Networking Academy

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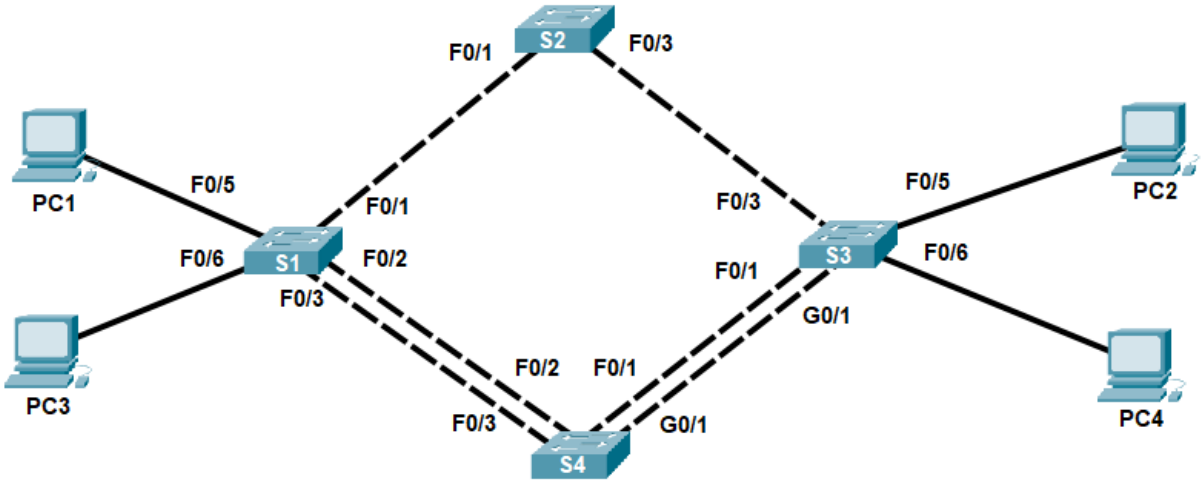
Lab 2.1 – Observing STP and Configuring PVST+

This activity comes with an accompanying Packet Tracer file with a partially configured network. Make sure to download the Packet Tracer file from the Animospace assignment page.



Addressing Table

Device	Interface	IP Address	Subnet Mask
PC1	NIC	192.168.1.1	255.255.255.0
PC2	NIC	192.168.1.2	255.255.255.0
PC3	NIC	192.168.2.1	255.255.255.0
PC4	NIC	192.168.2.2	255.255.255.0

Objectives

Part 1: Determine the Root Bridge and Port Roles

Part 2: Observe STP Port Selection Based on Path Cost

Part 3: Observe STP Port Selection Based on Port Priority

Part 4: Implement Load Balancing using PVST+ Configuration

Background / Scenario

Redundancy increases the availability of devices in the network topology by protecting the network from a single point of failure. Redundancy in a switched network is accomplished through the use of multiple switches or multiple links between switches. When physical redundancy is introduced into a network design, loops and duplicate frames can occur.

The Spanning Tree Protocol (STP) was developed as a Layer 2 loop-avoidance mechanism for redundant links in a switched network. STP ensures that there is only one logical path between all destinations on the network by intentionally blocking redundant paths that could cause a loop.

The Per-VLAN Spanning Tree (PVST) protocol is a Cisco proprietary enhancement of STP that maintains a separate spanning tree instance per VLAN in the network. This allows each spanning tree to be independently fine-tuned to implement load balancing in the network.

Part 1: Determine the Root Bridge

Every spanning-tree instance (switched LAN or broadcast domain) has a switch designated as the root bridge. The root bridge serves as a reference point for all spanning-tree calculations to determine which redundant paths to block.

An election process determines which switch becomes the root bridge. The switch with the lowest bridge identifier (BID) becomes the root bridge. The BID is made up of a bridge priority value and the MAC address of the switch.

Step 1: Temporarily disable selected ports on the switches.

Temporarily deactivate ports F0/2 and G0/1 on **S4**.

```
S4(config)# interface f0/2
S4(config-if)# shutdown
S4(config-if)# interface g0/1
S4(config-if)# shutdown
S4(config-if)# end
```

Step 2: Display spanning tree information.

a. Issue the **show spanning-tree** command on S1. The Bridge ID Priority is calculated by adding the priority value and the extended system ID. The extended system ID is always the VLAN number. Currently, all four switches have equal Bridge ID Priority values (32769 = 32768 + 1, where default priority = 32768, VLAN number = 1); therefore, the switch with the lowest MAC address becomes the root bridge. The root bridge is identified by the switch in the command output under the Root ID section

```
S1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.64C4.1250
              Cost        38
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000B.BEBB.35C4
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20
Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Fa0/1               Root FWD 19        128.1    P2p
Fa0/3               Altn FWD 19        128.3    P2p
Fa0/5               Desg FWD 19        128.5    P2p
```

b. Use the **show spanning-tree** command on the rest of switches to gather information about the spanning tree status of each switch. Complete the table.

Switch	Port	Port Role (Root, Desg, Altn)	Status (FWD, BLK…)
S1	F0/1	Root	**BLK**
	F0/3	**Altn**	**FWD**
S2	F0/1	**Desg**	**FWD**
	F0/3	**Root**	**FWD**
S3	F0/1	**Desg**	**FWD**
	F0/3	**Desg**	**FWD**
S4	F0/1	**Root**	**FWD**
	F0/3	**Desg**	**FWD**

Based on the output from your switches, answer the following questions.

Which switch is the root bridge?	S3

Why did spanning tree select this switch as the root bridge?

It has the lowest mac-address for its bridge ID among all switches (0005.5E62.0442)

Notice that Packet Tracer uses a different color for the link light on one of the connections between the switches. What do you think does this link light mean?

Green Light means forwarding, orange light means blocking.

Why did the spanning tree algorithm select this port as the non-designated (blocked) port?

It is because Fa0/3 has a higher path cost to the root bridge.

Given the resulting spanning tree, what path do data frames take to go from PC1 to PC2?

Port Fa0 of PC1 -> Port Fa0/5 of S1 -> Port Fa0/1 of S1 -> Port Fa0/1 of S2 -> Port Fa0/3 of S2 -> Port Fa0/3 of S3 -> Port Fa0/5 of S3 -> Port Fa0 of PC2

Part 2: Observe STP Port Selection Based on Path Cost

The spanning tree algorithm (STA) uses the root bridge as the reference point and then determines which ports to block, based on path cost. The port with the lower path cost is preferred. If path costs are equal, then spanning tree compares BIDs. If the BIDs are equal, then the port priorities are used to break the tie. Lower values are always preferred. In Part 2, you will change the path cost to control which port is blocked by spanning tree.

Step 1: Determine current path cost.

With the current topology, all switches are linked using Fast Ethernet connections which use a default link cost of 19. The spanning tree algorithm aggregates the cost of each individual link to determine the overall path costs which is used as basis to select the least cost path to the root bridge.

Issue the **show spanning-tree** command on S1. The Root ID section indicates the total cost of the least cost path calculated by the switch to reach the root bridge.

```
S1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0001.64C4.1250
             Cost        38
             Port        1(FastEthernet0/1)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000B.BEBB.35C4
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  20
Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Fa0/1               Root FWD 19        128.1    P2p
Fa0/3               Altn FWD 19        128.3    P2p
Fa0/5               Desg FWD 19        128.5    P2p
Fa0/6               Desg FWD 19        128.6    P2p
```

Notice that the cost is currently 38. This is because to reach the root bridge (S3) through S2, S1 crosses two Fast Ethernet links with a cost of 19 each.

What would have been the path cost of S1 to S3 if going through S4?	38

Step 2: Change path cost.

You will now change the cost of the path going through S4 to influence the path of S1 to the root bridge by swapping the Fast Ethernet connection from S4 to the root bridge with a Gigabit connection. Deactivate F0/1 on **S4** and activate G0/1 instead.

```
S4(config)# interface f0/1
S4(config-if)# shutdown
S4(config-if)# interface g0/1
S4(config-if)# no shutdown
```

Step 3: Observe spanning tree changes.

Wait 30 seconds for the spanning-tree to adjust to the new topology (or you may click on the fast-forward button of Packet Tracer). Re-issue the **show spanning-tree** command **S1**. Observe that the path cost to root has now changed and the spanning tree is now blocking the port connected to S2.

```
S1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.64C4.1250
              Cost        23
              Port        3(FastEthernet0/3)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000B.BEBB.35C4
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20
Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Fa0/1               Altn FWD 19        128.1    P2p
Fa0/3               Root FWD 19        128.3    P2p
Fa0/5               Desg FWD 19        128.5    P2p
Fa0/6               Desg FWD 19        128.6    P2p
```

Why did spanning tree change the previously blocked port to a root port, and block the port that was a root port on the other S2?

> This is because the new path cost using S4 is 23, which is lower than the previous path cost using S2 (38).

How did the swapping of connection types between S4 and S3 affect the cost of the path? Hint: Observe the cost of the G0/1 port using **show spanning-tree** command on S4.

> The connection type of the new path from S4 to S3 uses a gigabit ethernet port instead of a fast ethernet port. Thus, instead of having a path cost of 19, it instead has a path cost of 4.

Part 3: Observe STP Port Selection Based on Port Priority

If path costs are equal, then spanning tree compares BIDs. If the BIDs are equal, then the port priorities are used to break the tie. The default port priority value is **128**. STP aggregates the port priority with the port number / port ID to break ties. Lower values are always preferred. In Part 3, you will activate the redundant paths between S4 and S3 to observe how STP selects a port using the port priority.

a. Activate the redundant link between S1 and S4 by enabling F0/2 on S4.

```
S4(config)# interface f0/2
S4(config-if)# no shutdown
S4(config-if)# end
```

b. Wait 30 seconds for STP to complete the port transition process (or you may click on the fast-forward button of Packet Tracer), and then issue the **show spanning-tree** command on S1. Observe that the root port has moved to the lower numbered port linked to the upstream switch and blocked the previous root port.

```
S1# show spanning-tree
```

```
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.64C4.1250
              Cost        23
              Port        2(FastEthernet0/2)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000B.BEBB.35C4
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Altn BLK 19        128.1    P2p
Fa0/2            Root FWD 19        128.2    P2p
Fa0/3            Altn BLK 19        128.3    P2p
Fa0/5            Desg FWD 19        128.5    P2p
Fa0/6            Desg FWD 19        128.6    P2p
```

What port did STP select as the root port on S1?	Fa0/2

Why did STP select this port as the root port on S1?

Despite having the same path cost and the same BID, Fa0/2 has a lower port priority of 128.2 compared to Fa0/3, which has a higher port priority of 128.3.

c. Adjust the port priority of the upstream switch **S4** to influence the selection of the root port on S1 by issuing the interface **spanning-tree vlan port-priority** command. Port priorities are set at 128 by default and may be adjusted in increments of 16.

```
S4(config)# interface f0/3
S4(config-if)# spanning-tree vlan 1 port-priority 112
```

d. Wait for the spanning tree to adjust to the new topology (or you may click on the fast-forward button of Packet Tracer) then issue the **show spanning-tree** command on **S4**. Confirm that the port priority has now changed for F0/3.

```
S4# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.64C4.1250
              Cost        4
              Port        25(GigabitEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
```

```
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0030.F250.0126
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/2            Desg FWD 19        128.2    P2p
Fa0/3            Desg FWD 19        112.3    P2p
Gi0/1            Root FWD 4         128.25   P2p
```

e. Issue the **show spanning-tree** command on S1. Observe that the root port has again moved back to F0/3 from F0/2.

```
S1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0001.64C4.1250
             Cost        23
             Port        3(FastEthernet0/3)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000B.BEBB.35C4
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Altn BLK 19        128.1    P2p
Fa0/2            Altn BLK 19        128.2    P2p
Fa0/3            Root FWD 19        128.3    P2p
Fa0/5            Desg FWD 19        128.5    P2p
Fa0/6            Desg FWD 19        128.6    P2p
```

Part 4: Implement Load Balancing using PVST+ Configuration

The default STP variant used on Cisco switches is Per VLAN Spanning Tree Protocol (PVST+). PVST+ creates a separate spanning tree instance per VLAN which makes it possible to fine-tune each spanning tree to effectively balance the traffic load in the network. In Part 4, you will use PVST+ to adjust the spanning trees to create different paths for traffic of different VLANs.

Step 1: Modify the switch topology.

a. Disconnect the G0/1 and F0/2 links of S4 to S3 and S1 respectively.

b. Reenable the F0/1 interface of S4.

```
S4(config)# interface f0/1
S4(config-if)# no shutdown
S4(config-if)# end
```

Step 2: Create a new VLAN in the network.

a. Configure ports connecting **ALL** switches as trunks. A sample configuration is shown below.

```
S1(config)# interface range f0/1-3
S1(config-if-range)# switchport mode trunk
S1(config-if-range)# end
```

b. Create VLAN 2 on **ALL** switches. A sample configuration is shown below

```
S1(config)# vlan 2
```

c. Assign fa0/6 on S1 and S3 to VLAN 2

```
S1(config)# interface f0/6
S1(config)# switchport access vlan 2

S3(config)# interface f0/6
S3(config)# switchport access vlan 2
```

d. Test connectivity between hosts.

Can PC1 ping PC2?	Yes
Can PC3 ping PC4?	Yes

If any of these do not work, recheck your configurations and troubleshoot VLAN and trunk configurations as necessary.

Step 3: Adjust the spanning tree of each VLAN

Spanning trees may be manipulated by adjusting the bridge priority of switches to influence root bridge election.

In PVST+, the lower 12 bits of the 20-bit BPDU bridge priority field is repurposed to contain the VLAN ID of the spanning tree; hence when adjusting the bridge priority, one can only do so in increments of 4096.

a. Issue the **show spanning-tree** command on the switches. Observe that there are now two spanning tree details listed in the output – each corresponding to a VLAN currently active in the network.

```
S1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.64C4.1250
              Cost        38
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000B.BEBB.35C4
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
```

```
Fa0/1            Root FWD 19        128.1    P2p
Fa0/3            Altn BLK 19        128.3    P2p
Fa0/5            Desg FWD 19        128.5    P2p


VLAN0002
  Spanning tree enabled protocol ieee
  Root ID    Priority    32770
             Address     0001.64C4.1250
             Cost        38
             Port        1(FastEthernet0/1)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32770  (priority 32768 sys-id-ext 2)
             Address     000B.BEBB.35C4
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Root FWD 19        128.1    P2p
Fa0/3            Altn BLK 19        128.3    P2p
Fa0/6            Desg FWD 19        128.6    P2p
```

Currently, all switches are set equally at the default bridge priority value.

What is the bridge priority value of the switches for VLAN 1?	32769
What is the bridge priority value of the switches for VLAN 2?	32770

Why do the bridge priorities appear to be different values between VLAN 1 and VLAN2?

This is because of the vlan they are in. The bridge id priority is calculated by adding the priority value and the extended system id, which has the vlan number in it.

b. Influence the flow of traffic for each VLAN by manipulating the root bridge of their respective spanning trees through bridge priority adjustment. Set S2 as the primary and S4 as the secondary root bridges of VLAN 1; and S2 as secondary and S4 as primary root bridges of VLAN 2.

```
S2(config)# spanning-tree vlan 1 root primary
S2(config)# spanning-tree vlan 2 root secondary

S4(config)# spanning-tree vlan 2 root primary
S4(config)# spanning-tree vlan 1 root secondary
```

c. Wait approximately 30 seconds for the spanning trees to recalculate (or click the fast forward button a few times) then issue the **show spanning-tree** command on the switches.

Record the spanning tree information of each switch in the table below:

	VLAN 1			VLAN 2		
Switch	Bridge Priority	ort	Port Role	Bridge Priority	ort	Port Role
S1	32769	F0/1	Root	32770	F0/1	Desg
		F0/3	Desg		F0/3	Root
S2	24577	F0/1	Desg	28674	F0/1	Altn
		F0/3	Desg		F0/3	Root
S3	32769	F0/1	Desg	32770	F0/1	Root
		F0/3	Root		F0/3	Desg
S4	28673	F0/1	Root	24578	F0/1	Desg
		F0/3	Altn		F0/3	Desg

d. Observe the link lights of the switch trunks.

What has changed after the bridge priority adjustments?

All link lights are green, apart from the ports that are shut down.

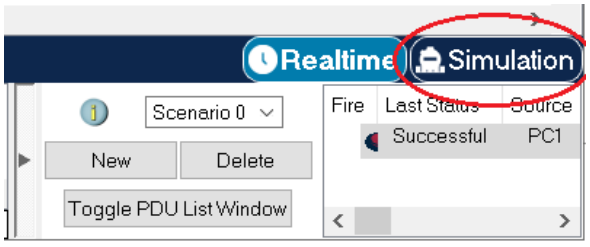
Why do you think have the recent configurations resulted in these link light changes?

Since each vlan was configured with its own spanning tree, one port can be blocking for a certain vlan but it could also be forwarding for another separate vlan.

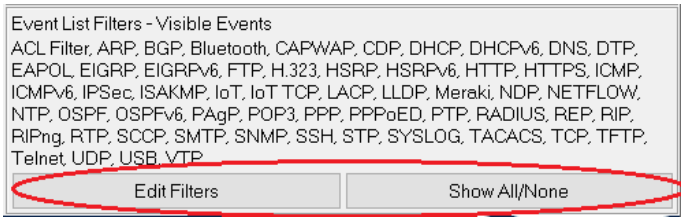
Step 4: Observe the paths traversed by VLAN traffic.

a. The simulation mode of Packet Tracer allows observation of packet movement through the network. Use this mode to view how the traffic of each VLAN travels through switch links based on their respective spanning trees.

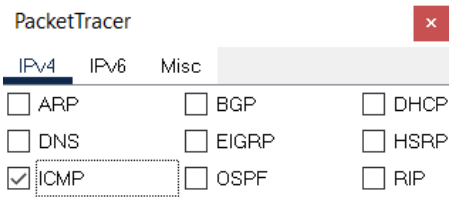
1) Switch Packet Tracer to simulation mode by clicking on the button on the lower right of the window.



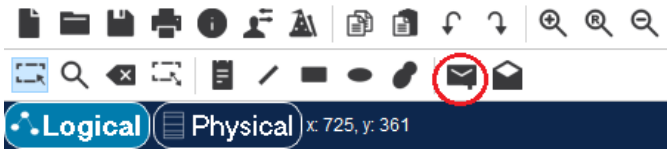
2) Edit the packet filter so that only ping packets will be observed. First click on the ‘Show All/None’ button then click on the ‘Edit Filters’ button



3) From the resulting pop-up window, enable ICMP then close the pop-up.

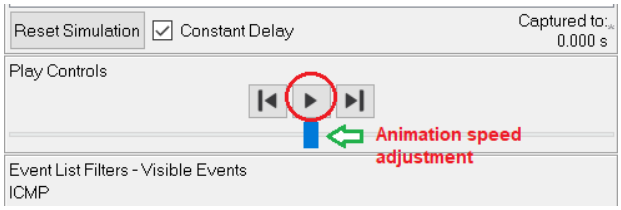


b. Simulate a ping from PC1 to PC2 by clicking on the simple PDU button of Packet Tracer.



Once your cursor changes to a PDU symbol, first click on PC1 (to specify the PDU source), then click on PC2 (to specify the destination)

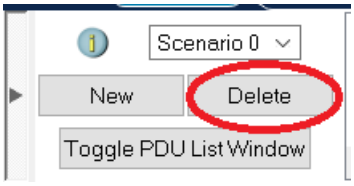
c. Click on the play button to begin the simulation then observe the path taken by the packet. You may adjust the animation speed by moving the speed slider to the right or left.



What path does the ping packet take to travel from PC1 to PC2?

Port Fa0 of PC1 -> Port Fa0/5 of S1 -> Port Fa0/1 of S1 -> Port Fa0/1 of S2 -> Port Fa0/3 of S2 -> Port Fa0/3 of S3 -> Port Fa0/5 of S3 -> Port Fa0 of PC2

d. Clear the simulation by clicking on the Delete button in the Scenario pane.



e. Perform a simulated ping between PC3 to PC4 this time using the same procedure and observe the path taken.

What path does the ping packet take to travel from PC3 to PC4?

Port Fa0 of PC3 -> Port Fa0/6 of S1 -> Port Fa0/3 of S1 -> Port Fa0/3 of S4 -> Port Fa0/1 of S4 -> Port Fa0/1 of S3 -> Port Fa0/6 of S3 -> Port Fa0 of PC4

Reflection

1. What is the value of having redundant paths in a switched network?

Redundant paths offer increased network availability and reliability since it prevents single points of failure in the network.

2. Based on your tests and observations, in what order does a switch prioritize the following factors when selecting which among its ports to assign as the root port? (1= first, 4= last)

2	Lowest upstream switch BID
4	Lowest upstream switch interface ID
1	Lowest path cost
3	Lowest upstream switch interface priority

3. How does the use of PVST+ contribute to more efficient utilization of switch links in a network?

PVST+ allows for load balancing by making it possible for one port to handle multiple vlans by blocking a certain vlan or forwarding another vlan, thus making the network more efficient.