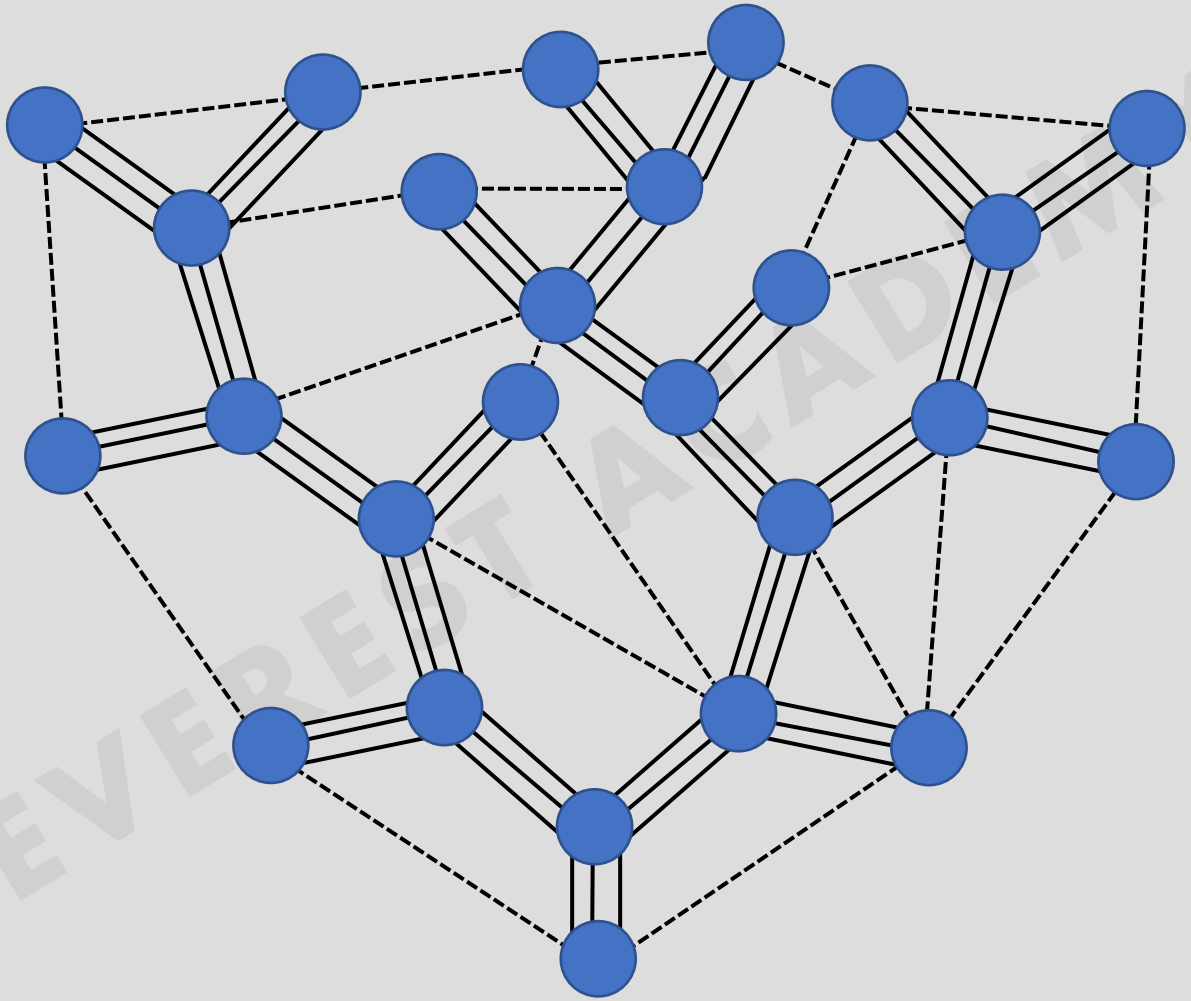
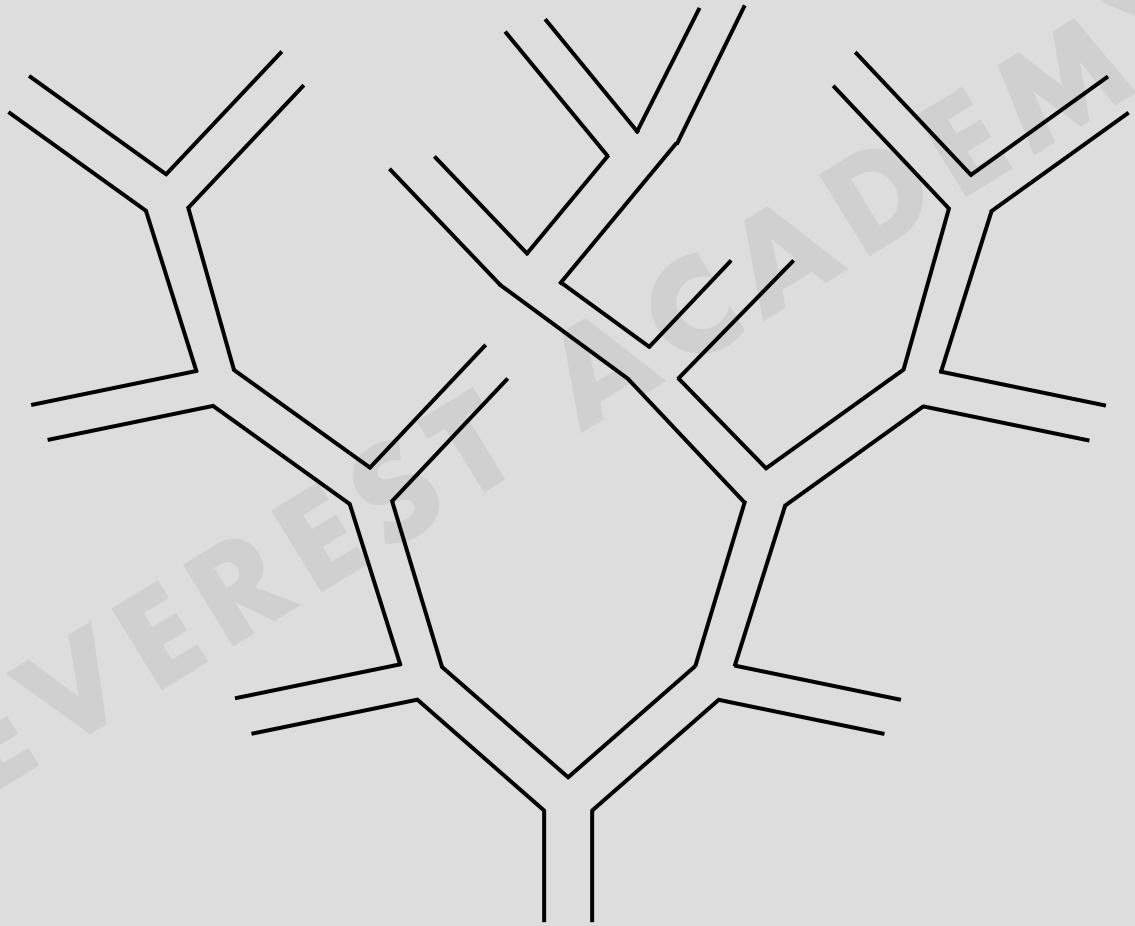
Spanning Tree Protocol (STP)



Spanning Tree Protocol (STP)



Spanning Tree Protocol (STP)

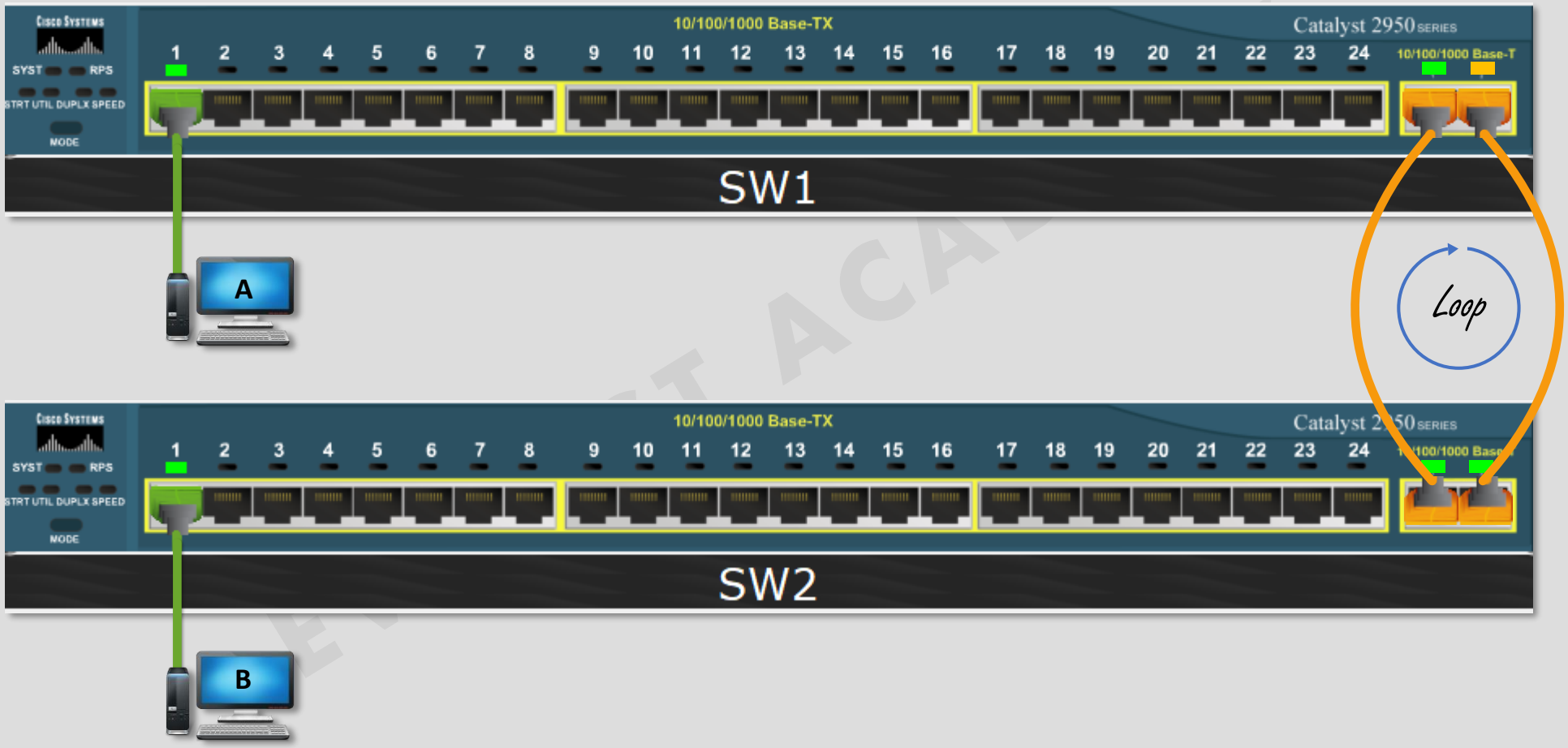
- ❖ **Spanning Tree Protocol (STP)** is a Layer 2 protocol that runs on bridges and switches.
- ❖ **Spanning Tree Protocol (STP)** is enabled by default.
- ❖ **Spanning Tree Protocol (STP)** uses Spanning-Tree Algorithm (STA) to search for the redundant links between bridges and switches.
- ❖ **Spanning Tree Protocol (STP)** automatically disables the ports of the redundant links, thus preventing possible network loops.
- ❖ **Using redundant links** without enabling spanning tree protocol causes three problems on switched networks:

1. Broadcast storms : The forwarding of a frame repeatedly on the same links, consuming significant parts of the links' capacities.

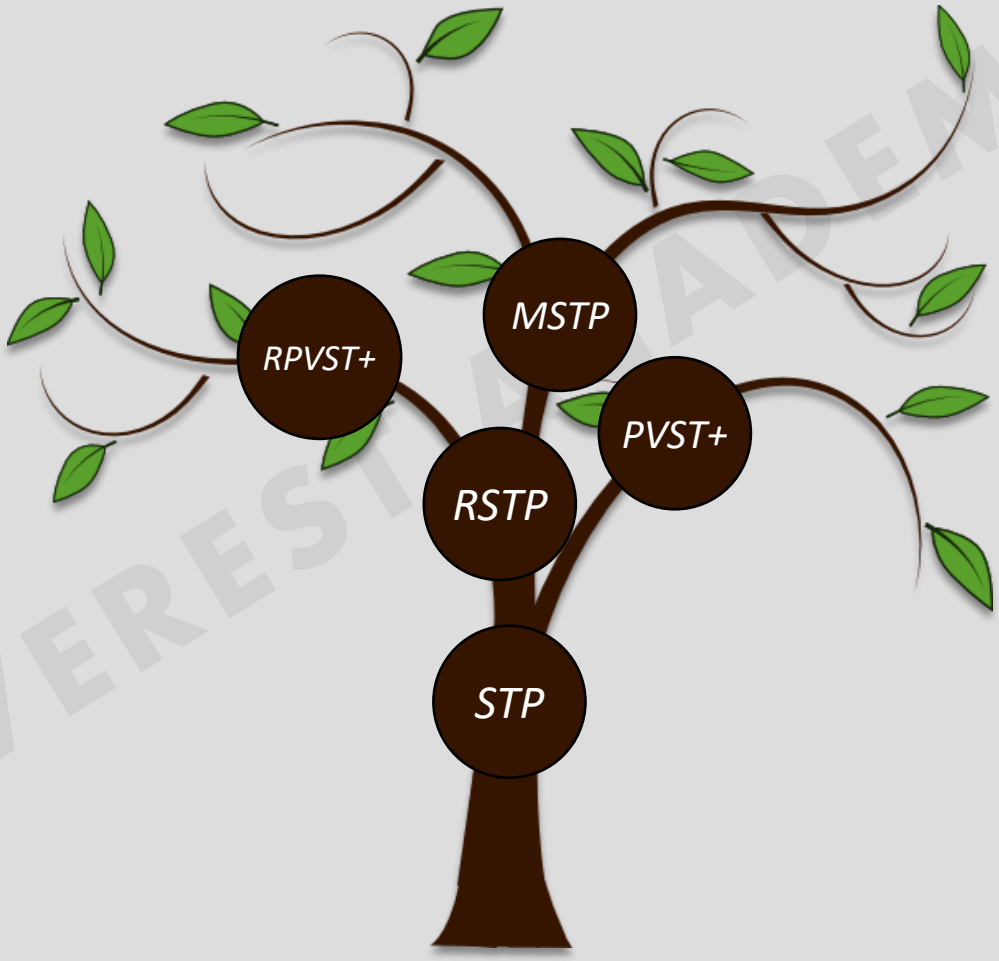
2. Multiple frame transmission: sending multiple copies of one frame to the intended host.

3. MAC table instability: updating the MAC Address Table with a new entries in reaction to looping frames.

Spanning Tree Protocol (STP)



Types of Spanning Tree Protocols



Types of Spanning Tree Protocols

❖ **In 1985.** the Digital Equipment Corporation (DEC) invented the first spanning tree protocol, called **DEC STP**.

❖ **In 1990,** the **IEEE** published the first standard of the spanning tree protocol (STP) as **802.1D**.

IEEE 802.1D is called Common Spanning Tree (**CST**), it creates **one spanning-tree instance** for the entire network.

❖ **Per-VLAN Spanning Tree (PVST+)** is a **Cisco *enhancement of STP*** that provides a separate **802.1D** spanning-tree **instance** for each VLAN configured in the network.

❖ **In 2001,** the **IEEE** introduced Rapid Spanning Tree Protocol (**RSTP**) as **802.1w**.

RSTP provides significantly **faster spanning tree convergence** after a topology change and it is backwards-compatible with standard STP.

❖ **Rapid Per-VLAN Spanning Tree (Rapid PVST**+) is a **Cisco *enhancement of RSTP*** that uses **PVST**+ and provides a separate **instance** of **802.1w** for each VLAN..

❖ **In 2002,** the **IEEE** introduced Multiple Spanning Tree Protocol (**MSTP**) as **802.1s**, That allows multiple VLANs to be managed by a single STP instance and supports per-VLAN STP.

❖ **In 2004,** the **IEEE** integrated **RSTP** into **802.1D** and obsoleted the original STP standard.

STP Standards and Configuration Options

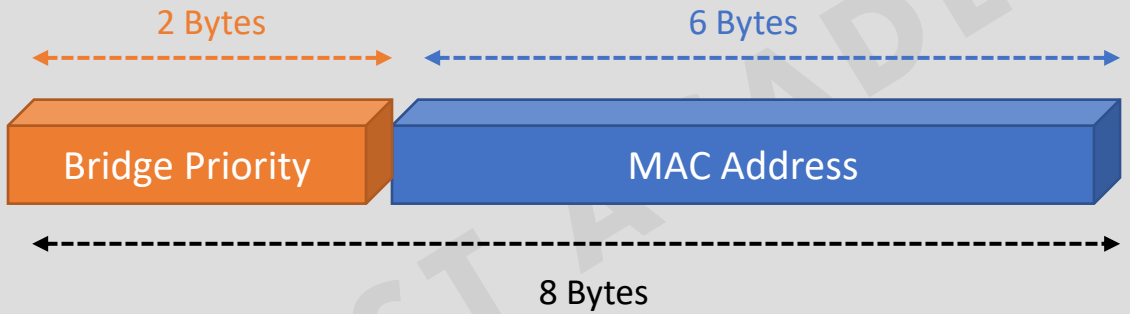
Name	Based on STP or RSTP?	# Trees	Original IEEE Standard	Configuration Command
STP	STP	1 (CST)	IEEE 802.1D	N/A
PVST+	STP	1/VLAN	IEEE 802.1D	*#spanning-tree mode pvst*
RSTP	RSTP	1 (CST)	IEEE 802.1w	N/A
Rapid PVST+	RSTP	1/VLAN	IEEE 802.1w	*#spanning-tree mode rapid-pvst*
MSTP	RSTP	1 or more*	IEEE 802.1s	*#spanning-tree mode mst*

```
Switch(config)#spanning-tree mode ?
  mst         Multiple spanning tree mode
  pvst        Per-Vlan spanning tree mode
  rapid-pvst  Per-Vlan rapid spanning tree mode
```

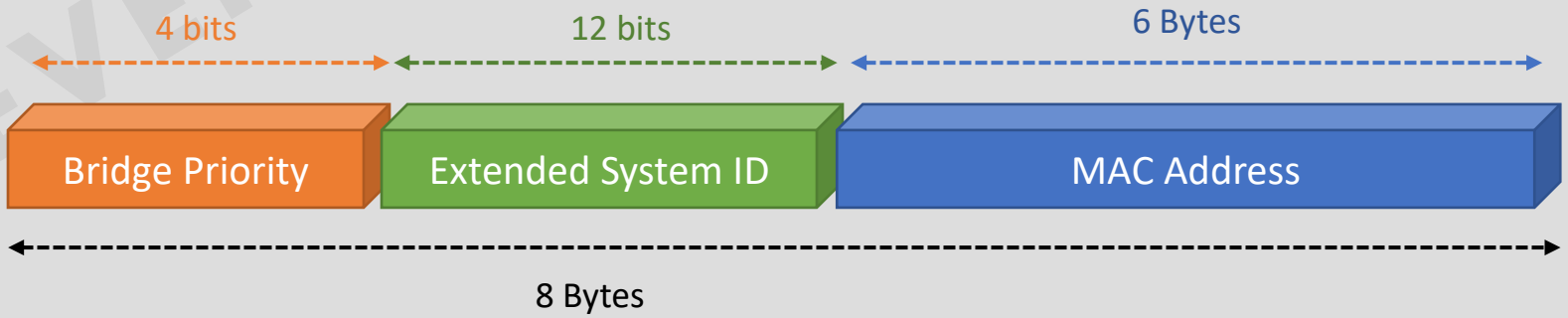
Bridge ID (BID)

❖ **Bridge ID or BID** is an **8-byte field** which is divided into two parts. The first part is a **2-byte Bridge Priority field** while the second part is the **6-byte burned-in MAC address** of the switch.

❑ Bridge ID without Extended System ID, one Spanning Tree instance:

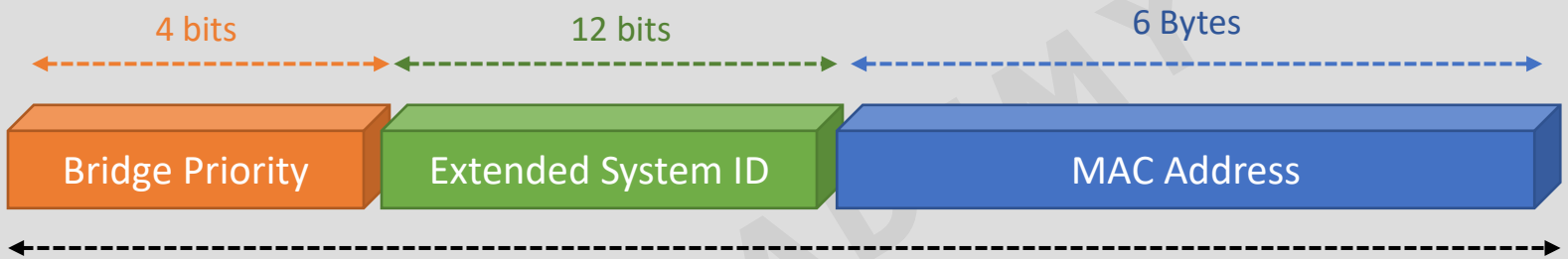


❑ Bridge ID with Extended System ID, Multiple Spanning Tree instances :



Bridge ID with Extended System ID

❑ Bridge ID with Extended System ID, Multiple Spanning Tree instances :



Bridge Priority				Extended System ID											
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

VLAN ID = 1

- Bridge Priority Field can only be set in increments of **4096**.
- 0, **4096**, **8192**, 12288, **16384**, 20480, 24576, 28672, ***32768***, 36864, 40960, 45056, 49152, 53248, 57344, 61440.
- Cisco Switch default bridge priority is **32768** or **0x8000**.

Bridge ID with Extended System ID

Name	Based on STP or RSTP?	# Trees	Original IEEE Standard	Configuration Command
STP	STP	1 (CST)	IEEE 802.1D	N/A
PVST+	STP	1/VLAN	IEEE 802.1D	*#spanning-tree mode pvst*

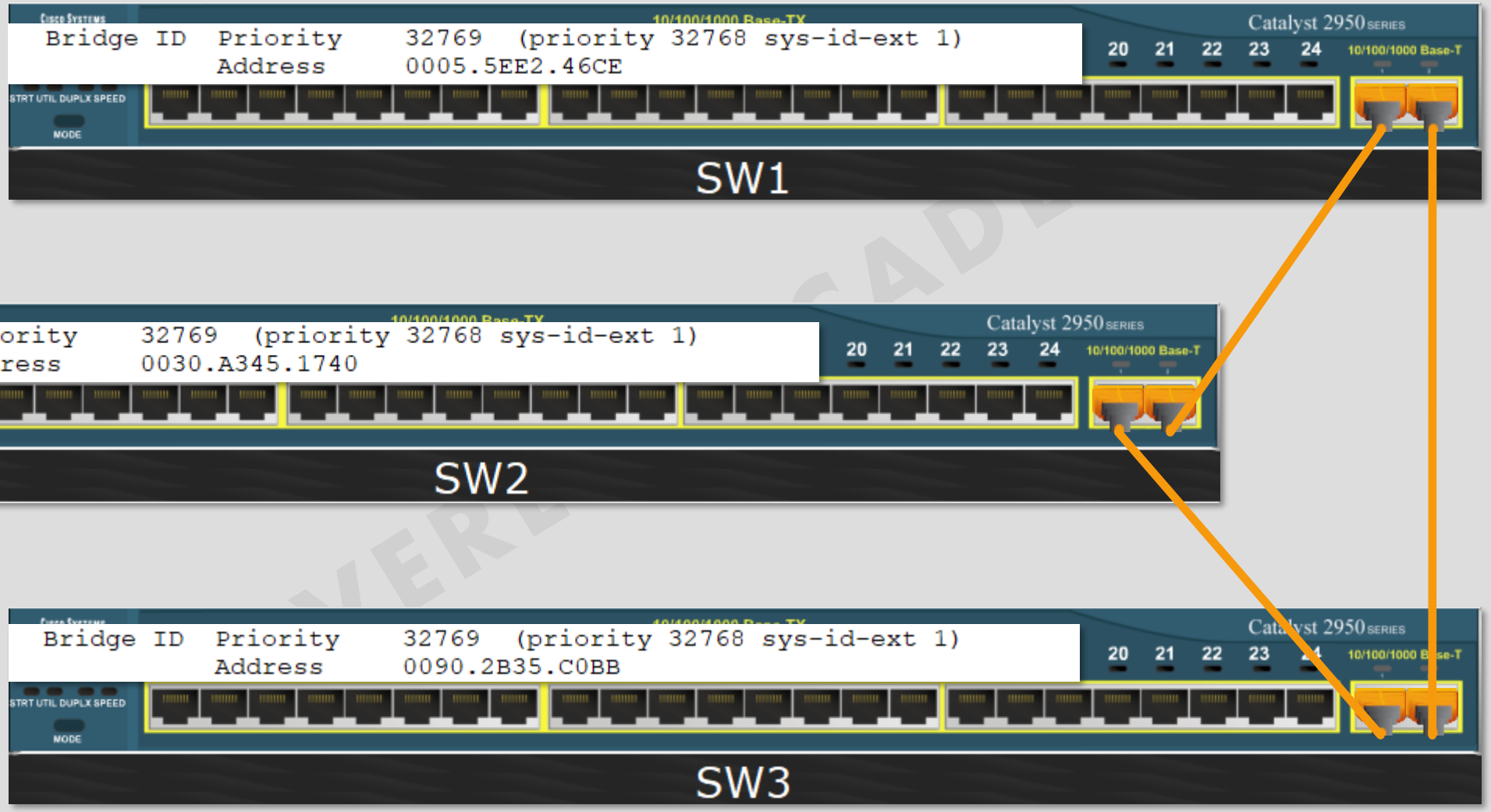
```
Switch#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0014.f251.0700
              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     0014.f251.0700
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

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

Bridge ID Examples

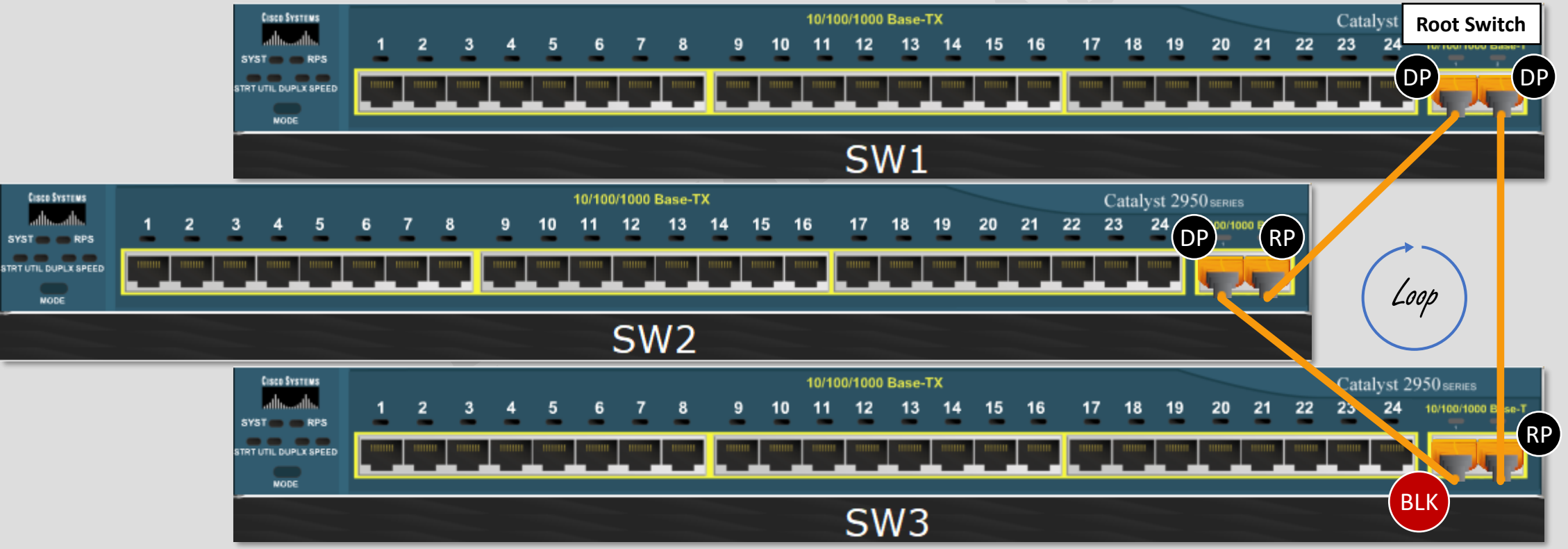


How Spanning Tree Works

❖ **The STP algorithm** creates a spanning tree of interfaces that forward frames by choosing the interfaces that should be placed into a **forwarding state** and choosing the interfaces that should be placed into a **blocking state**.

❖ **STP** uses three criteria to choose whether to put an interface in forwarding state or blocking state:

1. STP elects a root switch.
2. STP selects root ports (RPs).
3. STP selects designated ports (DPs).



Bridge Protocol Data Units (BPDU)

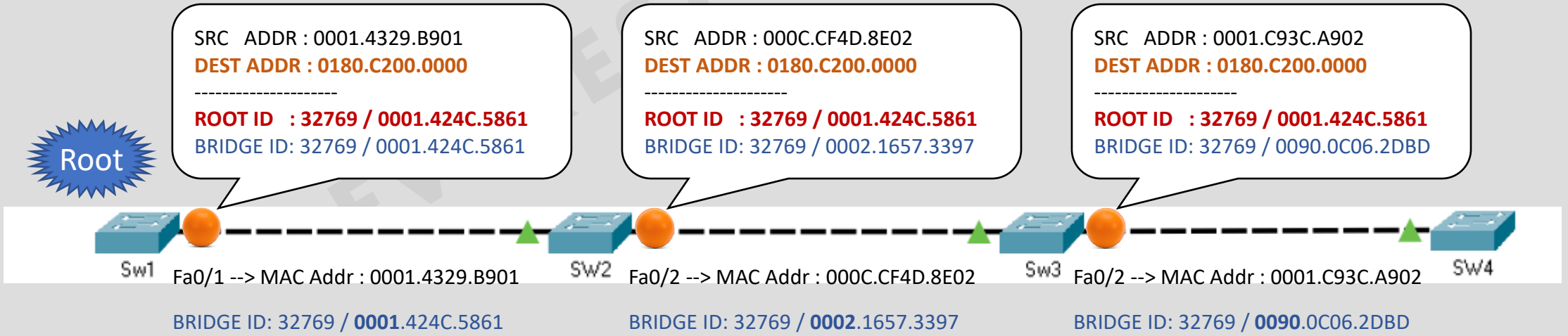
❖ **Bridge Protocol Data Units (BPDUs)** are frames that contain information about the spanning tree protocol (STP).

❖ **STP** sends **BPDUs** using a unique source MAC address from its origin port to a multicast address with destination MAC (**01:80:C2:00:00:00**)

❖ **BPDU Messages :**

1. **Configuration BPDU (Hello BPDU) ,** sent by the **root bridge** to provide information to all switches every 2 seconds.

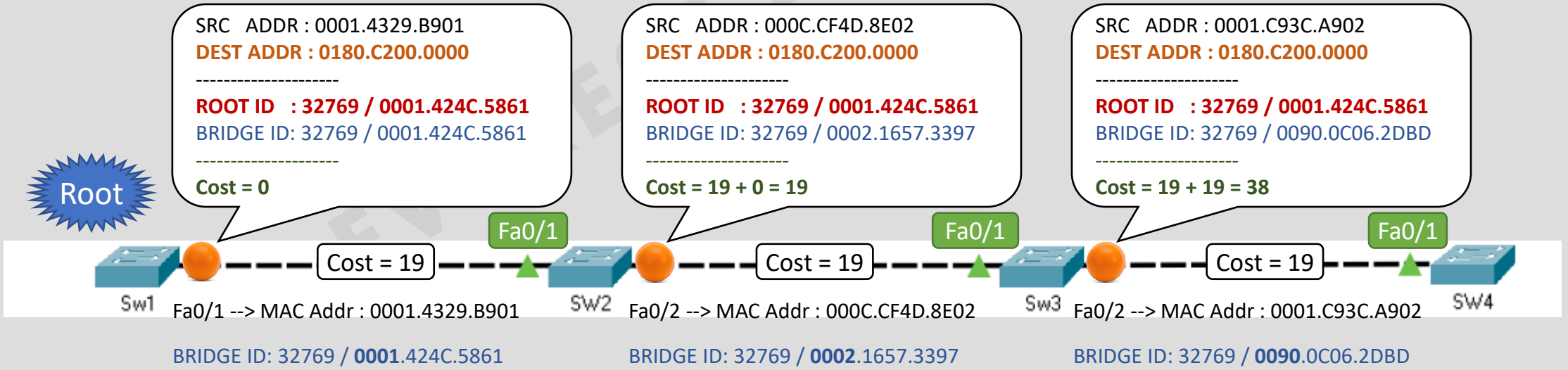
2. **TCN (Topology Change Notification),** sent by **bridges** towards the **root bridge** to notify changes in the topology.



Port Cost

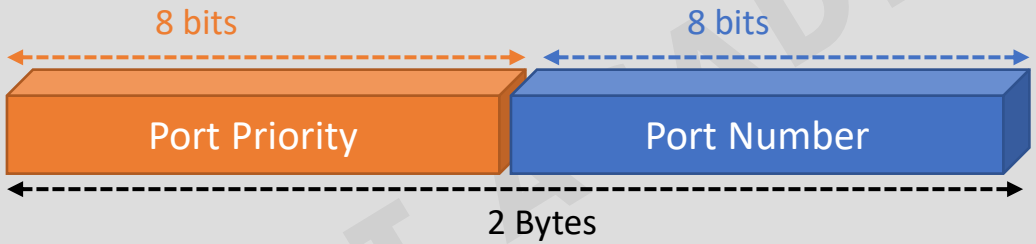
❖ **The port cost** is defined by the speed at which the port operates.

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



Port Identifier

- **Port identifier** is a 16-bit field, 8 bits for the **port priority** and 8 bits for the **port number**.
- **The port priority** is a value from 0 to 255 and **defaults** to 128 for all ports.
- **The port number** can range from 0 to 255 and represents the port's actual physical mapping.



128.1

128 1

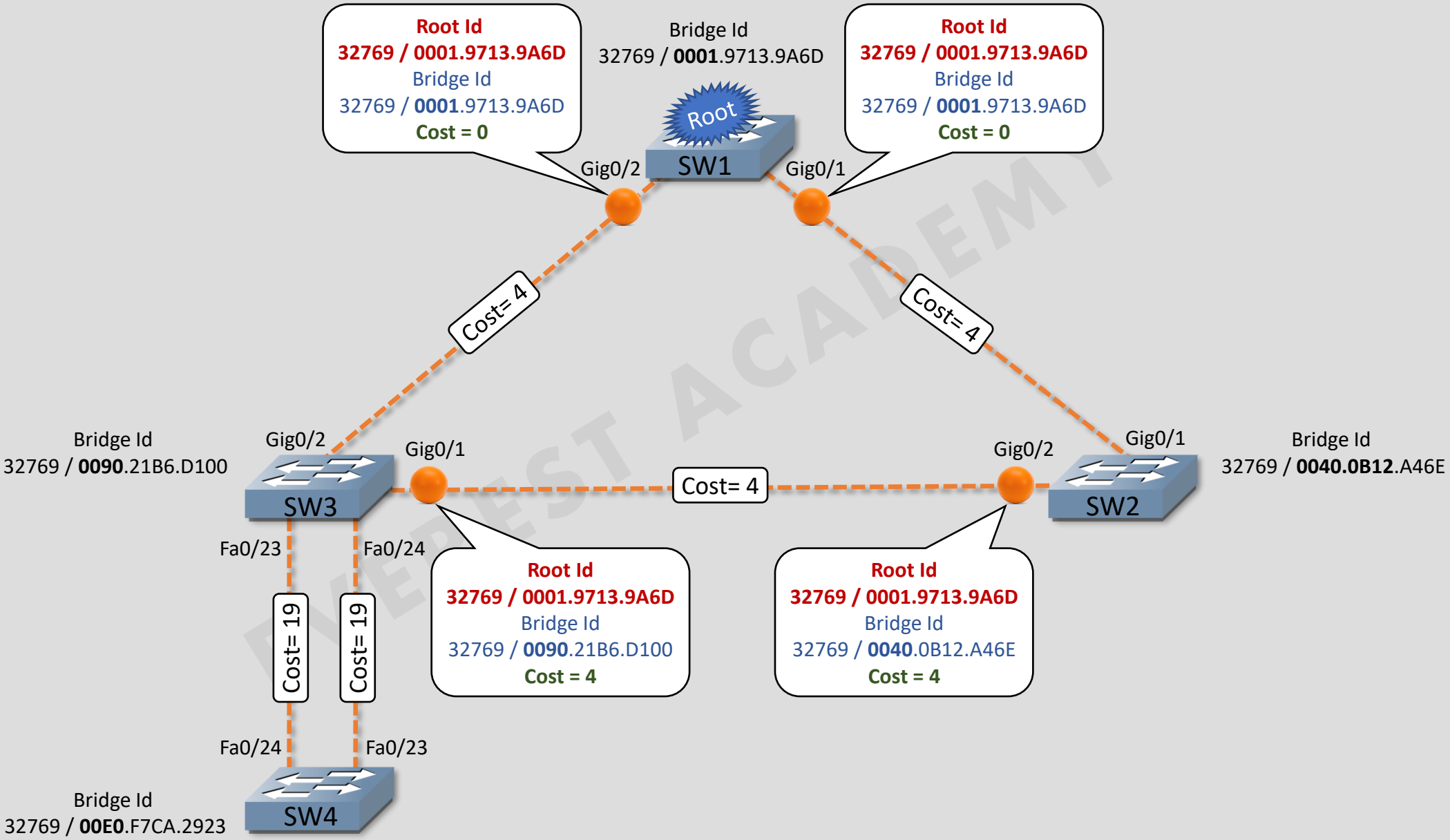
1000 0000 0000 0001

0x8001

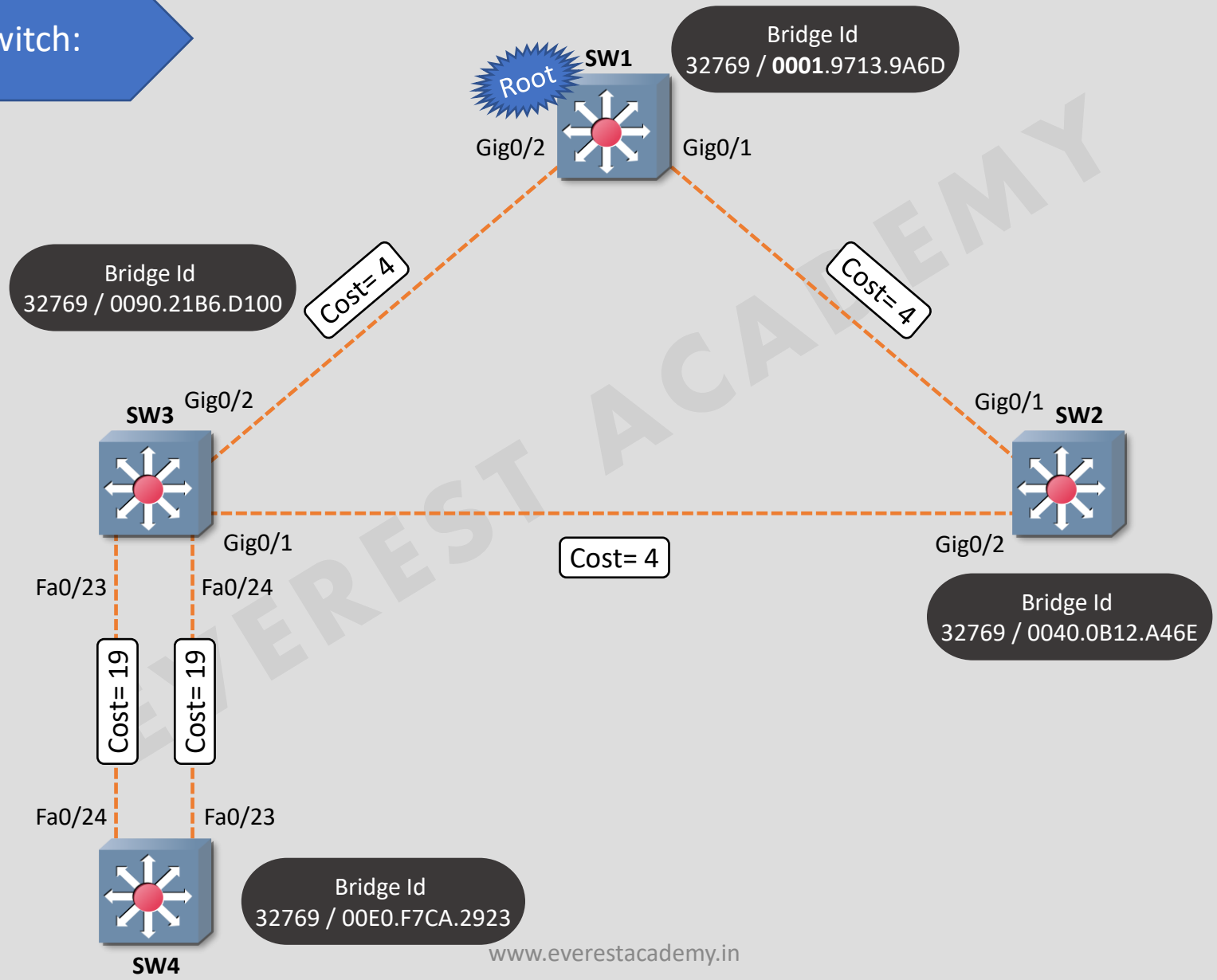
32769

Wireshark BPDU Frame

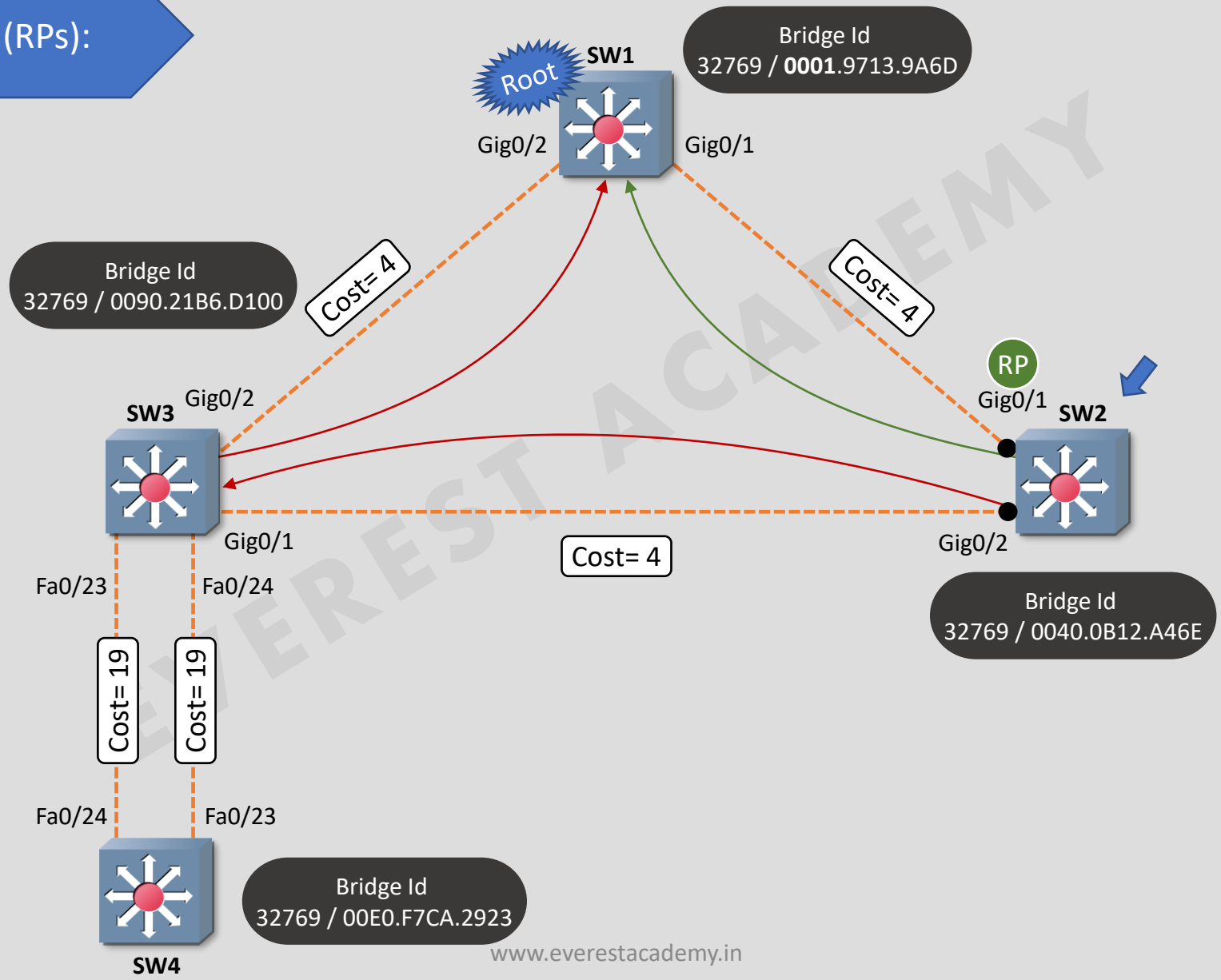
```
> Frame 1: 60 bytes on wire (480 bits), 60 bytes captured (480 bits)
> IEEE 802.3 Ethernet
> Logical-Link Control
v Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
  v BPDU flags: 0x00
      0... .... = Topology Change Acknowledgment: No
      .... ...0 = Topology Change: No
  v Root Identifier: 32768 / 100 / 00:1c:0e:87:78:00
      Root Bridge Priority: 32768
      Root Bridge System ID Extension: 100
      Root Bridge System ID: Cisco_87:78:00 (00:1c:0e:87:78:00)
    Root Path Cost: 4
  v Bridge Identifier: 32768 / 100 / 00:1c:0e:87:85:00
      Bridge Priority: 32768
      Bridge System ID Extension: 100
      Bridge System ID: Cisco_87:85:00 (00:1c:0e:87:85:00)
    Port identifier: 0x8004
    Message Age: 1
    Max Age: 20
    Hello Time: 2
    Forward Delay: 15
```



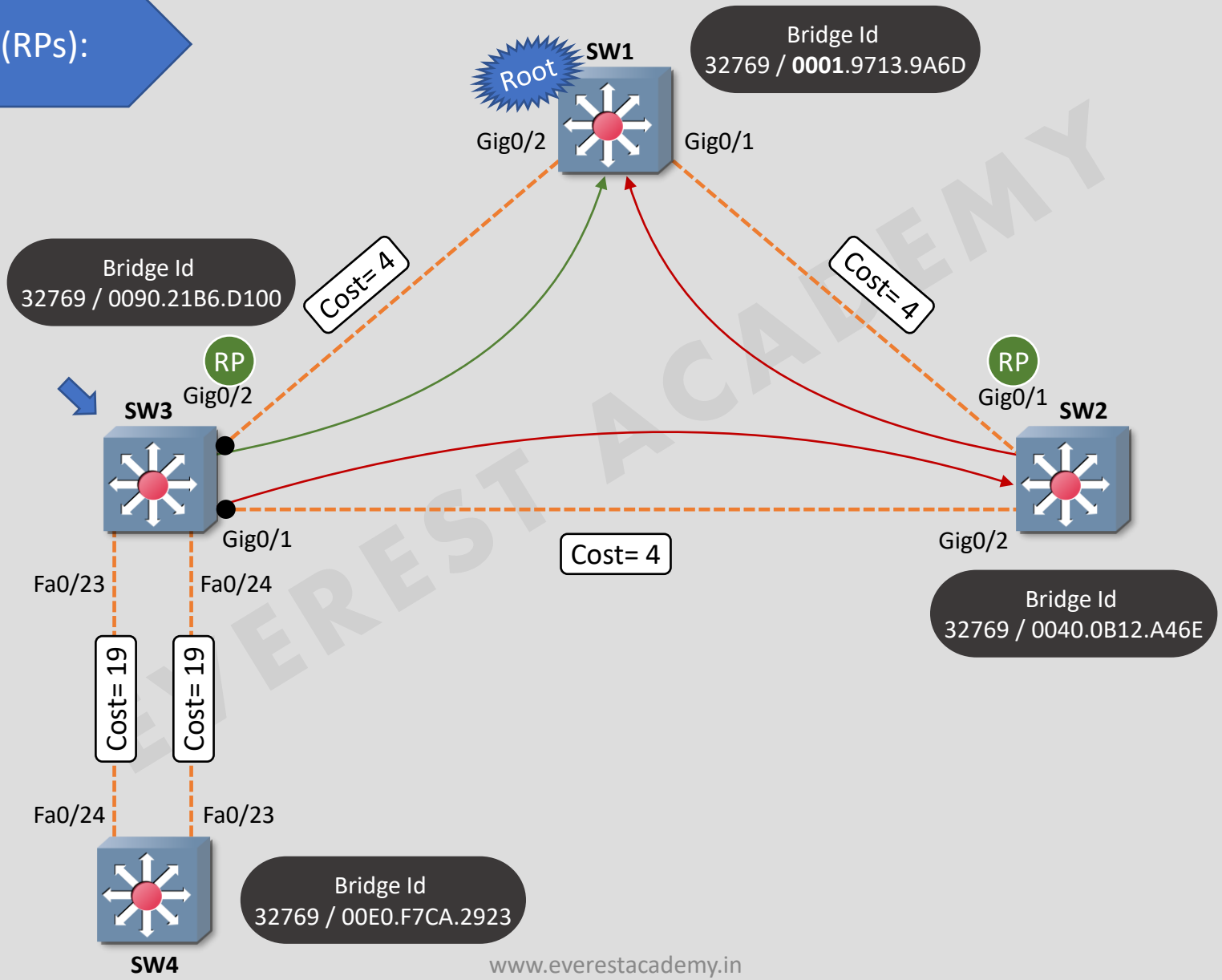
1. Electing The Root switch:



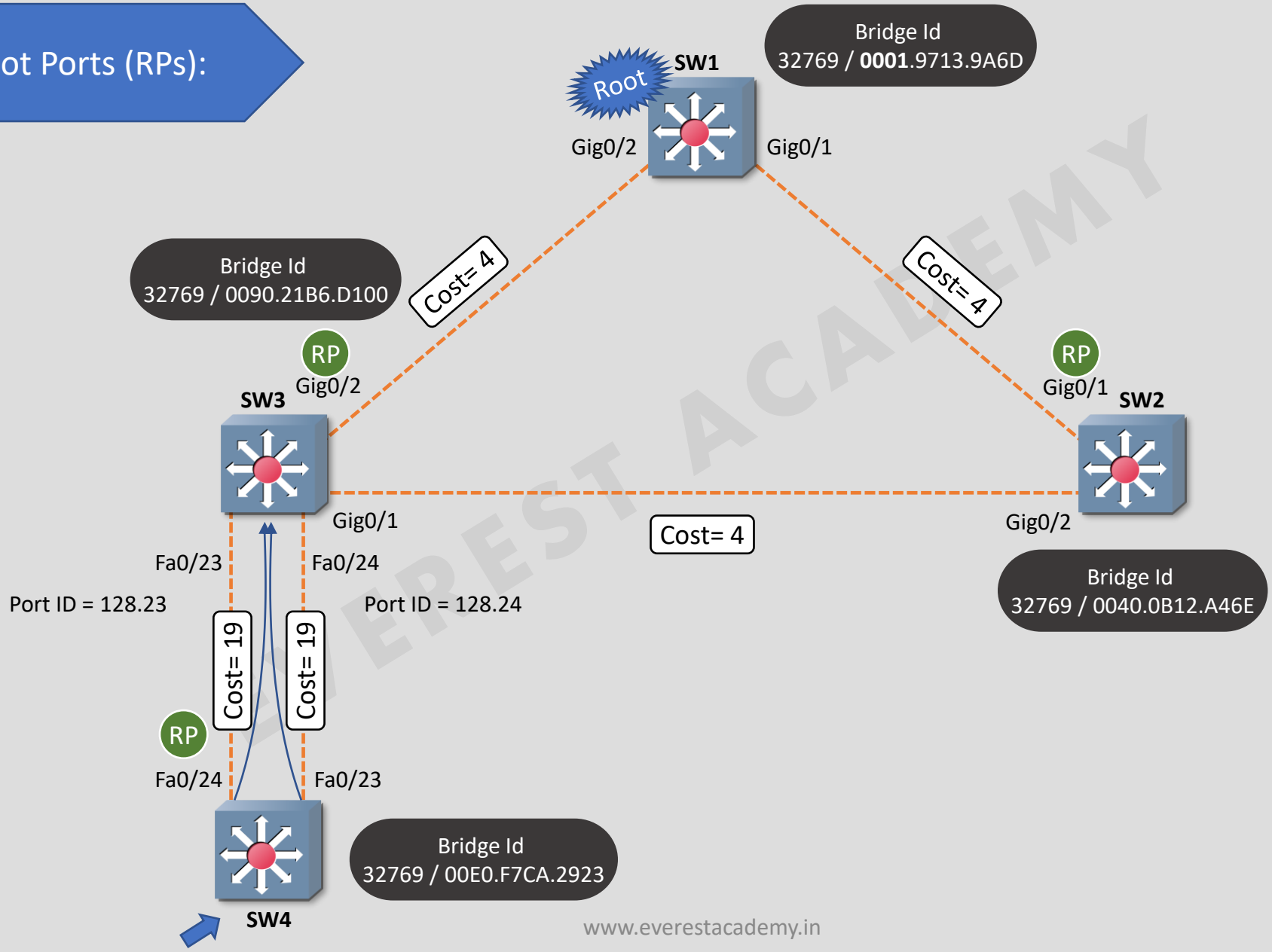
2. Selecting Root Ports (RPs):



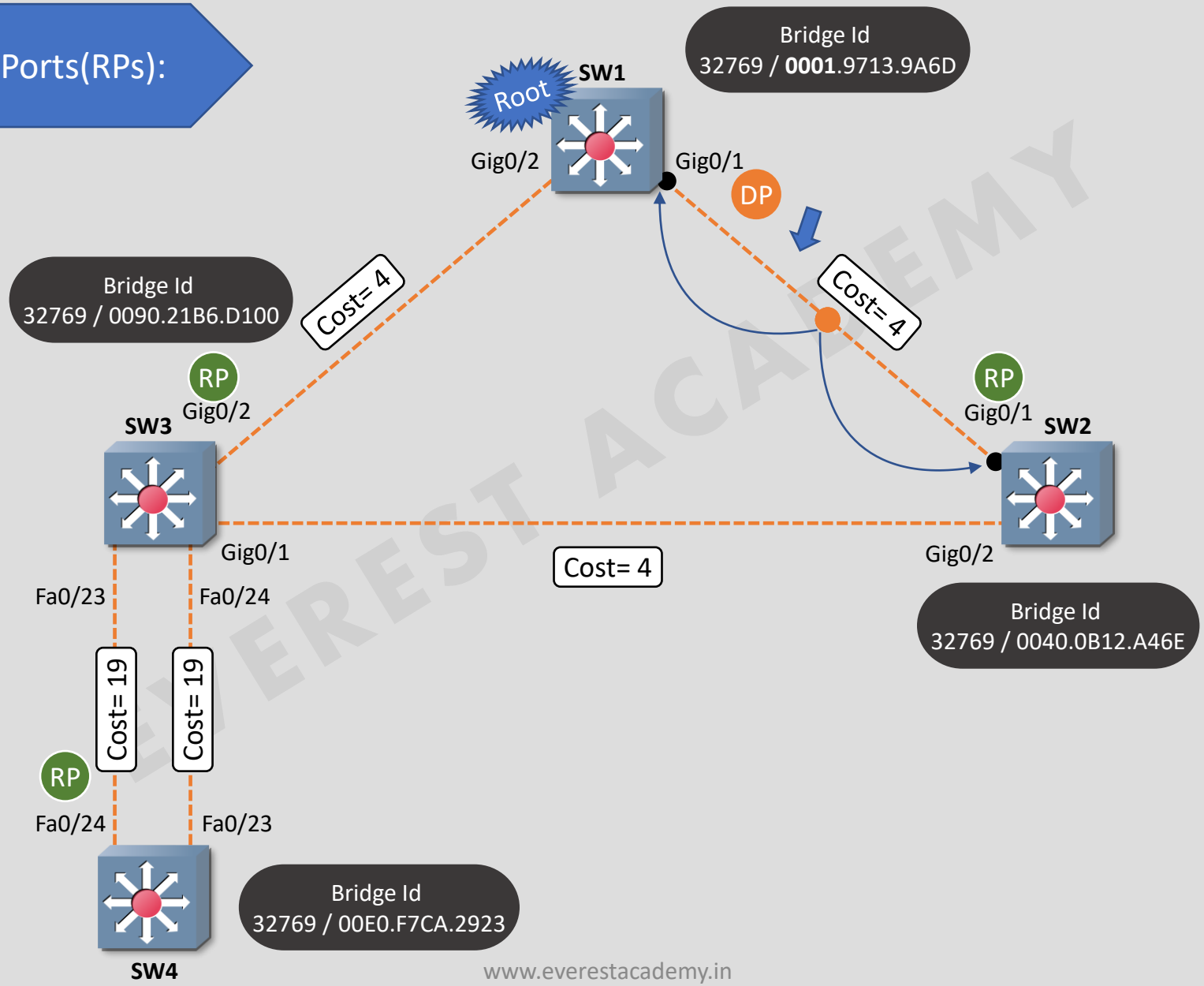
2. Selecting Root Ports (RPs):



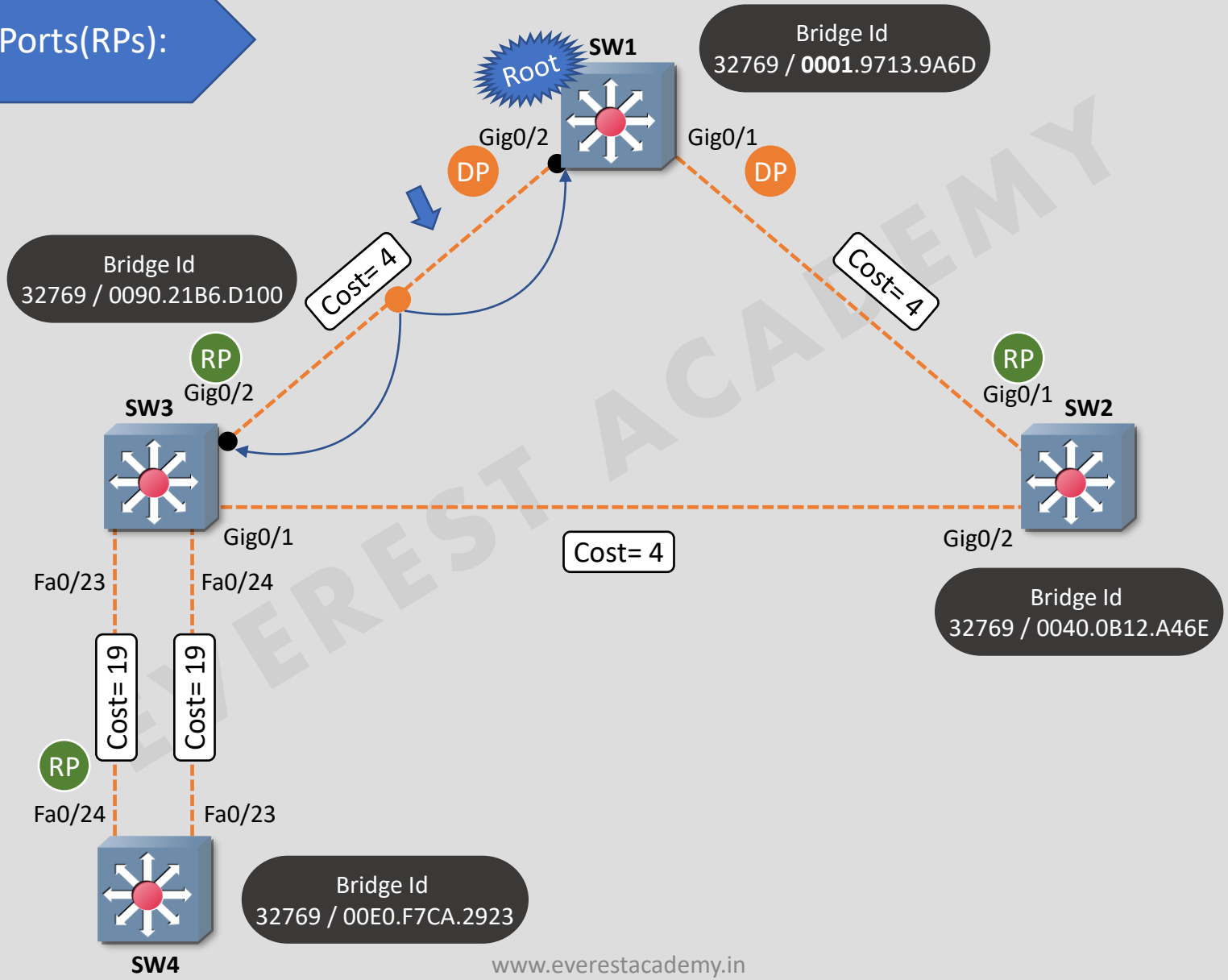
2. Selecting Root Ports (RPs):



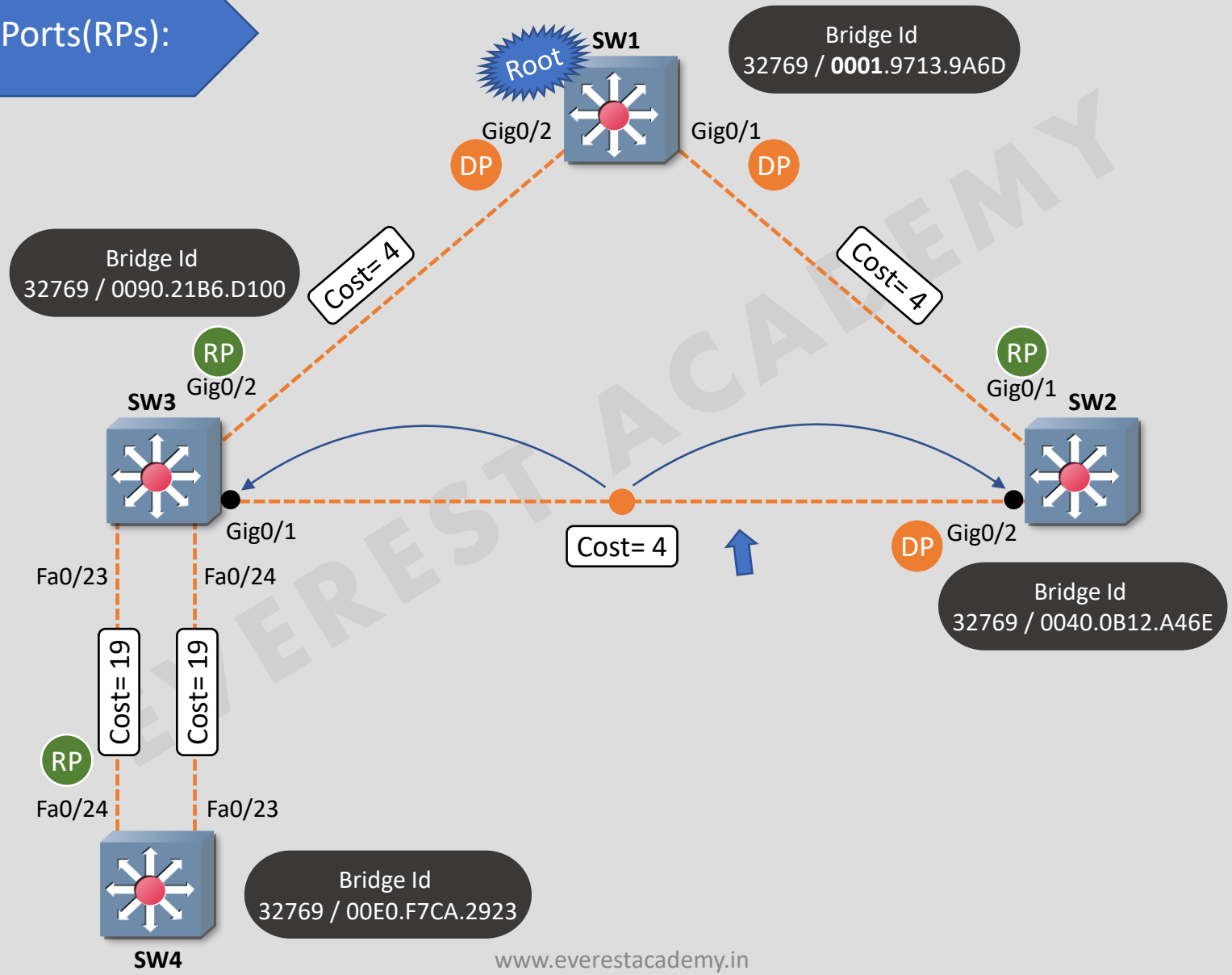
2. Selecting Designated Ports(RPs):



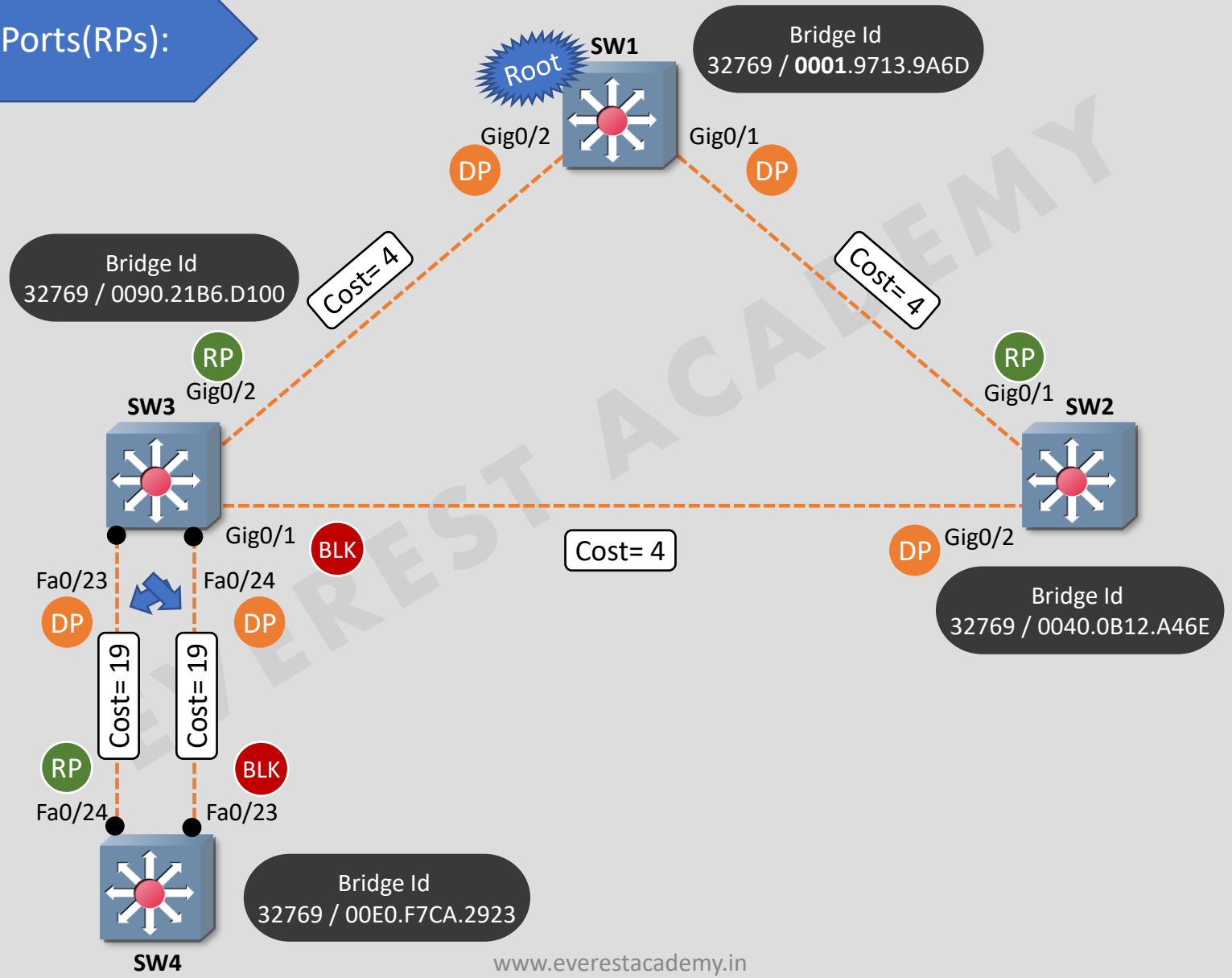
2. Selecting Designated Ports(RPs):



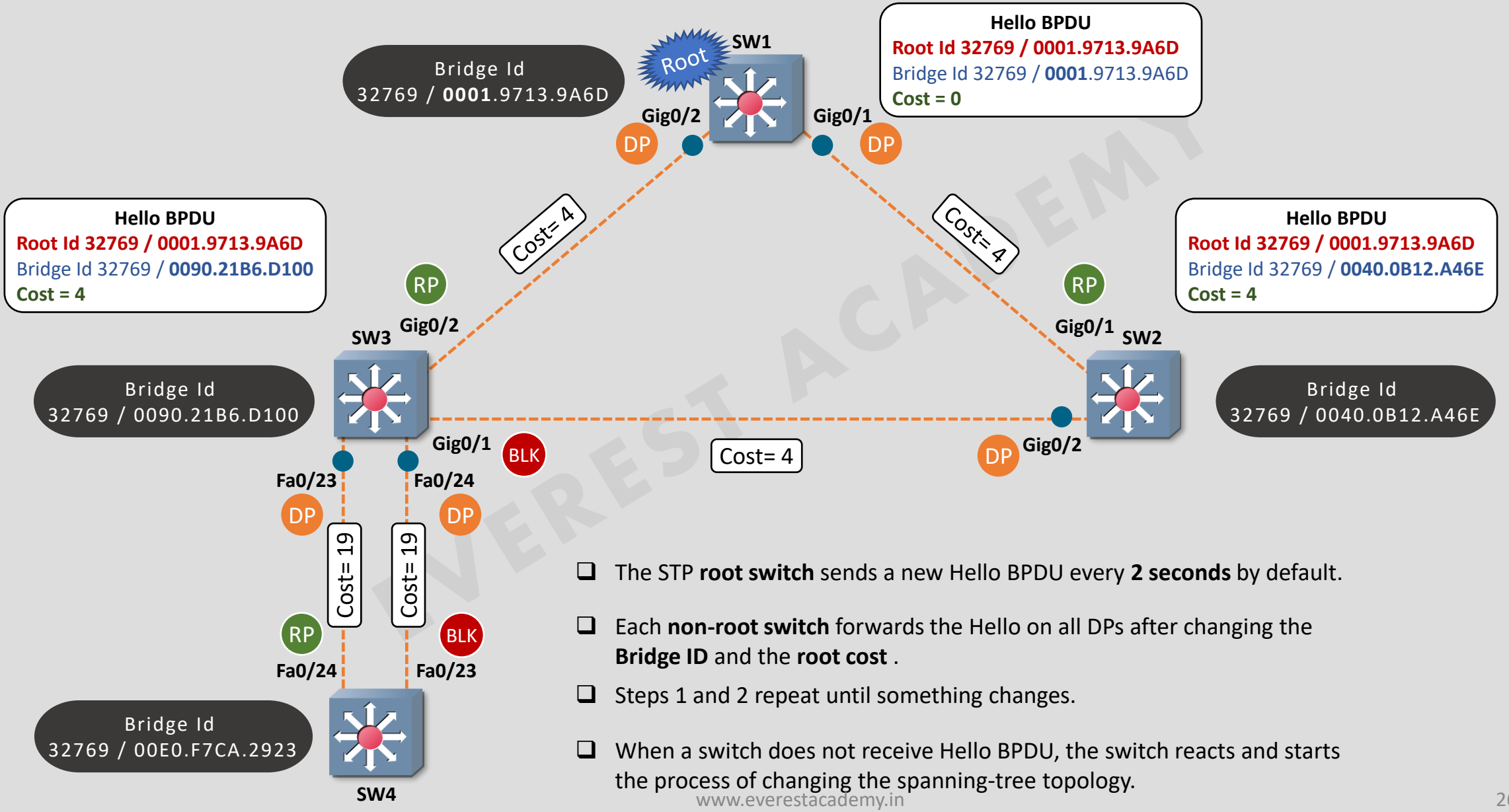
2. Selecting Designated Ports(RPs):



2. Selecting Designated Ports(RPs):



STP Convergence



- The STP **root switch** sends a new Hello BPDU every **2 seconds** by default.
- Each **non-root switch** forwards the Hello on all DPs after changing the **Bridge ID** and the **root cost** .
- Steps 1 and 2 repeat until something changes.
- When a switch does not receive Hello BPDU, the switch reacts and starts the process of changing the spanning-tree topology.

STP Timers

❖ **Hello Timer :** the time between each configuration BPDUs that is sent on a designated port (DP).

- **Default value :** 2 seconds.

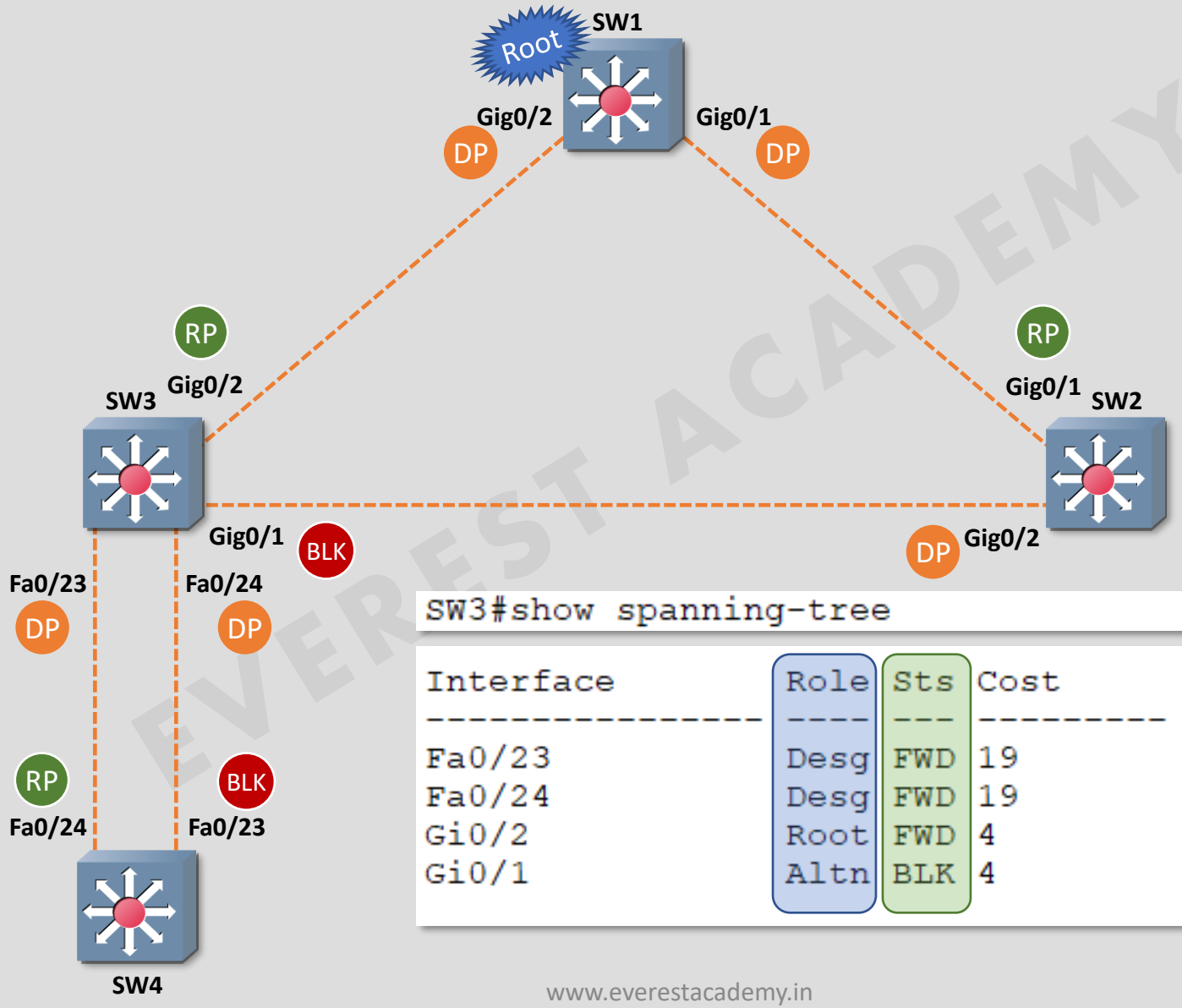
❖ **MaxAge :** the time interval that a switch stores a configuration BPDU before discarding it.

- **Default value :** 10 times Hello.

❖ **Forward delay :** the time interval that a switch port spends in both the **Listening** and **Learning** states.

- **Default value :** 15 seconds.

Port Roles and Port States




```
SW3#show spanning-tree

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ------
Fa0/23           Desg FWD 19        128.23   P2p
Fa0/24           Desg FWD 19        128.24   P2p
Gi0/2            Root FWD 4         128.26   P2p
Gi0/1            Altn BLK 4         128.25   P2p
```

Port Roles and Port States

STP 802.1D

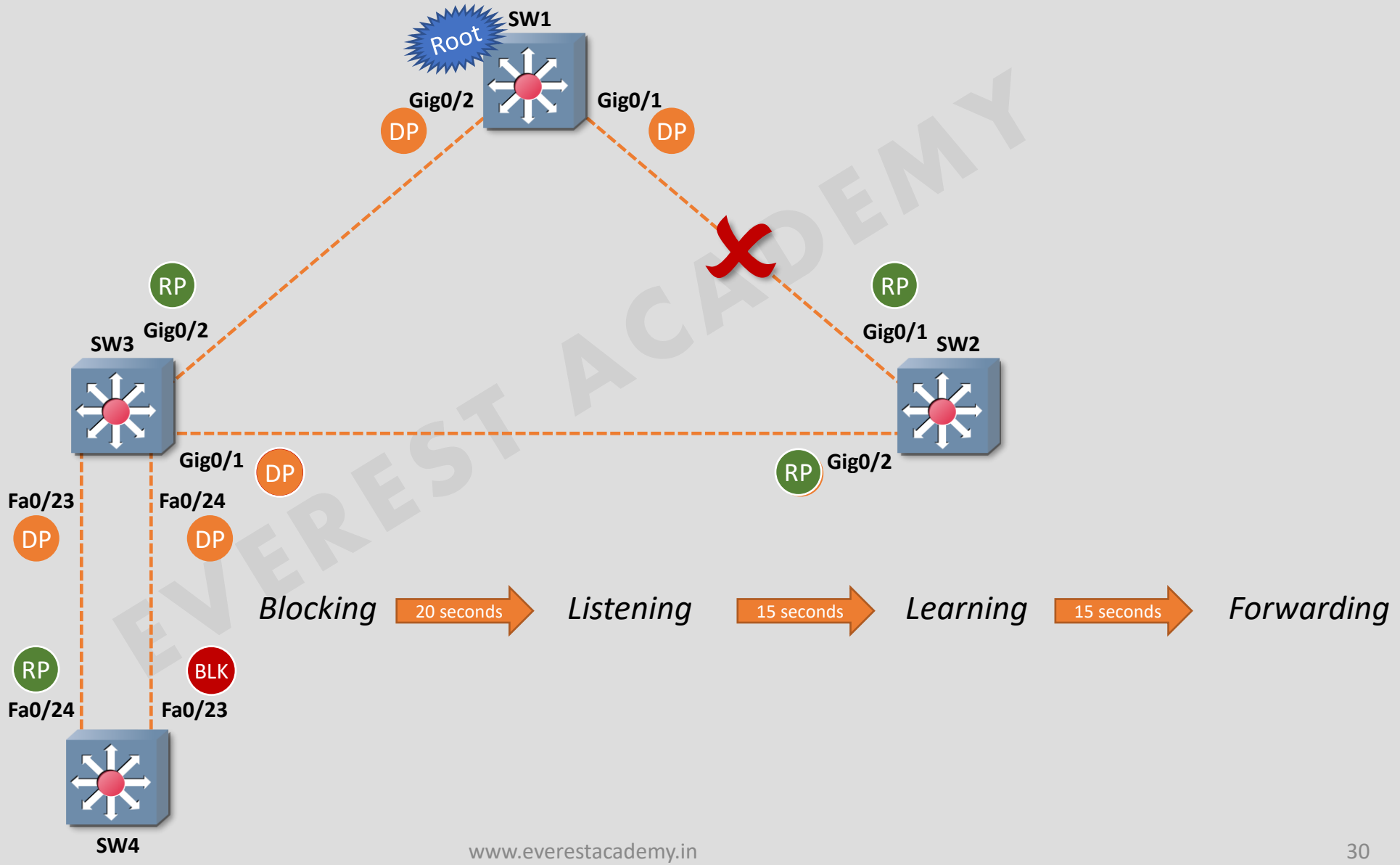
Role	State
Disabled	Disabled
Root Port	Forwarding
Designated Port	
Non-Designated	Blocking
Transition	Listening
	Learning

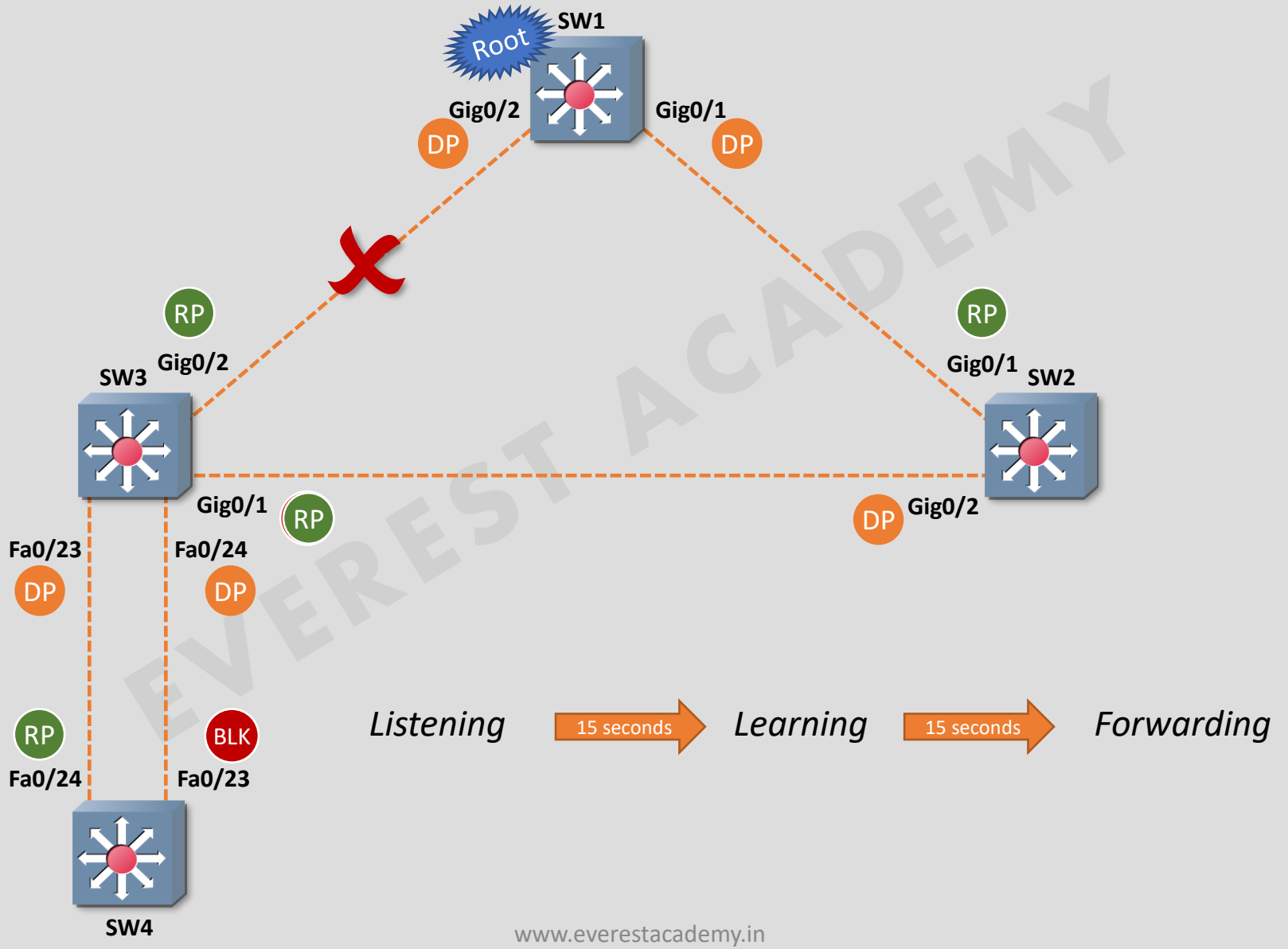
PVST+

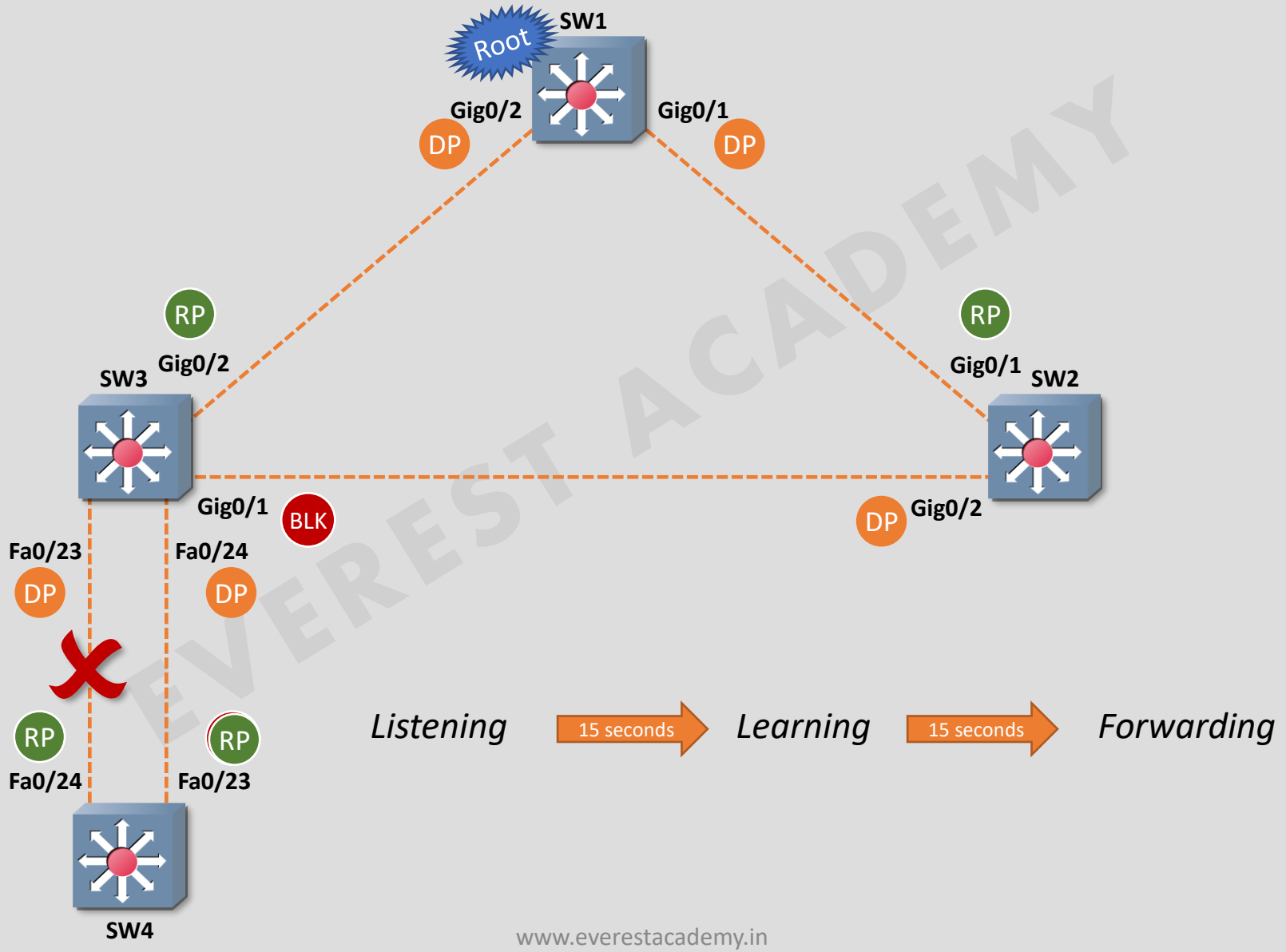
Role	State
Disabled	Disabled
Root Port	Forwarding
Designated Port	
Alternate	Blocking
Transition	Listening
	Learning

Disabled → *Listening* (15 seconds) → *Learning* (15 seconds) → *Forwarding*

Blocking (20 seconds) → *Listening* (15 seconds) → *Learning* (15 seconds) → *Forwarding*







Rapid STP (802.1w)

- In 2001, the IEEE introduced Rapid Spanning Tree Protocol (RSTP) as 802.1w.
- In 2004, IEEE integrated RSTP into the STP 802.1D standard.
- RSTP provides significantly faster spanning tree convergence after a topology change.
- RSTP is backwards-compatible with standard STP.
- Most modern networks use RSTP instead of STP.
- The most recent models and IOS versions of Cisco switches default to use RSTP (RPVST+) instead of STP (PVST+).
- STP takes a long time to converge (50 seconds).
- RSTP takes few seconds to converge (6 seconds).
- RSTP can replace a root port, without any waiting to reach a forwarding.
- RSTP can replace a designated port, without any waiting to reach a forwarding state.
- With STP, only root switch generates configuration BPDU and sends it to all other switches.
- With RSTP, each switch independently generates its own configuration BPDU.
- RSTP allows for queries between neighbors, rather than waiting on timers to expire.

Port Roles and Port States

STP/PVST+

Role	*State*
Disabled	Disabled
Alternat	Blocking
Transition	Listening (15 sec)
	Learning (15 sec)
Root Port	Forwarding
Designated Port	

RSTP/RPVST+

Role	*State*
Disabled	Discarding
Alternate	Discarding
Backup	
Transition	*Learning*
Root Port	Forwarding
Designated Port	

STP BPDU and RSTP BPDU

STP BPDU

```
Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
    BPDU flags: 0x00
        0... .... = Topology Change Acknowledgment: No
        .... ...0 = Topology Change: No
    Root Identifier: 32768 / 1 / 50:00:00:01:00:00
    Root Path Cost: 0
    Bridge Identifier: 32768 / 1 / 50:00:00:01:00:00
    Port identifier: 0x8001
    Message Age: 0
    Max Age: 20
    Hello Time: 2
    Forward Delay: 15
```

RSTP BPDU

```
Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Rapid Spanning Tree (2)
    BPDU Type: Rapid/Multiple Spanning Tree (0x02)
    BPDU flags: 0x0e, Port Role: Designated, Proposal
        0... .... = Topology Change Acknowledgment: No
        .0.. .... = Agreement: No
        ..0. .... = Forwarding: No
        ...0 .... = Learning: No
        .... 11.. = Port Role: Designated (3)
        .... ..1. = Proposal: Yes
        .... ...0 = Topology Change: No
    Root Identifier: 32768 / 1 / 50:00:00:01:00:00
    Root Path Cost: 0
    Bridge Identifier: 32768 / 1 / 50:00:00:01:00:00
    Port identifier: 0x8001
    Message Age: 0
    Max Age: 20
    Hello Time: 2
    Forward Delay: 15
    Version 1 Length: 0
```

STP and RSTP Port Costs

Data rate	STP cost	RSTP cost
10 Mbit/s	100	2,000,000
100 Mbit/s	19	200,000
1 Gbit/s	4	20,000
2 Gbit/s	3	10,000
10 Gbit/s	2	2,000
100 Gbit/s	N/A	200
1 Tbit/s	N/A	20

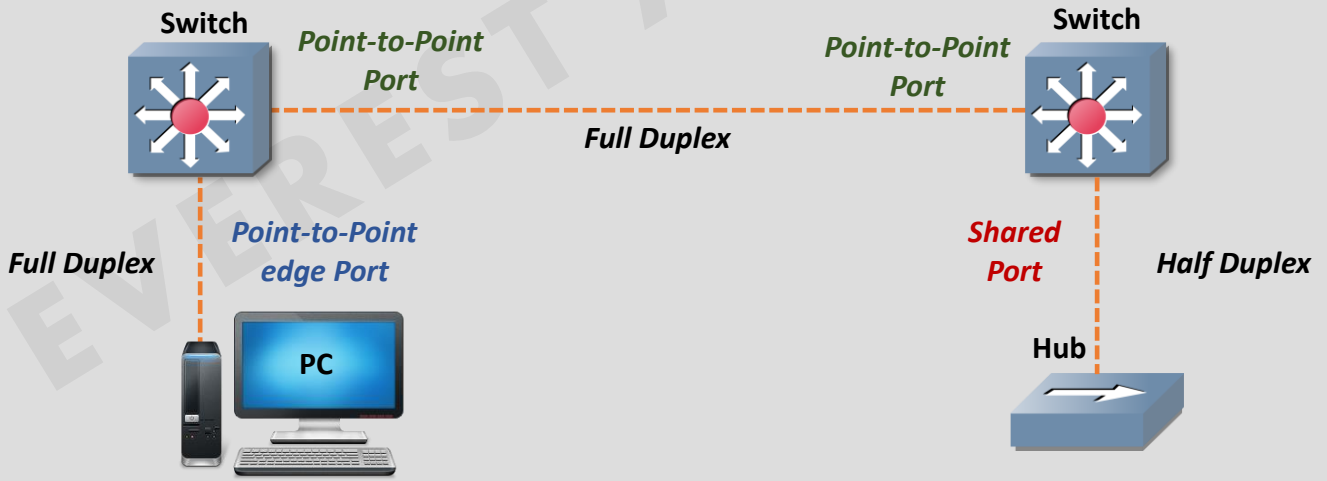
RSTP Port Types

- Point-to-Point Edge ports—These are the interfaces/ports connected to hosts. These interfaces are immediately moved to the forwarding state.

- Point-to-Point Ports—These are the interfaces/ports connected directly to neighboring switches over a point-to-point link.

  - RSTP negotiates with the neighbor switch for rapid convergence/transition only when the link is point-to-point

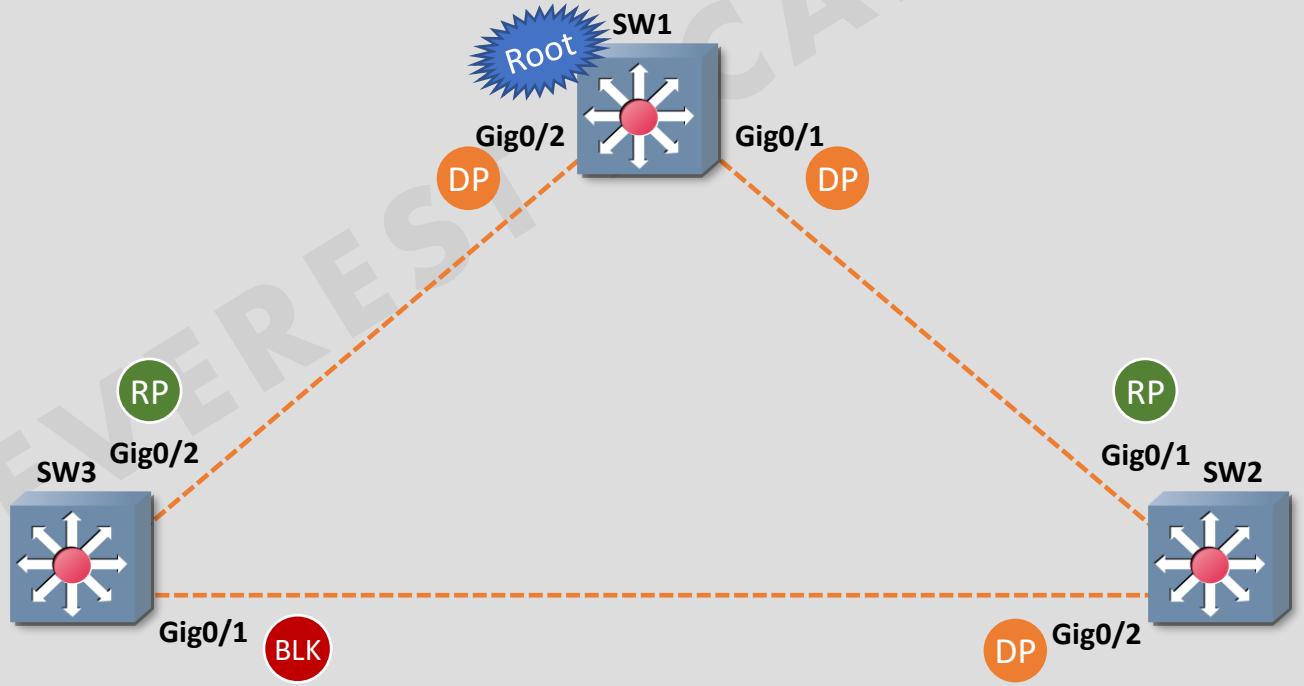
- Shared Ports—These are the interfaces/ports that operate in half-duplex mode (Hub).



Configuring RSTP

SW# configure terminal
SW(config)# spanning-tree mode rapid-pvst
SW(config)# end
SW1# show spanning-tree

```
SW#show spanning-tree
VLAN0001
  Spanning tree enabled protocol rstp
  Root ID     Priority    32769
```



STP PortFast and BPDU Guard

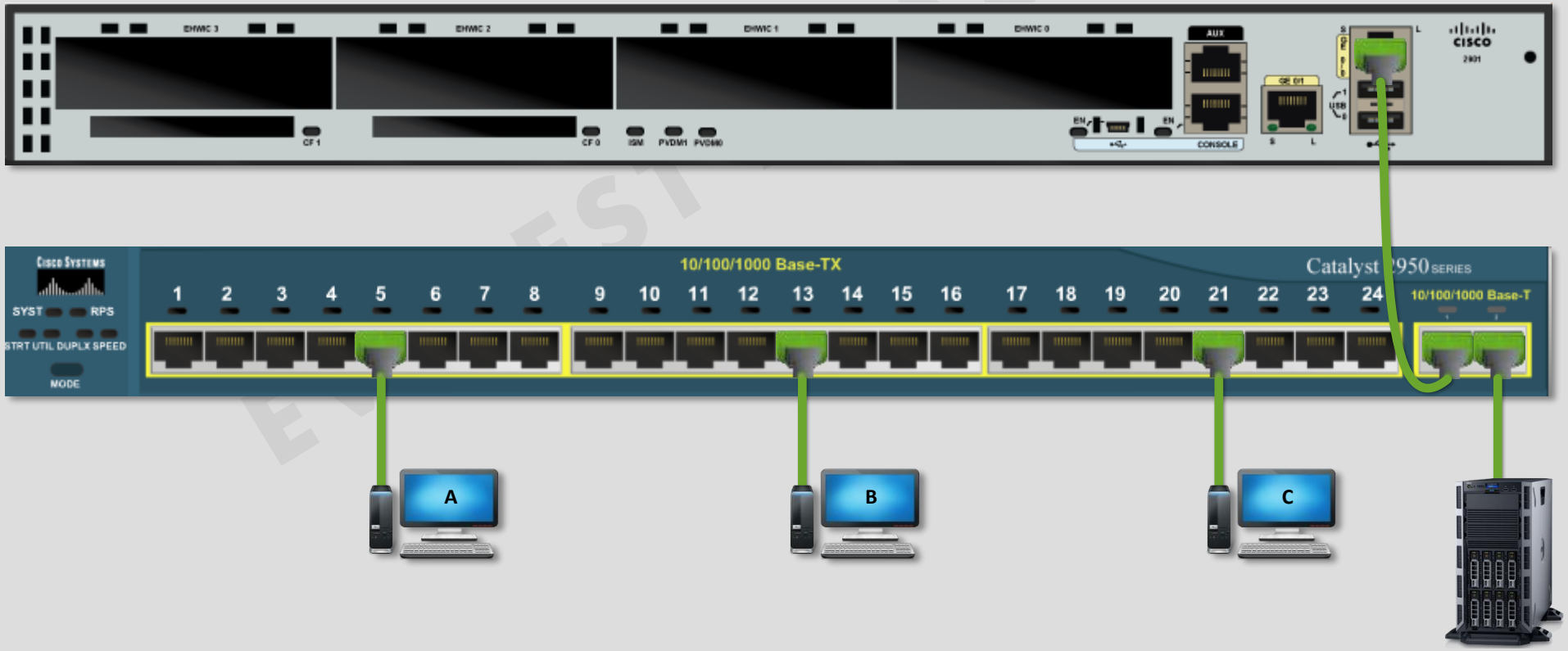
- **PortFast** is a Cisco proprietary feature that causes a switch port to enter **forwarding** state immediately, bypassing the **listening** and **learning** states.
- **PortFast** minimizes the spanning-tree convergence time.
- **PortFast** feature can be enabled on an **access** port connected to an *workstation* such as a computer or a printer or on a **trunk** port connected to a *router* or a *server*.
- **Enabling** PortFast feature on a switch port connected to another switch port can causes **broadcast storms**.
- **PortFast** is useful for DHCP. Without PortFast, a PC can send a DHCP request before the port is in forwarding state, denying the host from getting an IP address.
- **BPDU Guard** feature Prevents accidental connection of switching devices to PortFast-enabled ports.
- **BPDU Guard** puts an interface configured for STP PortFast into the **err-disable** state upon receipt of a BPDU.

Configuring PortFast and BPDU Guard

```
SW1> enable
SW1# configure terminal
SW1(config)# spanning-tree portfast default
SW1(config)# spanning-tree portfast bpduguard default
SW1(config)# end
SW1# show spanning-tree summary
SW1# show spanning-tree interface _____ portfast
```

```
SW1> enable
SW1# configure terminal
SW1(config)# interface range fa0/1 - 24
SW1(config-if)# spanning-tree portfast
SW1(config-if)# spanning-tree bpduguard enable
SW1(config-if)# end
SW1#
```

```
SW1> enable
SW1# configure terminal
SW1(config)# interface range Gig0/1 - 2
SW1(config-if)# spanning-tree portfast trunk
SW1(config-if)# spanning-tree bpduguard enable
SW1(config-if)# end
SW1#
```



Configuring PortFast