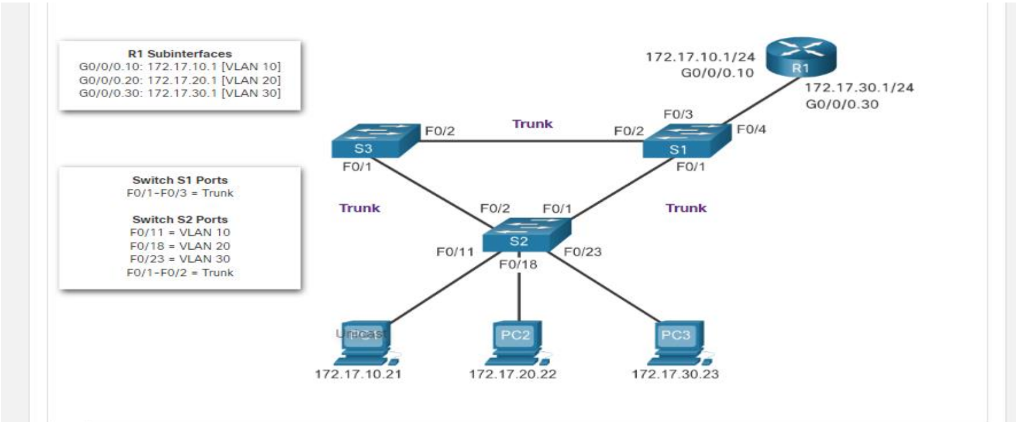
MODULE 4: Inter-VLAN Routing
WEEK 4

Learning Outcomes:
After completing this course you are expected to demonstrate the following:

Troubleshoot inter-VLAN routing on Layer 3 devices and describe options for configuring inter-VLAN routing.

A. Engage



Click Play in the figure to view an animation how a router-on-a-stick performs its routing function.

B. Explore

Video Animation
Router – on – a – Stick Inter – VLAN Routing

Netacad Academy account
https://contenthub.netacad.com/srwe/4.1.3

C. Explain

As seen in the animation, PC1 on VLAN 10 is communicating with PC3 on VLAN 30. When R1 accepts the tagged unicast traffic on VLAN 10, it routes that traffic to VLAN 30, using its configured subinterfaces. Switch S2 removes the VLAN tag of the unicast frame and forwards the frame out to PC3 on port F0/23.

Note: The router-on-a-stick method of inter-VLAN routing does not scale beyond 50 VLANs.

D. Elaborate

4.1.1. What is Inter – VLAN Routing?

VLANs are used to segment switched Layer 2 networks for a variety of reasons. Regardless of the reason, hosts in one VLAN cannot communicate with hosts in another VLAN unless there is a router or a Layer 3 switch to provide routing services.

Inter-VLAN routing is the process of forwarding network traffic from one VLAN to another VLAN.

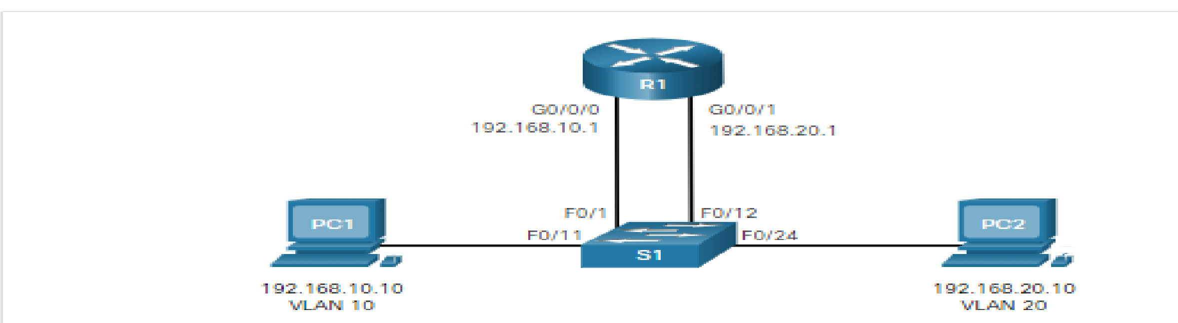
There are three inter-VLAN routing options:

- **Legacy Inter-VLAN routing** - This is a legacy solution. It does not scale well.
- **Router-on-a-Stick** - This is an acceptable solution for a small to medium-sized network.
- **Layer 3 switch using switched virtual interfaces (SVIs)** - This is the most scalable solution for medium to large organizations.

4.1.2 Legacy Inter-VLAN Routing

- The first inter-VLAN routing solution relied on using a router with multiple Ethernet interfaces. Each router interface was connected to a switch port in different VLANs. The router interfaces served as the default gateways to the local hosts on the VLAN subnet.
- Legacy inter-VLAN routing using physical interfaces works, but it has a significant limitation. It is not reasonably scalable because routers have a limited number of physical interfaces. Requiring one physical router interface per VLAN quickly exhausts the physical interface capacity of a router.
- Note: This method of inter-VLAN routing is no longer implemented in switched networks and is included for explanation purposes only.

For example, refer to the topology where R1 has two interfaces connected to switch S1.



Notice in the example MAC address table of S1 is populated as follows:

- Fa0/1 port is assigned to VLAN 10 and is connected to the R1 G0/0/0 interface.
- Fa0/11 port is assigned to VLAN 10 and is connected to PC1.
- Fa0/12 port is assigned to VLAN 20 and is connected to the R1 G0/0/1 interface.
- Fa0/11 port is assigned to VLAN 20 and is connected to PC2.

MAC Address table for S1

Port	MAC Address	VLAN
F0/1	R1 G0/0/0 MAC	10
F0/11	PC1 MAC	10
F0/12	R1 G0/0/1 MAC	20
F0/24	PC2 MAC	20

When PC1 sends a packet to PC2 on another network, it forwards it to its default gateway 192.168.10.1. R1 receives the packet on its G0/0/0 interface and examines the destination address of the packet. R1 then routes the packet out its G0/0/1 interface to the F0/12 port in VLAN 20 on S1. Finally, S1 forwards the frame to PC2.

In our example, R1 required two separate Ethernet interfaces to route between VLAN 10 and VLAN 20. What if there were six (or more) VLANs to interconnect? A separate interface would be required for each VLAN. Obviously, this solution is not scalable.

4.1.3 Router – on – a – Stick Inter – VLAN Routing

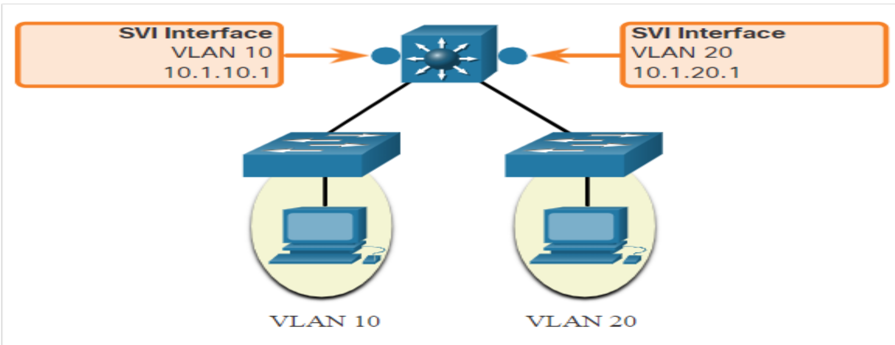
The 'router-on-a-stick' inter-VLAN routing method overcomes the limitation of the legacy inter-VLAN routing method. It only requires one physical Ethernet interface to route traffic between multiple VLANs on a network.

- A Cisco IOS router Ethernet interface is configured as an 802.1Q trunk and connected to a trunk port on a Layer 2 switch. Specifically, the router interface is configured using subinterfaces to identify routable VLANs.
- The configured subinterfaces are software-based virtual interfaces. Each is associated with a single physical Ethernet interface. Subinterfaces are configured in software on a router. Each subinterface is independently configured with an IP address and VLAN assignment. Subinterfaces are configured for different subnets that correspond to their VLAN assignment. This facilitates logical routing.
- When VLAN-tagged traffic enters the router interface, it is forwarded to the VLAN subinterface. After a routing decision is made based on the destination IP network address, the router determines the exit interface for the traffic. If the exit interface is configured as an 802.1q subinterface, the data frames are VLAN-tagged with the new VLAN and sent back out the physical interface.

4.1.4 Inter – VLAN Routing on a Layer 3 Switch

The modern method of performing inter-VLAN routing is to use Layer 3 switches and switched virtual interfaces (SVI). An SVI is a virtual interface that is configured on a Layer 3 switch, as shown in the figure.

Note: A Layer 3 switch is also called a multilayer switch as it operates at Layer 2 and Layer 3. However, in this course we use the term Layer 3 switch.



Inter-VLAN SVIs are created the same way that the management VLAN interface is configured. The SVI is created for a VLAN that exists on the switch. Although virtual, the SVI performs the same functions for the VLAN as a router interface would. Specifically, it provides Layer 3 processing for packets that are sent to or from all switch ports associated with that VLAN.

The following are advantages of using Layer 3 switches for inter-VLAN routing:

- They are much faster than router-on-a-stick because everything is hardware switched and routed.
- There is no need for external links from the switch to the router for routing.
- They are not limited to one link because Layer 2 EtherChannels can be used as trunk links between the switches to increase bandwidth.
- Latency is much lower because data does not need to leave the switch in order to be routed to a different network.
- They more commonly deployed in a campus LAN than routers.

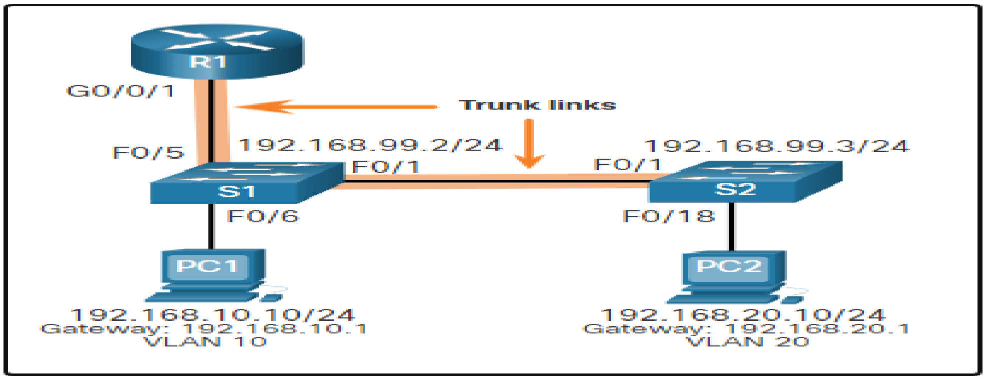
The only disadvantage is that Layer 3 switches are more expensive.

4.2 Router – on – a – Stick Inter – VLAN Routing

4.2.1. Router – on – a – Stick Scenario

In the previous topic, three different ways to create inter-VLAN routing were listed, and legacy inter-VLAN routing was detailed. This topic details show to configure router-on-a-stick inter-VLAN routing. You can see in the figure that the router is not in the center of the topology but instead, appears to be on a stick near the border, hence the name.

In the figure, the R1 GigabitEthernet 0/0/1 interface is connected to the S1 FastEthernet 0/5 port. The S1 FastEthernet 0/1 port is connected to the S2 FastEthernet 0/1 port. These are trunk links that are required to forward traffic within and between VLANs.



To route between VLANs, the R1 GigabitEthernet 0/0/1 interface is logically divided into three subinterfaces, as shown in the table. The table also shows the three VLANs that will be configured on the switches.

Router R1 Subinterfaces

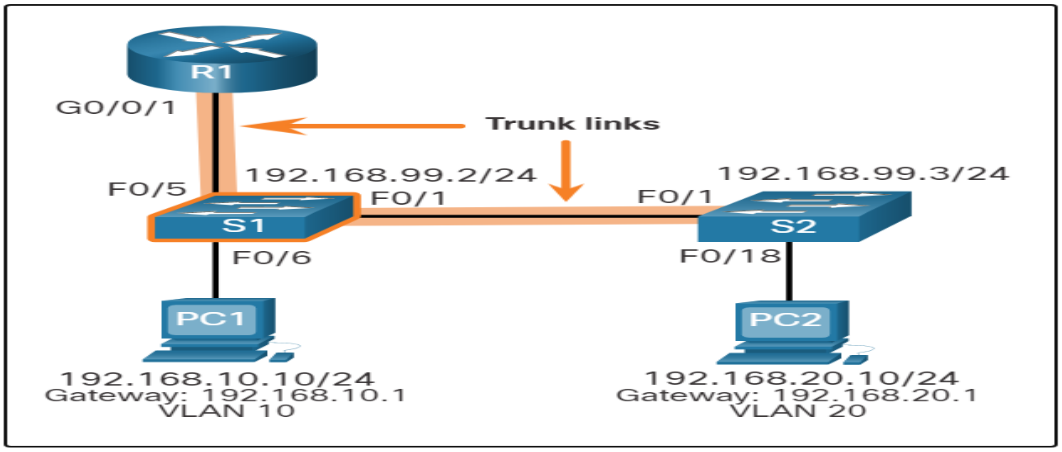
Subinterace	VLAN	IP Address
G0/0/1.10	**10**	**192.168.10.1/24**
G0/0/1.20	**20**	**192.168.20.2/24**
G0/0/1.30	**99**	**192.168.99.1/24**

Assume that R1, S1, and S2 have initial basic configurations. Currently, PC1 and PC2 cannot **ping** each other because they are on separate networks. Only S1 and S2 can **ping** each other, but they but are unreachable by PC1 or PC2 because they are also on different networks.

To enable devices to ping each other, the switches must be configured with VLANs and trunking, and the router must be configured for inter-VLAN routing.

4.2.2 S1 VLAN and Trunking Configuration

Complete the following steps to configure S1 with VLANs and trunking:



1. Create and name the VLANs.

First, the VLANs are created and named. VLANs are only created after you exit out of VLAN subconfiguration mode.

```
S1(config)# vlan 10
S1(config-vlan)# name LAN10
S1(config-vlan)# exit
S1(config)# vlan 20
S1(config-vlan)# name LAN20
S1(config-vlan)# exit
S1(config)# vlan 99
S1(config-vlan)# name Management
S1(config-vlan)# exit
S1(config)#
```

2. Create t

Next, the management interface is created on VLAN 99 along with the default gateway of R1.

```
S1(config)# interface vlan 99
S1(config-if)# ip add 192.168.99.2 255.255.255.0
S1(config-if)# no shut
S1(config-if)# exit
S1(config)# ip default-gateway 192.168.99.1
S1(config)#
```

3. Configure access ports.

Next, port Fa0/6 connecting to PC1 is configured as an access port in VLAN 10. Assume PC1 has been configured with the correct IP address and default gateway.

```
S1(config)# interface fa0/6
S1(config-if)# switchport mode access
S1(config-if)# switchport access vlan 10
S1(config-if)# no shut
S1(config-if)# exit
S1(config)#
```

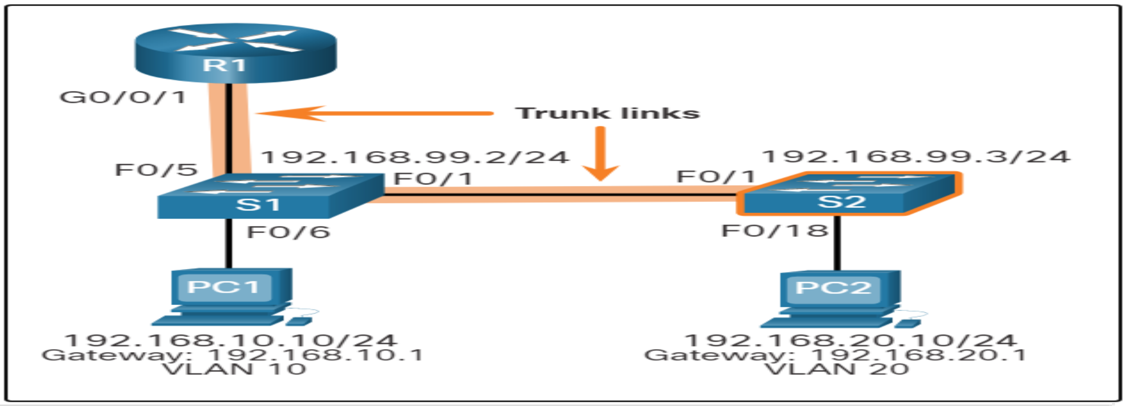
4. Configure trunking ports.

Finally, ports Fa0/1 connecting to S2 and Fa05 connecting to R1 are configured as trunk ports.

```
S1(config)# interface fa0/1
S1(config-if)# switchport mode trunk
S1(config-if)# no shut
S1(config-if)# exit
S1(config)# interface fa0/5
S1(config-if)# switchport mode trunk
S1(config-if)# no shut
S1(config-if)# end
*Mar  1 00:23:43.093: %LINEPROTO-5-UPDOWN: Line protocol on Interface
FastEthernet0/1, changed state to up
*Mar  1 00:23:44.511: %LINEPROTO-5-UPDOWN: Line protocol on Interface
FastEthernet0/5, changed state to up
```

4.2.3 S2 VLAN and Trunking Configuration

The configuration for S2 is similar to S1.




```
S2(config)# vlan 10
S2(config-vlan)# name LAN10
S2(config-vlan)# exit
S2(config)# vlan 20
S2(config-vlan)# name LAN20
S2(config-vlan)# exit
S2(config)# vlan 99
S2(config-vlan)# name Management
S2(config-vlan)# exit
S2(config)#
S2(config)# interface vlan 99
S2(config-if)# ip add 192.168.99.3 255.255.255.0
S2(config-if)# no shut
S2(config-if)# exit
S2(config)# ip default-gateway 192.168.99.1
S2(config)# interface fa0/18
S2(config-if)# switchport mode access
S2(config-if)# switchport access vlan 20
S2(config-if)# no shut
S2(config-if)# exit
S2(config)# interface fa0/1
S2(config-if)# switchport mode trunk
S2(config-if)# no shut
S2(config-if)# exit
S2(config-if)# end
*Mar  1 00:23:52.137: %LINEPROTO-5-UPDOWN: Line protocol on Interface
FastEthernet0/1, changed state to up
```

4.2.4 R1 Subinterface Configuration

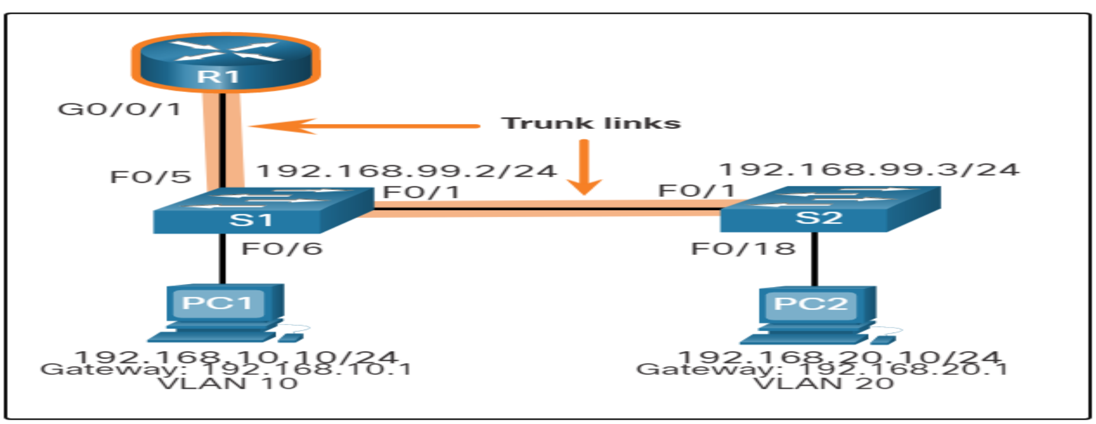
The router-on-a-stick method requires you to create a subinterface for each VLAN to be routed.
A subinterface is created using the **interface** *interface_id subinterface_id* global configuration mode command. The subinterface syntax is the physical interface followed by a period and a subinterface number. Although not required, it is customary to match the subinterface number with the VLAN number.
Each subinterface is then configured with the following two commands:

- **encapsulation dot1q** *vlan_id* **[native]** - This command configures the subinterface to respond to 802.1Q encapsulated traffic from the specified *vlan-id*. The **native** keyword option is only appended to set the native VLAN to something other than VLAN 1.
- **ip address** *ip-address subnet-mask* - This command configures the IPv4 address of the subinterface. This address typically serves as the default gateway for the identified VLAN.
- Repeat the process for each VLAN to be routed. Each router subinterface must be assigned an IP address on a unique subnet for routing to occur.

When all subinterfaces have been created, enable the physical interface using the **no shutdown** interface configuration command. If the physical interface is disabled, all subinterfaces are disabled.

In the following configuration, the R1 G0/0/1 subinterfaces are configured for VLANs 10, 20, and 99.

The physical network topology shows two PCs, two switches, and a router. PC1 has IP address 192.168.10.10/24. PC2 has IP address 192.168.20.10/24. PC1 connects to Switch S1 on switch port F0/6. PC2 connects to Switch S2 on switch port F0/18. Switch S1 and Switch S2 are interconnected to each other on switchport F0/1. Switch S1 is connected to router R1 on switch port F0/5 which connects to the G0/0/1 interfaces on R1. The management IP address on S1 is 192.168.99.2/24. The management IP address on S1 is 192.168.99.3/24



```
R1(config)# interface G0/0/1.10
R1(config-subif)# description Default Gateway for VLAN 10
R1(config-subif)# encapsulation dot1Q 10
R1(config-subif)# ip add 192.168.10.1 255.255.255.0
R1(config-subif)# exit
R1(config)#
R1(config)# interface G0/0/1.20
R1(config-subif)# description Default Gateway for VLAN 20
R1(config-subif)# encapsulation dot1Q 20
R1(config-subif)# ip add 192.168.20.1 255.255.255.0
R1(config-subif)# exit
R1(config)#
R1(config)# interface G0/0/1.99
R1(config-subif)# description Default Gateway for VLAN 99
R1(config-subif)# encapsulation dot1Q 99
R1(config-subif)# ip add 192.168.99.1 255.255.255.0
R1(config-subif)# exit
R1(config)#
R1(config)# interface G0/0/1
R1(config-if)# description Trunk link to S1
R1(config-if)# no shut
R1(config-if)# end
R1#
*Sep 15 19:08:47.015: %LINK-3-UPDOWN: Interface GigabitEthernet0/0/1,
changed state to down
*Sep 15 19:08:50.071: %LINK-3-UPDOWN: Interface GigabitEthernet0/0/1,
changed state to up
*Sep 15 19:08:51.071: %LINEPROTO-5-UPDOWN: Line protocol on Interface
GigabitEthernet0/0/1, changed state to up
R1#
```

4.2.5 Verify Connectivity Between PC1 and PC2

The router-on-a-stick configuration is complete after the switch trunk and the router subinterfaces have been configured. The configuration can be verified from the hosts, router, and switch.

From a host, verify connectivity to a host in another VLAN using the **ping** command. It is a good idea to first verify the current host IP configuration using the **ipconfig** Windows host cor

```
C:\Users\PC1> ipconfig
Windows IP Configuration
Ethernet adapter Ethernet0:
  Connection-specific DNS Suffix . :
  Link-local IPv6 Address          : fe80::5c43:ee7c:2959:da68%6
  IPv4 Address                     : 192.168.10.10
  Subnet Mask                      : 255.255.255.0
  Default Gateway                  : 192.168.10.1
C:\Users\PC1>
```

The output confirms the IPv4 address and default gateway of PC1. Next, use **ping** to verify connectivity with PC2 and S1, as shown in the figure. The **ping** output successfully confirms inter-VLAN routing is operating

```
C:\Users\PC1> ping 192.168.20.10
Pinging 192.168.20.10 with 32 bytes of data:
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Ping statistics for 192.168.20.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss).
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
C:\Users\PC1>
C:\Users\PC1> ping 192.168.99.2
Pinging 192.168.99.2 with 32 bytes of data:
Request timed out.
Request timed out.
Reply from 192.168.99.2: bytes=32 time=2ms TTL=254
Reply from 192.168.99.2: bytes=32 time=1ms TTL=254
Ping statistics for 192.168.99.2:
    Packets: Sent = 4, Received = 2, Lost = 2 (50% loss).
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 2ms, Average = 1ms
C:\Users\PC1>
```

4.2.6 Router – on – a – Stick Inter – VLAN Routing Verification

In addition to using **ping** between devices, the following **show** commands can be used to verify and troubleshoot the router-on-a-stick configuration.

- **show ip route**

Verify that the subinterfaces are appearing in the routing table of R1 by using the **show ip route** command. Notice that there are three connected routes (C) and their respective exit interfaces for each routable VLAN. The output confirms that the correct subnets, VLANs, and subinterfaces are active.

```
R1# show ip route | begin Gateway
Gateway of last resort is not set
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0/1.10
L        192.168.10.1/32 is directly connected, GigabitEthernet0/0/1.10
      192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.20.0/24 is directly connected, GigabitEthernet0/0/1.20
L        192.168.20.1/32 is directly connected, GigabitEthernet0/0/1.20
      192.168.99.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.99.0/24 is directly connected, GigabitEthernet0/0/1.99
L        192.168.99.1/32 is directly connected, GigabitEthernet0/0/1.99
R1#
```

- **show ip interface brief**

Another useful router command is **show ip interface brief,** as shown in the output. The output confirms that the subinterfaces have the correct IPv4 address configured, and that they are operational.

```
R1# show ip interface brief | include up
GigabitEthernet0/0/1   unassigned      YES unset  up                    up
Gi0/0/1.10             192.168.10.1    YES manual up                    up
Gi0/0/1.20             192.168.20.1    YES manual up                    up
Gi0/0/1.99             192.168.99.1    YES manual up                    up
R1#
```

- **show interfaces**

Subinterfaces can be verified using the **show interfaces** *subinterface-id* command, as shown.

```
R1# show interfaces g0/0/1.10
GigabitEthernet0/0/1.10 is up, line protocol is up
  Hardware is ISR4221-2x1GE, address is 10b3.d605.0301 (bia 10b3.d605.0301)
  Description: Default Gateway for VLAN 10
  Internet address is 192.168.10.1/24
  MTU 1500 bytes, BW 100000 Kbit/sec, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation 802.1Q Virtual LAN, Vlan ID  10.
  ARP type: ARPA, ARP Timeout 04:00:00
  Keepalive not supported
  Last clearing of "show interface" counters never
R1#
```

- **show interfaces trunk**

The misconfiguration could also be on the trunking port of the switch. Therefore, it is also useful to verify the active trunk links on a Layer 2 switch by using the **show interfaces**

trunk command, as shown in the output. The output confirms that the link to R1 is trunking for the required VLANs.

Note: Although VLAN 1 was not explicitly configured, it was automatically included because control traffic on trunk links will always be forwarded on VLAN 1.

```
S1# show interfaces trunk
Port        Mode             Encapsulation  Status        Native vlan
Fa0/1       on               802.1q         trunking      1
Fa0/5       on               802.1q         trunking      1
Port        Vlans allowed on trunk
Fa0/1       1-4094
Fa0/5       1-4094
Port        Vlans allowed and active in management domain
Fa0/1       1,10,20,99
Fa0/5       1,10,20,99
Port        Vlans in spanning tree forwarding state and not pruned
Fa0/1       1,10,20,99
Fa0/5       1,10,20,99
S1#
```

4.3 Inter – VLAN Routing using Layer 3 Switches

4.3.1. Layer 3 Switch Inter-VLAN Routing

Modern, enterprise networks rarely use router-on-a-stick because it does not scale easily to meet requirements. In these very large networks, network administrators use Layer 3 switches to configure inter-VLAN routing.

Inter-VLAN routing using the router-on-a-stick method is simple to implement for a small to medium-sized organization. However, a large enterprise requires a faster, much more scalable method to provide inter-VLAN routing.

Enterprise campus LANs use Layer 3 switches to provide inter-VLAN routing. Layer 3 switches use hardware-based switching to achieve higher-packet processing rates than routers. Layer 3 switches are also commonly implemented in enterprise distribution layer wiring closets.

Capabilities of a Layer 3 switch include the ability to do the following:

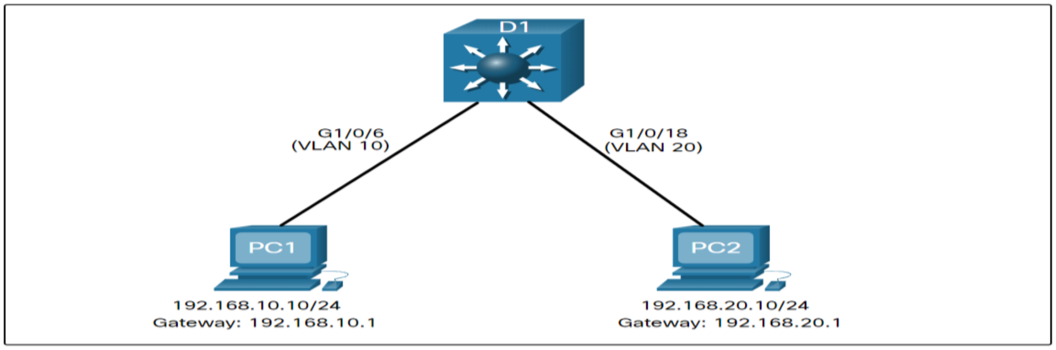
- Route from one VLAN to another using multiple switched virtual interfaces (SVIs).
- Convert a Layer 2 switchport to a Layer 3 interface (i.e., a routed port). A routed port is similar to a physical interface on a Cisco IOS router.

To provide inter-VLAN routing, Layer 3 switches use SVIs. SVIs are configured using the same **interface vlan** *vlan-id* command used to create the management SVI on a Layer 2 switch. A Layer 3 SVI must be created for each of the routable VLANs.

4.3.2 Layer 3 Switch Scenario

In the figure, the Layer 3 switch, D1, is connected to two hosts on different VLANs. PC1 is in VLAN 10 and PC2 is in VLAN 20, as shown. The Layer 3 switch will provide inter-VLAN routing services to the two hosts.

The physical network topology shows two PCs, a switch, and a router. PC1 on the left has IP address 192.168.10.10, gateway address of 192.168.10.1/24, is in VLAN 10, and is connected the switch on port G1/0/6. PC2 on the right has IP address 192.168.20.10, gateway address of 192.168.20.10/24, is in VLAN 20, and is connected the switch on port G1/0/18.



The table shows the IP addresses for each VLAN.

D1 VLAN IP Addresses

VLAN Interface	IP Address
10	192.168.10.1/24
20	192.168.20.1/24

4.3.3 Layer 3 Switch Configuration

Complete the following steps to configure S1 with VLANs and trunking:

1. Create the VLANs.

First, create the two VLANs as shown in the output

```
D1(config)# vlan 10
D1(config-vlan)# name LAN10
D1(config-vlan)# vlan 20
D1(config-vlan)# name LAN20
D1(config-vlan)# exit
D1(config)#
```

2. Create the SVI VLAN interfaces.

Configure the SVI for VLANs 10 and 20. The IP addresses that are configured will serve as the default gateways to the hosts in the respective VLANs. Notice the informational messages showing the line protocol on both SVIs changed to up.

```
D1(config)# interface vlan 10
D1(config-if)# description Default Gateway SVI for 192.168.10.0/24
D1(config-if)# ip add 192.168.10.1 255.255.255.0
D1(config-if)# no shut
D1(config-if)# exit
D1(config)#
D1(config)# int vlan 20
D1(config-if)# description Default Gateway SVI for 192.168.20.0/24
D1(config-if)# ip add 192.168.20.1 255.255.255.0
D1(config-if)# no shut
D1(config-if)# exit
D1(config)#
*Sep 17 13:52:16.053: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan10, changed state to up
*Sep 17 13:52:16.160: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan20, changed state to up
```

3. Configure access ports.

Next, configure the access ports connecting to the hosts and assign them to their respective VLANs.

```
D1(config)# interface GigabitEthernet1/0/6
D1(config-if)# description Access port to PC1
D1(config-if)# switchport mode access
D1(config-if)# switchport access vlan 10
D1(config-if)# exit
D1(config)#
D1(config)# interface GigabitEthernet1/0/18
D1(config-if)# description Access port to PC2
D1(config-if)# switchport mode access
D1(config-if)# switchport access vlan 20
D1(config-if)# exit
```

4. Enable IP routing.

First, create the two VLANs as shown in the output.

```
D1(config)# ip routing
D1(config)#
```

4.3.4 Layer 3 Switch Inter – VLAN Routing Verification

Inter-VLAN routing using a Layer 3 switch is simpler to configure than the router-on-a-stick method. After the configuration is complete, the configuration can be verified by testing connectivity between the hosts.

From a host, verify connectivity to a host in another VLAN using the **ping** command. It is a good idea to first verify the current host IP configuration using the **ipconfig** Windows host command. The output confirms the IPv4 address and default gateway of PC1.

```
C:\Users\PC1> ipconfig
Windows IP Configuration
Ethernet adapter Ethernet0:
  Connection-specific DNS Suffix . :
  Link-local IPv6 Address          : fe80::5c43:ee7c:2959:da68%6
  IPv4 Address                     : 192.168.10.10
  Subnet Mask                      : 255.255.255.0
  Default Gateway                  : 192.168.10.1
C:\Users\PC1>
```

Next, verify connectivity with PC2 using the **ping** Windows host command, as shown in the output. The **ping** output successfully confirms inter-VLAN routing is operating.

```
C:\Users\PC1> ping 192.168.20.10
Pinging 192.168.20.10 with 32 bytes of data:
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Reply from 192.168.20.10: bytes=32 time<1ms TTL=127
Ping statistics for 192.168.20.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
C:\Users\PC1>
```

4.3.5 Routing on a Layer 3 Switch

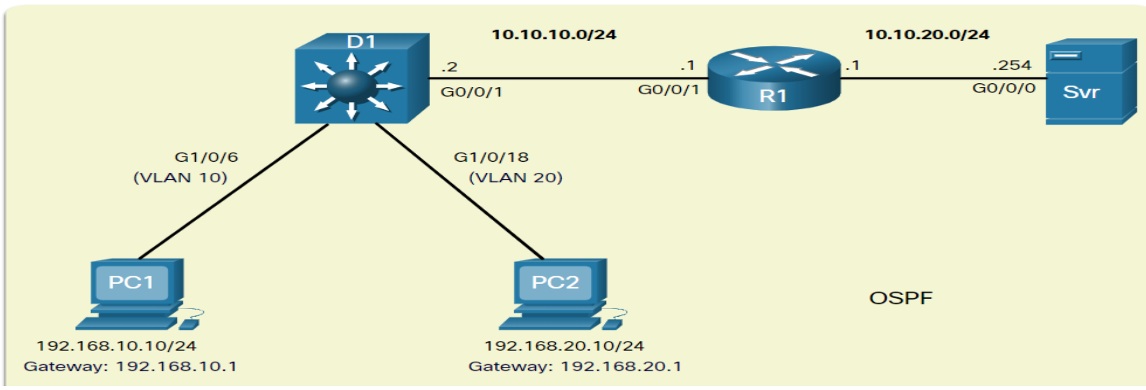
If VLANs are to be reachable by other Layer 3 devices, then they must be advertised using static or dynamic routing. To enable routing on a Layer 3 switch, a routed port must be configured.

A routed port is created on a Layer 3 switch by disabling the switchport feature on a Layer 2 port that is connected to another Layer 3 device. Specifically, configuring the **no switchport** interface configuration command on a Layer 2 port converts it into a Layer 3 interface. Then the interface can be configured with an IPv4 configuration to connect to a router or another Layer 3 switch.

4.3.6 Routing Scenario on a Layer 3 Switch

In the figure, the previously configured D1 Layer 3 switch is now connected to R1. R1 and D1 are both in an Open Shortest Path First (OSPF) routing protocol domain. Assume inter-VLAN has been successfully implemented on D1. The G0/0/1 interface of R1 has also been configured and enabled. Additionally, R1 is using OSPF to advertise its two networks, 10.10.10.0/24 and 10.20.20.0/24.

Note: OSPF routing configuration is covered in another course. In this module, OSPF configuration commands will be given to you in all activities and assessments. It is not required that you understand the configuration in order to enable OSPF routing on the Layer 3 switch.



4.3.7 Routing Configuration on a Layer 3 Switch

Complete the following steps to configure D1 to route with R1:

1. Configure the routed port.

Configure G1/0/1 to be a routed port, assign it an IPv4 address, and enable it.

```
D1(config)# interface GigabitEthernet1/0/1
D1(config-if)# description routed Port Link to R1
D1(config-if)# no switchport
D1(config-if)# ip address 10.10.10.2 255.255.255.0
D1(config-if)# no shut
D1(config-if)# exit
D1(config)#
```

2. Enable routing.

Ensure IPv4 routing is enabled with the **ip routing** global configuration command.

```
D1(config)# ip routing
D1(config)#
```

3. Configure routing.

Configure the OSPF routing protocol to advertise the VLAN 10 and VLAN 20 networks, along with the network that is connected to R1. Notice the message informing you that an adjacency has been established with R1.

```
D1(config)# router ospf 10
D1(config-router)# network 192.168.10.0 0.0.0.255 area 0
D1(config-router)# network 192.168.20.0 0.0.0.255 area 0
D1(config-router)# network 10.10.10.0 0.0.0.3 area 0
D1(config-router)# ^Z
D1#
*Sep 17 13:52:51.163: %OSPF-5-ADJCHG: Process 10, Nbr 10.20.20.1 on GigabitEthernet1/0/1 from LOADING to FULL, Loading Done
D1#
```

4.4. Troubleshoot Inter – Vlan Routing

4.4.1. Common Inter-VLAN Issues

By now, you know that when you configure and verify, you must also be able to troubleshoot. This topic discusses some common network problems associated with inter-VLAN routing.

There are a number of reasons why an inter-VAN configuration may not work. All are related to connectivity issues. First, check the physical layer to resolve any issues where a cable might be connected to the wrong port. If the connections are correct, then use the list in the table for other common reasons why inter-VLAN connectivity may fail.

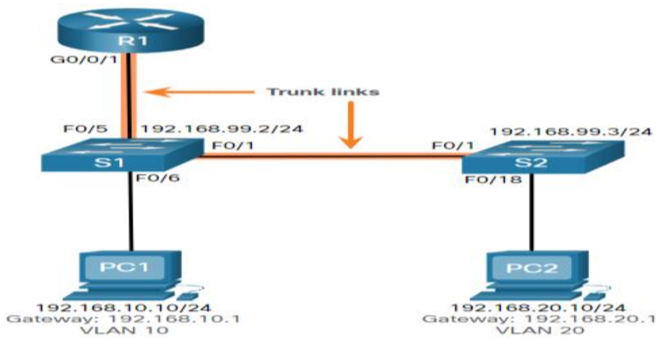
Issue Type	How to Fix	How to Verify
Missing VLANs	Create (or re-create) the VLAN if it does not exist. Ensure host port is assigned to the correct VLAN.	**show vlan [brief]** **show interfaces switchport** **ping**
Switch Trunk Port Issues	Ensure trunks are configured correctly. Ensure port is a trunk port and enabled.	**show interfaces trunk** **show running-config**
Switch Access Port Issues	Assign correct VLAN to access port. Ensure port is an access port and enabled. Host is incorrectly configured in the wrong subnet.	**show interfaces switchport** **show running-config interface** **ipconfig**
Router	Router subinterface IPv4 address is incorrectly configured.	**show ip interface brief** **show interfaces**

Issue Type	How to Fix	How to Verify
Configuration Issues	Router subinterface is assigned to the VLAN ID.	

4.4.2. Troubleshoot Inter – VLAN Routing Scenario

Examples of some of these inter-VLAN routing problems will now be covered in more detail.

This topology will be used for all of these issues.



The VLAN and IPv4 addressing information for R1 is shown in the table.

Router R1 Subinterfaces

Subinterface	VLAN	IP Address
G0/0/0.10	10	192.168.10.1/24
G0/0/0.20	20	192.168.20.1/24
G0/0/0.30	99	192.168.99.1/24

4.4.3. Missing VLANs

An inter-VLAN connectivity issue could be caused by a missing VLAN. The VLAN could be missing if it was not created, it was accidently deleted, or it is not allowed on the trunk link.

For example, PC1 is currently connected to VLAN 10, as shown in the **show vlan brief** command output.

```
S1# show vlan brief
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/2, Fa0/3, Fa0/4, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
10   LAN10                            active    Fa0/6
20   LAN20                            active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
S1#
```

Now assume that VLAN 10 is accidently deleted, as shown in the following output.

```
S1(config)# no vlan 10
S1(config)# do show vlan brief
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/2, Fa0/3, Fa0/4, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
20   LAN20                            active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
S1(config)#
```

Notice VLAN 10 is now missing from the output. Also notice that port Fa0/6 has not been reassigned to the default VLAN. The reason is because when you delete a VLAN, any ports assigned to that VLAN become inactive. They remain associated with the VLAN (and thus inactive) until you assign them to a new VLAN or recreate the missing VLAN.

Use the **show interface** *interface-id* **switchport** command to verify the VLAN membership.

```
S1(config)# do show interface fa0/6 switchport
Name: Fa0/6
Switchport: Enabled
Administrative Mode: static access
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: Off
Access Mode VLAN: 10 (Inactive)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
(Output omitted)
```

Recreating the missing VLAN would automatically reassign the hosts to it, as shown in the following output.

```
S1(config)# vlan 10
S1(config-vlan)# do show vlan brief
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/2, Fa0/3, Fa0/4, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
20   LAN20                            active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
S1(config-vlan)#
```

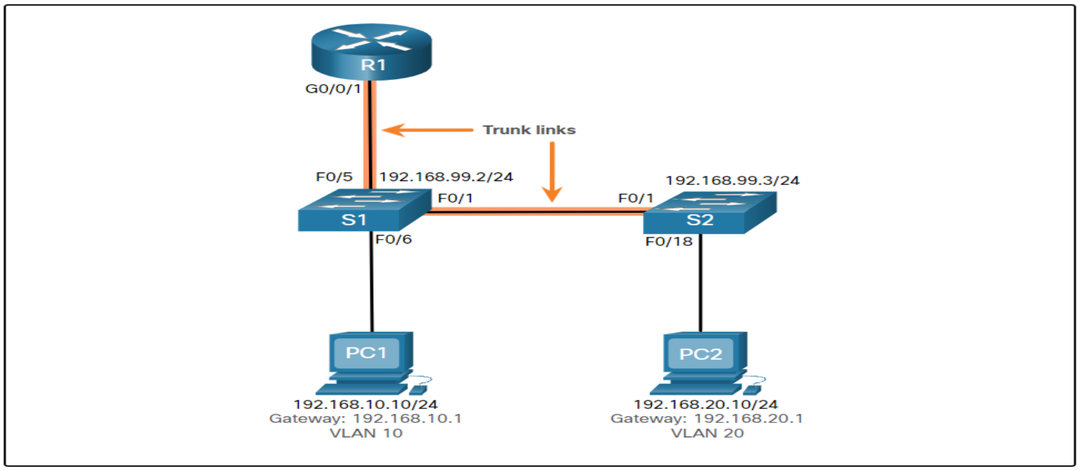
Notice that the VLAN has not been created as expected. The reason is because you must exit from VLAN sub-configuration mode to create the VLAN, as shown in the following output.

```
S1(config-vlan)# exit
S1(config)# do show vlan brief
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/2, Fa0/3, Fa0/4, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
10   VLAN0010                         active    Fa0/6
20   LAN20                            active
99   Management                       active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
S1(config)#
```

Now notice that the VLAN is included in the list and that the host connected to Fa0/6 is on VLAN 10.

4.4.4. Switch Trunk Port Issues

Another issue for inter-VLAN routing includes misconfigured switch ports. In a legacy inter-VLAN solution, this could be caused when the connecting router port is not assigned to the correct VLAN.
However, with a router-on-a-stick solution, the most common cause is a misconfigured trunk port.
For example, assume PC1 was able to connect to hosts in other VLANs until recently. A quick look at maintenance logs revealed that the S1 Layer 2 switch was recently accessed for routine maintenance. Therefore, you suspect the problem may be related to that switch.



On S1, verify that the port connecting to R1 (i.e., F0/5) is correctly configured as a trunk link using the **show interfaces trunk** command, as shown.

```
S1# show interfaces trunk
Port        Mode             Encapsulation  Status        Native vlan
Fa0/1       on               802.1q         trunking      1
Port        Vlans allowed on trunk
Fa0/1       1-4094
Port        Vlans allowed and active in management domain
Fa0/1       1,10,20,99
Port        Vlans in spanning tree forwarding state and not pruned
Fa0/1       1,10,20,99
S1#
```

The Fa0/5 port connecting to R1 is mysteriously missing from the output. Verify the interface configuration using the **show running-config interface fa0/5** command, as shown.

```
S1# show running-config interface fa0/5
Building configuration...
Current configuration : 96 bytes
!
interface FastEthernet0/5
 description Trunk link to R1
 switchport mode trunk
 shutdown
end
S1#
```

As you can see, the port was accidently shut down. To correct the problem, re-enable the port and verify the trunking status, as shown in the output.

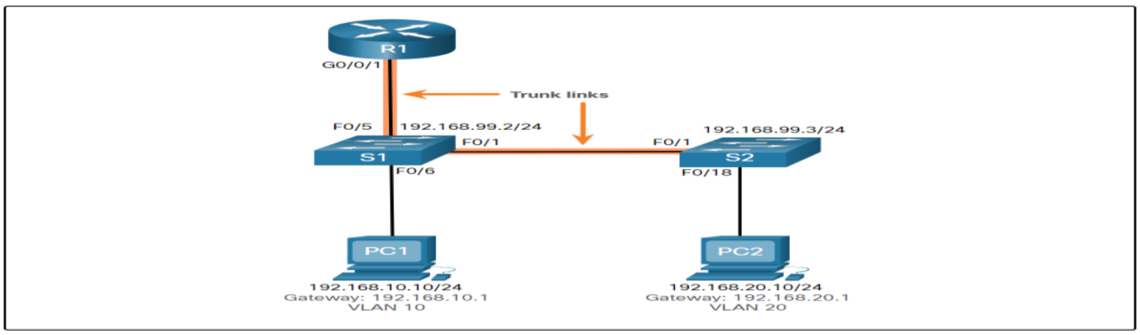
```
S1(config)# interface fa0/5
S1(config-if)# no shut
S1(config-if)#
*Mar  1 04:46:44.153: %LINK-3-UPDOWN: Interface FastEthernet0/5, changed state to up
S1(config-if)#
*Mar  1 04:46:47.962: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/5, changed state to up
S1(config-if)# do show interface trunk
Port        Mode             Encapsulation  Status        Native vlan
Fa0/1       on               802.1q         trunking      1
Fa0/5       on               802.1q         trunking      1
Port        Vlans allowed on trunk
Fa0/1       1-4094
Fa0/5       1-4094
Port        Vlans allowed and active in management domain
Fa0/1       1,10,20,99
Fa0/5       1,10,20,99
Port        Vlans in spanning tree forwarding state and not pruned
Fa0/1       1,10,20,99
Fa0/1       1,10,20,99
S1(config-if)#
```

To reduce the risk of a failed inter-switch link disrupting inter-VLAN routing, redundant links and alternate paths should be part of the network design.

4.4.5. Switch Access Port Issues

When a problem is suspected with a switch access port configuration, use verification commands to examine the configuration and identify the problem.

Assume PC1 has the correct IPv4 address and default gateway but is not able to **ping** its own default gateway. PC1 is supposed to be connected to a VLAN 10 port.



Verify the port configuration on S1 using the **show interfaces** *interface-id* **switchport** command.

```
S1# show interface fa0/6 switchport
Name: Fa0/6
Switchport: Enabled
Administrative Mode: static access
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: Off
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
```

The Fa0/6 port has been configured as an access port as indicated by “static access”. However, it appears that it has not been configured to be in VLAN 10. Verify the configuration of the interface.

```
S1# show running-config interface fa0/6
Building configuration...
Current configuration : 87 bytes
!
interface FastEthernet0/6
 description PC-A access port
 switchport mode access
end
S1#
```

Assign port Fa0/6 to VLAN 10 and verify the port assignment.

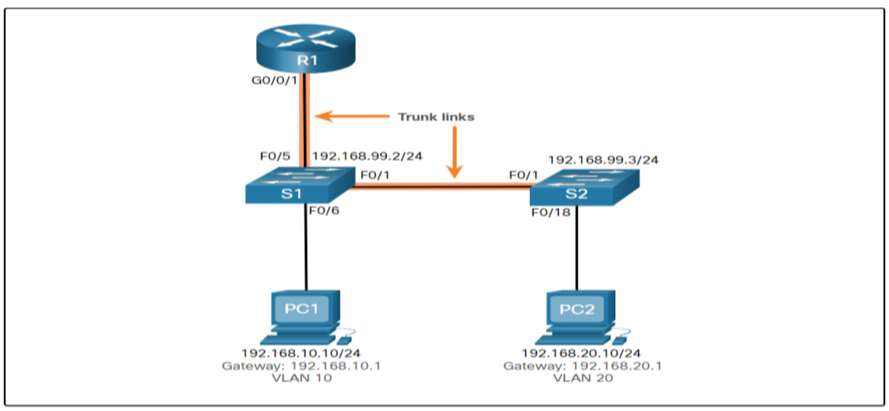
```
S1# configure terminal
S1(config)# interface fa0/6
S1(config-if)# switchport access vlan 10
S1(config-if)#
S1(config-if)# do show interface fa0/6 switchport
Name: Fa0/6
Switchport: Enabled
Administrative Mode: static access
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: Off
Access Mode VLAN: 10 (VLAN0010)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
(Output omitted)
```

PC1 is now able to communicate with hosts on other VLANs.

4.4.6. Router Configuration Issues

Router-on-a-stick configuration problems are usually related to subinterface misconfigurations. For example, an incorrect IP address was configured or the wrong VLAN ID was assigned to the subinterface.

For example, R1 should be providing inter-VLAN routing for users in VLANs 10, 20, and 99. However, users in VLAN 10 cannot reach any other VLAN.



You verified the switch trunk link and all appears to be in order. Verify the subinterface status using the **show ip interface brief** command.

```
R1# show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0/0   unassigned      YES unset  administratively down down
GigabitEthernet0/0/1   unassigned      YES unset  up                    up
Gi0/0/1.10             192.168.10.1    YES manual up                    up
Gi0/0/1.20             192.168.20.1    YES manual up                    up
Gi0/0/1.99             192.168.99.1    YES manual up                    up
Serial0/1/0            unassigned      YES unset  administratively down down
Serial0/1/1            unassigned      YES unset  administratively down down
R1#
```

The subinterfaces have been assigned the correct IPv4 addresses and they are operational. Verify which VLANs each of the subinterfaces is on. To do so, the **show interfaces** command is useful but it generates a great deal of additional unrequired output. The command output can be reduced using IOS command filters as shown in the output.

```
R1# show interfaces | include Gig|802.1Q
GigabitEthernet0/0/0 is administratively down, line protocol is down
GigabitEthernet0/0/1 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  1., loopback not set
GigabitEthernet0/0/1.10 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  100.
GigabitEthernet0/0/1.20 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  20.
GigabitEthernet0/0/1.99 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  99.
R1#
```

The pipe symbol (|) along with some select keywords is a useful method to help filter command output. In this example, the keyword **include** was used to identify that only lines containing the letters "Gig" or "802.1Q" will be displayed. Because of the way the **show interface** output is naturally listed, using these filters produces a condensed list of interfaces and their assigned VLANs.

Notice that the G0/0/1.10 interface has been incorrectly assigned to VLAN 100 instead of VLAN 10. This is confirmed by looking at the configuration of the R1 GigabitEthernet 0/0/1.10 subinterface, as shown.

```
R1# show running-config interface g0/0/1.10
Building configuration...
Current configuration : 146 bytes
!
interface GigabitEthernet0/0/1.10
 description Default Gateway for VLAN 10
 encapsulation dot1Q 100
 ip address 192.168.10.1 255.255.255.0
end
R1#
```

To correct this problem, configure subinterface G0/0/1.10 to be on the correct VLAN using the **encapsulation dot1q 10** subinterface configuration mode command.

```
R1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# interface gigabitEthernet 0/0/1.10
R1(config-subif)# encapsulation dot1Q 10
R1(config-subif)# end
R1#
R1# show interfaces | include Gig|802.1Q
GigabitEthernet0/0/0 is administratively down, line protocol is down
GigabitEthernet0/0/1 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  1., loopback not set
GigabitEthernet0/0/1.10 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  10.
GigabitEthernet0/0/1.20 is up, line protocol is up
  Encapsulation 802.1Q Virtual LAN, Vlan ID  20.
GigabitEthernet0/0/1.99 is up, line protocol is up
R1#
```

When the subinterface has been assigned to the correct VLAN, it is accessible by devices on that VLAN and the router can perform inter-VLAN routing.

With verification, router configuration problems are quickly addressed, allowing inter-VLAN routing to function properly.

E. Evaluate

Packet Tracer Activity

1. **Packet Tracer 4.2.7: Configure Router-on-a-Stick Inter-VLAN Routing**
   In this Packet Tracer, you will complete the following objectives:
   - Part 1: Add VLANs to a Switch
   - Part 2: Configure Subinterfaces
   - Part 3: Test connectivity with Inter-VLAN Routing
2. **Lab Activity 4.2.8: Configure Router-on-a-Stick Inter-VLAN Routing**
   In this lab, you will complete the following objectives:
   - Part 1: Build the Network and Configure Basic Device Settings
   - Part 2: Configure Switches with VLANs and Trunking
   - Part 3: Configure Trunk-Based Inter-VLAN Routing
3. **Packet Tracer 4.3.8: Configure Layer 3 Switching and inter-VLAN Routing**
   In this Packet Tracer, you will complete the following objectives:
   - Part 1: Configure Layer 3 Switching
   - Part 2: Configure Inter-VLAN Routing
   - Part 3: Configure IPv6 Inter-VLAN Routing
4. **Packet Tracer 4.4.8– Troubleshoot Inter-VLAN Routing**
   In this Packet Tracer activity, you will complete the following objectives:
   - Part 1: Locate Network Problems
   - Part 2: Implement the Solution
   - Part 3: Verify Network Connectivity
5. **Lab Activity 4.4.9: Troubleshoot Inter-VLAN Routing**
   In this lab, you will complete the following objectives:
   - Part 1: Build the Network and Load Device Configurations
   - Part 2: Troubleshoot the Inter-VLAN Routing Configuration
   - Part 3: Verify VLAN Configuration, Port Assignment and Trunking
   - Part 4: Test Layer 3 Connectivity
6. **Packet Tracer 4.5.1: Inter-VLAN Routing Challenge**
   In this Packet Tracer activity, you will demonstrate and reinforce your ability to implement inter-VLAN routing, including configuring IP addresses, VLANs, trunking, and subinterfaces.
7. **Lab Activity 4.5.2: Implement Inter-VLAN Routing**
   In this lab, you will complete the following objectives:
   - Part 1: Build the Network and Configure Basic Device Settings
   - Part 2: Create VLANs and Assign Switch Ports
   - Part 3: Configure an 802.1Q Trunk between the Switches
   - Part 4: Configure Inter-VLAN Routing on the S1 Switch
   - Part 5: Verify Inter-VLAN Routing is Working

8. **ONLINE ASSESSMENT**

After this Module of VLAN, Assessment Exam will be activated, covering Modules 1-4: Switching Concept, VLANs, and InterVLAN using CISCO Networking Academy Account. https://www.netacad.com

Instruction: Module Quiz 4.5.4: Check your understanding of Inter-VLAN Routing by choosing the BEST answer to the following questions.

1. PC is to access a web server on another network. Which inter-VLAN method will provide the highest bandwidth at Layer 3 and also provide a default gateway for the PC?
   a. router on a stick
   b. multilayer switch with routing enabled
   c. trunked interface between the router and the switch
   d. a Layer 2 switch
2. Which scalable method must be implemented in order to provide inter-VLAN routing on a switched network with more than 1000 VLANs?
   a. configuring static routes on a Layer 2 switch device
   b. routing traffic internally to a Layer 3 switch device
   c. connecting each physical router interface to a different physical switch port, with each switch port assigned to a different VLAN
   d. connecting a router interface to a switch port that is configured in trunk mode to route packets between VLANs, with each VLAN assigned to a router subinterface
3. When configuring a router as part of a router-on-a-stick inter-VLAN routing topology, where should the IP address be assigned?
   a. to the interface
   b. to the subinterface
   c. to the SVI
   d. to the VLAN
4. A small college uses VLAN 10 for the classroom network and VLAN 20 for the office network. What is needed to enable communication between these two VLANs while using legacy inter-VLAN routing?
   a. A router with at least two LAN interfaces should be used.
   b. Two groups of switches are needed, each with ports that are configured for one VLAN.
   c. A router with one VLAN interface is needed to connect to the SVI on a switch.
   d. A switch with a port that is configured as trunk is needed to connect to a router.
5. What is a disadvantage of using multilayer switches for inter-VLAN routing?
   a. Multilayer switches have higher latency for Layer 3 routing.
   b. Multilayer switches are more expensive than router-on-a-stick implementations.
   c. Spanning tree must be disabled in order to implement routing on a multilayer switch.
   d. Multilayer switches are limited to using trunk links for Layer 3 routing.
6. Which type of inter-VLAN communication design requires the configuration of multiple subinterfaces?
   a. router on a stick
   b. routing via a multilayer switch

c. routing for the management VLAN
d. legacy inter-VLAN routing

7. What is a disadvantage of using router-on-a-stick inter-VLAN routing?
   a. does not support VLAN-tagged packets
   b. requires the use of more physical interfaces than legacy inter-VLAN routing
   c. does not scale well beyond 50 VLANs
   d. requires the use of multiple router interfaces configured to operate as access links
8. What is the meaning of the number 10 in the encapsulation dot1Q 10 native router subinterface command?
   a. the interface number
   b. the subinterface number
   c. the subnet number
   d. the VLAN ID
9. While configuring inter-VLAN routing on a multilayer switch, a network administrator issues the no switchport command on an interface that is connected to another switch. What is the purpose of this command?
   a. to create a routed port for a single network
   b. to provide a static trunk link
   c. to create a switched virtual interface
   d. to provide an access link that tags VLAN traffic
10. A network administrator enters the following command sequence on a Cisco 3560 switch. What is the purpose of these commands?
    Switch(config)# interface gigabitethernet 0/1
    Switch(config-if)# no switchport
    a. to shut down the Gi0/1 port
    b. to make the Gi0/1 port a routed port
    c. to enable the Gi0/1 port as a switch virtual interface
    d. to enable the Gi0/1 port as a bridge virtual interface
11. What operational mode should be used on a switch port to connect it to a router for router-on-a-stick inter-VLAN routing?
    a. Trunk
    b. Access
    c. dynamic auto
    d. dynamic desirable
12. Which sentence correctly describes the SVI inter-VLAN routing method?
    a. Subinterfaces have to be created.
    b. The encapsulation type must be configured on the SVI.
    c. An SVI is needed for each VLAN.
    d. A physical interface is needed for every VLAN that is created.
13. How is traffic routed between multiple VLANs on a multilayer switch?
    a. Traffic is routed via physical interfaces.
    b. Traffic is routed via internal VLAN interfaces.
    c. Traffic is broadcast out all physical interfaces.
    d. Traffic is routed via subinterfaces.

14. What is required to perform router-on-a-stick inter-VLAN routing?
    a. a Layer 2 switch that is configured with multiple trunk ports
    b. a router with multiple physical interfaces
    c. a multilayer switch
    d. a router that is configured with multiple subinterfaces
15. An administrator was troubleshooting a router-on-a-stick topology and concluded that the problem was related to the configuration of VLANs on the router subinterfaces. Which two commands can the administrator use in the router to identify the problem? (Choose two.)
    a. show controllers
    b. show ip interface
    c. show ip protocols
    d. show running-config
    e. show vlan

References

1. *CCNAv7 Switching, Routing and Wireless Essential*
   https://www.netacad.com

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