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# Network Revolution in the IT Industry: Transforming Connectivity and Innovation

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## I. SPANNING TREE PROTOCOL (STP) OVERVIEW

Spanning Tree Protocol (STP) is a Layer 2 protocol essential in Ethernet networks to prevent network loops. Redundant paths in a network can cause:

- 1) Broadcast storms: Excessive traffic that floods the network.
- 2) Multiple frame copies: Duplication of frames, creating confusion.
- 3) MAC table instability: Incorrect MAC address mapping due to looped traffic.

STP ensures there is always a single active path between devices in a network by blocking redundant paths until needed.

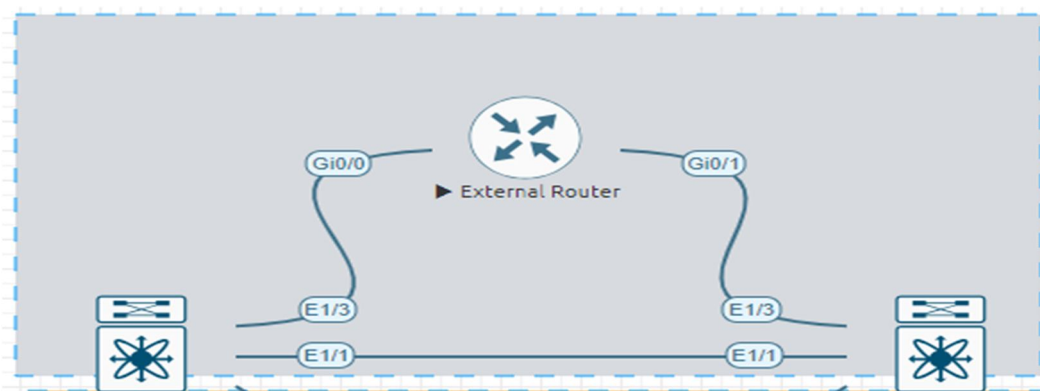
## II. KEY FEATURES OF TRADITIONAL STP

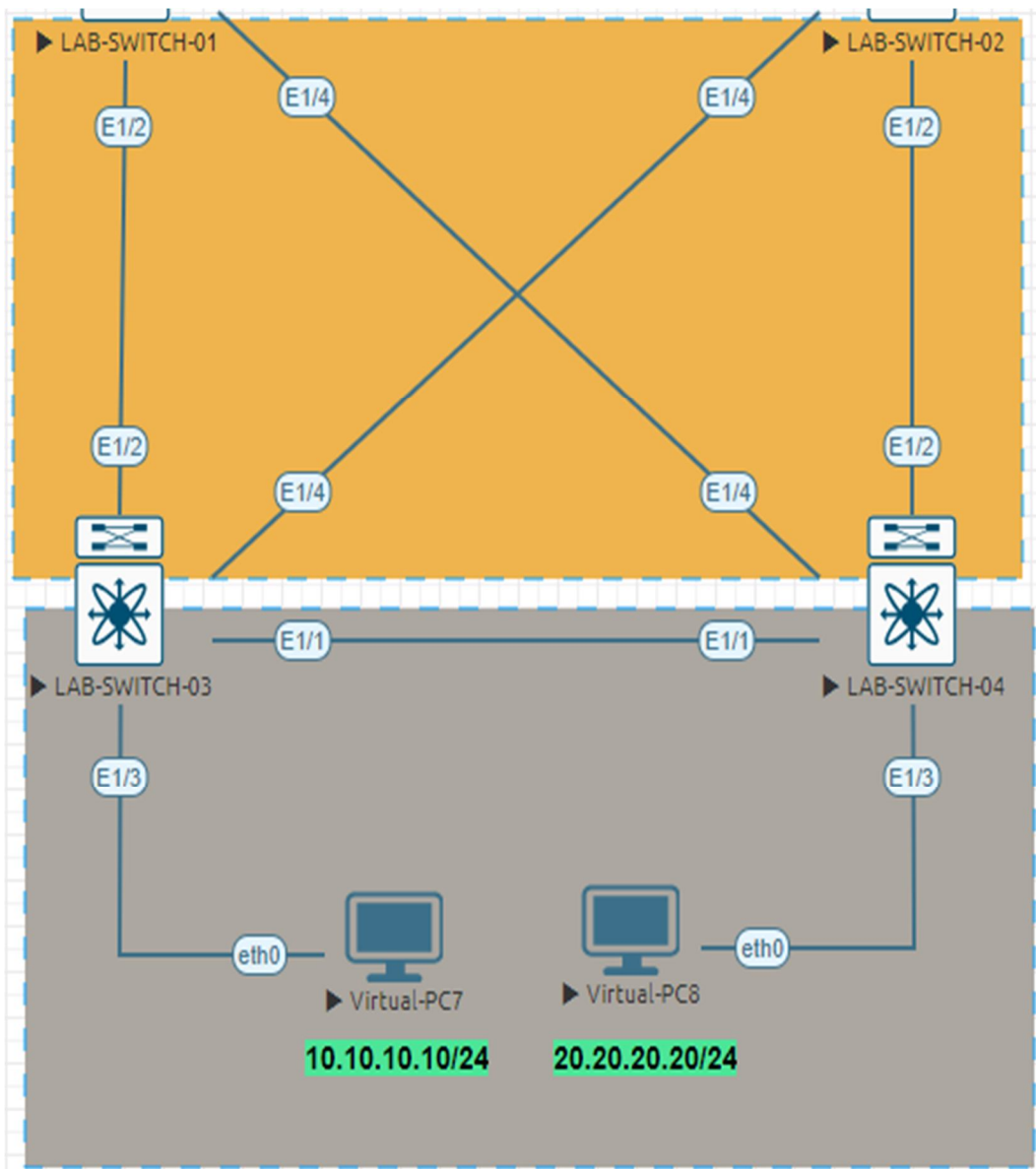
- 1) IEEE Standard: Defined by the IEEE 802.1D specification.
- 2) Root Bridge Election: Utilizes Bridge Protocol Data Units (BPDUs) to elect a Root Bridge, which acts as the central reference point in the network topology.
- 3) Port States:
  - Blocking: Prevents loops by not forwarding frames.
  - Listening: Monitors BPDUs but doesn't forward traffic.
  - Learning: Builds MAC address tables without forwarding frames.
  - Forwarding: Operates normally by forwarding frames.
  - Disabled: No activity on the port.
- 4) Timers:
  - Hello Time: **Interval between BPDUs transmissions (default: 2 seconds).**
  - Forward Delay: **Time spent in the listening and learning states (default: 15 seconds each).**
  - Max Age: Time before considering a BPDU invalid (default: 20 seconds).
- 5) Redundant Path Management: Blocks redundant paths and only activates them when the primary path fails.

## III. LIMITATIONS OF TRADITIONAL STP

- 1) Convergence Time: Takes 30-50 seconds to stabilize the network after a topology change.
- 2) Inefficiency: Redundant links remain blocked, resulting in underutilized bandwidth.

### A. Base Topology





### B. Configuration Details

- Created two Layer 3 VLANs (VLAN 10 and VLAN 20) on LAB-SWITCH-01, making it the Root Bridge for these VLANs.
- Configured LAB-SWITCH-02 as the Backup Root Bridge for both VLANs.
- Assigned Higher HSRP Priority to LAB-SWITCH-01, ensuring it is the active switch for both VLANs.

#### Switch Roles:

- LAB-SWITCH-01: Root Bridge for VLANs 10 and 20.
- LAB-SWITCH-02: Backup Root Bridge for VLANs 10 and 20.

### C. Traffic Flow (Layer 2 STP)

#### Due to STP:

- Looped interfaces or redundant links are blocked to prevent Layer 2 loops.
- Traffic for VLANs 10 and 20 flows through a single active link, while the second link operates in a standby state.



#### LAB-SWITCH-01 – Root Bridge for Vlan 10, 20

```
LAB-SWITCH-01# sh spanning-tree root
```

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32769 5001.0000.1b08	0	2	20	15	This bridge is root
VLAN0010	32778 5001.0000.1b08	0	2	20	15	This bridge is root
VLAN0020	32788 5001.0000.1b08	0	2	20	15	This bridge is root

```
LAB-SWITCH-01#
```

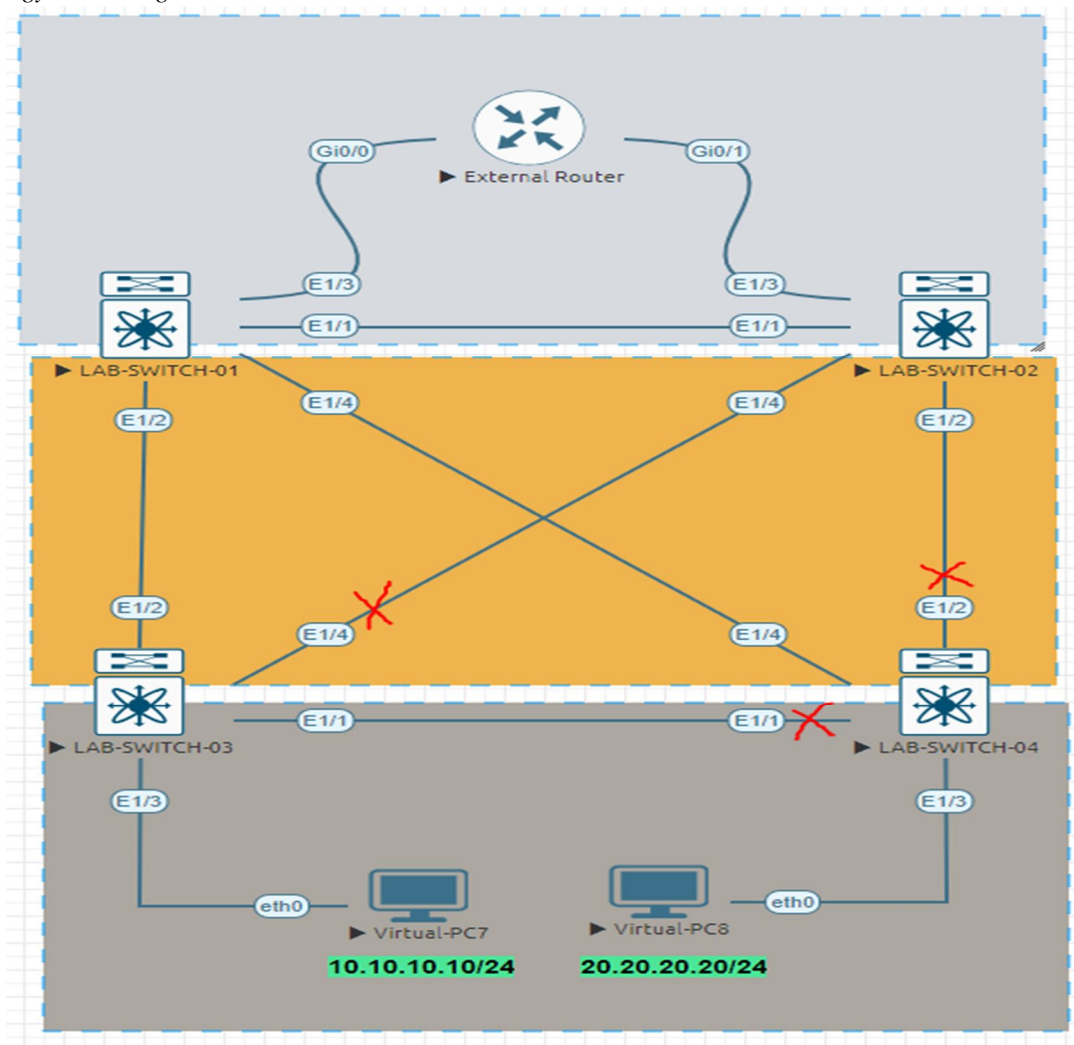
#### LAB-SWITCH-02 – Backup Root Bridge for Vlan 10, 20

```
LAB-SWITCH-02# sho spanning-tree root
```

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32769 5001.0000.1b08	4	2	20	15	Ethernet1/1
VLAN0010	32778 5001.0000.1b08	8	2	20	15	Ethernet1/4
VLAN0020	32788 5001.0000.1b08	8	2	20	15	Ethernet1/4

```
LAB-SWITCH-02#
```

#### D. Base Topology – Blocking links



### LAB-SWITCH-01: Spanning-Tree status

```
LAB-SWITCH-01# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID      Priority    32778
                Address     5001.0000.1b08
                This bridge is the root
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority    32778 (priority 32768 sys-id-ext 10)
                Address     5001.0000.1b08
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Desg FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/3         Desg FWD 4         128.3    P2p
Eth1/4         Desg FWD 4         128.4    P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID      Priority    32788
                Address     5001.0000.1b08
                This bridge is the root
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority    32788 (priority 32768 sys-id-ext 20)
                Address     5001.0000.1b08
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Desg FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/3         Desg FWD 4         128.3    P2p
Eth1/4         Desg FWD 4         128.4    P2p

LAB-SWITCH-01#
```

### LAB-SWITCH-02 : Spanning-Tree status

```
LAB-SWITCH-02# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID      Priority    32778
                Address     5001.0000.1b08
                Cost         4
                Port         1 (Ethernet1/1)
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority    32778 (priority 32768 sys-id-ext 10)
                Address     5002.0000.1b08
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Root FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/3         Desg FWD 4         128.3    P2p
Eth1/4         Desg FWD 4         128.4    P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID      Priority    32788
                Address     5001.0000.1b08
                Cost         4
                Port         1 (Ethernet1/1)
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority    32788 (priority 32768 sys-id-ext 20)
                Address     5002.0000.1b08
                Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Root FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/3         Desg FWD 4         128.3    P2p
Eth1/4         Desg FWD 4         128.4    P2p

LAB-SWITCH-02#
```

### LAB-SWITCH-03 : Spanning-Tree status

```
LAB-SWITCH-03# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID      Priority      32778
                Address      5001.0000.1b08
                Cost          4
                Port          2 (Ethernet1/2)
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority      32778 (priority 32768 sys-id-ext 10)
                Address      5003.0000.1b08
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost          Prio.Nbr Type
-----
Eth1/1         Desg FWD 4             128.1    P2p
Eth1/2         Root FWD 4             128.2    P2p
Eth1/3         Desg FWD 4             128.3    P2p
Eth1/4         Altn BLK 4             128.4    P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID      Priority      32788
                Address      5001.0000.1b08
                Cost          4
                Port          2 (Ethernet1/2)
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority      32788 (priority 32768 sys-id-ext 20)
                Address      5003.0000.1b08
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost          Prio.Nbr Type
-----
Eth1/1         Desg FWD 4             128.1    P2p
Eth1/2         Root FWD 4             128.2    P2p
Eth1/4         Altn BLK 4             128.4    P2p

LAB-SWITCH-03#
```

### LAB-SWITCH-04 : Spanning-Tree status

```
LAB-SWITCH-04# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID      Priority      32778
                Address      5001.0000.1b08
                Cost          4
                Port          4 (Ethernet1/4)
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority      32778 (priority 32768 sys-id-ext 10)
                Address      5004.0000.1b08
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost          Prio.Nbr Type
-----
Eth1/1         Altn BLK 4             128.1    P2p
Eth1/2         Altn BLK 4             128.2    P2p
Eth1/4         Root FWD 4             128.4    P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID      Priority      32788
                Address      5001.0000.1b08
                Cost          4
                Port          4 (Ethernet1/4)
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID    Priority      32788 (priority 32768 sys-id-ext 20)
                Address      5004.0000.1b08
                Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost          Prio.Nbr Type
-----
Eth1/1         Altn BLK 4             128.1    P2p
Eth1/2         Altn BLK 4             128.2    P2p
Eth1/3         Desg FWD 4             128.3    P2p
Eth1/4         Root FWD 4             128.4    P2p

LAB-SWITCH-04#
```



#### LAB-SWITCH-01: HSRP Status

```
LAB-SWITCH-01# sh hsrp brief
*:IPv6 group  #:group belongs to a bundle
                P indicates configured to preempt.
                |
Interface      Grp  Prio P State   Active addr    Standby addr    Group addr
Vlan10         1    110 P Active   local          10.10.10.2      10.10.10.3
(conf)
Vlan20         2    110 P Active   local          20.20.20.2      20.20.20.3
(conf)
LAB-SWITCH-01#
```

#### LAB-SWITCH-02 : HSRP Status

```
LAB-SWITCH-02# sh hsrp brief
*:IPv6 group  #:group belongs to a bundle
                P indicates configured to preempt.
                |
Interface      Grp  Prio P State   Active addr    Standby addr    Group addr
Vlan10         1    100 Standby 10.10.10.1     local          10.10.10.3
(conf)
Vlan20         2    100 Standby 20.20.20.1     local          20.20.20.3
(conf)
LAB-SWITCH-02#
```

### IV. BUSINESS CHALLENGE

From a business perspective:

- 1) Blocking expensive fiber links leads to resource underutilization.
- 2) All VLAN traffic passing through a single link increases operational costs and reduces network efficiency.

### V. IMPLEMENTED SOLUTION

To optimize resource utilization and enhance network performance, the following solutions were implemented:

Per-VLAN Spanning Tree (PVST)

- 1) Configured separate primary and secondary paths for each VLAN to distribute traffic efficiently:
  - VLAN 10: Uses Link A as its primary path.
  - VLAN 20: Uses Link B as its primary path.
- 2) HSRP Configuration
- 3) Increased HSRP priority for VLAN 20 on the secondary switch to ensure smooth traffic flow at both Layer 2 and Layer 3.
- 4) To address this issue, we have implemented the following solutions to optimize resource utilization and enhance network performance:
- 5) For example, VLAN 10 uses Link A as its primary path, while VLAN 20 uses Link B.

```
LAB-SWITCH-02(config)# spanning-tree vlan 20 priority 4096
```





### LAB-SWITCH-02: Spanning-Tree Status

```
LAB-SWITCH-02# sh spanning-tree vlan 10, 20 brie

VLAN0010
Spanning tree enabled protocol rstp
Root ID      Priority      32778
              Address      5001.0000.1b08
              Cost         4
              Port         1 (Ethernet1/1)
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID     Priority      32778 (priority 32768 sys-id-ext 10)
              Address      5002.0000.1b08
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Root FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/4         Desg FWD 4         128.4    P2p

VLAN0020
Spanning tree enabled protocol rstp
Root ID      Priority      4116
              Address      5002.0000.1b08
              This bridge is the root
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID     Priority      4116 (priority 4096 sys-id-ext 20)
              Address      5002.0000.1b08
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Desg FWD 4         128.1    P2p
Eth1/2         Desg FWD 4         128.2    P2p
Eth1/4         Desg FWD 4         128.4    P2p

LAB-SWITCH-02#
```

### LAB-SWITCH-03: Spanning-Tree Status

```
LAB-SWITCH-03# sh spanning-tree vlan 10, 20 brie

VLAN0010
Spanning tree enabled protocol rstp
Root ID      Priority      32778
              Address      5001.0000.1b08
              Cost         4
              Port         2 (Ethernet1/2)
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID     Priority      32778 (priority 32768 sys-id-ext 10)
              Address      5003.0000.1b08
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Desg FWD 4         128.1    P2p
Eth1/2         Root FWD 4         128.2    P2p
Eth1/3         Desg FWD 4         128.3    P2p
Eth1/4         Altn BLK 4         128.4    P2p

VLAN0020
Spanning tree enabled protocol rstp
Root ID      Priority      4116
              Address      5002.0000.1b08
              Cost         4
              Port         4 (Ethernet1/4)
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID     Priority      32788 (priority 32768 sys-id-ext 20)
              Address      5003.0000.1b08
              Hello Time    2 sec Max Age 20 sec Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/1         Desg FWD 4         128.1    P2p
Eth1/2         Altn BLK 4         128.2    P2p
Eth1/4         Root FWD 4         128.4    P2p

LAB-SWITCH-03#
```

### LAB-SWITCH-04: Spanning-Tree Status

```
LAB-SWITCH-04# sh spanning-tree vlan 10, 20 brie
```

**VLAN0010**

Spanning tree **enabled** protocol **rstp**

<b>Root ID</b>	Priority	32778
	Address	5001.0000.1b08
	Cost	4
	Port	4 ( <b>Ethernet1/4</b> )
	Hello Time	2 sec Max Age 20 sec Forward Delay 15 sec

**Bridge ID** Priority 32778 (priority 32768 sys-id-ext 10)

Address	5004.0000.1b08
Hello Time	2 sec Max Age 20 sec Forward Delay 15 sec

Interface	Role	Sts	Cost	Prio.Nbr	Type
Eth1/1	Altn	<b>BLK</b>	4	128.1	P2p
Eth1/2	Altn	<b>BLK</b>	4	128.2	P2p
Eth1/4	<b>Root</b>	<b>FWD</b>	4	128.4	P2p

**VLAN0020**

Spanning tree **enabled** protocol **rstp**

<b>Root ID</b>	Priority	4116
	Address	5002.0000.1b08
	Cost	4
	Port	2 ( <b>Ethernet1/2</b> )
	Hello Time	2 sec Max Age 20 sec Forward Delay 15 sec

**Bridge ID** Priority 32788 (priority 32768 sys-id-ext 20)

Address	5004.0000.1b08
Hello Time	2 sec Max Age 20 sec Forward Delay 15 sec

Interface	Role	Sts	Cost	Prio.Nbr	Type
Eth1/1	Altn	<b>BLK</b>	4	128.1	P2p
Eth1/2	<b>Root</b>	<b>FWD</b>	4	128.2	P2p
Eth1/3	Desg	<b>FWD</b>	4	128.3	P2p
Eth1/4	Altn	<b>BLK</b>	4	128.4	P2p

```
LAB-SWITCH-04#
```

We need to increase the HSRP priority for VLAN 20 on the secondary switch to ensure smooth traffic flow not only at Layer 2 but also at Layer 3

### LAB-SWITCH-02: HSRP Status

```
LAB-SWITCH-02# show hsrp brief
```

\*:IPv6 group #:group belongs to a bundle  
P indicates configured to preempt.

Interface	Grp	Prio	P State	Active addr	<b>Standby</b> addr	Group addr
<b>Vlan10</b> (conf)	1	100	<b>Standby</b>	<b>10.10.10.1</b>	local	<b>10.10.10.3</b>
<b>Vlan20</b> (conf)	2	120	P Active	local	<b>20.20.20.1</b>	<b>20.20.20.3</b>

```
LAB-SWITCH-02#
```

#### LAB-SWITCH-01: HSRP Status

```
LAB-SWITCH-01# sh hsrp brief
*:IPv6 group  #:group belongs to a bundle
                P indicates configured to preempt.
                |
Interface      Grp   Prio P State      Active addr      Standby addr      Group addr
Vlan10         1    110 P Active      local            10.10.10.2        10.10.10.3
(conf)
Vlan20         2    110 P Standby     20.20.20.2      local            20.20.20.3
(conf)
LAB-SWITCH-01#
```

## VI. CISCO VIRTUAL PORT-CHANNEL (vPC)

Cisco's Virtual Port-Channel (vPC) is a groundbreaking feature available on Nexus switches. It enables two switches to function as a single logical switch to downstream devices, ensuring high availability, redundancy, and loop-free topologies.

### A. Why vPC is Needed?

Traditional Layer 2/Layer 3 designs heavily relied on STP, which has limitations:

- Redundant Path Blocking: STP blocks redundant links, wasting valuable bandwidth.
- Convergence Delays: Topology changes can cause high delays, impacting performance.

### B. vPC Advantages

- Enables active-active forwarding on multiple links.
- Eliminates STP blocking on redundant paths.
- Provides faster convergence, ensuring high availability.

### C. Key Benefits of vPC

- 1) Reduces STP Dependency: Minimizes reliance on STP for loop prevention.
- 2) Maximizes Link Utilization: Supports active-active forwarding, using all available links.
- 3) Simplifies Network Architecture: Makes dual-homed device configurations straightforward.
- 4) Improves Reliability and Performance: Enhances network uptime and efficiency.

### D. Base vPC Configuration

#### 1) vPC Peer-Link

A dedicated port-channel between two Nexus switches for synchronization.

#### 2) Downstream Devices

Devices connected to both switches via active-active links, leveraging vPC for optimal bandwidth and redundancy.

#### LAB-SWITCH-01: vPC status

```
LAB-SWITCH-01# sh run | sec vpc
feature vpc
vpc domain 1
  role priority 100
  peer-keepalive destination 1.1.1.2 source 1.1.1.1 vrf default
  vpc peer-link
  vpc 51
  vpc 52
LAB-SWITCH-01#
```





LAB-SWITCH-02: vPC status

```
LAB-SWITCH-02# sh run | sec vpc
feature vpc
vpc domain 1
  role priority 200
  peer-keepalive destination 1.1.1.1 source 1.1.1.2 vrf default
vpc peer-link
vpc 51
vpc 52
LAB-SWITCH-02#
```

Configuration for the downstream interface connected to the downstream switches

LAB-SWITCH-01

```
interface port-channel1
  switchport mode trunk
  spanning-tree port type network
  vpc peer-link

interface port-channel51
  switchport mode trunk
  vpc 51

interface port-channel52
  switchport mode trunk
  vpc 52

LAB-SWITCH-01#
```

LAB-SWITCH-02

```
interface port-channel1
  switchport mode trunk
  spanning-tree port type network
  vpc peer-link

interface port-channel51
  switchport mode trunk
  vpc 51

interface port-channel52
  switchport mode trunk
  vpc 52

LAB-SWITCH-02#
```



LAB-SWITCH-03 : Active interfaces connected to northbound devices

Group	Port-Channel	Type	Protocol	Member Ports
10	Po10 (SU)	Eth	LACP	Eth1/2 (P) Eth1/4 (P)
LAB-SWITCH-03#				

LAB-SWITCH-04 : Active interfaces connected to northbound devices

Group	Port-Channel	Type	Protocol	Member Ports
10	Po10 (SU)	Eth	LACP	Eth1/2 (P) Eth1/4 (P)
LAB-SWITCH-04#				

LAB-SWITCH-03 : Traffic is passing through both links without any blockage.

```
LAB-SWITCH-03# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID    Priority    32778
             Address    5001.0000.1b08
             Cost        3
             Port        4105 (port-channel10)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32778 (priority 32768 sys-id-ext 10)
             Address    5003.0000.1b08
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface    Role Sts Cost      Prio.Nbr Type
-----
Po10         Root FWD 3         128.4105 P2p
Eth1/3       Desg FWD 4         128.3     P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID    Priority    32788
             Address    5001.0000.1b08
             Cost        3
             Port        4105 (port-channel10)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32788 (priority 32768 sys-id-ext 20)
             Address    5003.0000.1b08
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface    Role Sts Cost      Prio.Nbr Type
-----
Po10         Root FWD 3         128.4105 P2p

LAB-SWITCH-03#
```

LAB-SWITCH-04 : Traffic is passing through both links without any blockage.

```
LAB-SWITCH-04# sh spanning-tree vlan 10,20 brief

VLAN0010
  Spanning tree enabled protocol rstp
  Root ID    Priority    32778
             Address    5001.0000.1b08
             Cost        3
             Port        4105 (port-channel10)
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID   Priority    32778 (priority 32768 sys-id-ext 10)
             Address    5004.0000.1b08
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec

Interface                Role Sts Cost      Prio.Nbr Type
-----
Po10                     Root FWD 3         128.4105 P2p

VLAN0020
  Spanning tree enabled protocol rstp
  Root ID    Priority    32788
             Address    5001.0000.1b08
             Cost        3
             Port        4105 (port-channel10)
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID   Priority    32788 (priority 32768 sys-id-ext 20)
             Address    5004.0000.1b08
             Hello Time  2 sec Max Age 20 sec Forward Delay 15 sec

Interface                Role Sts Cost      Prio.Nbr Type
-----
Po10                     Root FWD 3         128.4105 P2p
Eth1/3                   Desg FWD 4         128.3     P2p

LAB-SWITCH-04#
```

## VII. CONCLUSION

With the implementation of PVST and vPC, we addressed inefficiencies in traditional STP by enabling better resource utilization and ensuring a robust, scalable, and high-performing network. By increasing HSRP priority for VLAN 20 on the secondary switch, traffic flow has been optimized at both Layer 2 and Layer 3, enhancing overall network stability and business operations.





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