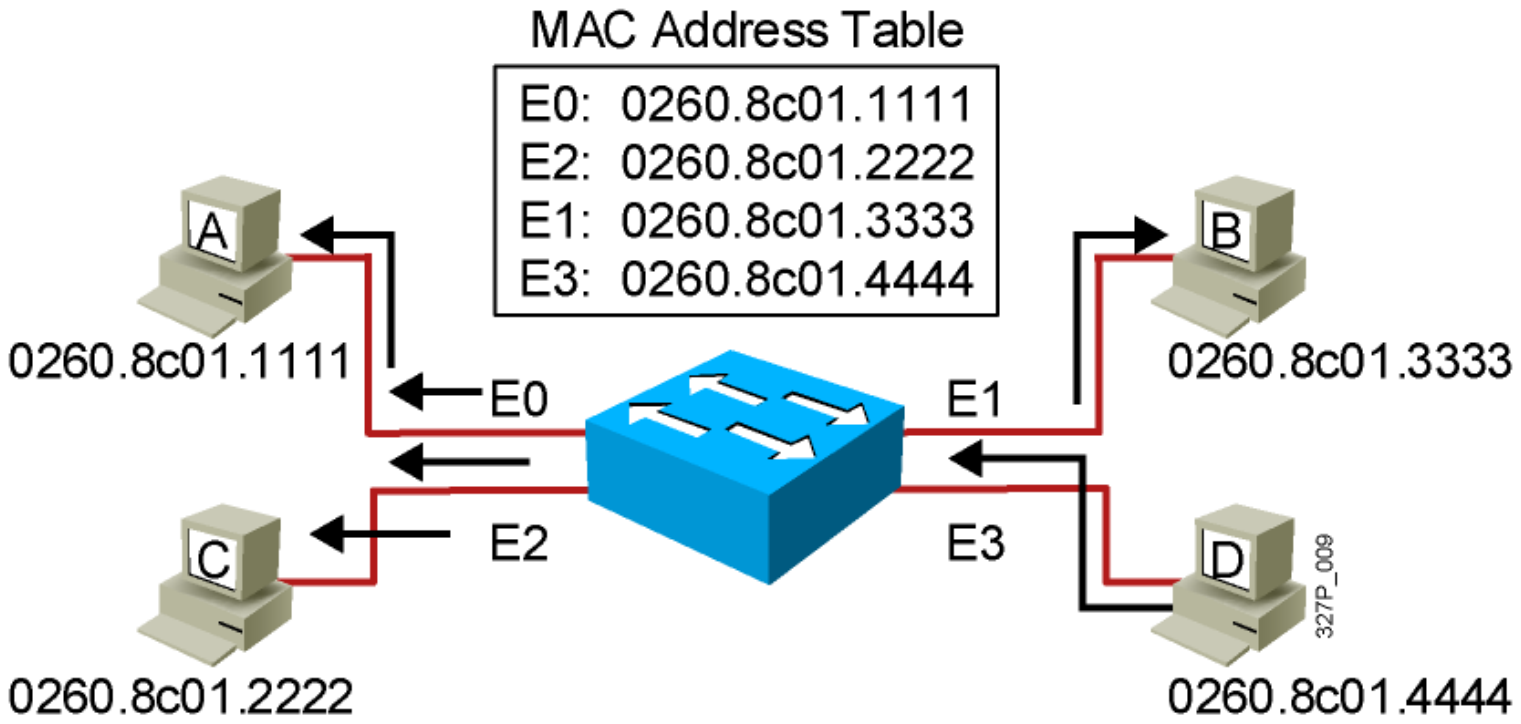
Improving Performance with Spanning Tree

Redundant Topology



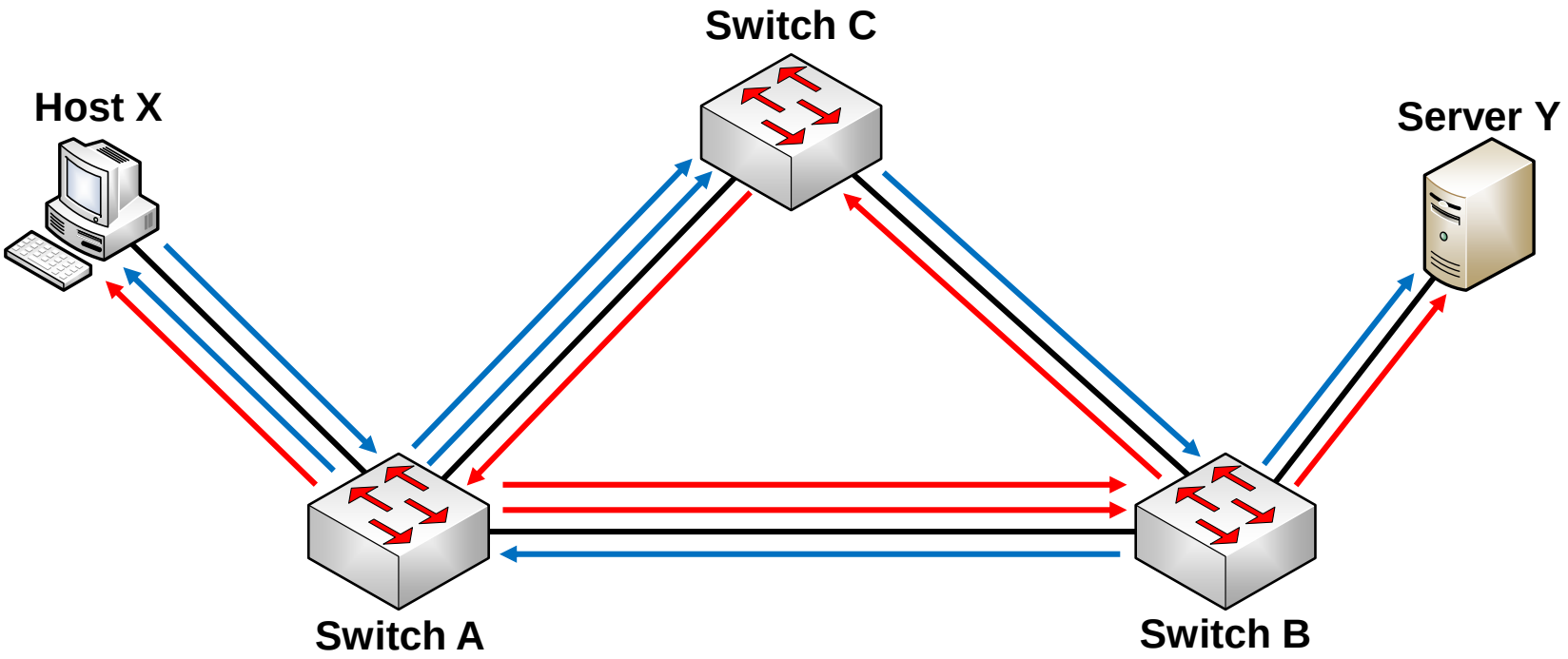
- Redundant topology eliminates single points of failure.
- Redundant topology causes broadcast storms, multiple frame copies, and MAC address table instability problems.

Broadcast Frames



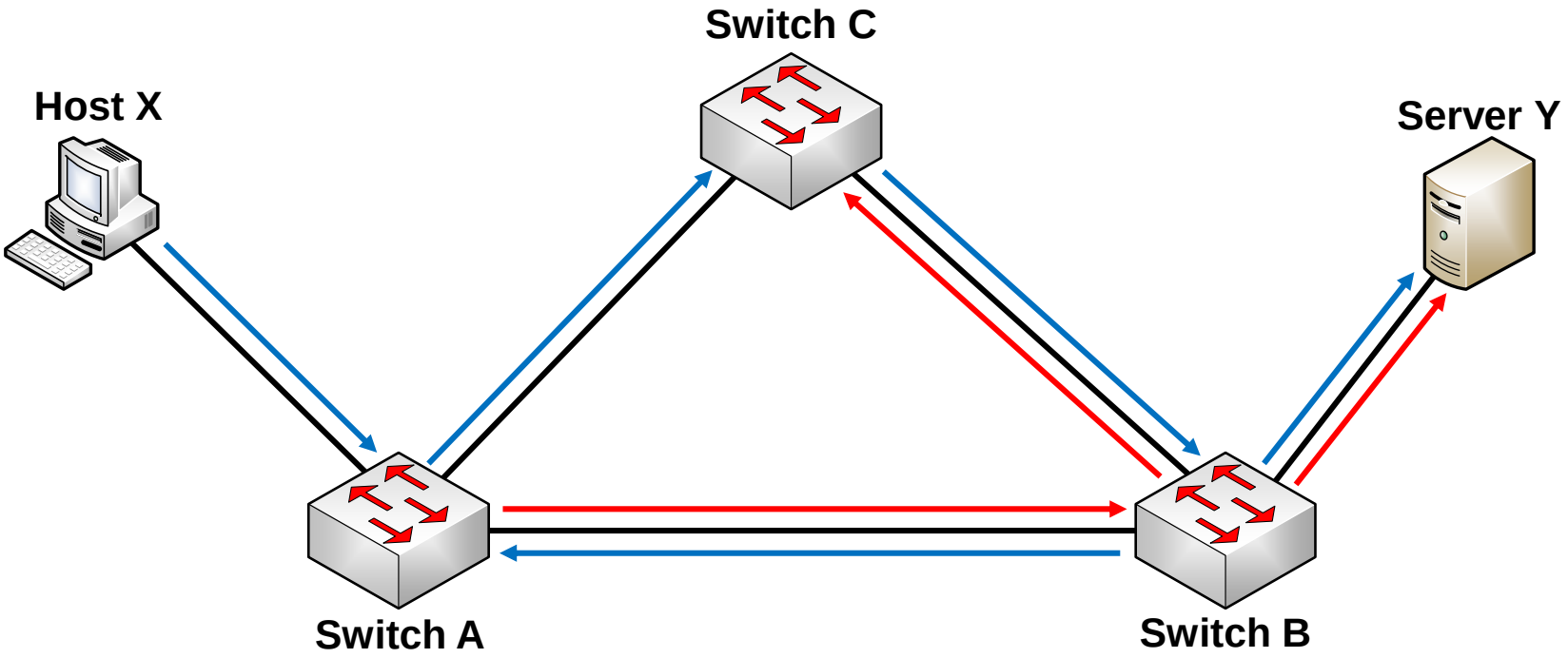
- Station D sends a broadcast frame.
- Broadcast frames are flooded to all ports except the originating port.

Broadcast Storms



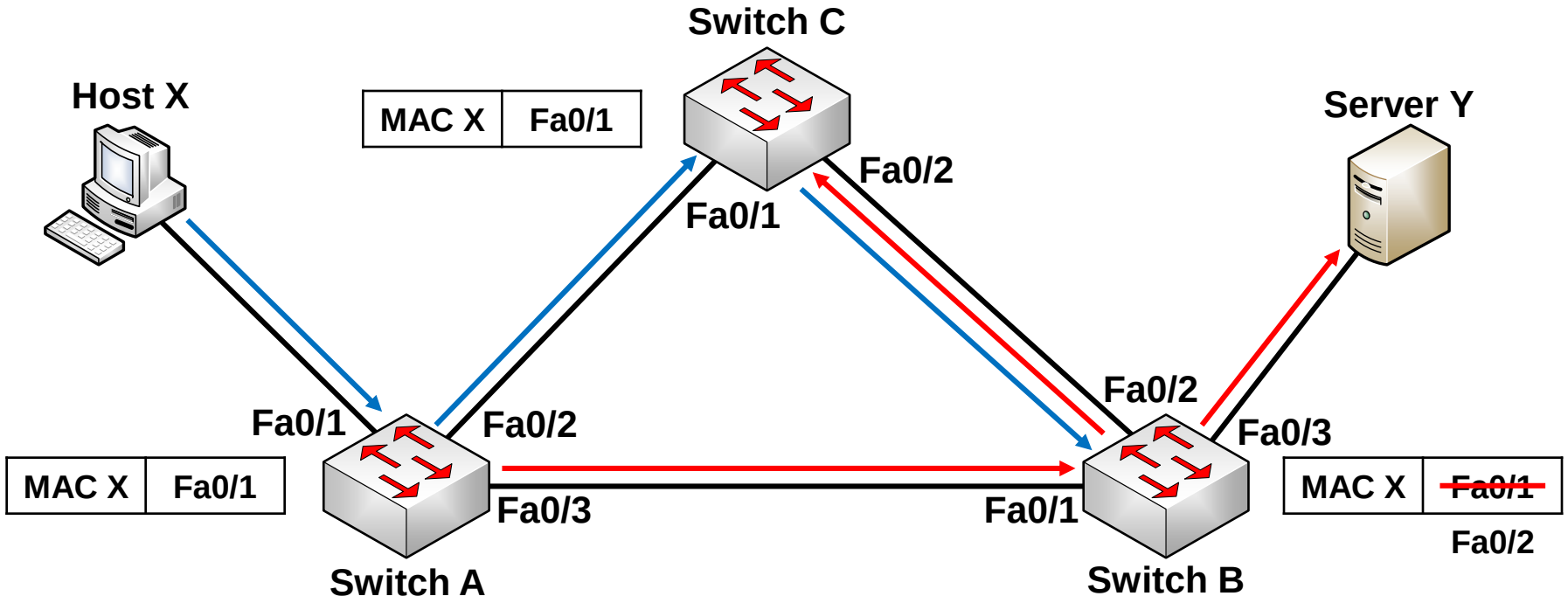
- Host X sends a broadcast.
- Switches continue to propagate broadcast traffic over and over.

Multiple Frame Copies



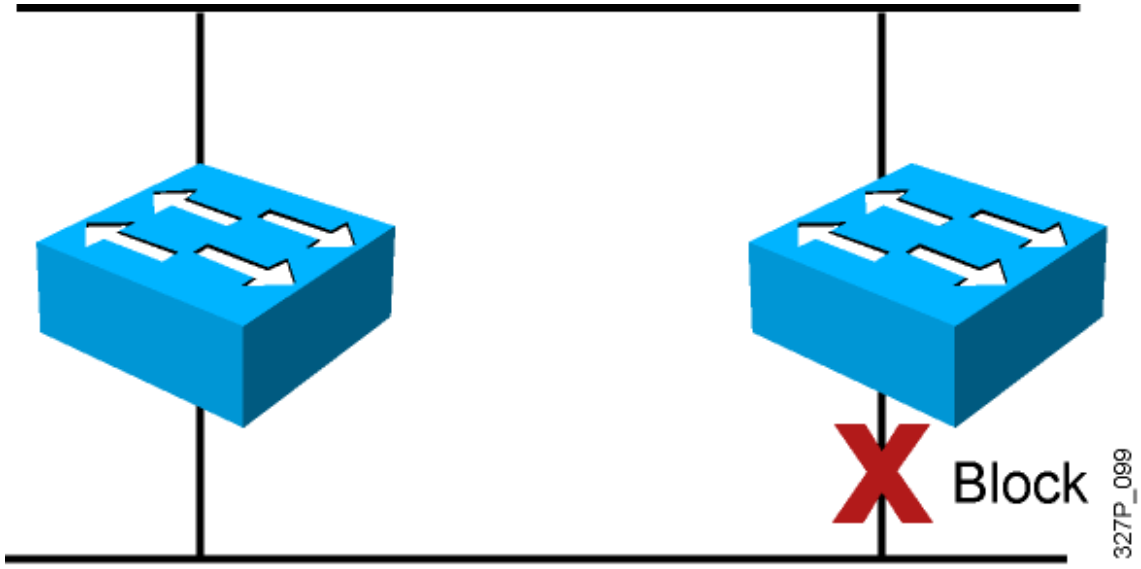
- Host X sends a unicast frame to Server Y.
- The MAC address of Server Y has not been learned by either switch.
- Server Y will receive two copies of the same frame.

MAC Database Instability



- Host X sends a unicast frame to Server Y.
- The MAC address of Server Y has not been learned by either switch.
- Switches B learn the MAC address of host X on port Fa0/1.
- Switches B then learn the MAC address of host X on port Fa0/2.
- MAC Address Flapping.

Loop Resolution with STP



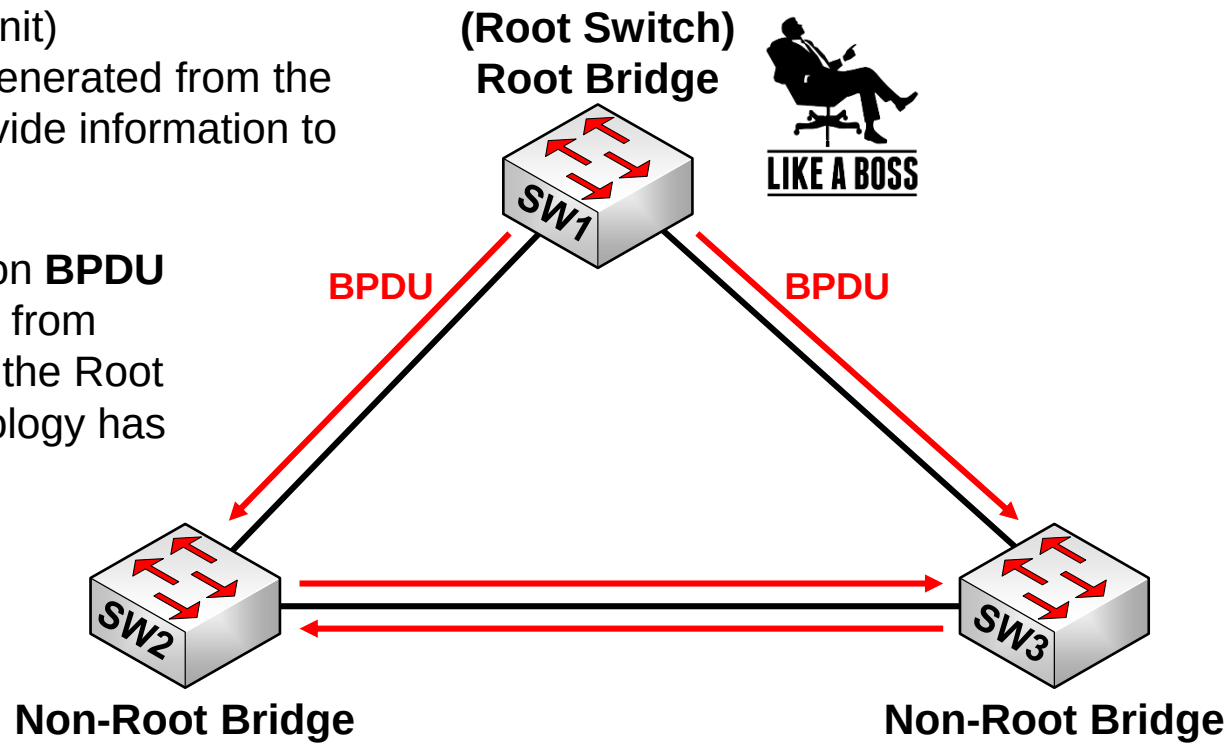
- STP (Spanning Tree Protocol)
- Provides a loop-free redundant network topology by placing certain ports in the blocking state
- Published in the IEEE 802.1D specification
- Enhanced with the Cisco PVST+ implementation

Spanning-Tree Operation (Step 1)

1. Elects one **Root Bridge** (one root bridge per broadcast domain)
   - **Root Bridge** = lowest **Bridge ID**
   - **All ports on Root Bridge** are **Designated Ports (DP)**

BPDU (**B**ridge **P**rotocol **D**ata **U**nit)

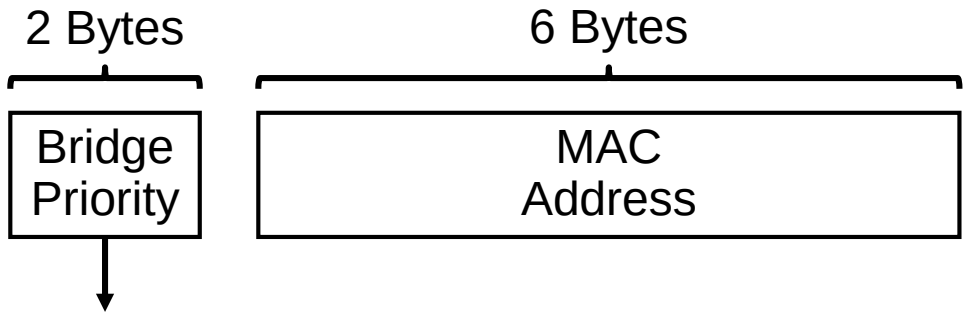
- **Configuration BPDU** are generated from the Root Bridge, in order to provide information to all switches.
- **T**opology **C**hange **N**otification **BPDU** (**TCN BPDU**) are generated from Non-Root Bridges to inform the Root Bridge that the network topology has changed.
- By default the BPDUs are sent every 2 seconds.

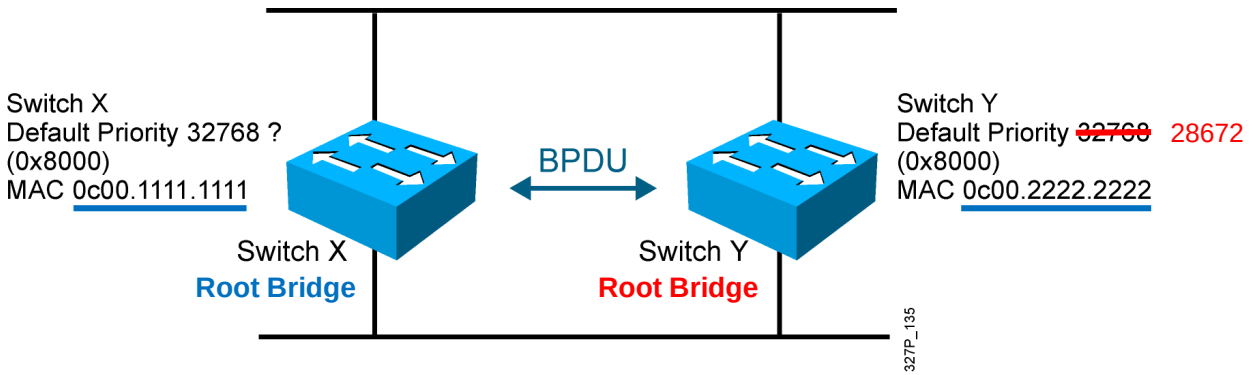


Spanning-Tree Operation (Step 1 - Cont.)

1. Elects one **Root Bridge** (one root bridge per broadcast domain)
   - **Root Bridge** = lowest **Bridge ID**
   - **All ports on Root Bridge** are **Designated Ports (DP)**

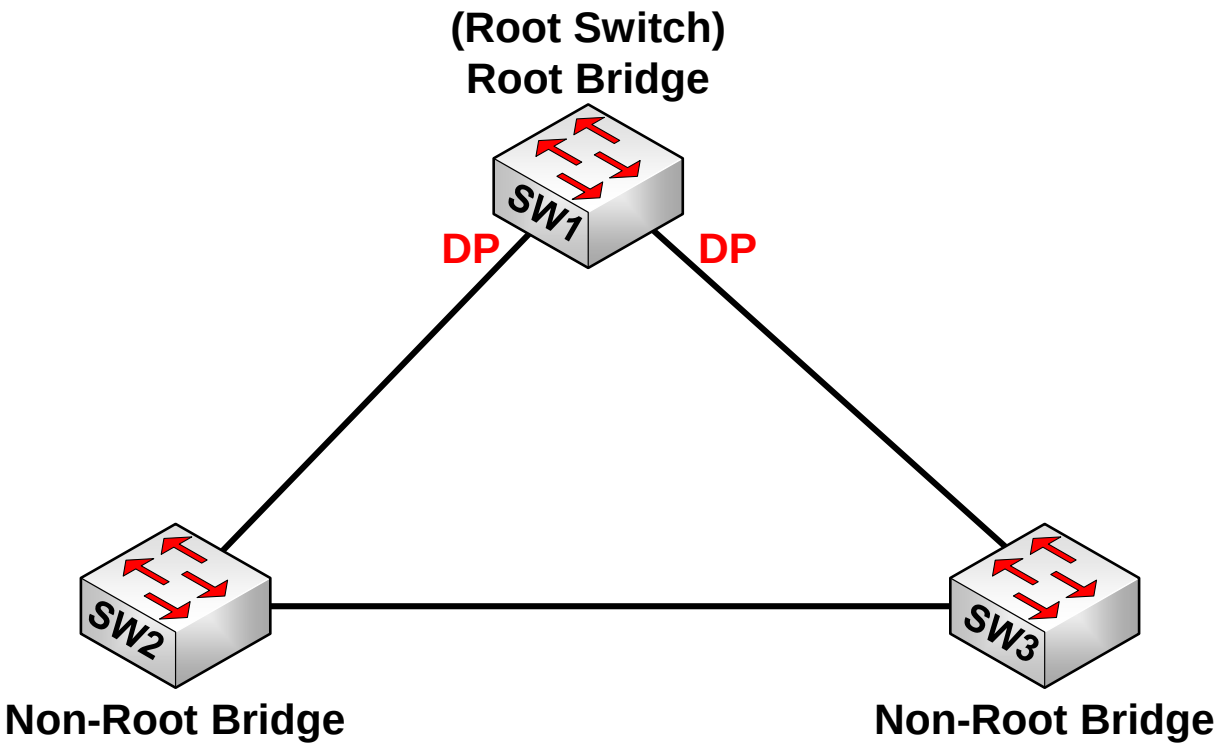
- Bridge ID (BID) is used to identify each switch.
- Bridge ID =





Spanning-Tree Operation (Step 1 - Cont.)

1. Elects one **Root Bridge** (one root bridge per broadcast domain)
   - **Root Bridge** = lowest **Bridge ID**
   - **All ports on Root Bridge** are **Designated Ports (DP)**



Spanning-Tree Operation (Step 2)

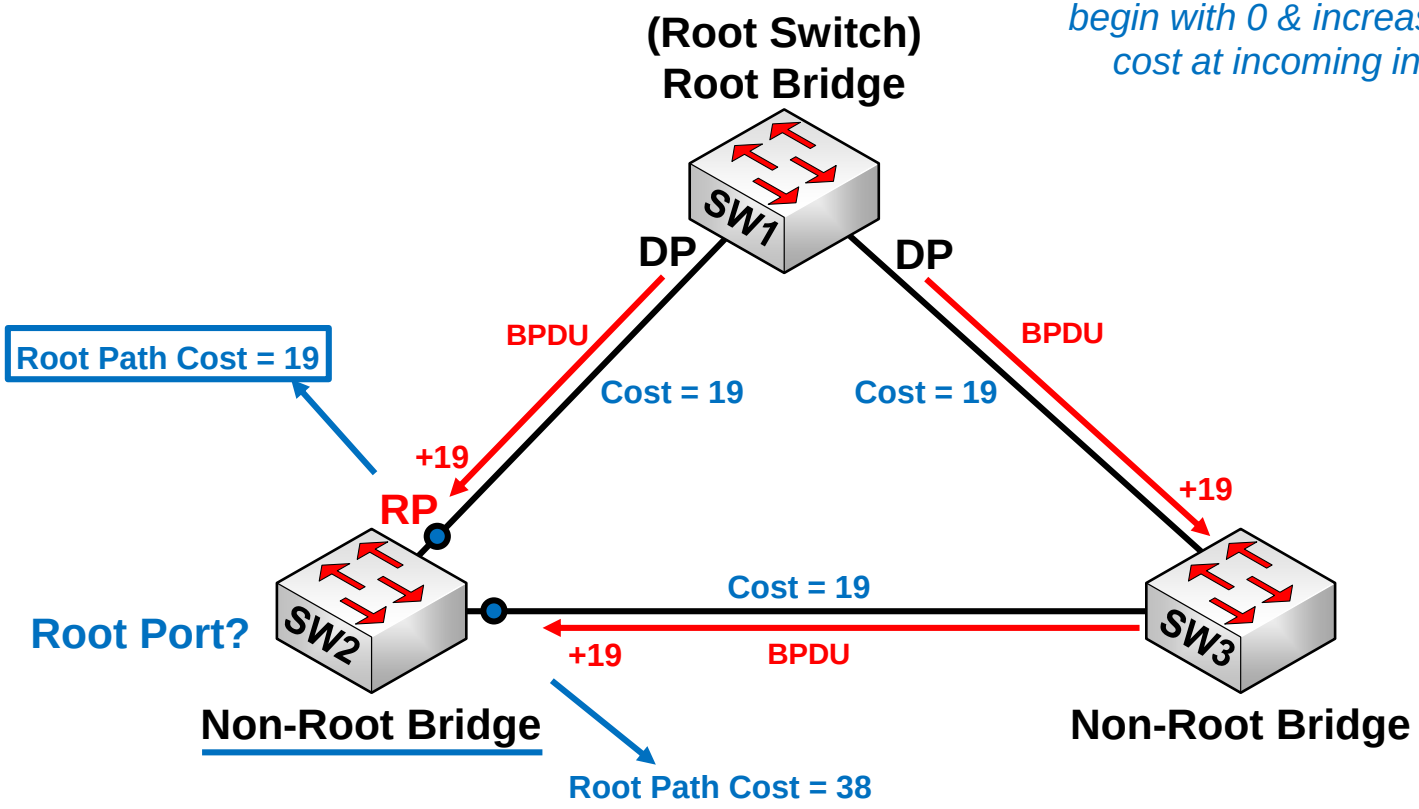
2. Selects **one root port (RP)** on **each non-root bridge**
   - **Root port** = port with **lowest Root Path Cost** (sum of the costs from the non-root bridge to the root bridge)

Link Type	Link Speed	Cost (Revised IEEE Specification)	Cost (Previous IEEE Specification)
10 GigabitEthernet	10 Gb/s	2	1
GigabitEthernet	1 Gb/s	4	1
FastEthernet	100 Mb/s	19	10
Ethernet	10 Mb/s	100	100

Spanning-Tree Operation (Step 2 - Cont.)

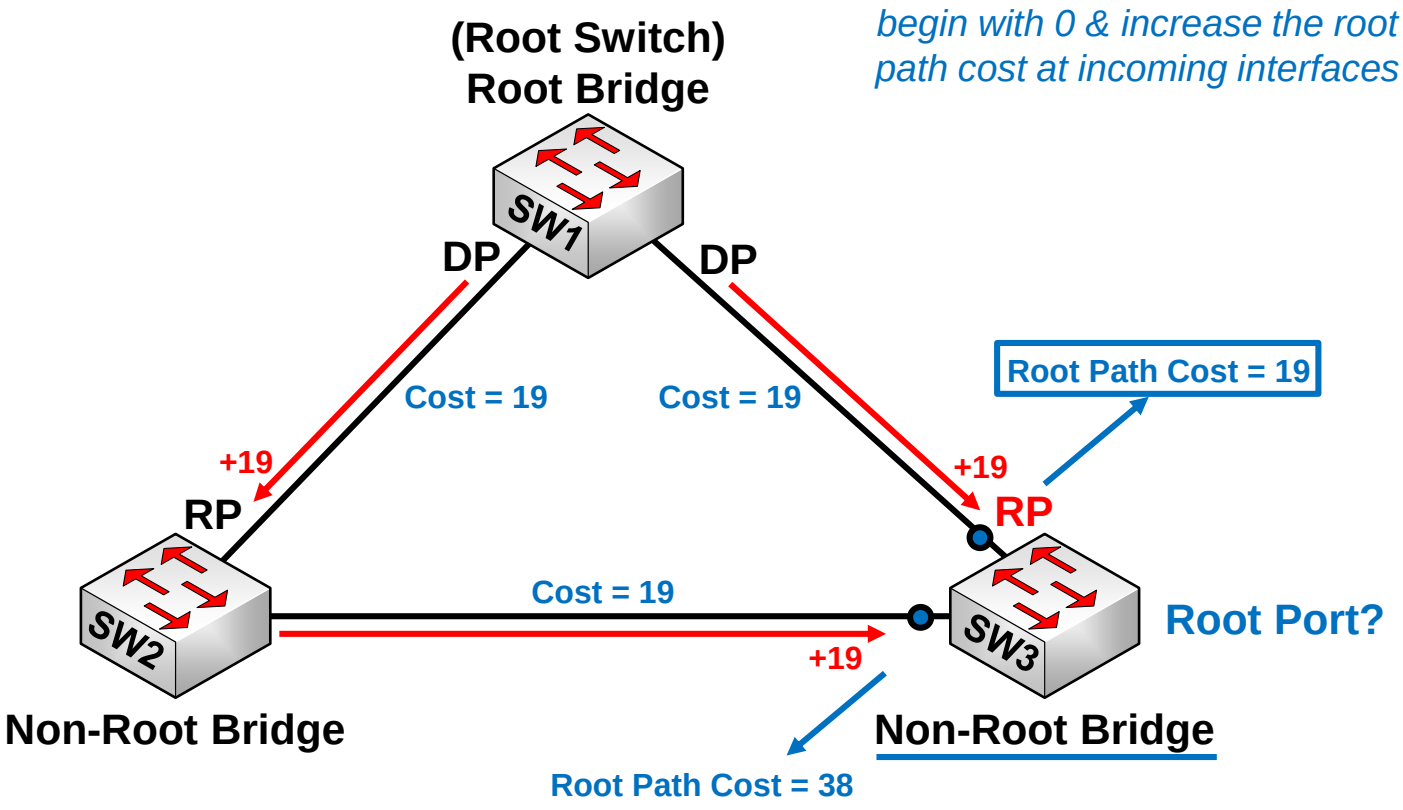
2. Selects **one root port (RP)** on **each non-root bridge**
   - **Root port** = port with **lowest Root Path Cost** (sum of the costs from the root bridge to the non-root bridge)

begin with 0 & increase the path cost at incoming interfaces



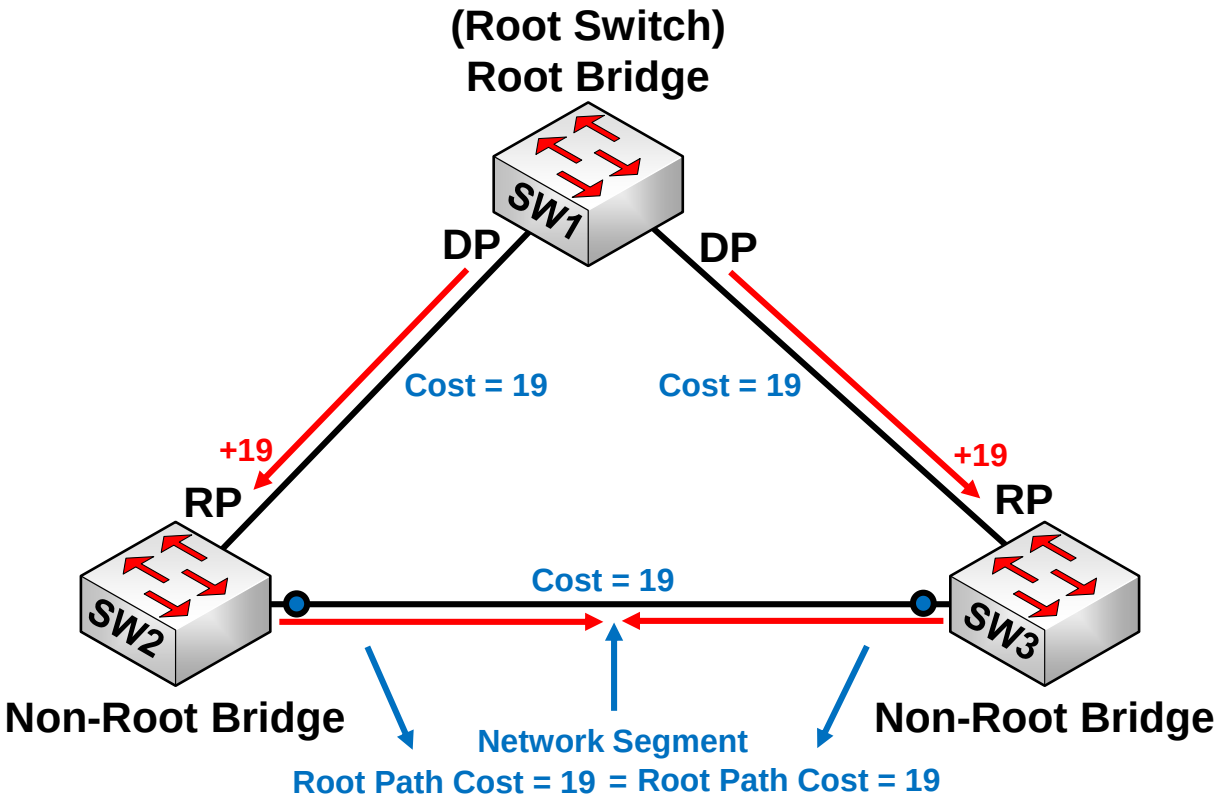
Spanning-Tree Operation (Step 2 - Cont.)

2. Selects **one root port (RP)** on **each non-root bridge**
   - **Root port** = port with **lowest Root Path Cost** (sum of the costs from the root bridge to the non-root bridge)



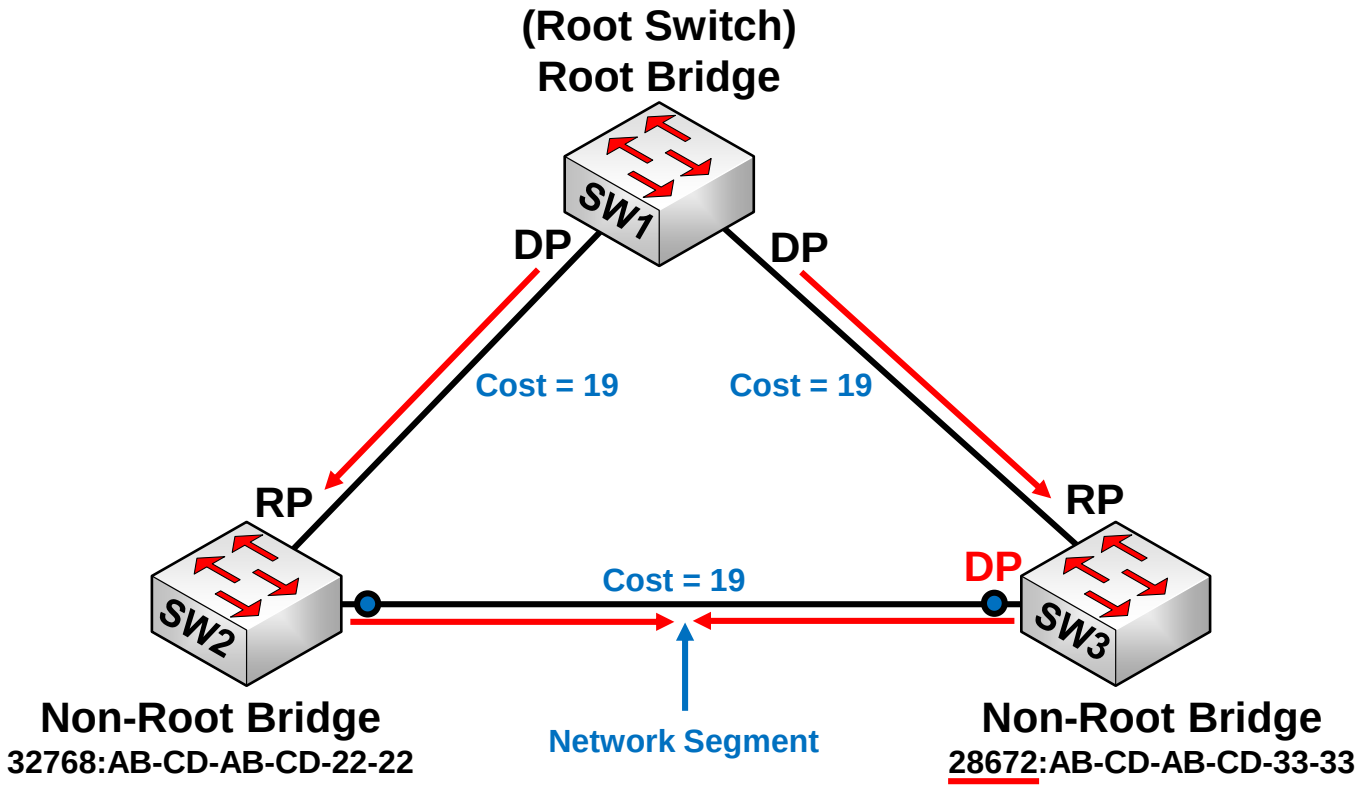
Spanning-Tree Operation (Step 3)

3. **One designated port** on **each network segment**
   - **Designated port = port on the bridge** that has the **lowest Root Path Cost**
   - **Tiebreaker: Sender Bridge ID**



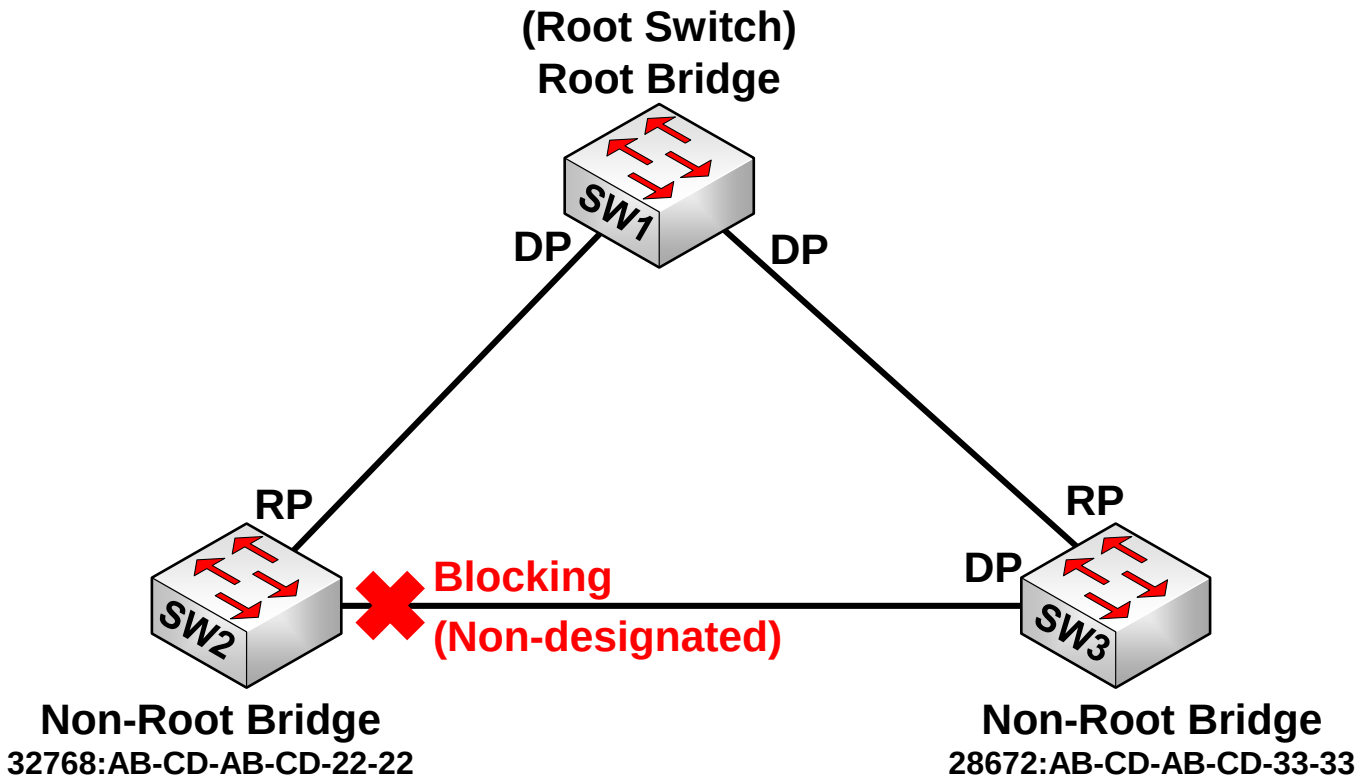
Spanning-Tree Operation (Step 3 - Cont.)

3. **One designated port** on **each network segment**
   - **Designated port** = **port on the bridge** that has the **lowest Root Path Cost**
   - **Tiebreaker: Sender Bridge ID**



Spanning-Tree Operation (Step 4)

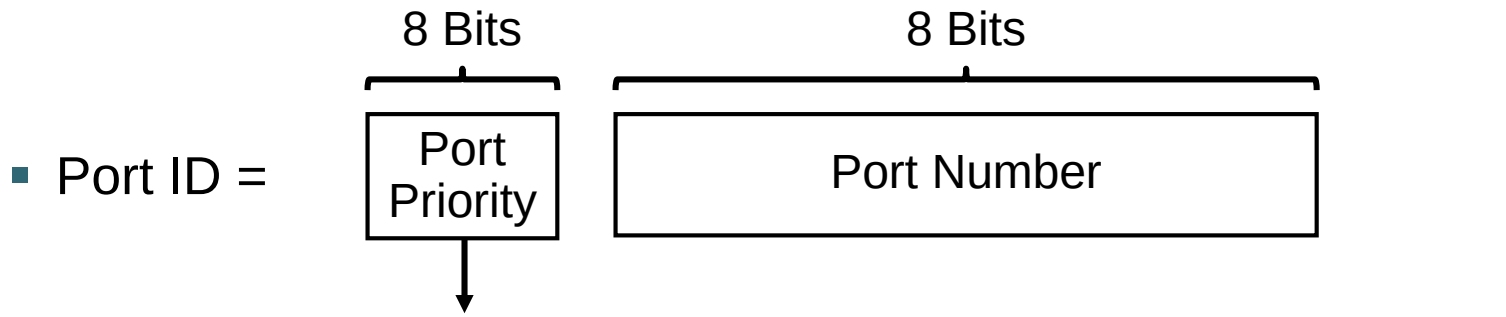
4. Non-designated ports are unused

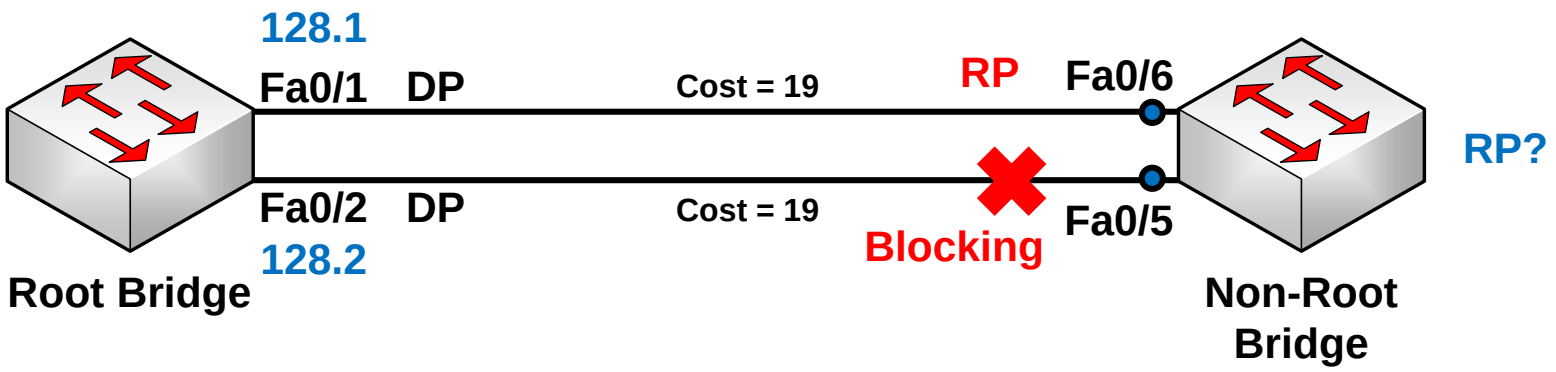


Spanning-Tree Operation (Port-ID)

Equal Sender Bridge ID? → the next tiebreaker will be

- **Sender Port ID**

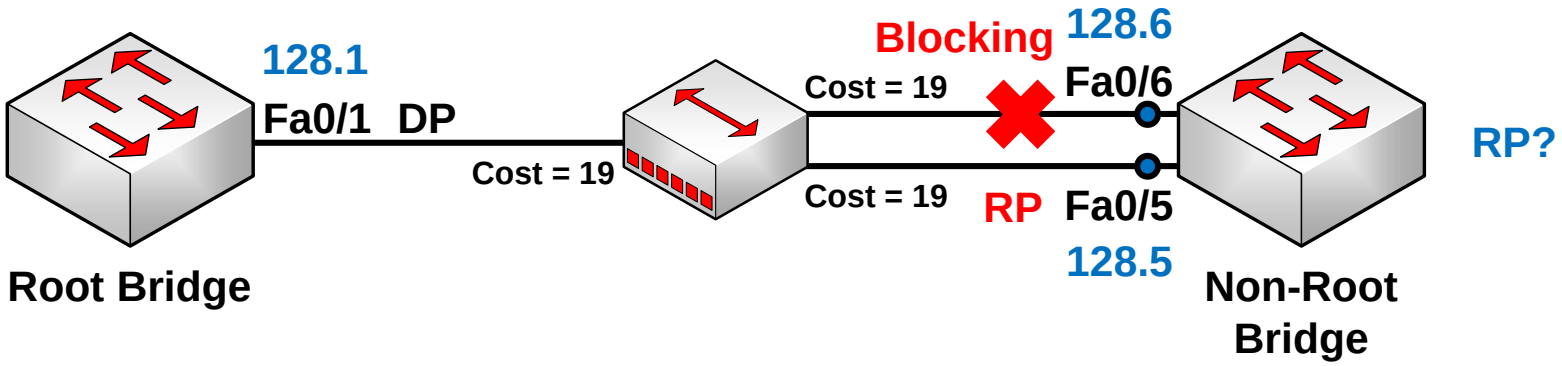




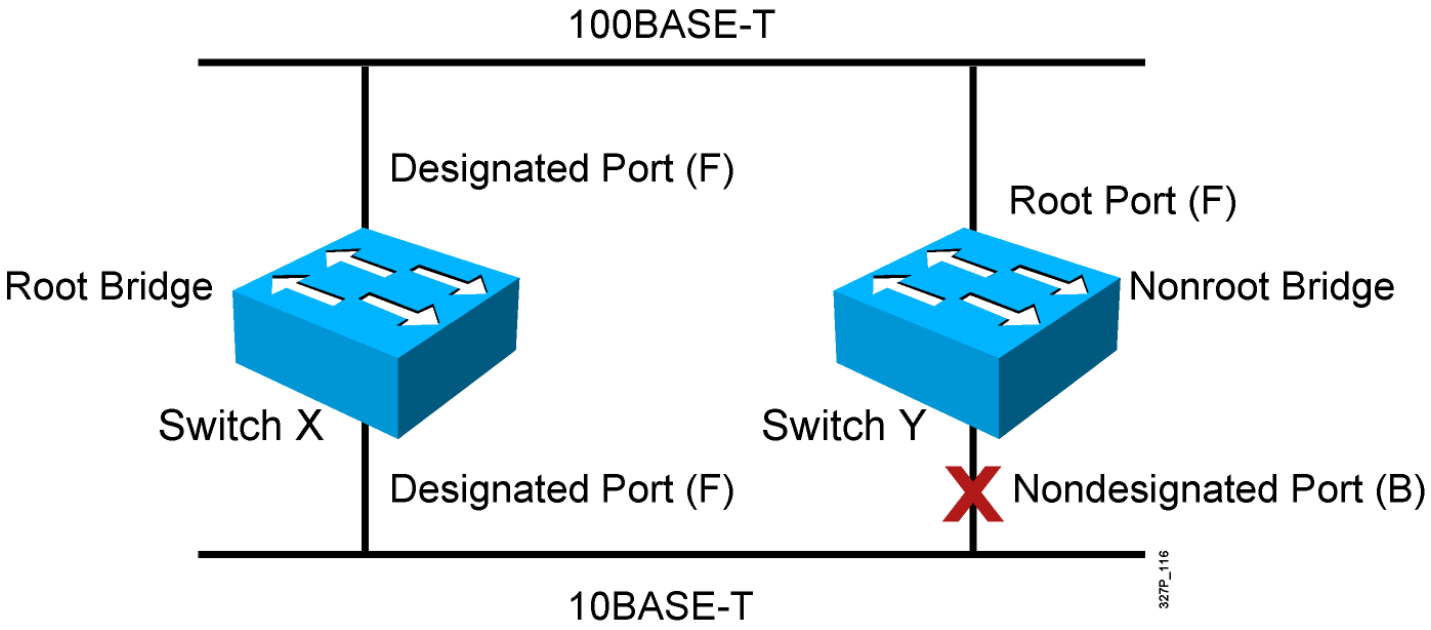
Spanning-Tree Operation (Port-ID - Cont.)

Equal Sender Port ID? → the next tiebreaker will be

- **Local Port ID**



Spanning-Tree Operation (Cont.)



- One root bridge per broadcast domain.
- One root port per non-root bridge.
- One designated port per segment.
- Non-designated ports are unused.

Spanning-Tree Operation (Summary)

- BID: (Priority+MAC)
- Port-ID: (Priority+Port Number)

1. Root Bridge (BID_{min}) → DP
2. RP (Root Path Cost)
3. DP (Root Path Cost)
4. Block ports

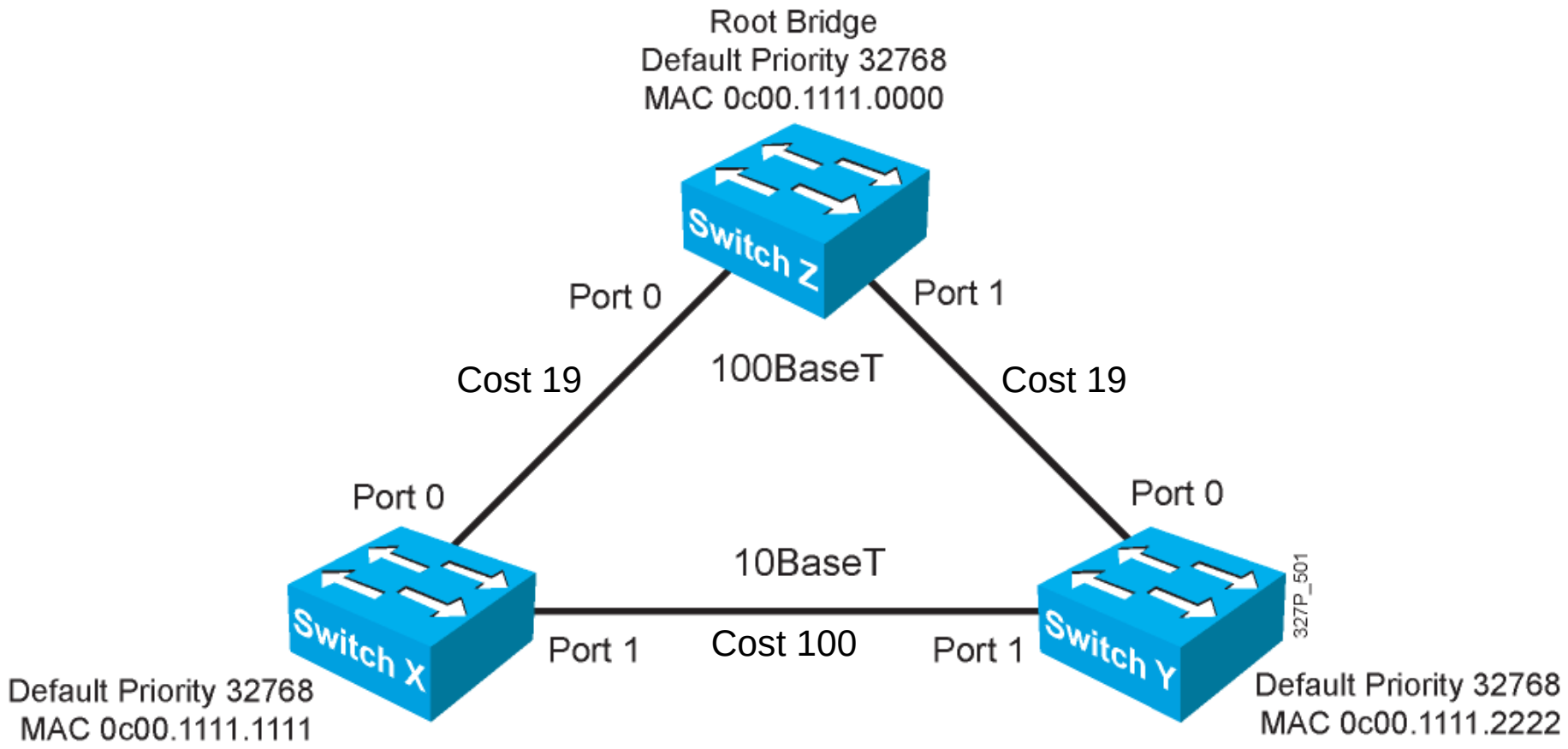
❖ TIE-BREAKER:
- Root Path Cost
- Sender Bridge-ID
- Sender Port-ID
- Local Port-ID

1. **ROOT BRIDGE ELECTION**
   - Root Bridge = lowest Bridge-ID (Bridge Priority + MAC Address)
   - All ports on Root Bridge are DP (Designated Ports)
   - *Notes: only one Root Bridge per broadcast domain*
2. **ROOT PORT ELECTION *(ON NON-ROOT BRIDGES)***
   - RP (Root Port) = port with lowest Root Path Cost
   - *Notes: only one Root Port per Non-root Bridge*
3. **DESIGNATED PORT ELECTION *(FOR EACH NETWORK SEGMENT)***
   - DP (Designated Port) = port with lowest Root Path Cost
   - *Notes: if one side of a network segment is RP → other side will be DP*
4. **BLOCK ALL NON-ROOT & NON-DESIGNATED PORTS**

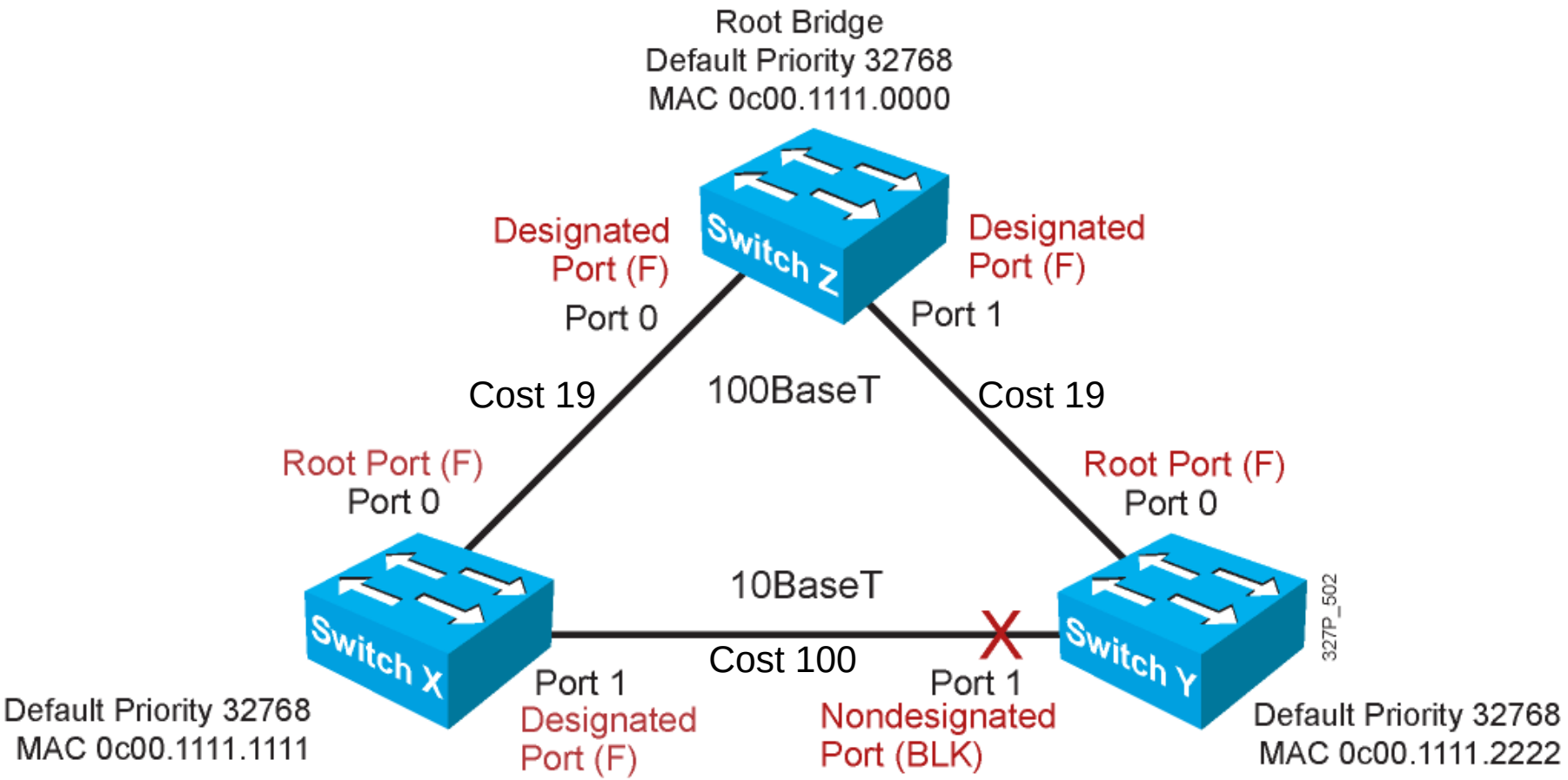
❖ **EXTRA TIE-BREAKER FOR ROOT PATH COST**
- Sender Bridge-ID
- Sender Port-ID (Port Priority + Port Number)
- Local Port-ID (Port Priority + Port Number)

Spanning-Tree Example

100BaseT → FastEthernet → Cost = 19
10BaseT → Ethernet → Cost = 100



Spanning-Tree Example (Cont.)



Spanning-Tree Exercise 1

Question: Root Switch?

Spanning-Tree Exercise 1 (Cont.)

Question: Root Switch?

Answer: SW2

Spanning-Tree Exercise 2

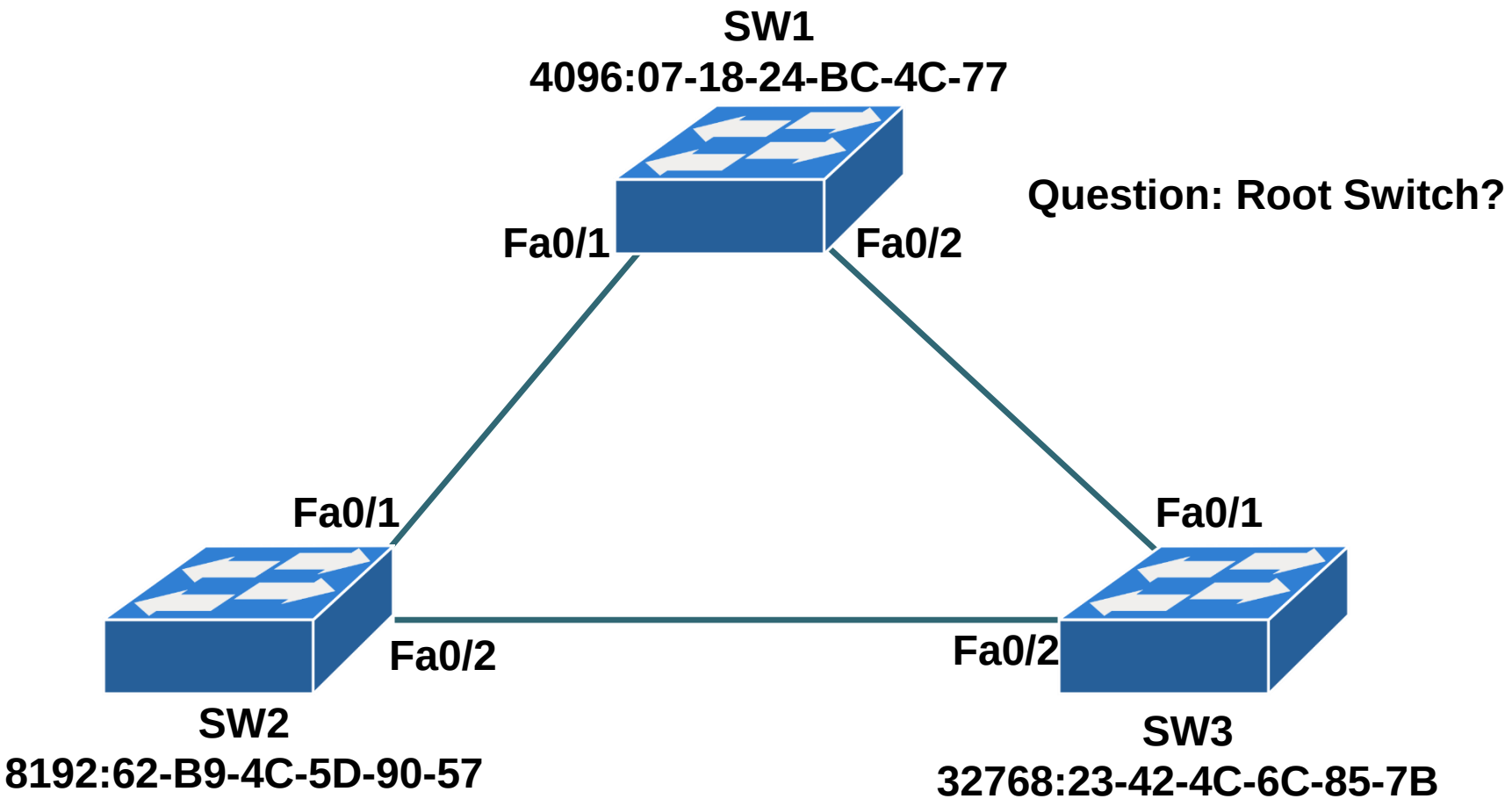
Question: Root Switch?

Spanning-Tree Exercise 2 (Cont.)

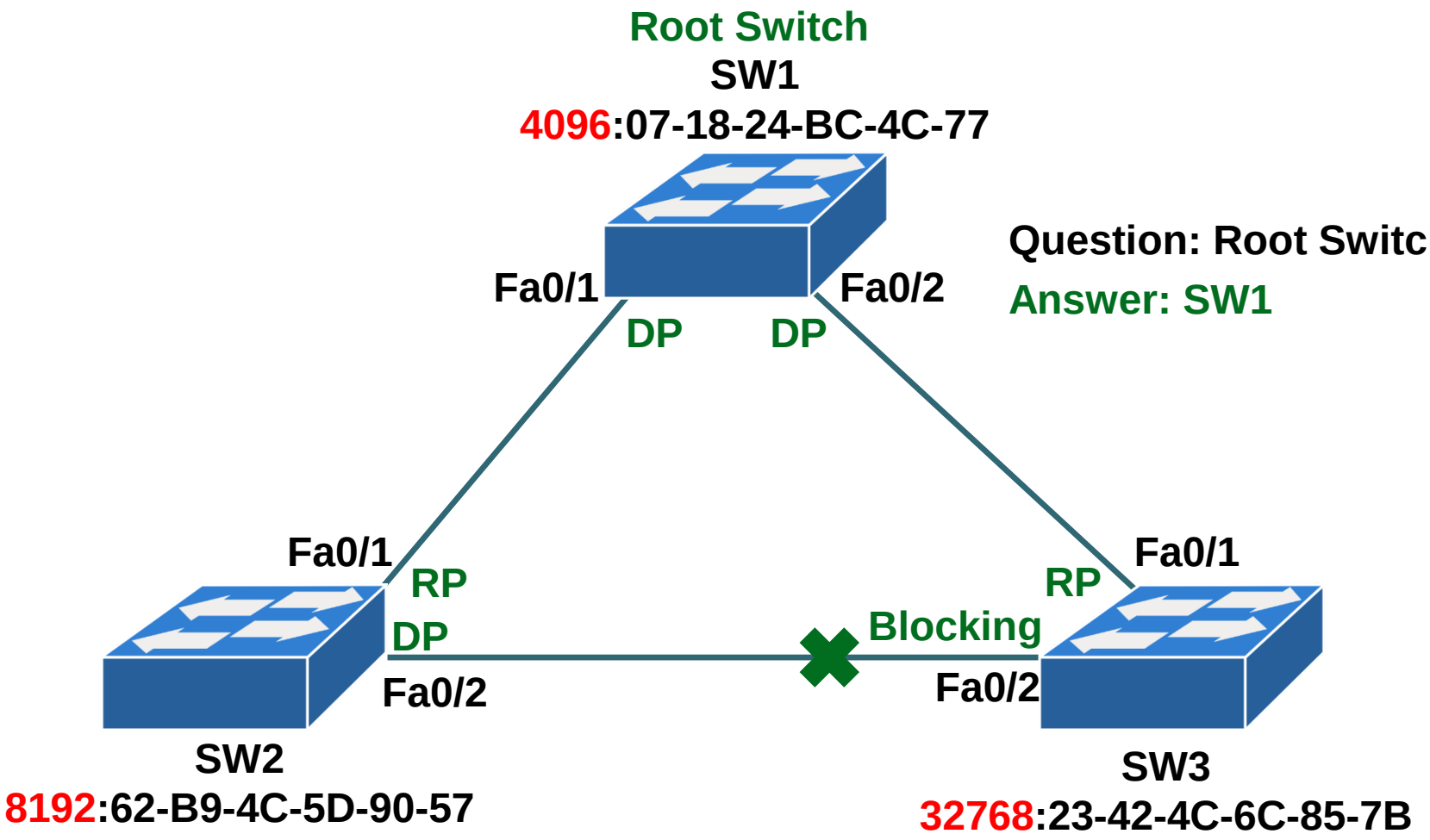
Question: Root Switch?

Answer: SW1

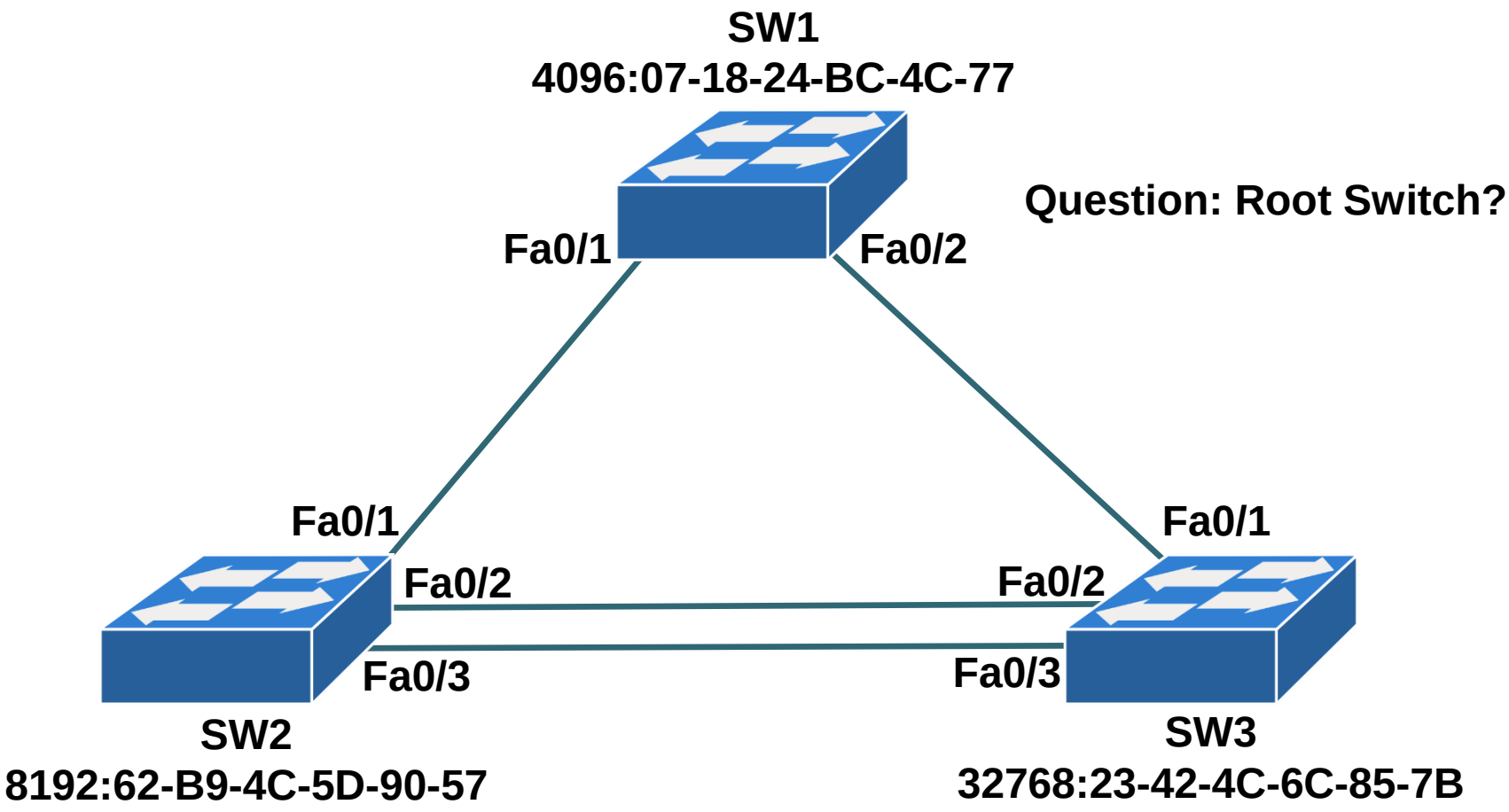
Spanning-Tree Exercise 3



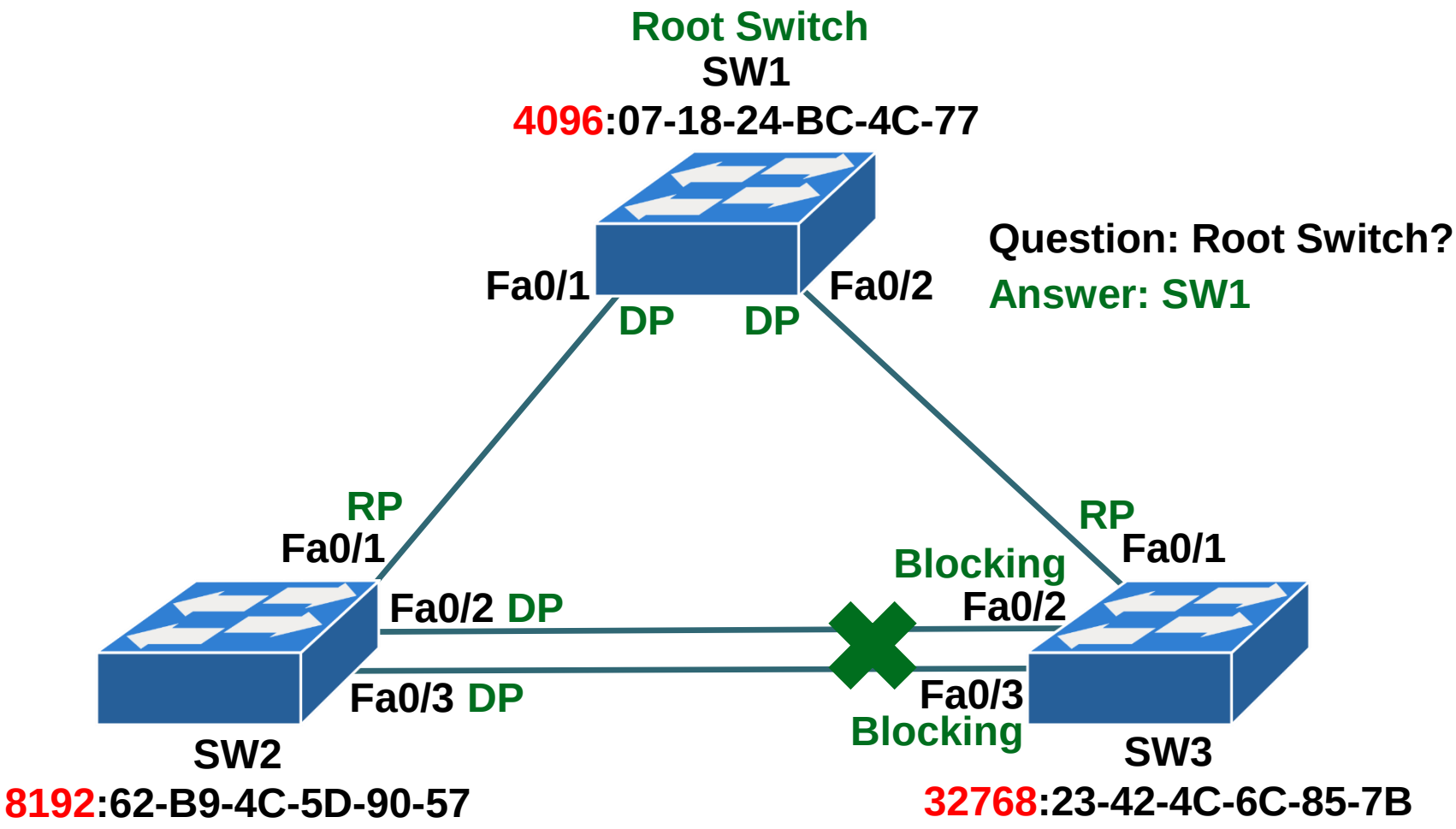
Spanning-Tree Exercise 3 (Cont.)



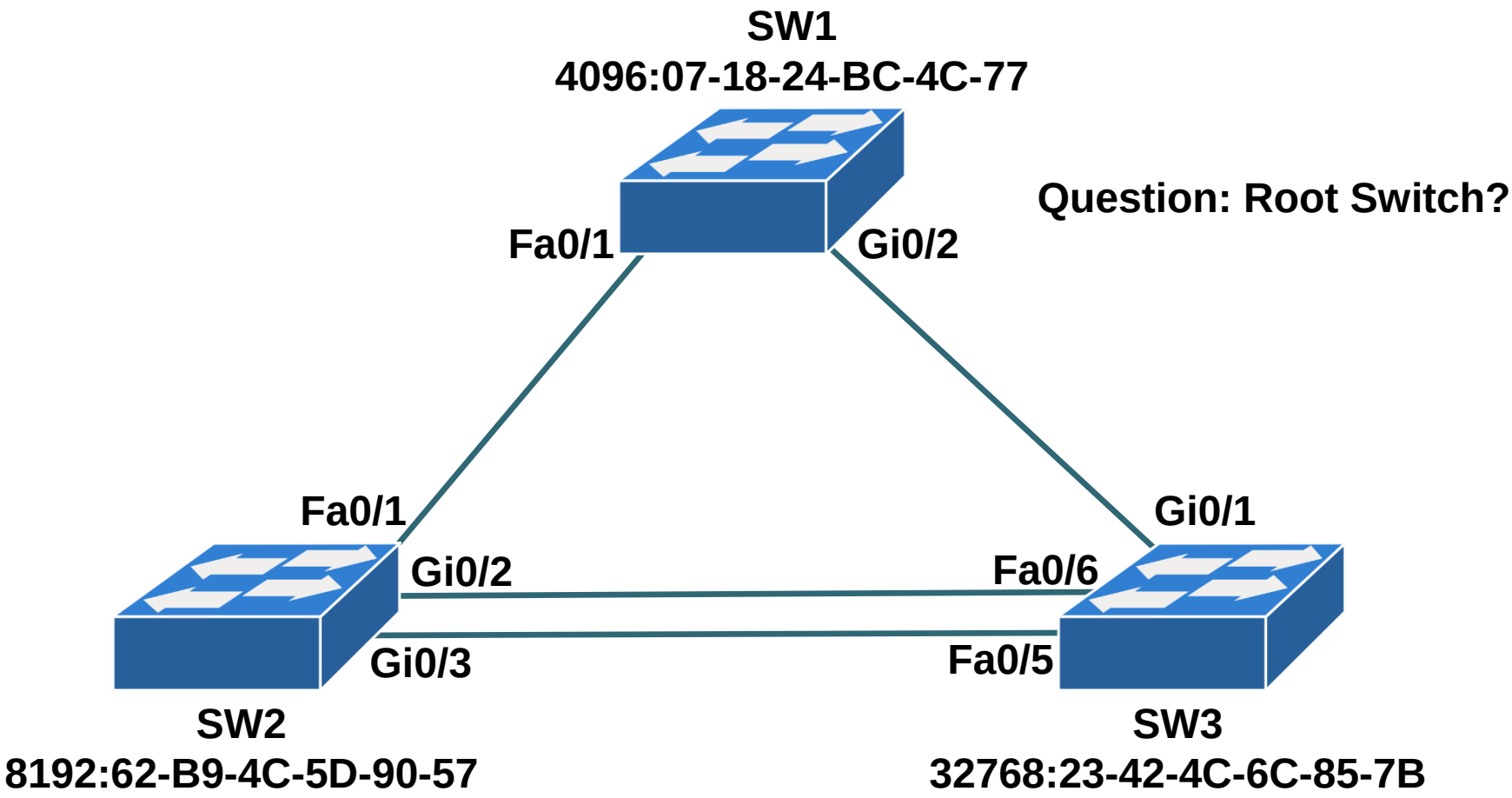
Spanning-Tree Exercise 4



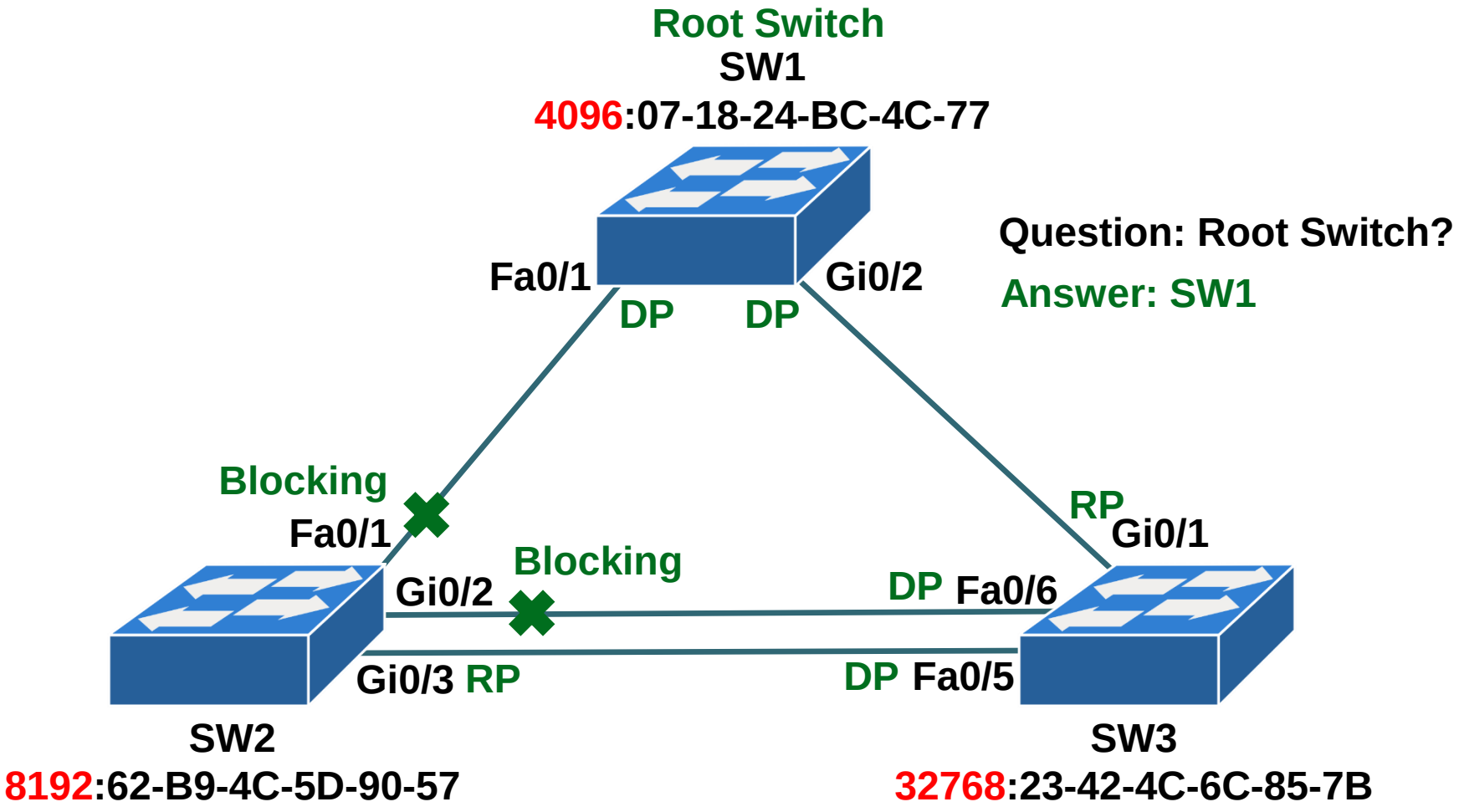
Spanning-Tree Exercise 4 (Cont.)



Spanning-Tree Exercise 5

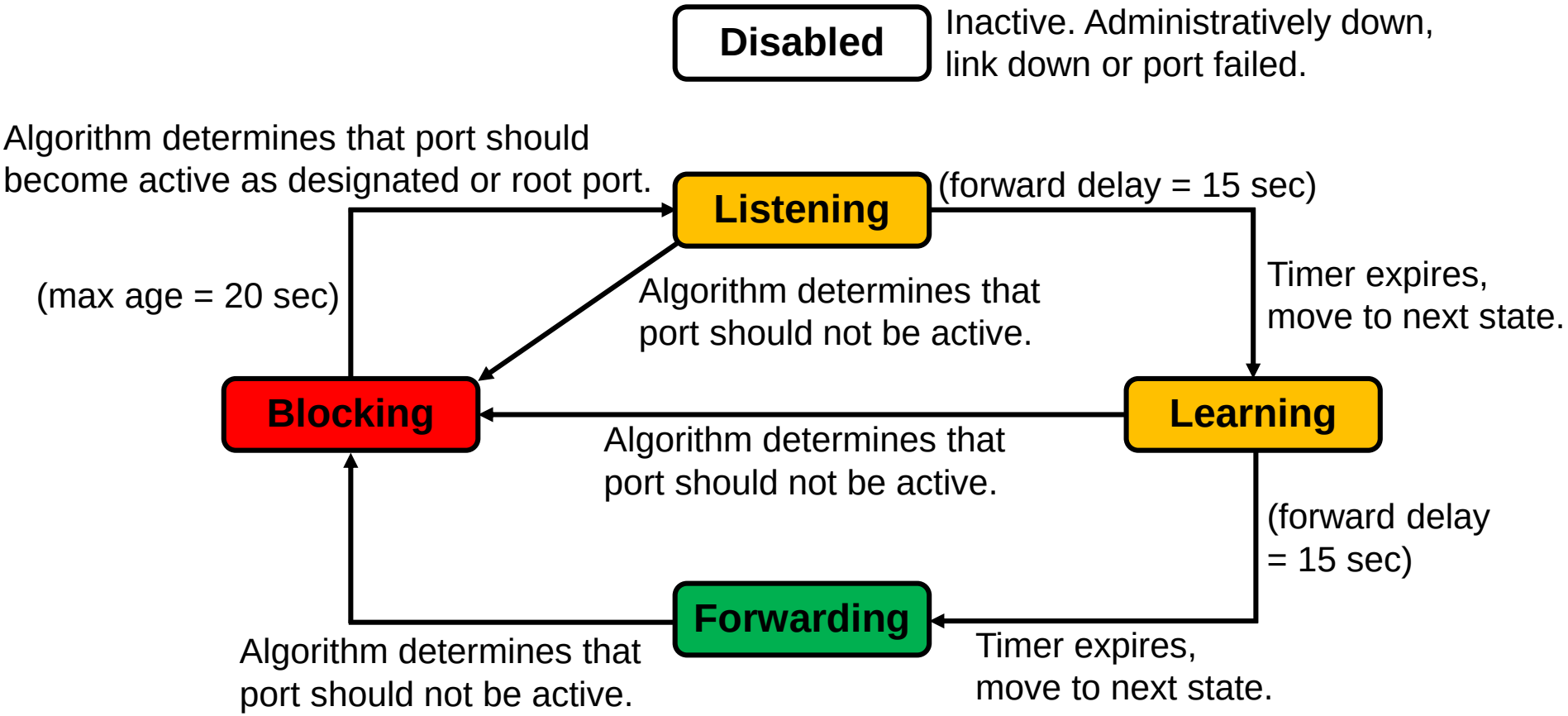


Spanning-Tree Exercise 5 (Cont.)



Spanning-Tree Port States

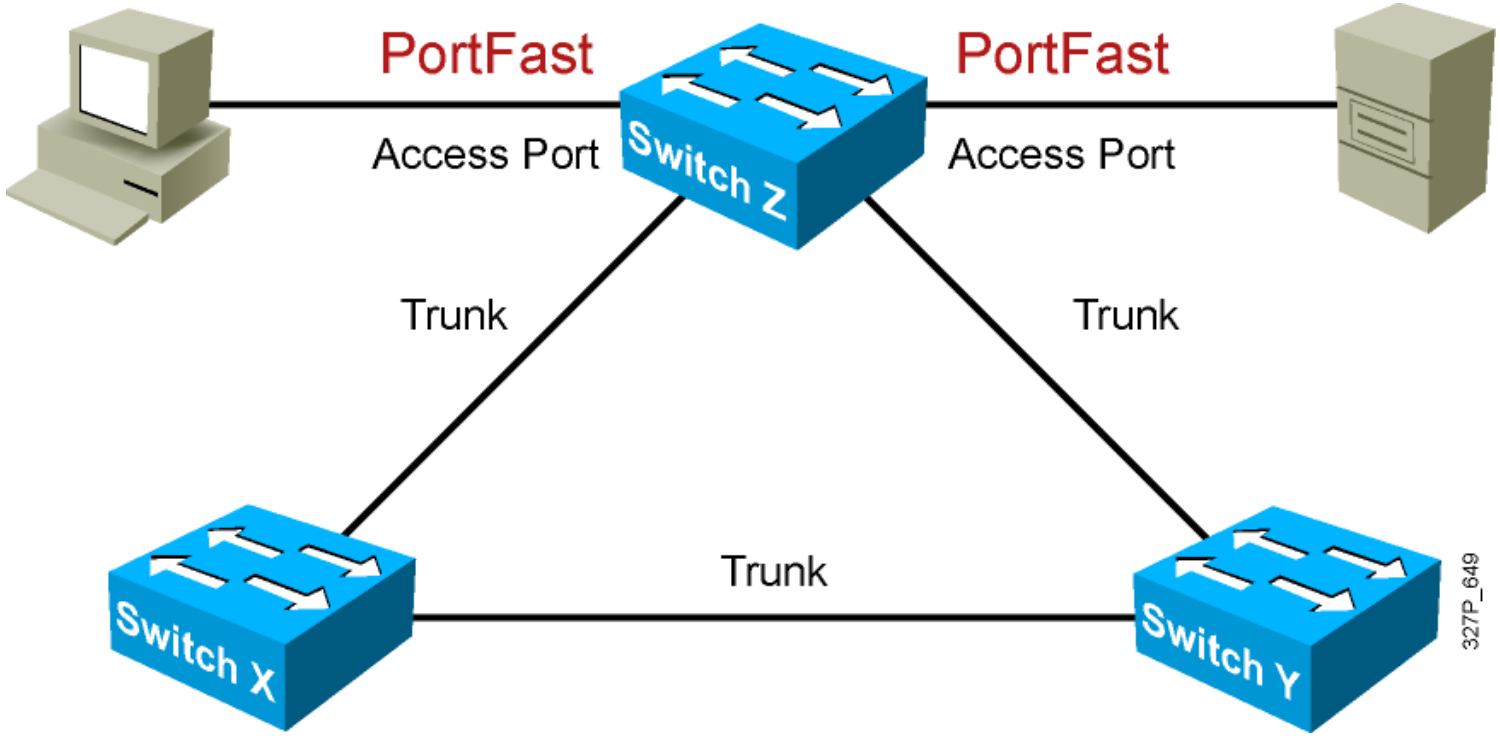
Spanning tree transits each port through several different states:



Spanning-Tree Port States (Cont.)

State	Receive BPDU	Send BPDU	Learn MAC Address	Forward Data Packet	LED Color on Switch
Disabled	NO	NO	NO	NO	OFF
Blocking	YES	NO	NO	NO	
Listening	YES	YES	NO	NO	
Learning	YES	YES	YES	NO	
Forwarding	YES	YES	YES	YES	

Spanning-Tree PortFast



- Bypass the listening and learning states (blocking state → forwarding state).
- PortFast is configured on access ports, not trunk ports.
- Disabled by default

Configuring and Verifying PortFast

```
SwitchX(config-if)# spanning-tree portfast
```

- Configures PortFast on an interface

OR

```
SwitchX(config)# spanning-tree portfast default
```

- Enables PortFast on all non-trunking interfaces

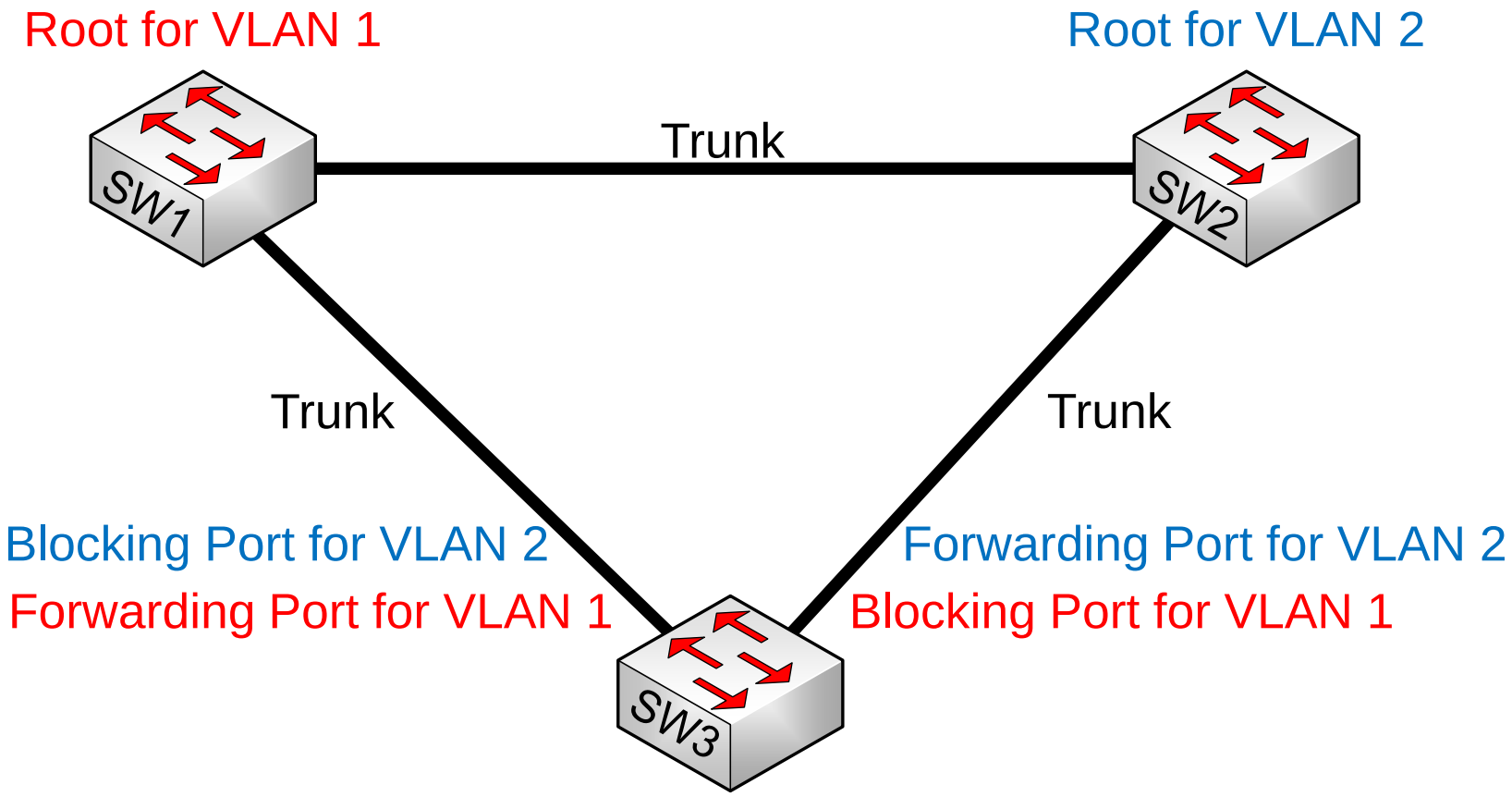
```
SwitchX# show running-config interface interface
```

- Verifies that PortFast has been configured on an interface

Spanning Tree Standards

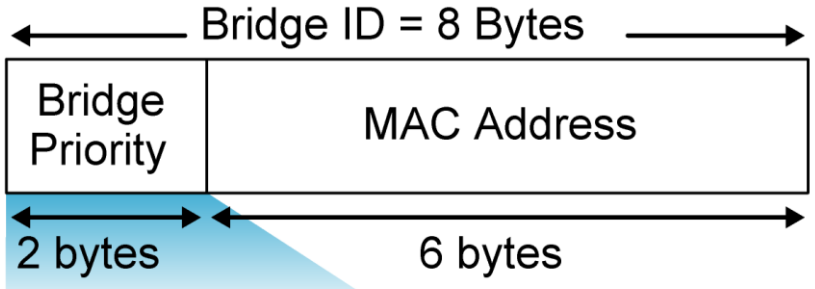
Standard	Description	Abbreviation
IEEE 802.1D	Spanning Tree Protocol ▪ Loop prevention ▪ Automatic reconfiguration of tree in case of topology changes ▪ Slow convergence (up to 50 seconds)	STP
IEEE 802.1Q	Common Spanning Tree + Virtual LAN ▪ Defines that 1 common spanning tree shall be used for all VLANs	CST
Cisco Proprietary	Per VLAN Spanning Tree Plus ▪ 1 STP instance per VLAN ▪ PVST+ is an improved variant of PVST	PVST+
IEEE 802.1w	Rapid Spanning Tree Protocol ▪ Improved STP with faster convergence ▪ Backward compatible with STP	RSTP
Cisco Proprietary	Per VLAN Rapid Spanning Tree ▪ 1 RSTP instance per VLAN	PVRST+
IEEE 802.1s	Multiple Spanning Tree Protocol ▪ Multiple VLANs mapped to 1 STP instance (tradeoff between CST and PVST)	MSTP

Per VLAN Spanning Tree Plus (PVST+)



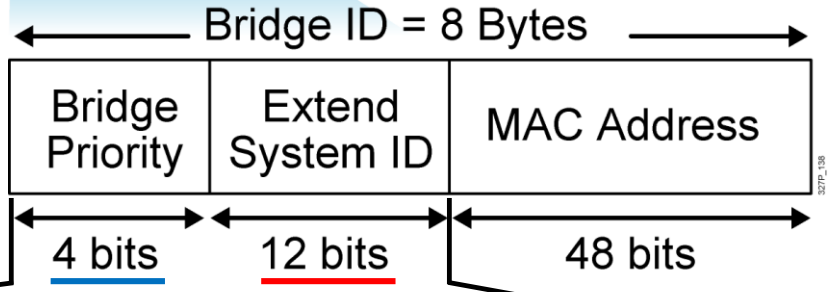
PVST+ Extended Bridge ID

Bridge ID without the extended system ID



Extended bridge ID with system ID

System ID = VLAN ID



Bridge Priority (4 Bits)				Extended System ID (12 Bits)											
32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

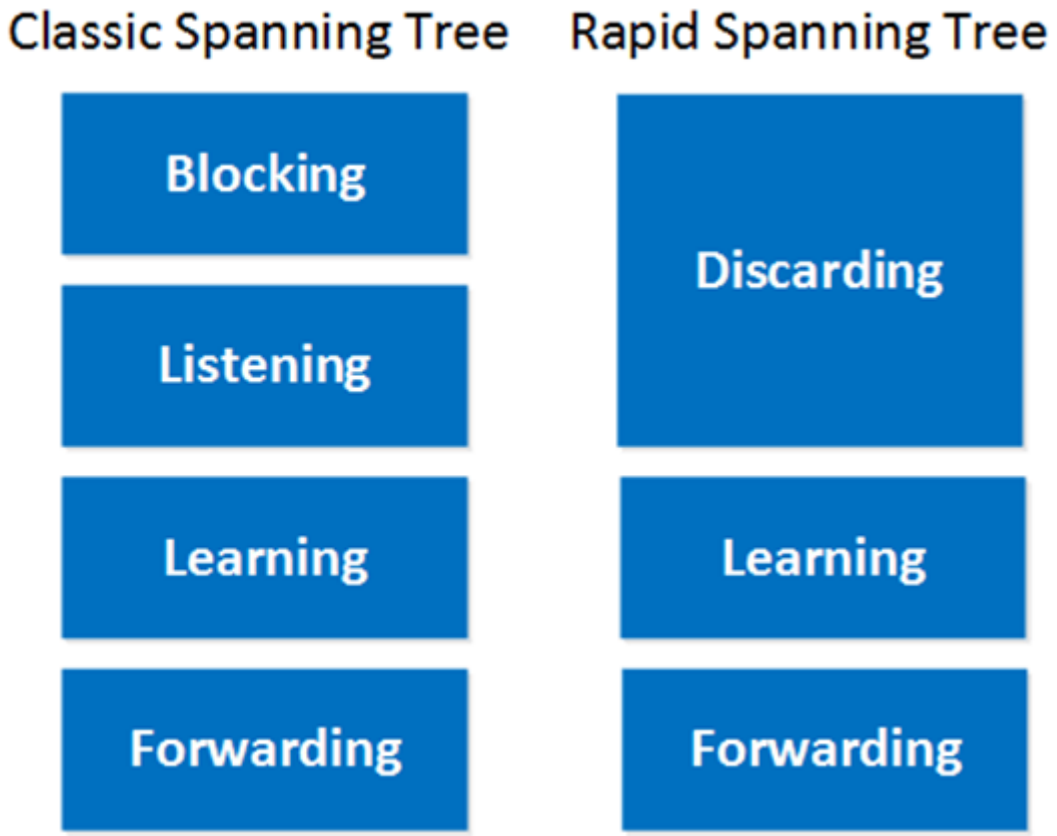
1000 = 32768
(Default Priority)

000000000001 = 1
(For VLAN 1)

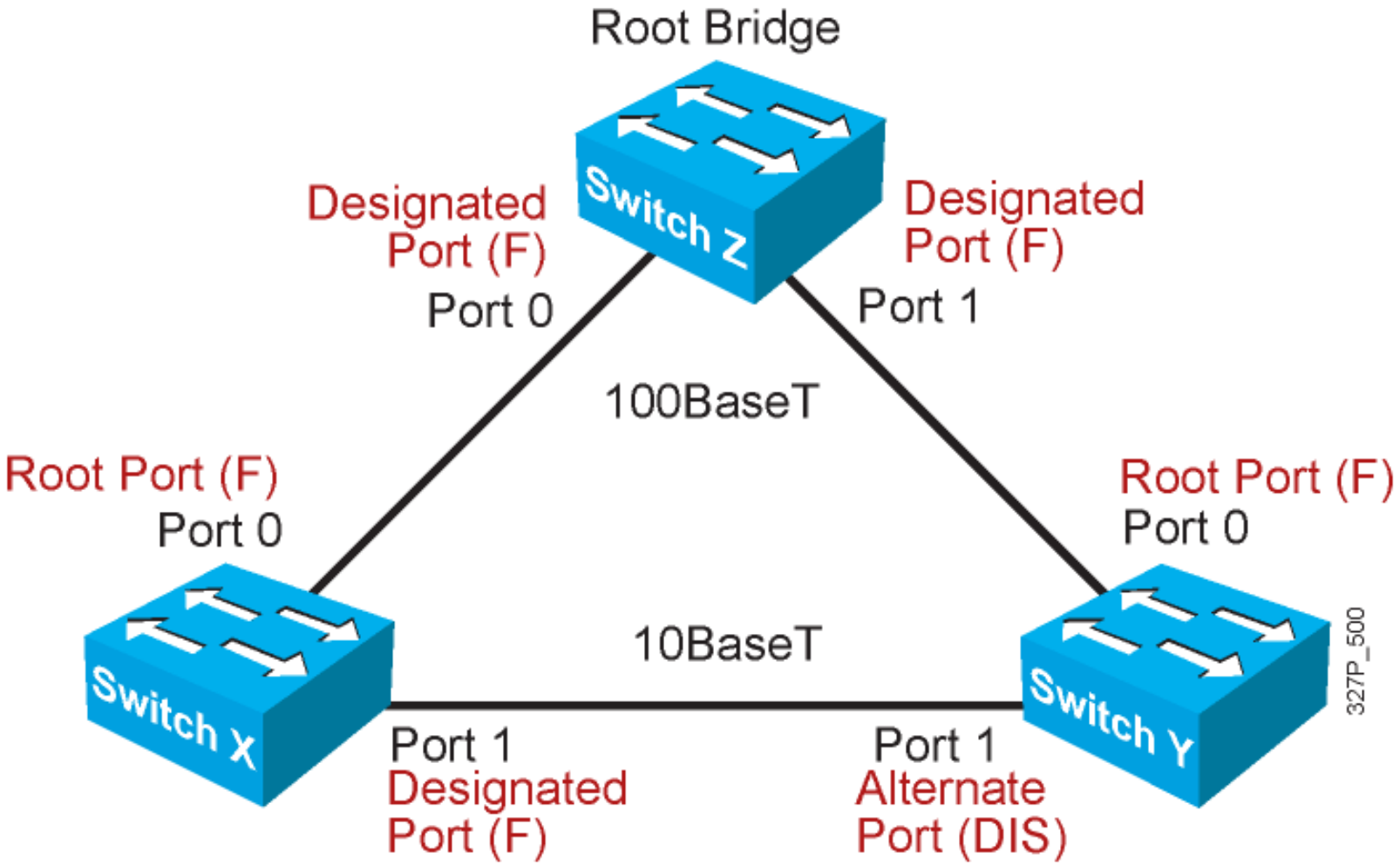
Example: Bridge Priority in BPDU for VLAN 1 will be 32768 + 1 = 32769

Rapid Spanning Tree Protocol (RSTP)

- IEEE 802.1w
- Added new port roles
  - Alternate Port: the alternate best path to the root-bridge. If the current root port fails the alternate port will take over
  - Backup Port: the redundant designated port. If there is already a designated port forwarding for that segment then this port will remain backup until it is needed
- Backward compatible with STP 802.1D.



Rapid Spanning Tree Protocol (RSTP) (Cont.)



Default Spanning-Tree Configuration

- **Cisco Catalyst switches support three types of STPs:**
  - PVST+
  - PVRST+
  - MSTP
- **The default STP for Cisco Catalyst switches is PVST+:**
  - A separate STP instance for each VLAN
  - One root bridge for all VLANs
  - No load sharing

PVRST+ Configuration Guidelines

1. **Enable PVRST+.**
2. **Designate and configure a switch to be the root bridge.**
3. **Designate and configure a switch to be the secondary root bridge.**
4. **Verify the configuration.**

PVRST+ Implementation Commands

```
SwitchX(config)# spanning-tree mode rapid-pvst
```

- Configures PVRST+

```
SwitchX# show spanning-tree vlan vlan# [detail]
```

- Verifies the spanning-tree configuration

```
SwitchX# debug spanning-tree pvst+
```

- Displays PVST+ event debug messages

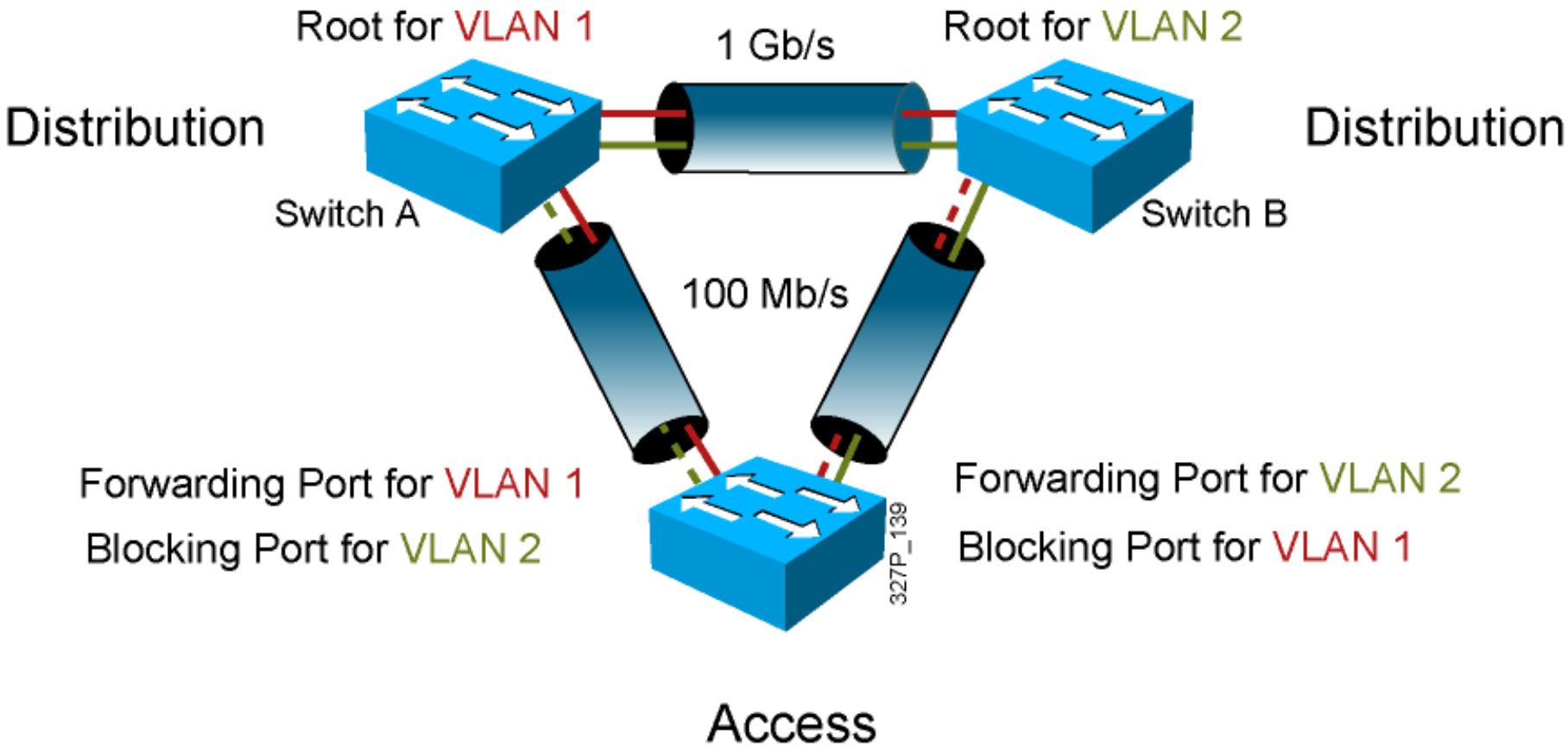
Verifying PVRST+

```
SwitchX# show spanning-tree vlan 30
VLAN0030
Spanning tree enabled protocol rstp
Root ID     Priority 24606
            Address 00d0.047b.2800
            This bridge is the root
            Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
Bridge ID   Priority 24606 (priority 24576 sys-id-ext 30)
            Address 00d0.047b.2800
            Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
            Aging Time 300

Interface Role Sts Cost Prio.Nbr  Type
--------- ----- --- ---  --------  ----
Gi1/1     Desg FWD  4    128.1     P2p
Gi1/2     Desg FWD  4    128.2     P2p
Gi5/1     Desg FWD  4    128.257   P2p
```

The spanning-tree mode is set to PVRST.

Configuring the Root and Secondary Bridges



Configuring the Root and Secondary Bridges: SwitchA

```
SwitchA(config)# spanning-tree vlan 1 root primary
```

- This command forces this switch to be the root for VLAN 1.
- Bridge Priority will be set to **24576** for VLAN 1.

```
SwitchA(config)# spanning-tree vlan 2 root secondary
```

- This command configures this switch to be the secondary root for VLAN 2.
- Bridge Priority will be set to **28672** for VLAN 2.

OR manual configuration

```
SwitchA(config)# spanning-tree vlan # priority priority
```

- This command statically configures the priority (increments of 4096).

Configuring the Root and Secondary Bridges: SwitchB

```
SwitchB(config)# spanning-tree vlan 2 root primary
```

- This command forces this switch to be the root for VLAN 2.
- Bridge Priority will be set to **24576** for VLAN 2.

```
SwitchB(config)# spanning-tree vlan 1 root secondary
```

- This command configures this switch to be the secondary root for VLAN 1.
- Bridge Priority will be set to **28672** for VLAN 1.

OR manual configuration

```
SwitchB(config)# spanning-tree vlan # priority priority
```

- This command statically configures the priority (increments of 4096).

Configuring Spanning Tree Interface Cost

```
SwitchX(config)# interface Fa0/0
SwitchX(config)# spanning-tree vlan 1 cost 101
```

- Change spanning-tree cost on an interface.

```
SwitchX#show spanning-tree interface Fa0/0

Vlan                 Role Sts Cost      Prio.Nbr Type
-------------------- ---- --- --------- -------- -------
VLAN0001             Desg FWD 101       128.1    P2p
```

- Verify the spanning-tree configuration on an interface.


CISCO