Spanning Tree Protocol – 802.1D

Foreword

As the enterprise network expands, multi-switched networks are introduced to provide link layer communication between a growing number of end systems. As new interconnections are formed between multiple enterprise switches, new opportunities for building ever resilient networks are made possible, however the potential for switching failure as a result of loops becomes ever more likely. It is necessary that the spanning tree protocol (STP) therefore be understood in terms of behavior in preventing switching loops, and how it can be manipulated to suit enterprise network design and performance.

Objectives

Upon completion of this section, trainees will be able to:

- Describe the issues faced when using a multi-switched network.

- Explain the loop prevention process of the spanning tree protocol.

- Configure parameters for managing the STP network design.
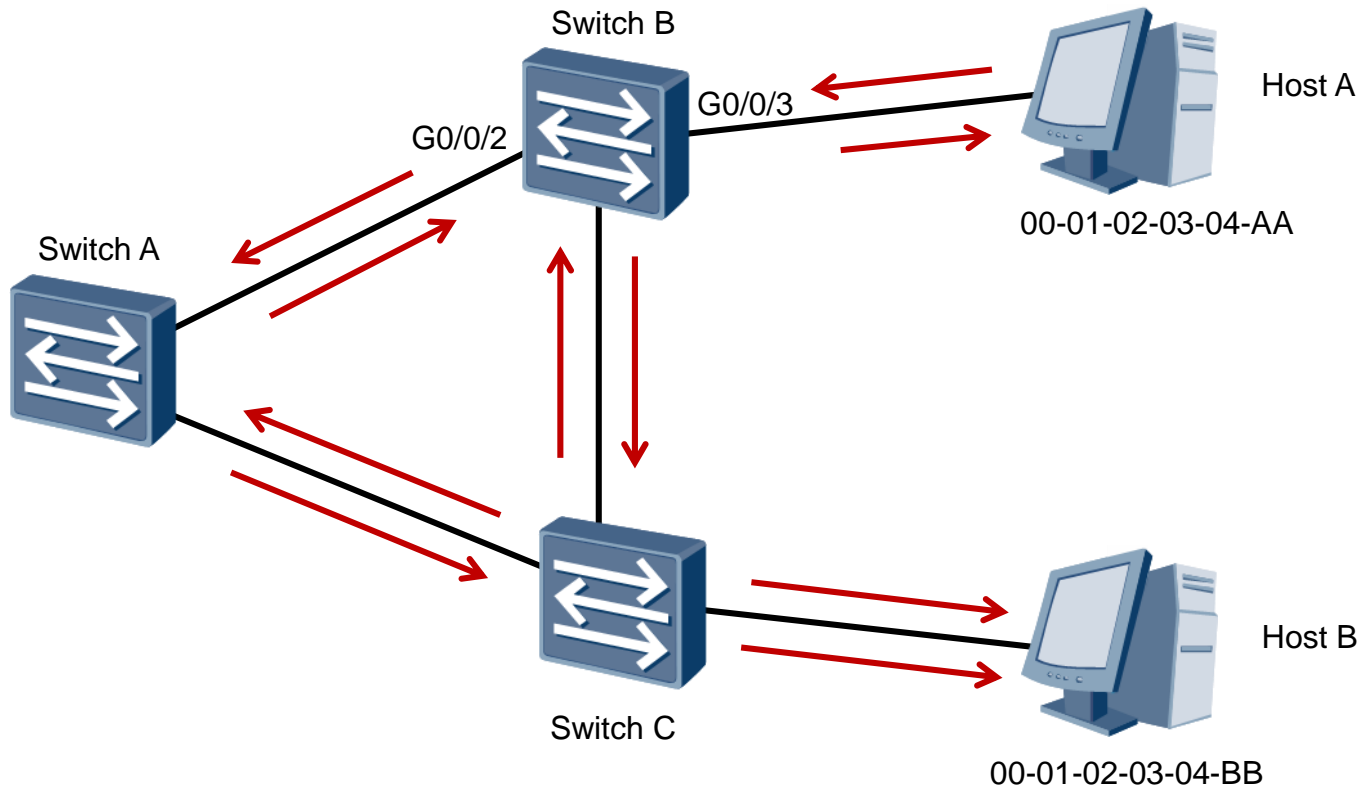
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Enterprise Network Basic Architecture

Layer 2 Redundancy

Switch A   Switch B
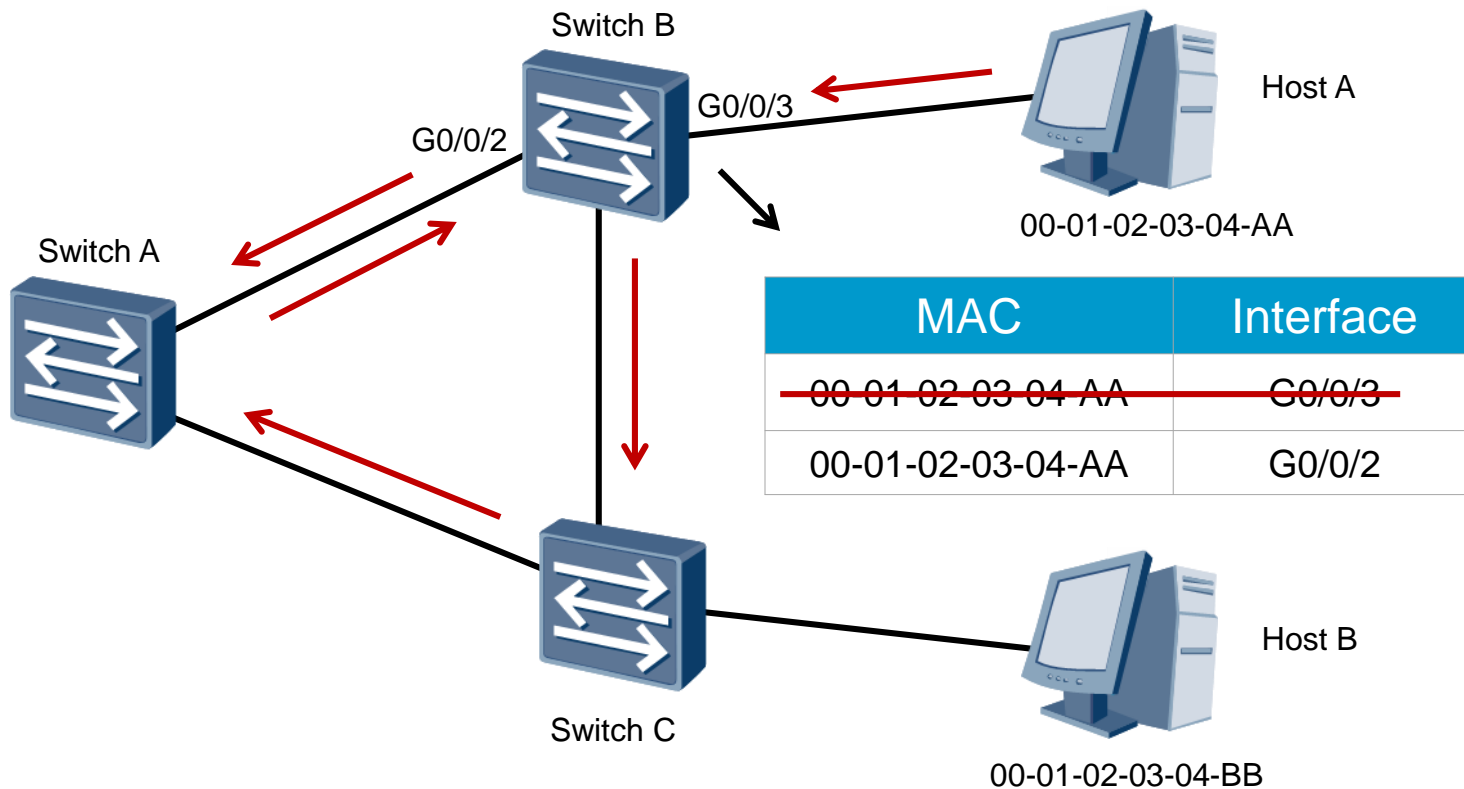
Switch C   Switch D   Switch E
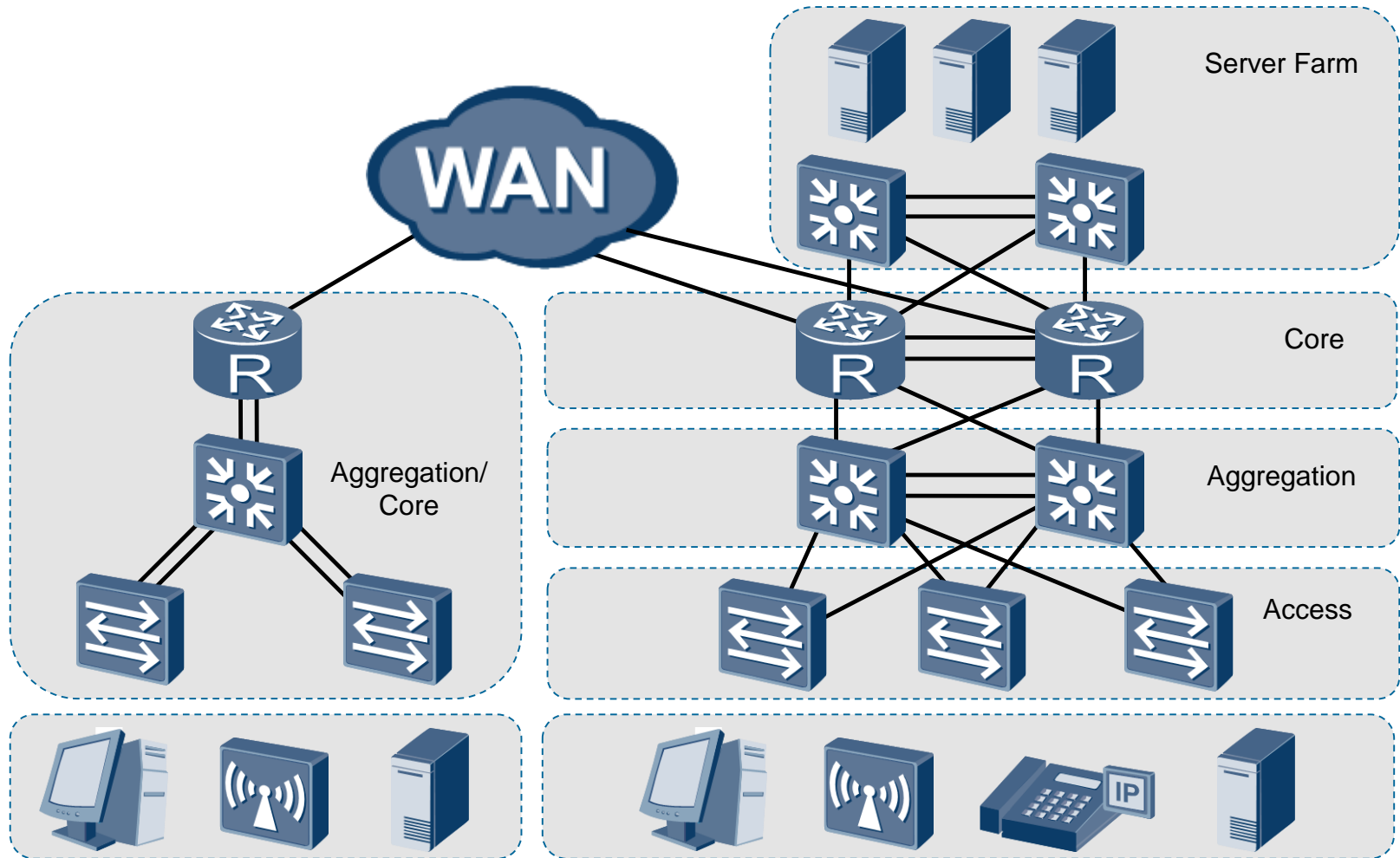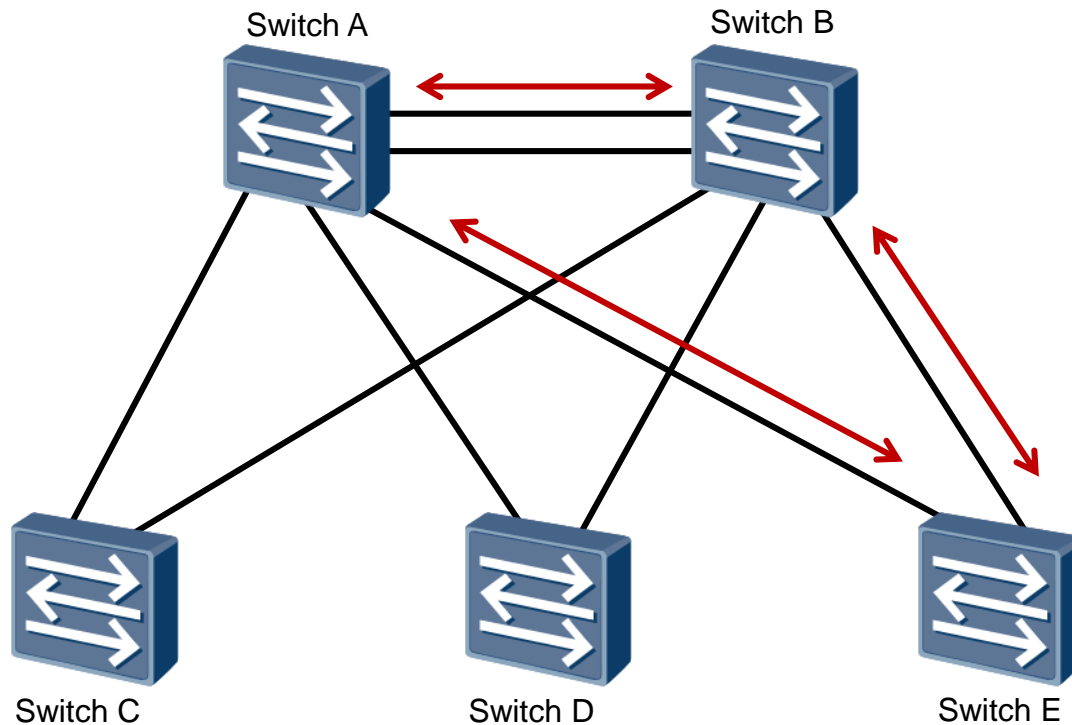
● Redundancy in a switching network minimizes connection failure but generates potential switching loops.

Broadcast Storms

● Switching loops allow for broadcast storms to occur and duplication of frames to be received by end stations.

MAC Instability

Switch B

G0/0/2

G0/0/3

Host A

00-01-02-03-04-AA

Switch A

MAC	Interface
~~00-01-02-03-04-AA~~	~~G0/0/3~~
00-01-02-03-04-AA	G0/0/2

Switch C

Host B

00-01-02-03-04-BB

● Receiving previously forwarded frames generates false MAC entries, and instability within the MAC address table.

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Resolving Layer 2 Redundancy Issues
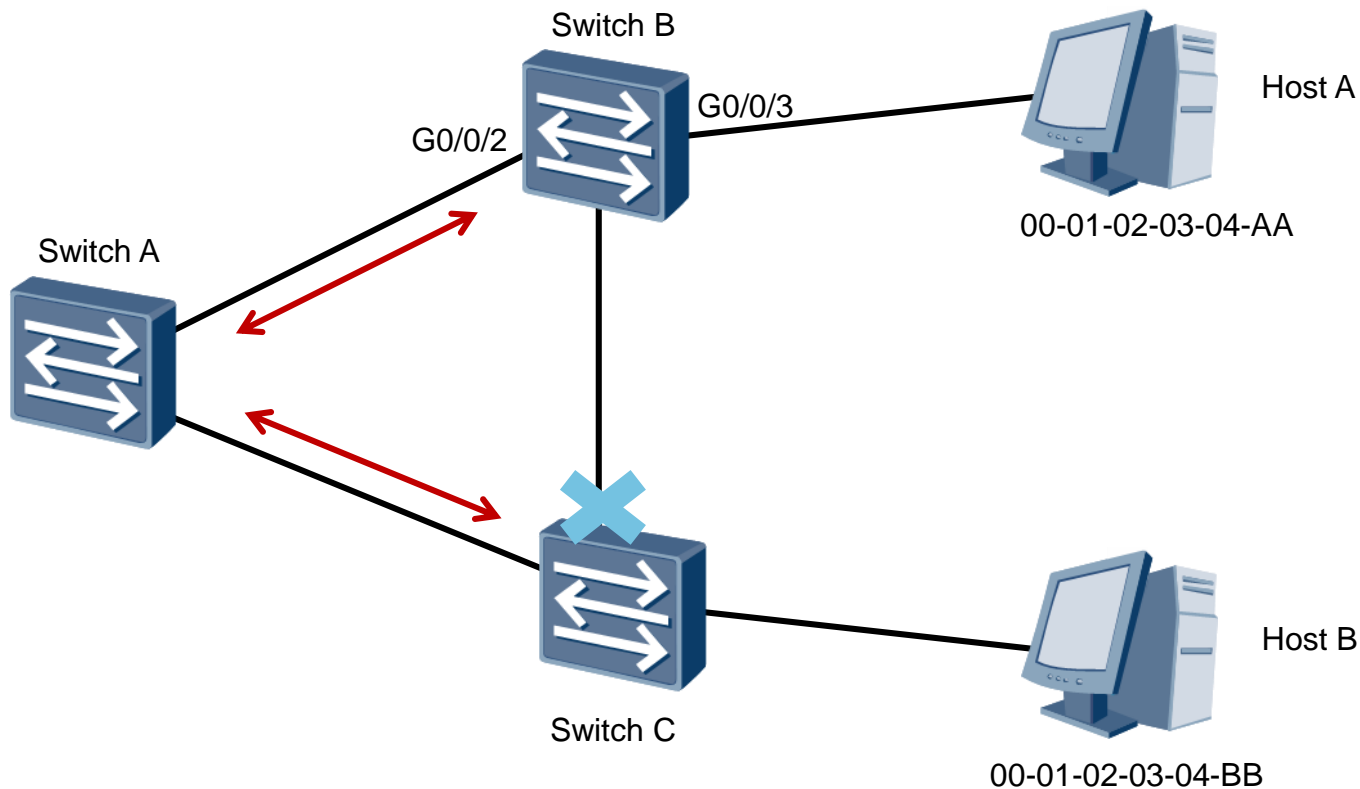
- Loops are eliminated by restricting traffic flow over redundant paths.

Algorhyme

I think that I shall never see
A graph more lovely than a tree.
A tree whose crucial property
Is loop-free connectivity.
A tree which must be sure to span
So packets can reach every LAN.
First the Root must be selected
By ID it is elected.
Least cost paths from Root are traced
In the tree these paths are placed.
A mesh is made by folks like me
Then bridges find a spanning tree.

The Spanning Tree Root Bridge
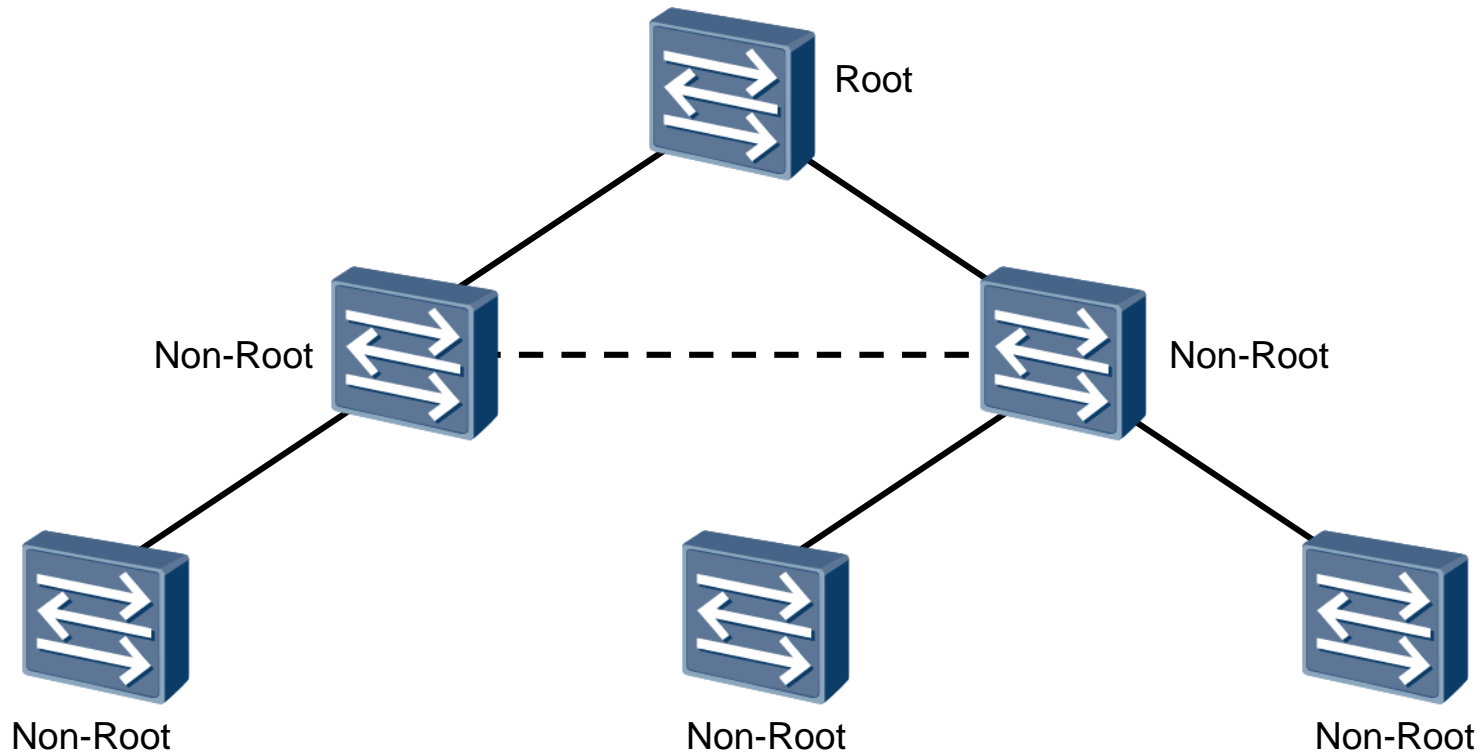
- An inverted tree architecture is created as a result of STP.

- The root bridge represents the base of the spanning tree.

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Bridge ID

4096 00-01-02-03-04-AA
Root

32768 00-01-02-03-04-BB

32768 00-01-02-03-04-CC

32768 00-01-02-03-04-DD

32768 00-01-02-03-04-EE

32768 00-01-02-03-04-FF
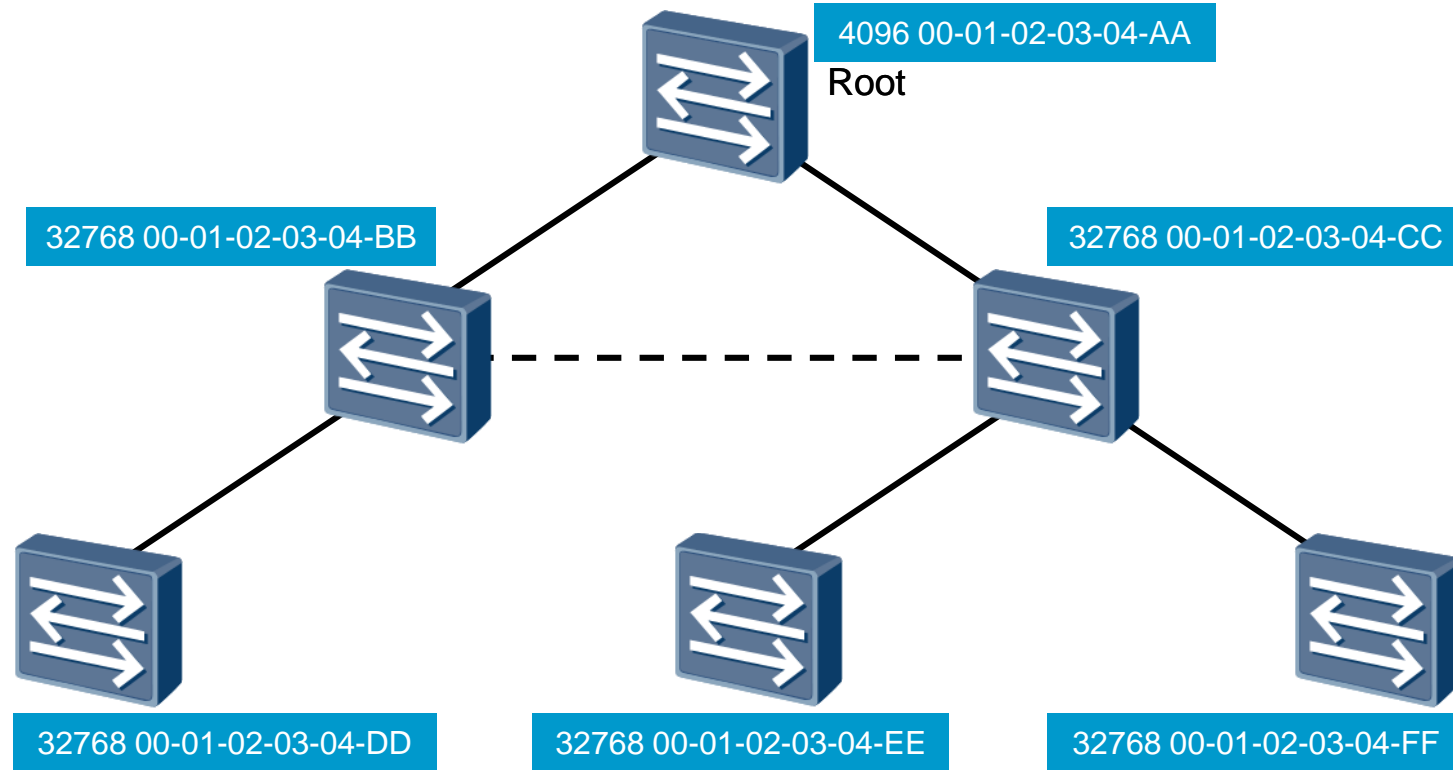
● Bridge Identifiers are used to elect the root bridge.

● The bridge priority can be manipulated to force root selection.

Bridge Protocol Data Unit
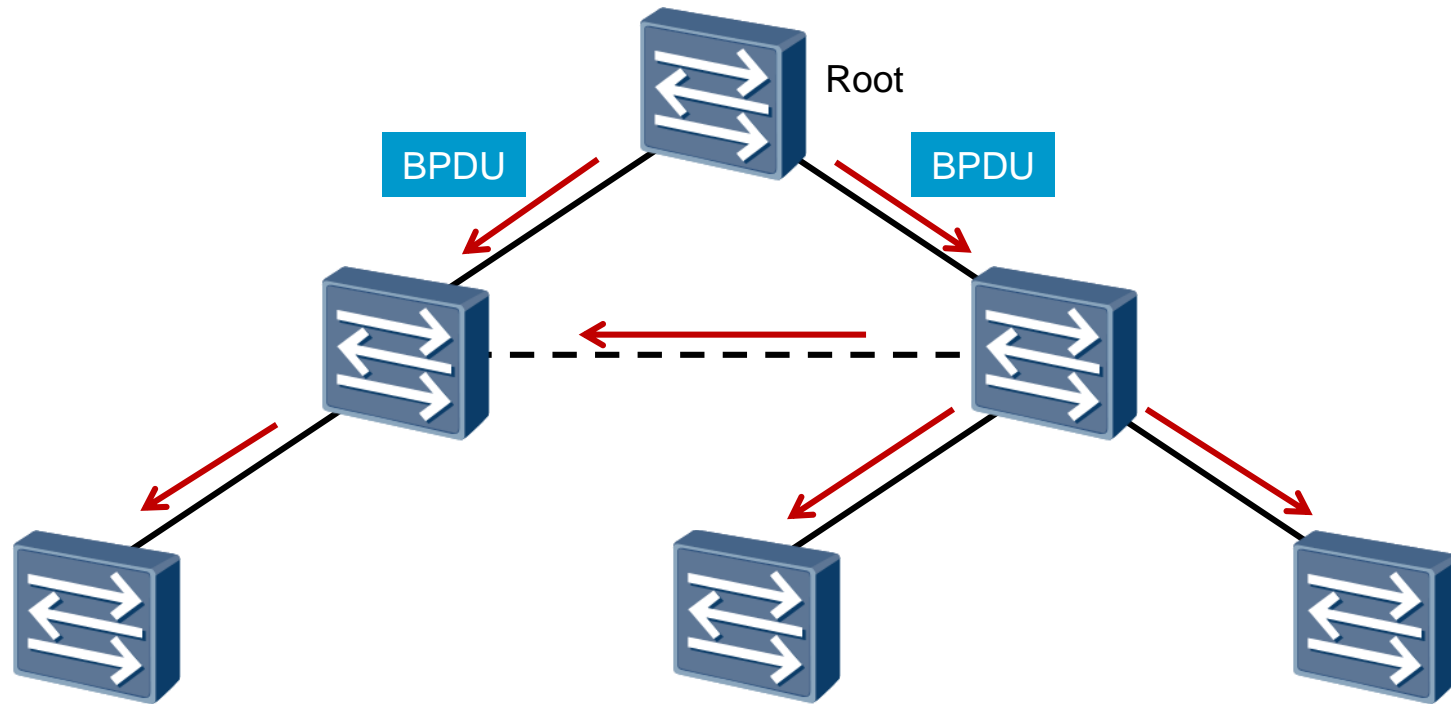
35 Byte

PID	PVI	BPDU Type	Flags	Root ID	RPC	Bridge ID	Port ID	Message Age	Max Age	Hello Time	Fwd Delay

Configuration   TCN

Configuration BPDU type: 0x00
TCN BPDU type: 0x80

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Bridge Protocol Data Unit

```
> Frame 3: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
> IEEE 802.3 Ethernet
∨ Logical-Link Control
    > DSAP: Spanning Tree BPDU (0x42)
    > SSAP: Spanning Tree BPDU (0x42)
    > Control field: U, func=UI (0x03)
∨ 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 / 0 / 4c:1f:cc:33:43:76
            Root Bridge Priority: 32768
            Root Bridge System ID Extension: 0
            Root Bridge System ID: HuaweiTe_33:43:76 (4c:1f:cc:33:43:76)
        Root Path Cost: 20000
    ∨ Bridge Identifier: 32768 / 0 / 4c:1f:cc:81:3d:4b
            Bridge Priority: 32768
            Bridge System ID Extension: 0
            Bridge System ID: HuaweiTe_81:3d:4b (4c:1f:cc:81:3d:4b)
        Port identifier: 0x8002
        Message Age: 1
        Max Age: 20
        Hello Time: 2
        Forward Delay: 15
```

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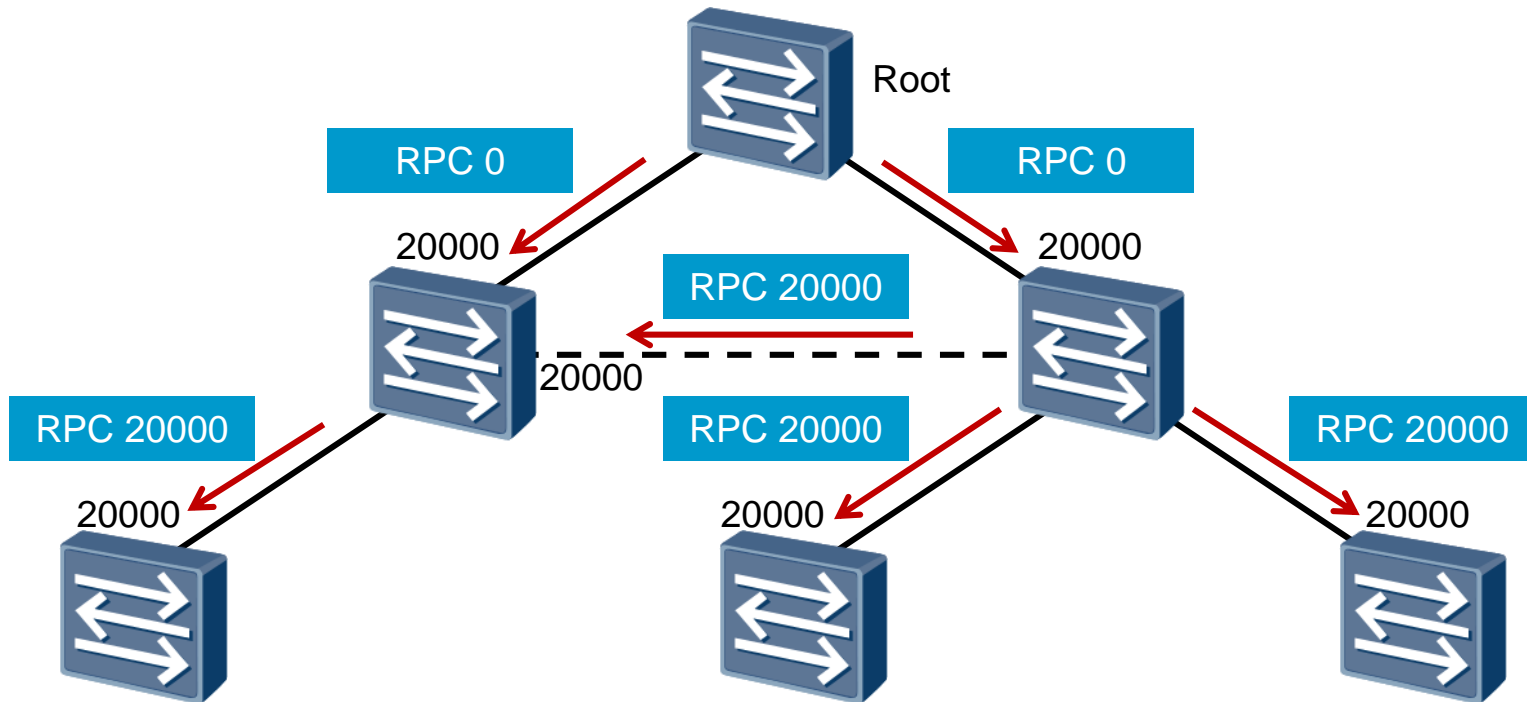
Path Cost

- Root path cost is carried in the BPDU and used to determine the shortest path to the root.

Path Cost Standards

Port Speed	802.1D	802.1t	Path Cost Legacy
10 Mbps	99	2 000 000	2 000
100 Mbps	18	200 000	200
1 Gbps	4	20 000	20
10 Gbps	2	2 000	2

● STP supports various path cost standards.

● The **802.1t** is the default standard used by Huawei switches.

● In generale: costo = 20 000 000 000 / kbps
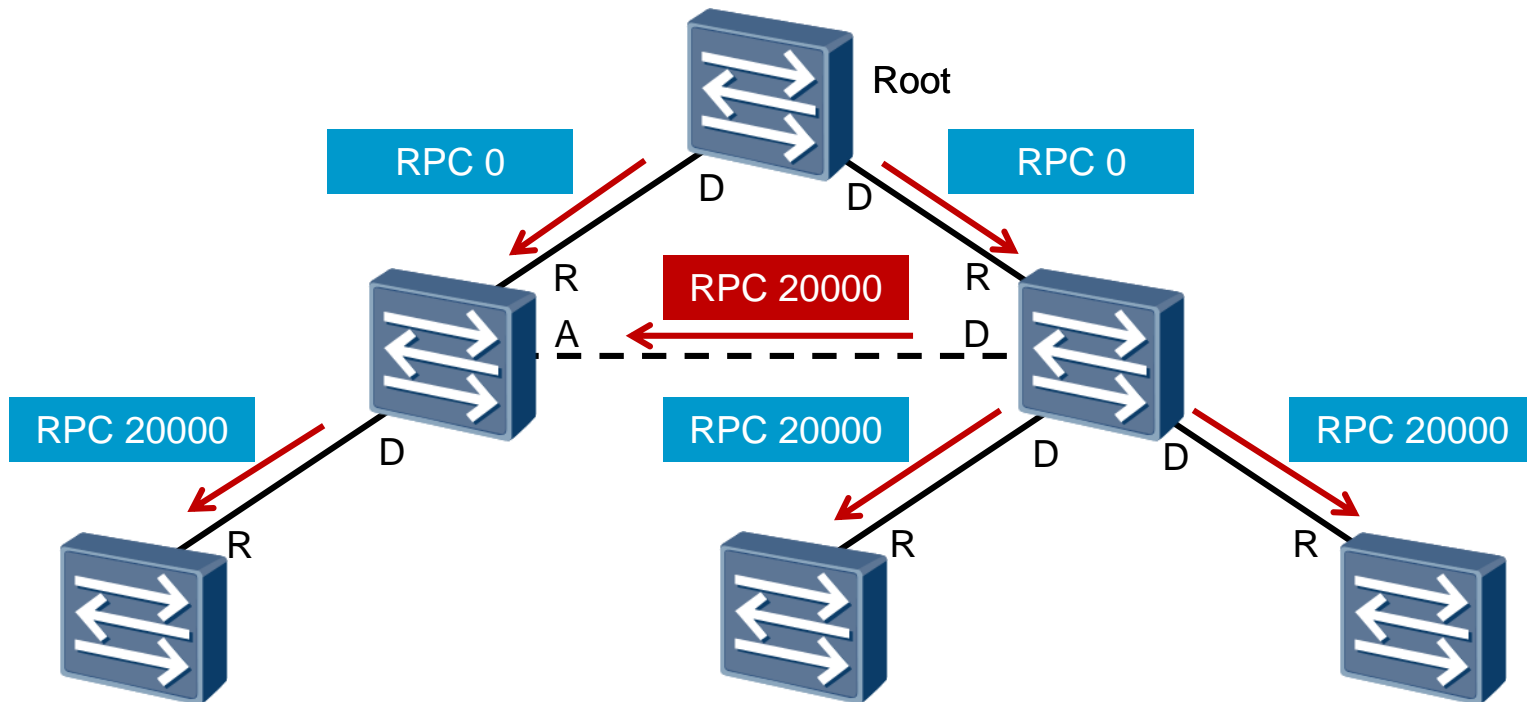
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Path Cost Standards

```
[Huawei]dis stp interface gig 0/0/2
-------[CIST Global Info][Mode STP]-------
CIST Bridge            :32768.4c1f-cc81-3d4b
Config Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
Active Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
CIST Root/ERPC         :32768.4c1f-cc33-4376 / 20000
CIST RegRoot/IRPC      :32768.4c1f-cc81-3d4b / 0
CIST RootPortId        :128.1
BPDU-Protection        :Disabled
TC or TCN received     :22
TC count per hello     :0
STP Converge Mode      :Normal
Time since last TC     :0 days 0h:5m:33s
Number of TC           :8
Last TC occurred       :GigabitEthernet0/0/1
----[Port2(GigabitEthernet0/0/2)][FORWARDING]----
 Port Protocol         :Enabled
 Port Role             :Designated Port
 Port Priority         :128
 Port Cost(Dot1T )     :Config=auto / Active=20000
 Designated Bridge/Port    :32768.4c1f-cc81-3d4b / 128.2
 Port Edged            :Config=default / Active=disabled
 Point-to-point        :Config=auto / Active=true
 Transit Limit         :147 packets/hello-time
 Protection Type       :None
 Port STP Mode         :STP
 Port Protocol Type    :Config=auto / Active=dot1s
 BPDU Encapsulation    :Config=stp / Active=stp
 PortTimes             :Hello 2s MaxAge 20s FwDly 15s RemHop 20
 TC or TCN send        :17
 TC or TCN received    :0
 BPDU Sent            :170
          TCN: 0, Config: 170, RST: 0, MST: 0
 BPDU Received         :1
          TCN: 0, Config: 1, RST: 0, MST: 0
[Huawei]
```

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Path Cost Standards

```
∨ Root Identifier: 32768 / 0 / 4c:1f:cc:33:43:76
      Root Bridge Priority: 32768
      Root Bridge System ID Extension: 0
      Root Bridge System ID: HuaweiTe_33:43:76 (4c:1f:cc:33:43:76)
  Root Path Cost: 20000
∨ Bridge Identifier: 32768 / 0 / 4c:1f:cc:81:3d:4b
      Bridge Priority: 32768
      Bridge System ID Extension: 0
      Bridge System ID: HuaweiTe_81:3d:4b (4c:1f:cc:81:3d:4b)
```
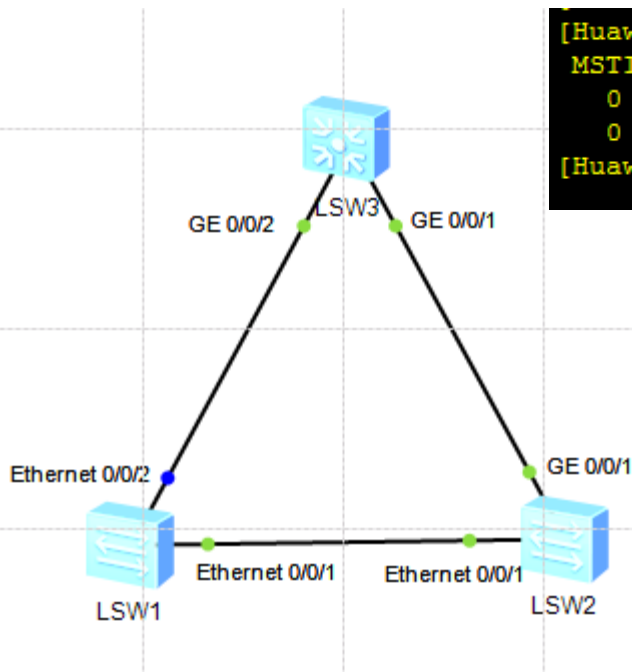
Spanning Tree Port Roles

- Spanning tree supports designated, root and alternate port roles.

- The root path cost enables port roles to be determined.

Spanning Tree Port Roles


```
[Huawei]dis stp brief
 MSTID   Port                         Role   STP State      Protection
    0      GigabitEthernet0/0/1         ROOT   FORWARDING       NONE
    0      GigabitEthernet0/0/2         DESI   FORWARDING       NONE
[Huawei] User interface con0 is available
```

```
<Huawei>dis stp brief
 MSTID   Port                         Role   STP State      Protection
    0      Ethernet0/0/1                DESI   FORWARDING       NONE
    0      GigabitEthernet0/0/1         DESI   FORWARDING       NONE
<Huawei>
```
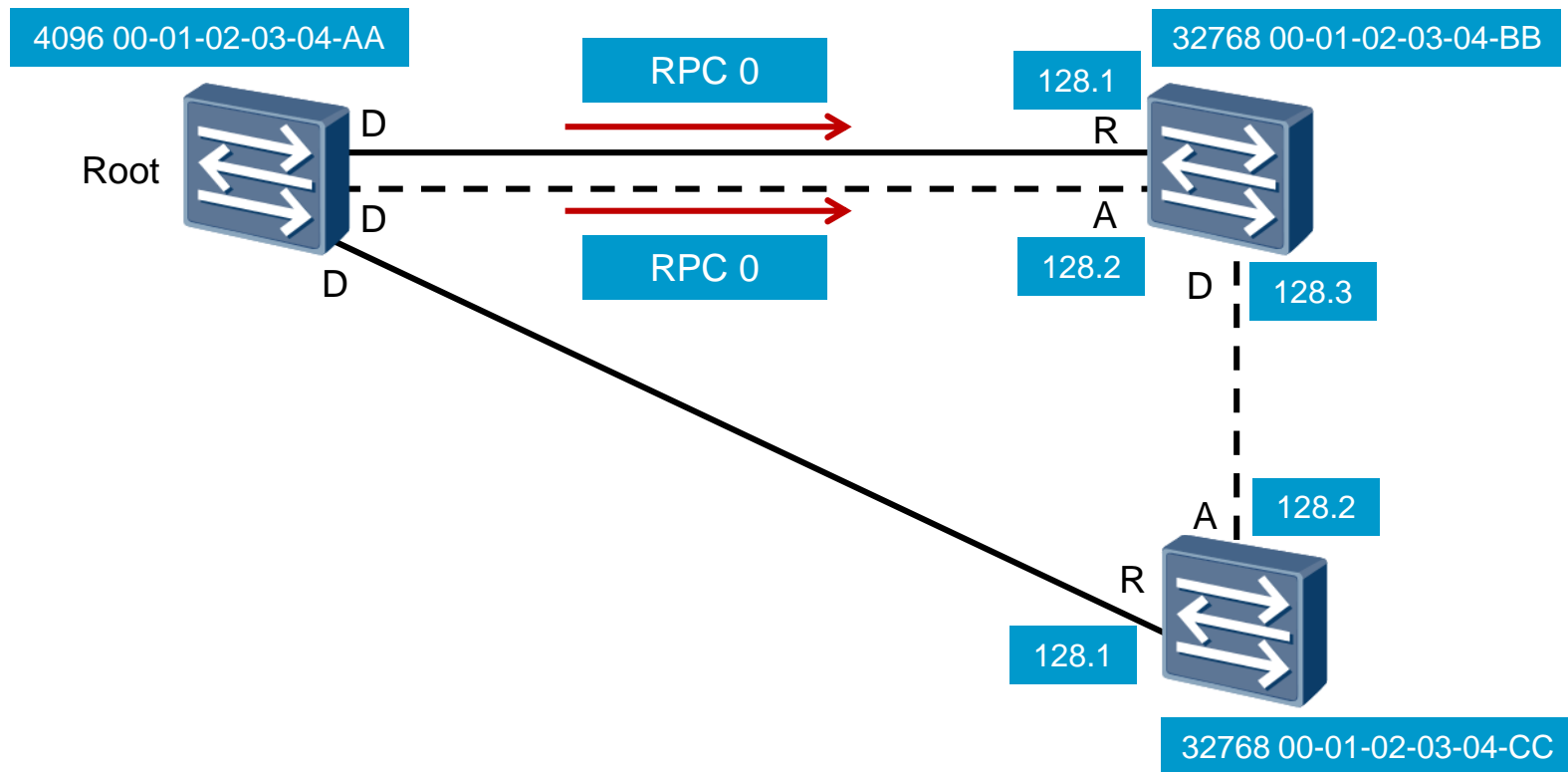
```
<Huawei>dis stp brief
 MSTID   Port                   Role   STP State      Protection
    0      Ethernet0/0/1          ROOT   FORWARDING       NONE
    0      Ethernet0/0/2          ALTE   DISCARDING       NONE
<Huawei>
```

Port ID

4096 00-01-02-03-04-AA

RPC 0

128.1

32768 00-01-02-03-04-BB

Root

D — R

D ---- A

D

RPC 0

128.2

D 128.3

128.1

A 128.2

R

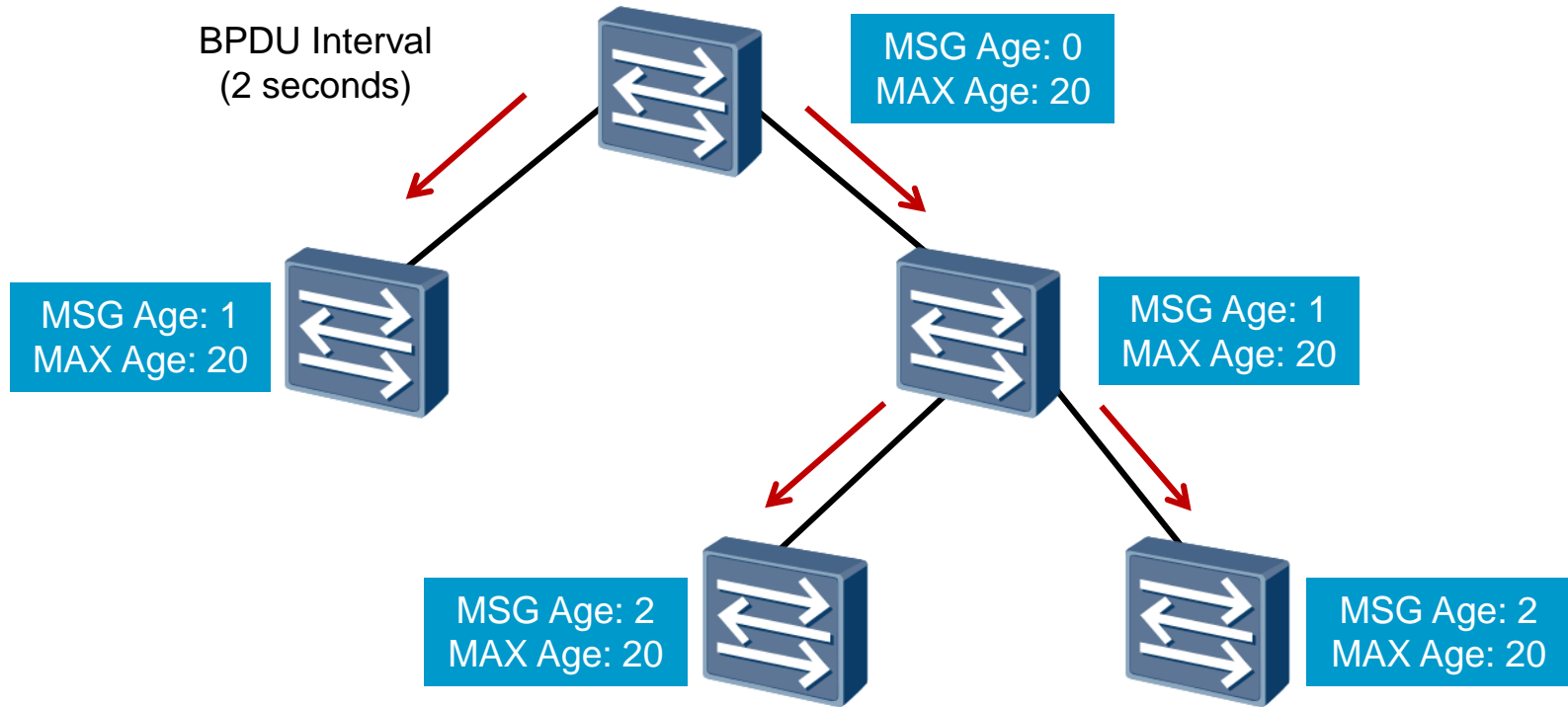128.1

32768 00-01-02-03-04-CC

● Where the root path cost is equal, a port identifier is used to determine the active and alternate paths to the root.
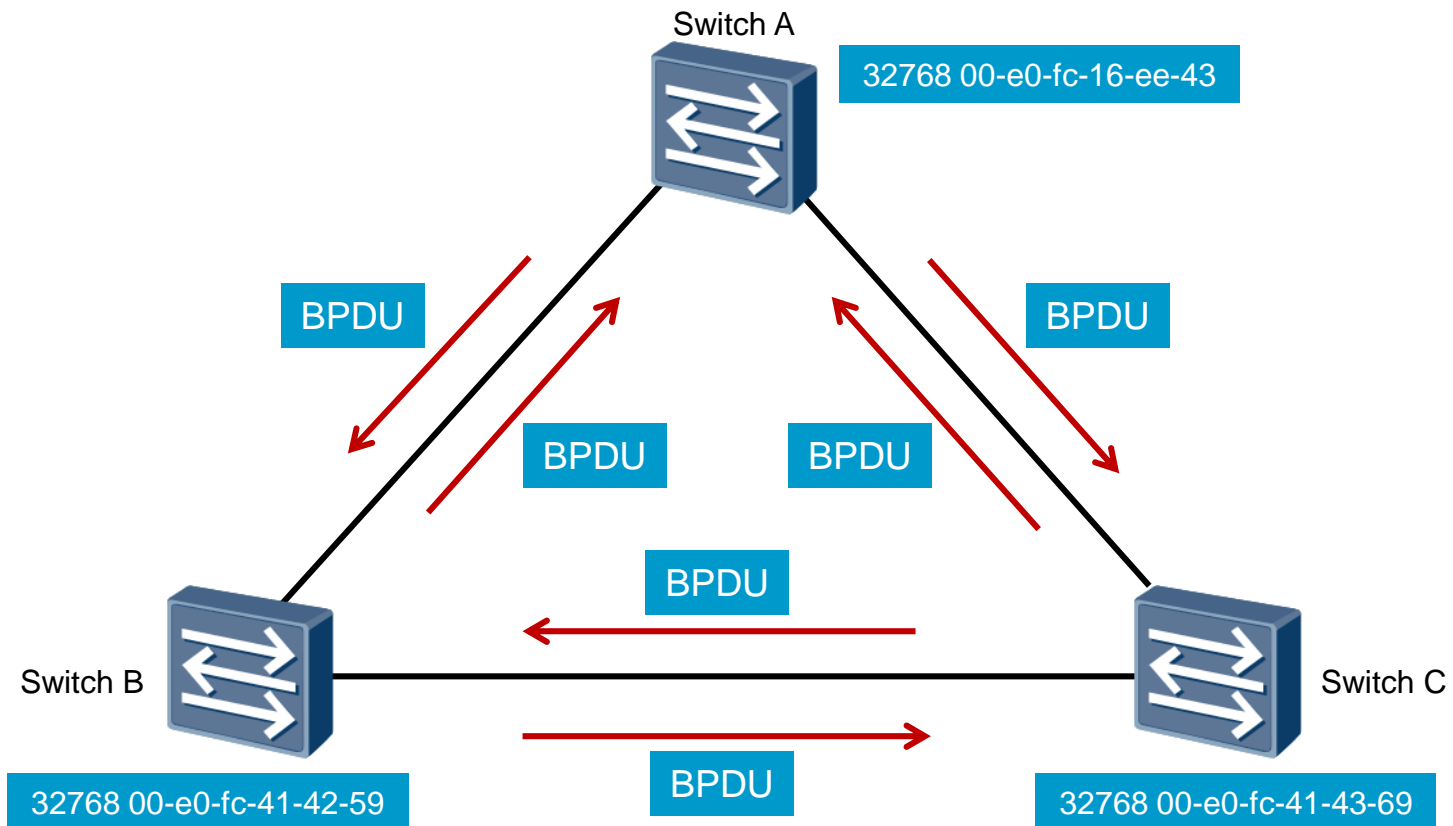
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Port ID

```
----[Port1(Ethernet0/0/1)][FORWARDING]----
Port Protocol          :Enabled
Port Role              :Designated Port
Port Priority          :128
Port Cost(Dot1T )      :Config=auto / Active=200000
Designated Bridge/Port    :32768.4c1f-cc33-4376 / 128.1
Port Edged             :Config=default / Active=disabled
Point-to-point         :Config=auto / Active=true
Transit Limit          :147 packets/hello-time
Protection Type        :None
Port STP Mode          :STP
Port Protocol Type     :Config=auto / Active=dot1s
BPDU Encapsulation     :Config=stp / Active=stp
PortTimes              :Hello 2s MaxAge 20s FwDly 15s RemHop 20
TC or TCN send         :17
TC or TCN received     :0
BPDU Sent              :178
         TCN: 0, Config: 170, RST: 0, MST: 8
BPDU Received          :1
         TCN: 0, Config: 1, RST: 0, MST: 0
<Huawei>
```

Timers

BPDU Interval
(2 seconds)

MSG Age: 0
MAX Age: 20

MSG Age: 1
MAX Age: 20

MSG Age: 1
MAX Age: 20

MSG Age: 2
MAX Age: 20

MSG Age: 2
MAX Age: 20

- The MAX Age represents the aging timer of a BPDU.

- BPDU are discarded when Message Age exceeds MAX Age.

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Root Election Process

Switch A

`32768 00-e0-fc-16-ee-43`

BPDU

BPDU

BPDU

BPDU

BPDU

Switch B

Switch C

BPDU

`32768 00-e0-fc-41-42-59`

`32768 00-e0-fc-41-43-69`

- All STP switches advertise BDPU to peers with self as root.

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Root Election Process

```
-------[CIST Global Info][Mode STP]-------
CIST Bridge            :32768.4c1f-cc33-4376
Config Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
Active Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
CIST Root/ERPC         :32768.4c1f-cc33-4376 / 0
CIST RegRoot/IRPC      :32768.4c1f-cc33-4376 / 0
CIST RootPortId        :0.0
BPDU-Protection        :Disabled
TC or TCN received     :5
TC count per hello     :0
STP Converge Mode      :Normal
Time since last TC     :0 days 0h:8m:37s
Number of TC           :7
Last TC occurred       :Ethernet0/0/1
```

```
-------[CIST Global Info][Mode STP]-------
CIST Bridge            :32768.4c1f-cc48-405c
Config Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
Active Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
CIST Root/ERPC         :32768.4c1f-cc33-4376 / 200000
CIST RegRoot/IRPC      :32768.4c1f-cc48-405c / 0
CIST RootPortId        :128.1
BPDU-Protection        :Disabled
TC or TCN received     :112
TC count per hello     :0
STP Converge Mode      :Normal
Time since last TC     :0 days 0h:0m:57s
Number of TC           :12
Last TC occurred       :Ethernet0/0/1
```

```
-------[CIST Global Info][Mode STP]-------
CIST Bridge            :32768.4c1f-cc81-3d4b
Config Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
Active Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
CIST Root/ERPC         :32768.4c1f-cc33-4376 / 20000
CIST RegRoot/IRPC      :32768.4c1f-cc81-3d4b / 0
CIST RootPortId        :128.1
BPDU-Protection        :Disabled
TC or TCN received     :52
TC count per hello     :0
STP Converge Mode      :Normal
Time since last TC     :0 days 0h:0m:28s
Number of TC           :10
Last TC occurred       :GigabitEthernet0/0/1
```

Port Role Establishment Process
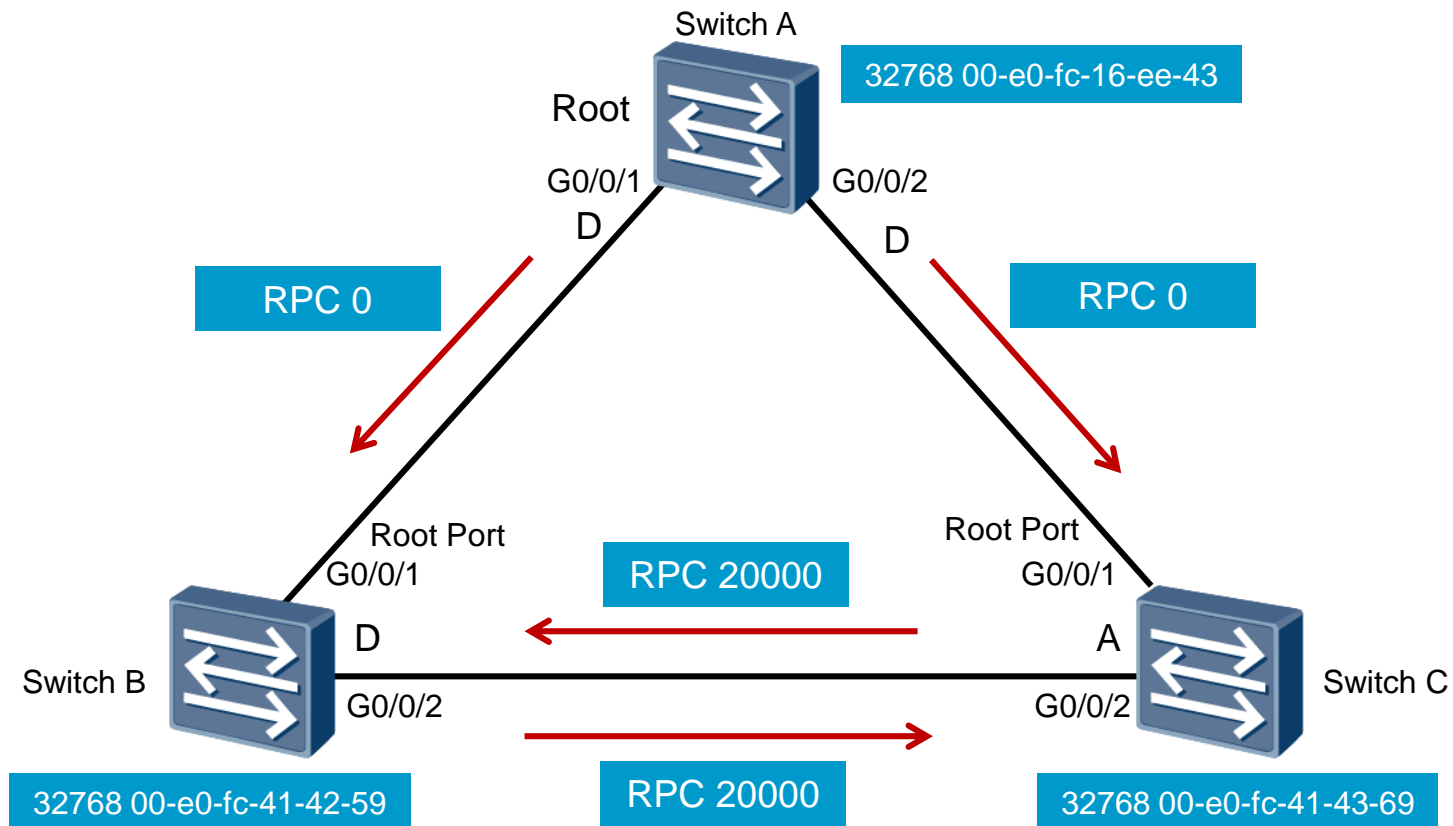
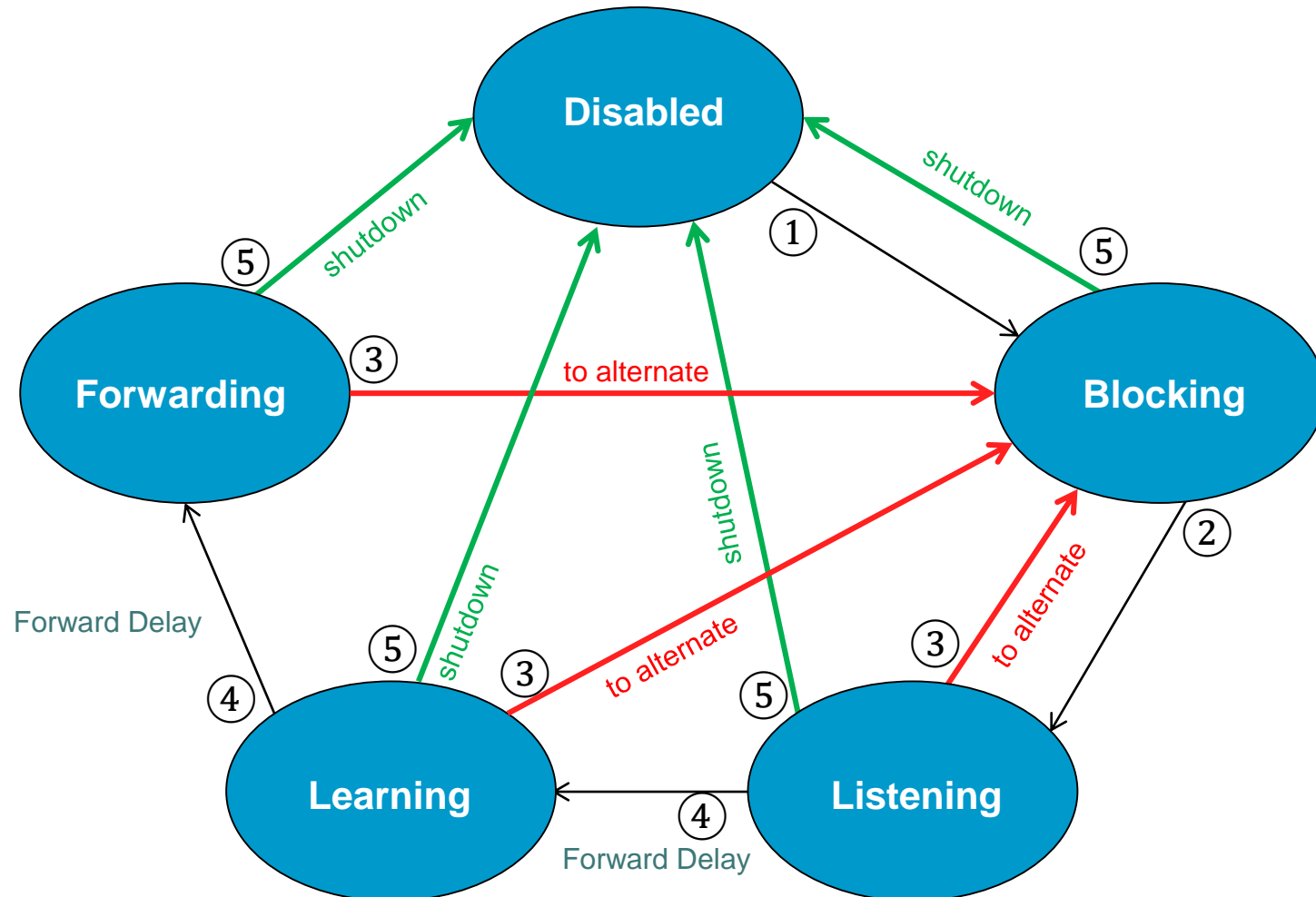- The Bridge ID and Root Path Cost are used to elect port roles.

Port State Transition

Timers:
Hello – 2s
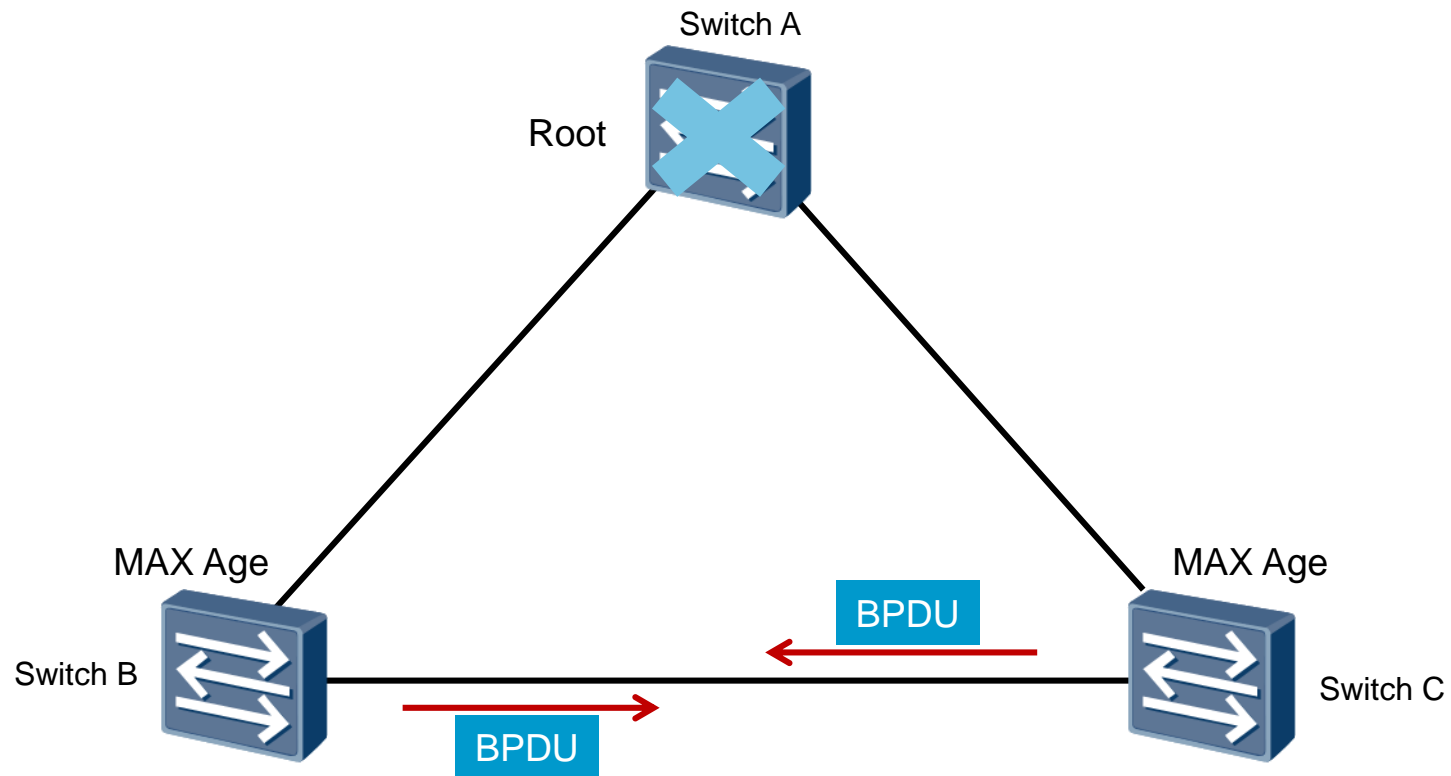Forward Delay (listening+learning) – 30s
Max Age – 10xHello – 20s

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Port Role - Port Status

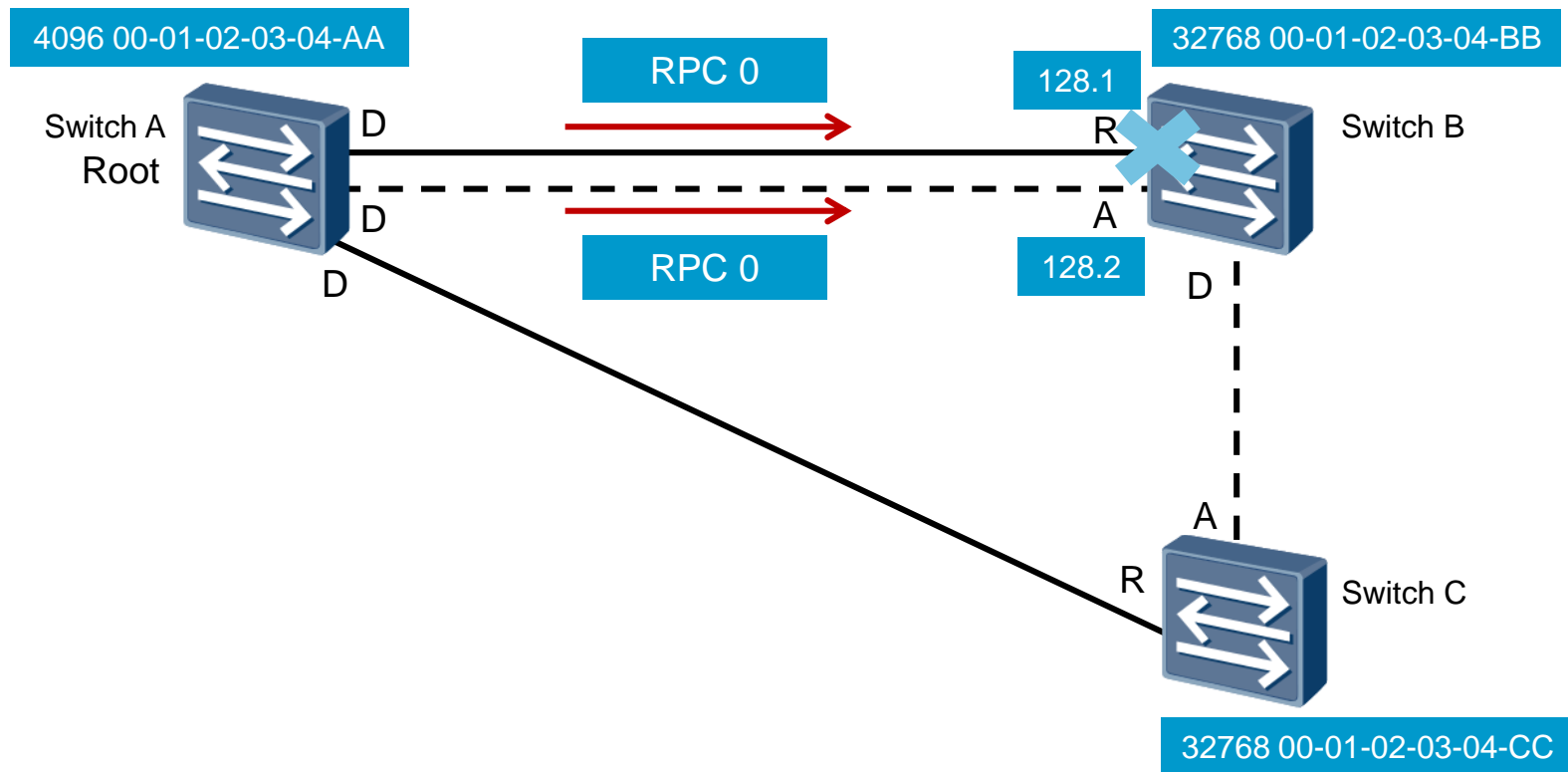| Stato	Data Forward	MAC Learning	Stable/Transitory
BLOCKING	NO	NO	STABLE
LISTENING	NO	NO	TRANSITORY
LEARNING	NO	YES	TRANSITORY
FORWARDING	YES	YES	STABLE
DISABLED	NO	NO	STABLE

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Root Failure

- Non root bridges wait for MAX Age before assuming loss of root.

- Re-convergence is then initiated, beginning with root election.

Indirect Link Failure
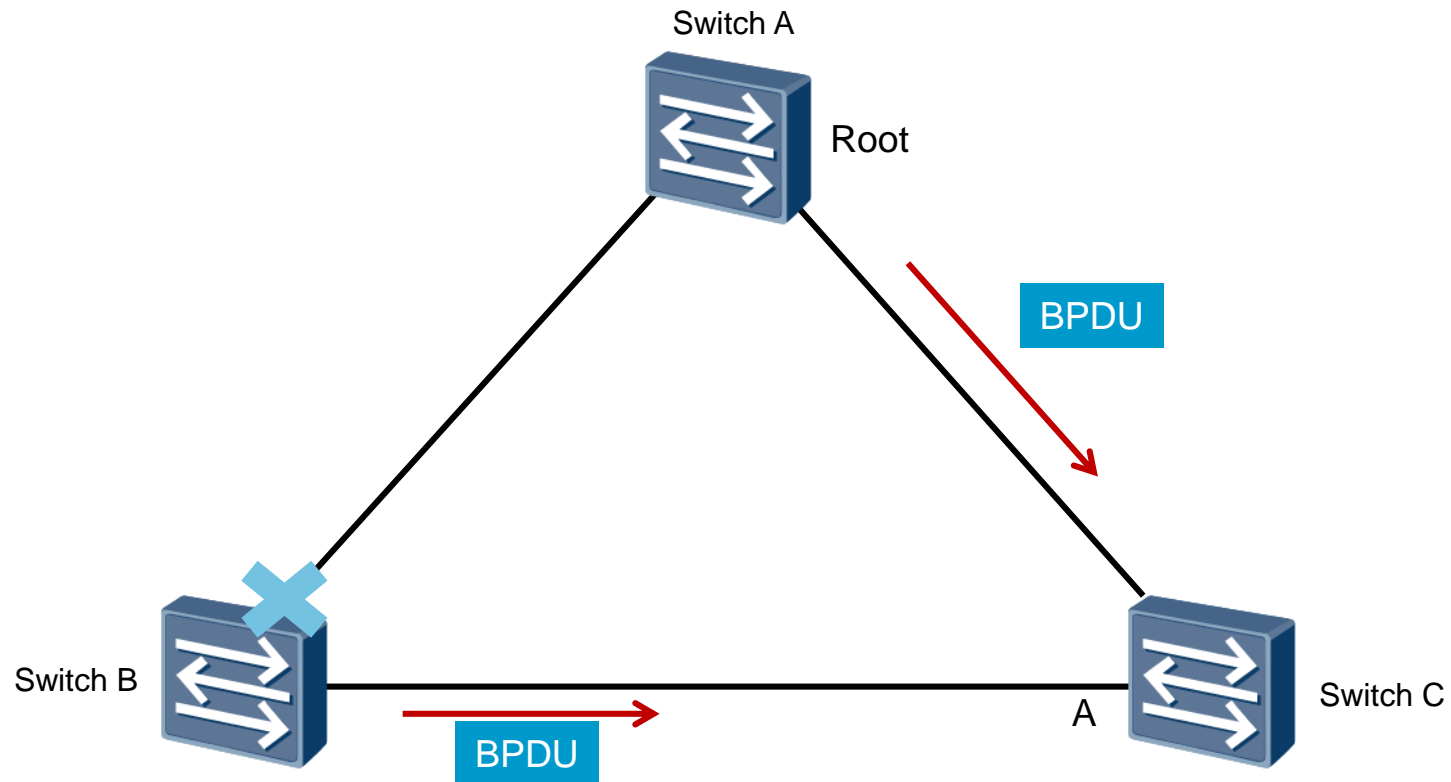
- Switch B begins root election, but BPDU is ignored by Switch C.

- Root BDPU is propagated to switch B after MAX Age expires.

Direct Link Failure

4096 00-01-02-03-04-AA		32768 00-01-02-03-04-BB

RPC 0

128.1

Switch A
Root

D

R

Switch B

D

A

128.2

D

RPC 0

D

A

R

Switch C

32768 00-01-02-03-04-CC

- Switch B detects failure and switches alternate port to root port.

- STP converges after 2x forward delay (30 seconds by default).

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Topology Change MAC Instability

MAC	Interface
00-01-02-03-04-AA	G0/0/3
00-01-02-03-04-BB	G0/0/2
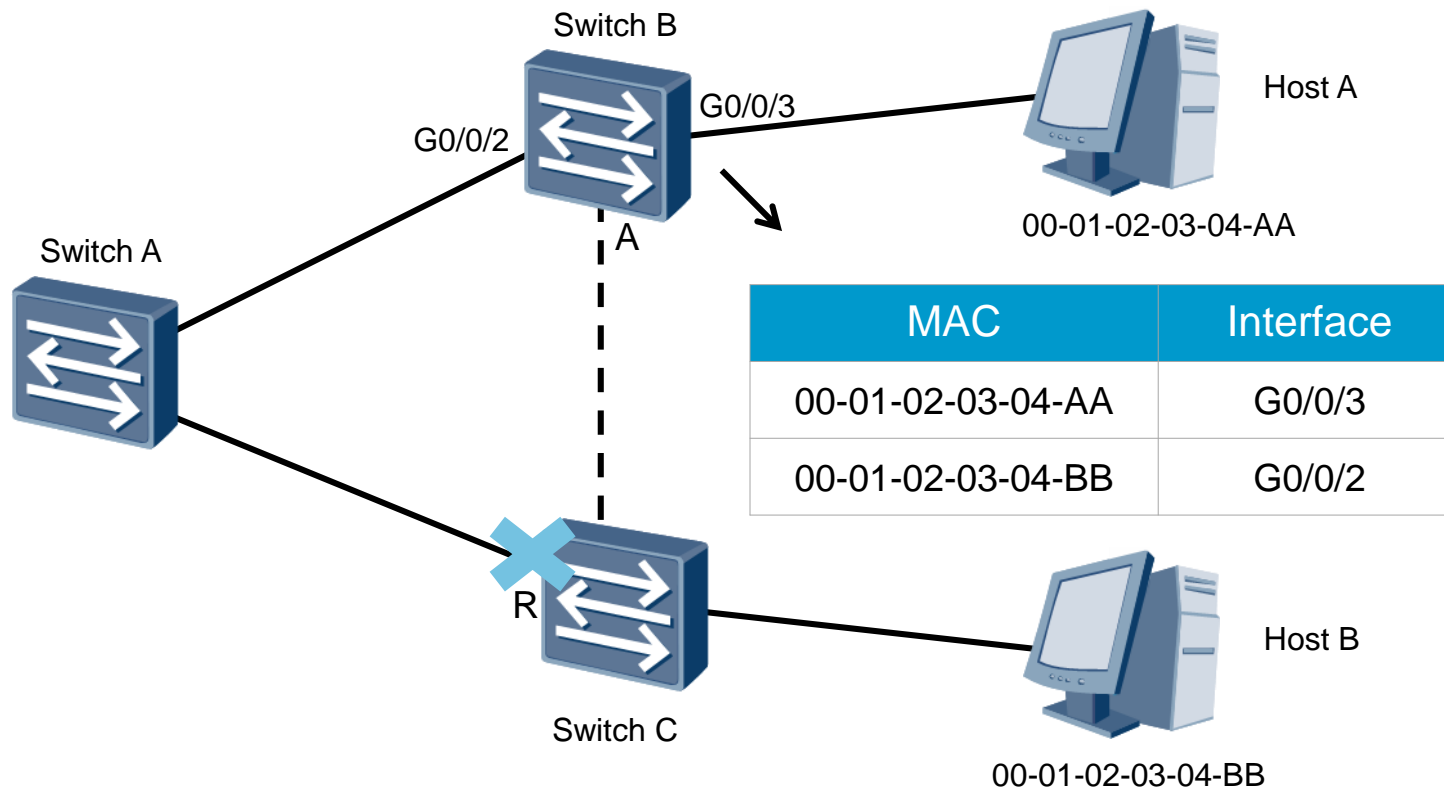
- Changes in the STP topology may invalidate MAC table entries.

- MAC table entries expire only after 300 seconds by default.

Topology Change Process
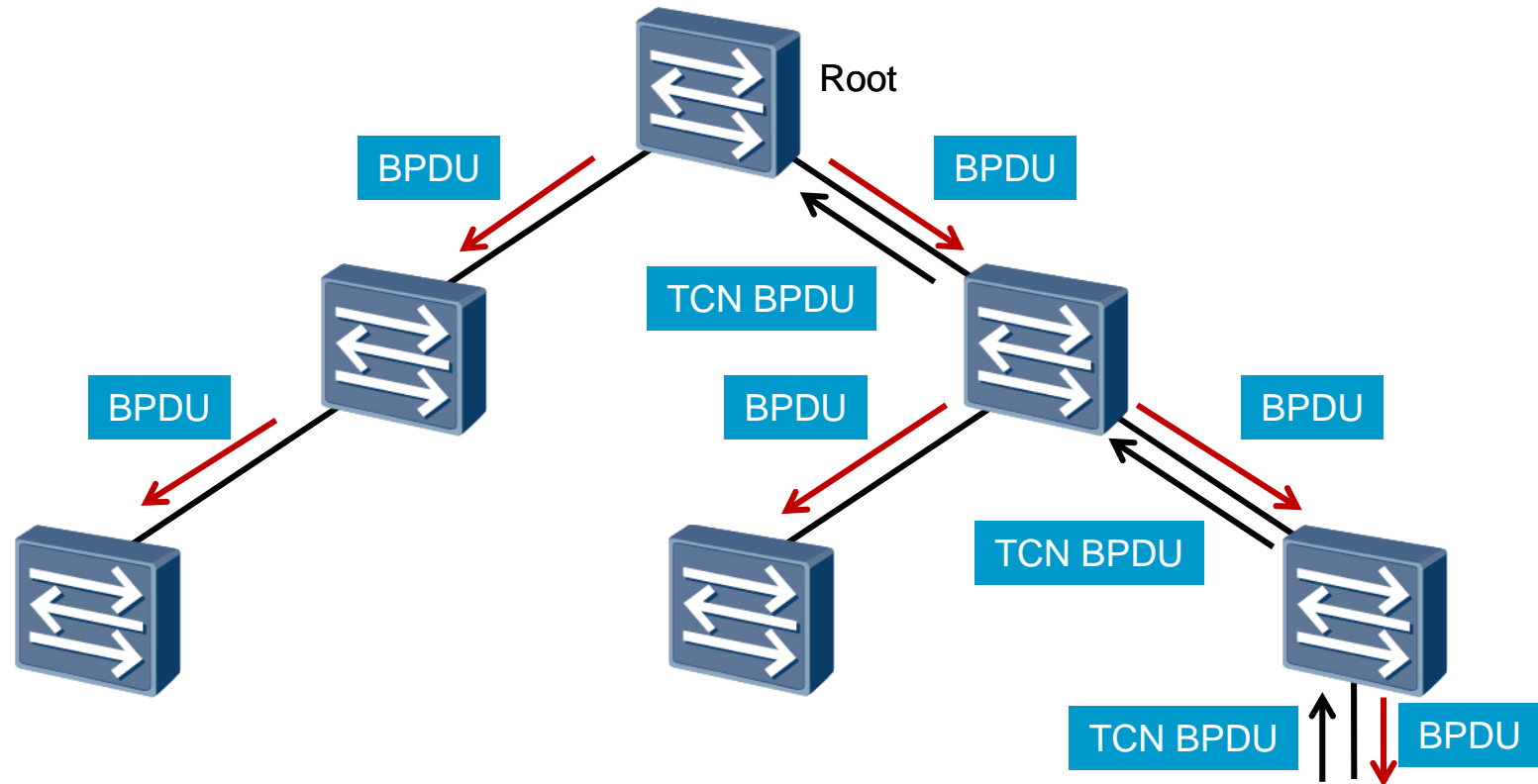
- Topology Change Notification informs root of topology change.

- Root flushes MAC entries using BPDU with TC bit set.

Topology Change Process

- TCN BPDU type 0x80;

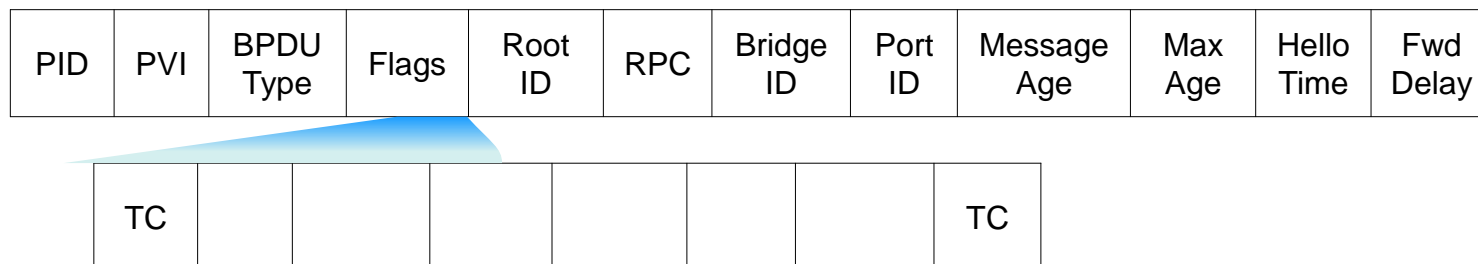 - Informa gli UPSTREAM switches che è avvenuto un cambiamento nella topologia ed il MAC unreach viene posto a 15s (era 300s);

- Come funziona:

  - Root Switch riceve TCN BPDU (upstream);

  - Root Switch emette BPDU con TC+TCA;

    - TCA attivo per 2xHello_time secondi;

    - TC attivo per 35s

PID	PVI	BPDU Type	Flags	Root ID	RPC	Bridge ID	Port ID	Message Age	Max Age	Hello Time	Fwd Delay

TC							TC

Topology Change MAC Refresh

MAC	Interface
00-01-02-03-04-AA	G0/0/3
~~00-01-02-03-04-BB~~	~~G0/0/2~~
00-01-02-03-04-BB	G0/0/1
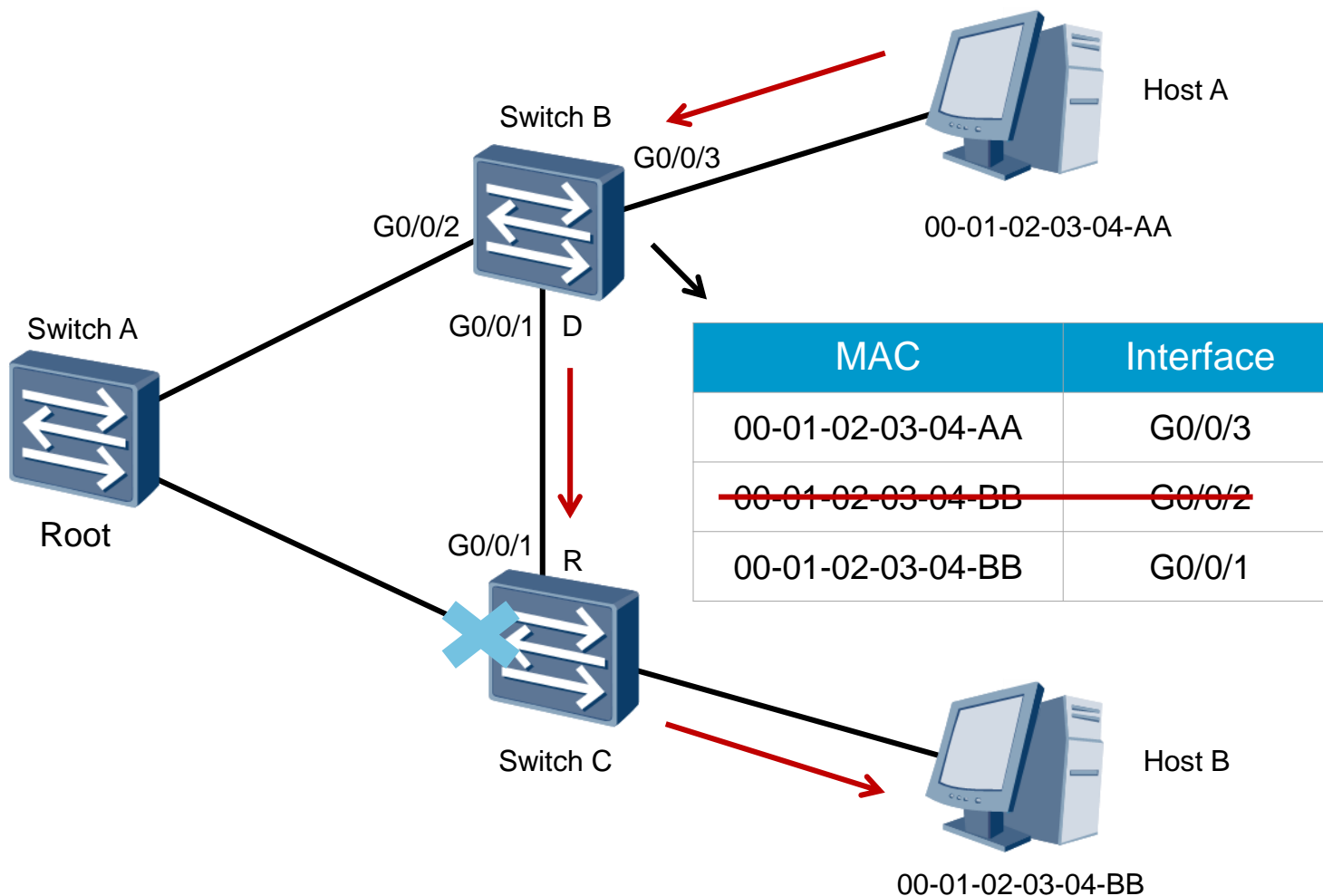
Topology Change MAC Refresh

Mini-Lab_Basic:07-stp_base

Topology Change MAC Refresh
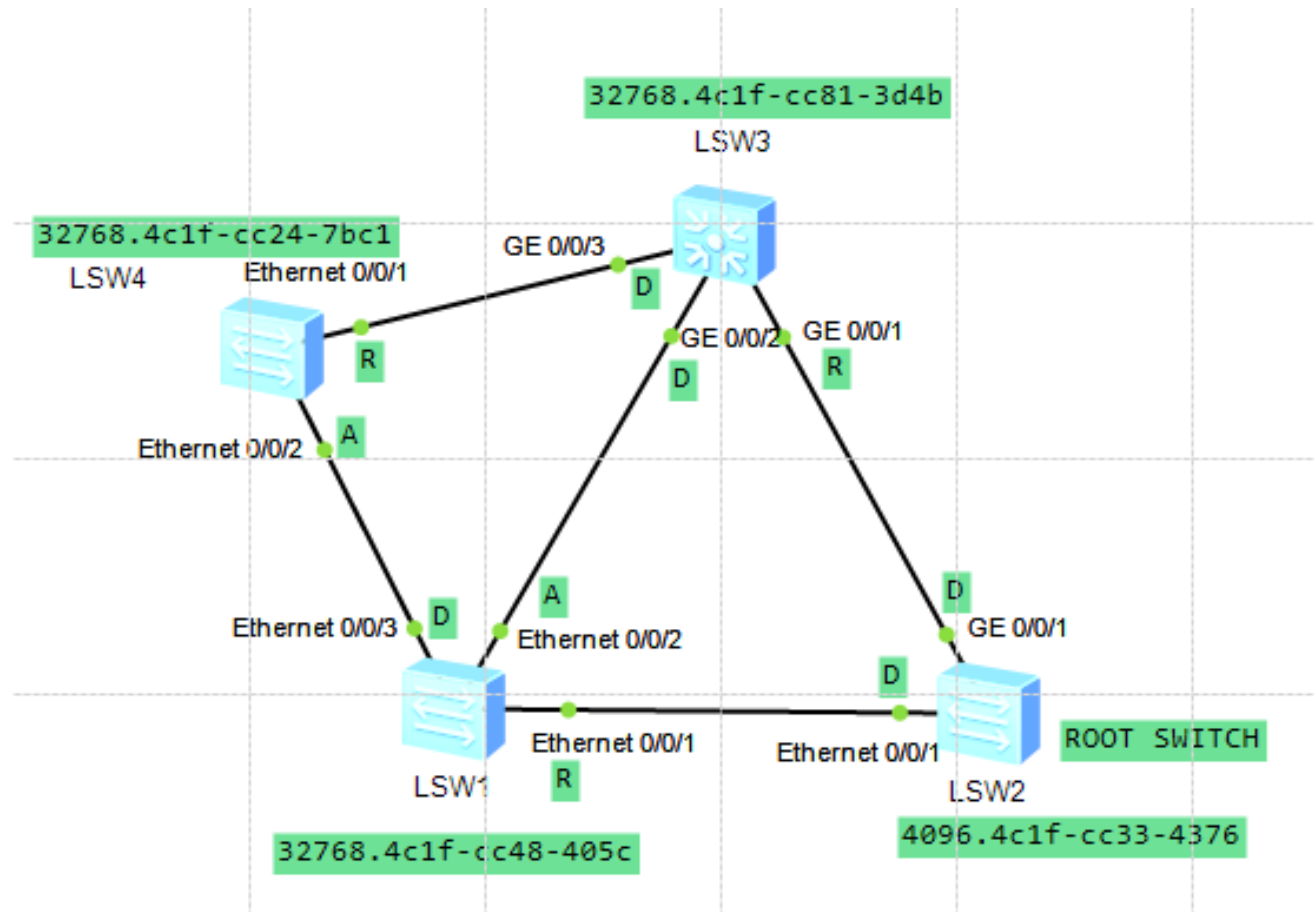
Topology Change MAC Refresh

```
60 127.891000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
61 129.610000  HuaweiTe_48:40:5c   Spanning-tree-(for-b… STP      60 Topology Change Notification
62 129.625000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
63 130.110000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
64 132.422000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
65 134.563000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
66 136.766000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
67 139.016000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
68 141.250000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
69 143.485000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
70 145.750000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
71 148.110000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
72 150.360000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
73 152.500000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
74 154.813000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
75 156.985000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
76 159.172000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
77 161.469000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
78 163.719000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
79 166.110000  HuaweiTe_33:43:76   Spanning-tree-(for-b… STP      60 Conf. TC + Root = 0/0/4c:1f:cc:33:43:76  Cost = 0  Port = 0x8001
```

```
> Frame 61: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
> IEEE 802.3 Ethernet
> Logical-Link Control
∨ Spanning Tree Protocol
     Protocol Identifier: Spanning Tree Protocol (0x0000)
     Protocol Version Identifier: Spanning Tree (0)
     BPDU Type: Topology Change Notification (0x80)
```
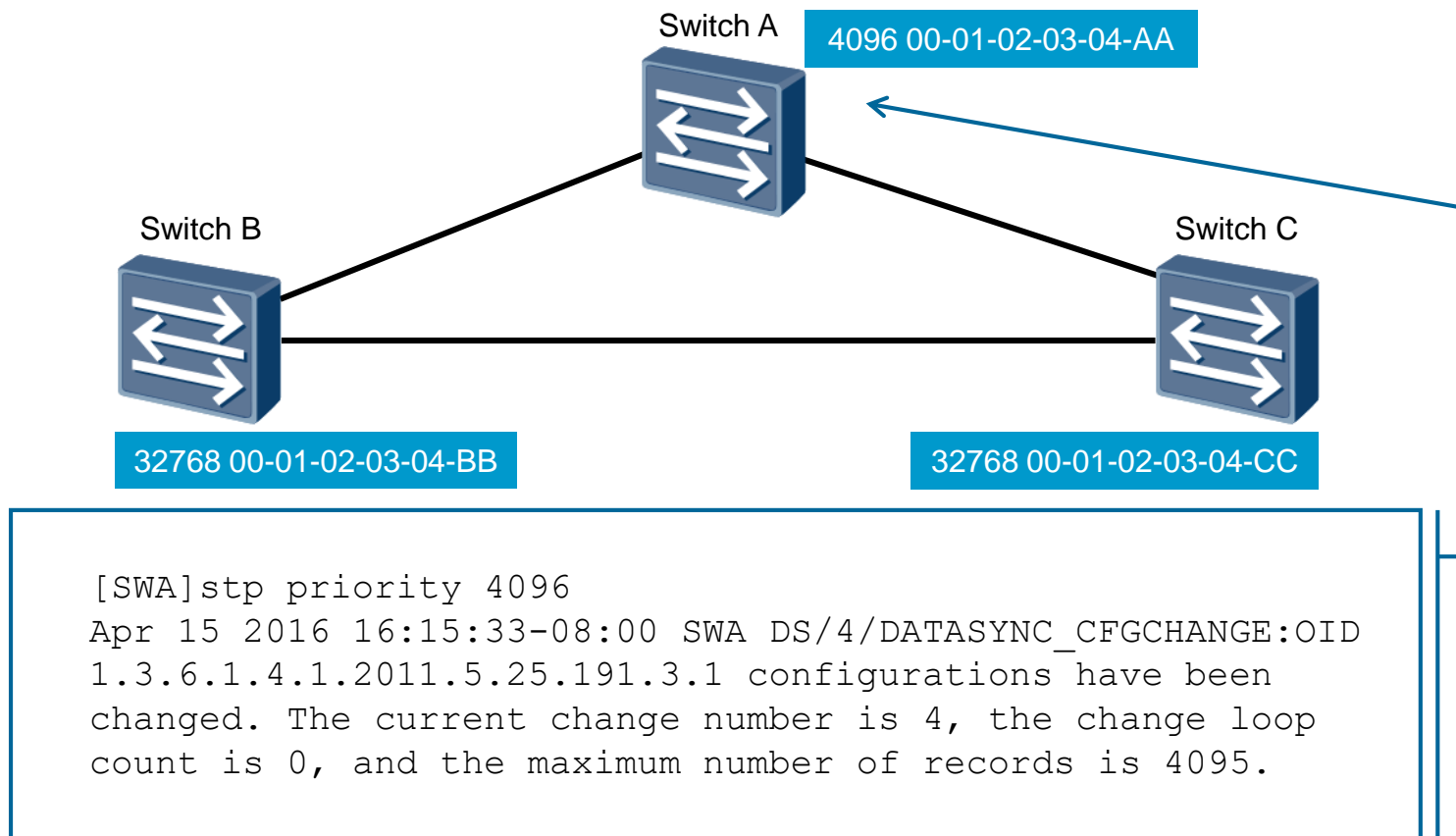
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Topology Change MAC Refresh

```
> Frame 62: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
> IEEE 802.3 Ethernet
> Logical-Link Control
∨ Spanning Tree Protocol
      Protocol Identifier: Spanning Tree Protocol (0x0000)
      Protocol Version Identifier: Spanning Tree (0)
      BPDU Type: Configuration (0x00)
   ∨ BPDU flags: 0x81, Topology Change Acknowledgment, Topology Change
         1... .... = Topology Change Acknowledgment: Yes
         .... ...1 = Topology Change: Yes
   ∨ Root Identifier: 0 / 0 / 4c:1f:cc:33:43:76
         Root Bridge Priority: 0
         Root Bridge System ID Extension: 0
         Root Bridge System ID: HuaweiTe_33:43:76 (4c:1f:cc:33:43:76)
      Root Path Cost: 0
   ∨ Bridge Identifier: 0 / 0 / 4c:1f:cc:33:43:76
         Bridge Priority: 0
         Bridge System ID Extension: 0
         Bridge System ID: HuaweiTe_33:43:76 (4c:1f:cc:33:43:76)
      Port identifier: 0x8001
      Message Age: 0
      Max Age: 20
      Hello Time: 2
      Forward Delay: 15
```
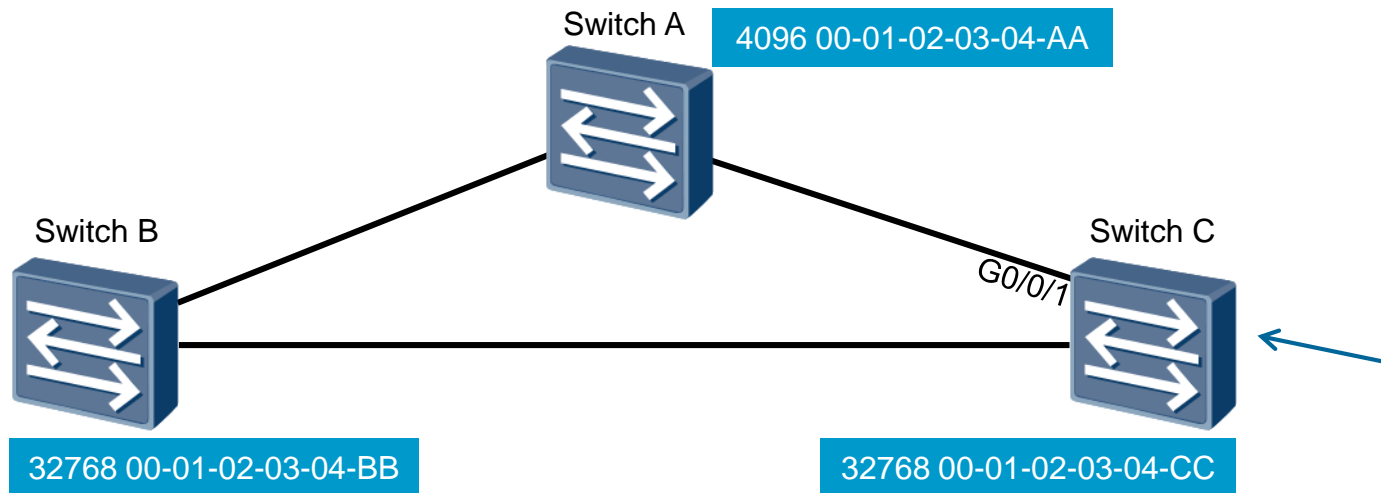
HUAWEI
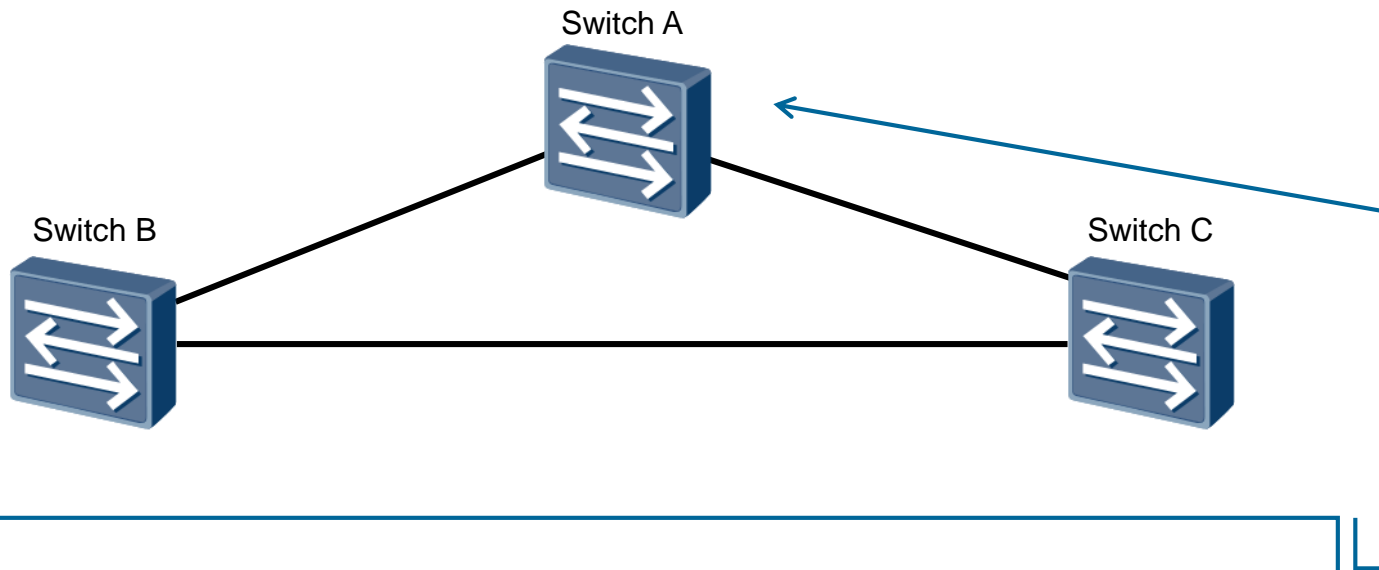
STP Modes


```
[SWA]stp mode ?
  mstp  Multiple Spanning Tree Protocol (MSTP) mode
  rstp  Rapid Spanning Tree Protocol (RSTP) mode
  stp   Spanning Tree Protocol (STP) mode
[SWA]stp mode stp
```

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Assigning The Root

Switch A

`4096 00-01-02-03-04-AA`

Switch B

Switch C

`32768 00-01-02-03-04-BB`

`32768 00-01-02-03-04-CC`

```
[SWA]stp priority 4096
Apr 15 2016 16:15:33-08:00 SWA DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.191.3.1 configurations have been
changed. The current change number is 4, the change loop
count is 0, and the maximum number of records is 4095.
```

● Root can be set manually or by defining the switch as primary.

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Assigning Path Cost

Switch A
4096 00-01-02-03-04-AA

Switch B

Switch C

G0/0/1

32768 00-01-02-03-04-BB

32768 00-01-02-03-04-CC

```
[SWC]stp pathcost-standard ?
  dot1d-1998   IEEE 802.1D-1998
  dot1t        IEEE 802.1T
  legacy       Legacy
[SWC]interface GigabitEthernet 0/0/1
[SWC-GigabitEthernet0/0/1]stp cost 2000
```

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Root Protection

Switch A

4096 00-01-02-03-04-AA

G0/0/1

Switch B

Switch C

32768 00-01-02-03-04-BB

32768 00-01-02-03-04-CC

```
[SWA]interface GigabitEthernet 0/0/1
[SWA-GigabitEthernet0/0/1]stp root-protection
```
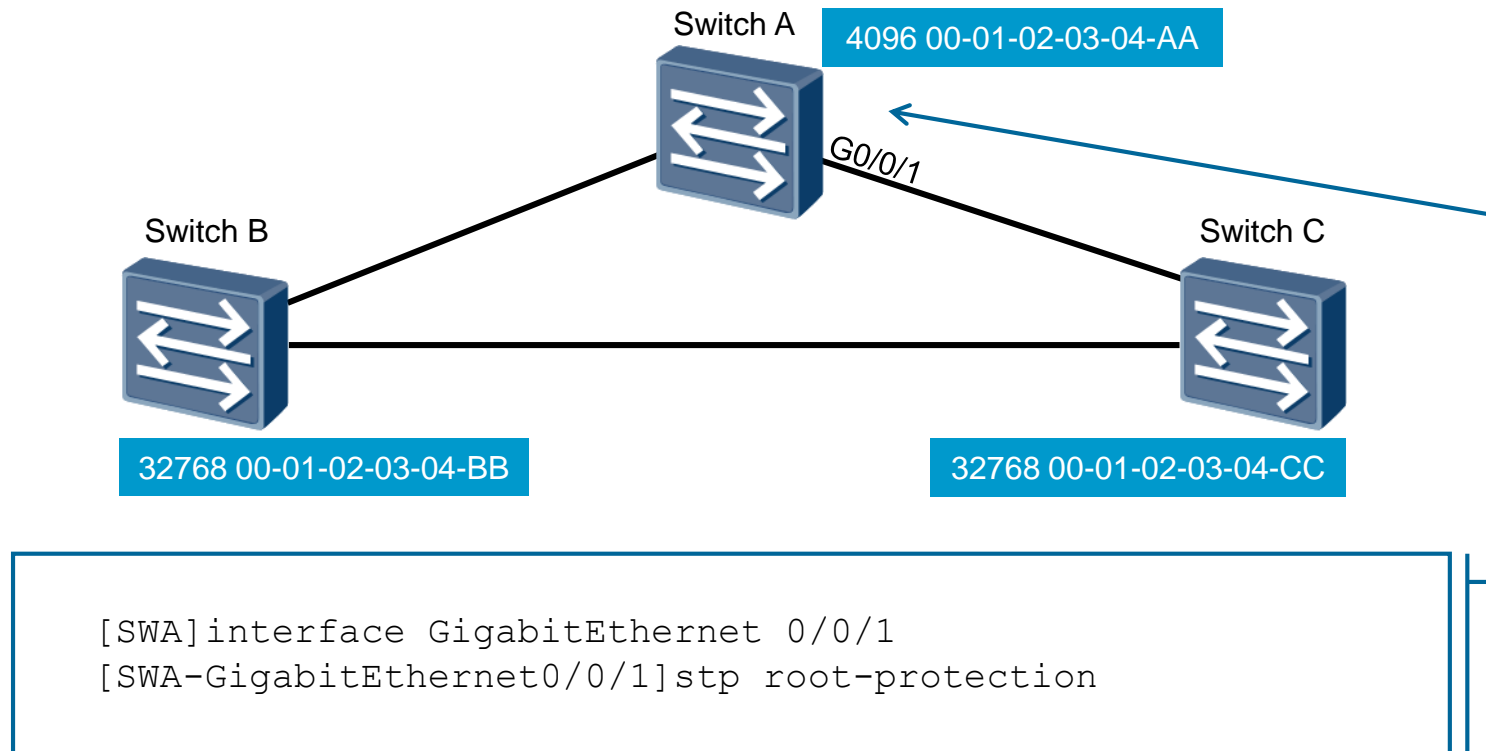
● Root protection prevents changes to the topology as a result of root bridge transition, caused by receiving higher priority BPDU.

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Configuration Validation

```
[SWA]display stp
-------[CIST Global Info][Mode STP]-------
CIST Bridge            :4096 .00-01-02-03-04-BB
Bridge Times           :Hello 2s MaxAge 20s FwDly 15s MaxHop 20
CIST Root/ERPC         :4096 .00-01-02-03-04-BB / 0
CIST RegRoot/IRPC      :4096 .00-01-02-03-04-BB / 0
CIST RootPortId        :0.0
BPDU-Protection        :Disabled
TC or TCN received     :37
TC count per hello     :0
STP Converge Mode      :Normal
Share region-configuration :Enabled
Time since last TC     :0 days 0h:1m:29s
……
```

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Configuration Validation

```
[SWA]display stp
……
----[Port1(GigabitEthernet0/0/1)][FORWARDING]----
 Port Protocol              :Enabled
 Port Role                  :Designated Port
 Port Priority              :128
 Port Cost(Dot1T )          :Config=2000 / Active=2000
 Designated Bridge/Port     :4096.00-01-02-03-04-BB / 128.1
 Port Edged                 :Config=default / Active=disabled
 Point-to-point             :Config=auto / Active=true
 Transit Limit              :147 packets/hello-time
 Protection Type            :Root
……
```

Summary

When the protocol stabilizes, the state should be as follows:

- **Root bridge**: The process (switch) with the lowest MAC address (or lowest combined priority+MAC address) is the root. This uses a leader election algorithm.

- **Root ports**: Each bridge has one root port. The root port on each bridge is the port of the bridge with the smallest distance from the root. If two ports are equidistant from the root, then the one going to the bridge with the lower MAC address is the root port. This uses a breadth-first search, if we assume rounds; however, if the network is asyncrhonous, it's more complicated.

- **Designated ports**: Each network segment (connecting bridges) has a designated port. Messages put on that network segment are forwarded to the rest of the network through the designated port. The designated port is on the bridge closest to the root. If there is a tie, it is on the bridge with the lowest MAC address. If the bridge selected by this rule has multiple ports on a network, it is the port with the lowest id.

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Summary

- In the event that a root bridge (switch) temporarily fails in the STP network, the next viable switch will take over as the root bridge. What will occur once the failed root bridge once again becomes active in the network?

- What is the difference between Path Cost and Root Path Cost?

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Thank you

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