Chapter 5: Inter-VLAN Routing

Routing & Switching

What is Inter-VLAN routing?

- Layer 2 switches cannot forward traffic between VLANs without the assistance of a router.

- Inter-VLAN routing is a process for forwarding network traffic from one VLAN to another, using a router.

Legacy Inter-VLAN Routing

In the past:

- Actual routers were used to route between VLANs.

- Each VLAN was connected to a different physical router interface.

- Packets would arrive on the router through one through interface, be routed and leave through another.

- Because the router interfaces were connected to VLANs and had IP addresses from that specific VLAN, routing between VLANs was achieved.

- Large networks with large number of VLANs required many router interfaces.

Router-on-a-Stick Inter-VLAN Routing

- The router-on-a-stick approach uses a different path to route between VLANs.

- One of the router's physical interfaces is configured as a 802.1Q trunk port so it can understand VLAN tags.

- Logical subinterfaces are created; one subinterface per VLAN.

- Each subinterface is configured with an IP address from the VLAN it represents.

- VLAN members (hosts) are configured to use the subinterface address as a default gateway.

- Only one of the router's physical interface is used.

Router-on-a-Stick Inter-VLAN Routing

- Disadvantages:
  - Does not scale well beyond 50 VLANs.
  - Routed traffic must contend for bandwidth on a single router interface.

- A network administrator needs to configure router-on-a-stick for the networks that are shown. How many subinterfaces will have to be created on the router if each VLAN that is shown is to be routed and each VLAN has its own subinterface?

4

R1

VLAN 7
172.16.7.2/28

10.1.4.3/29

10.1.5.76/24

10.1.4.18/28
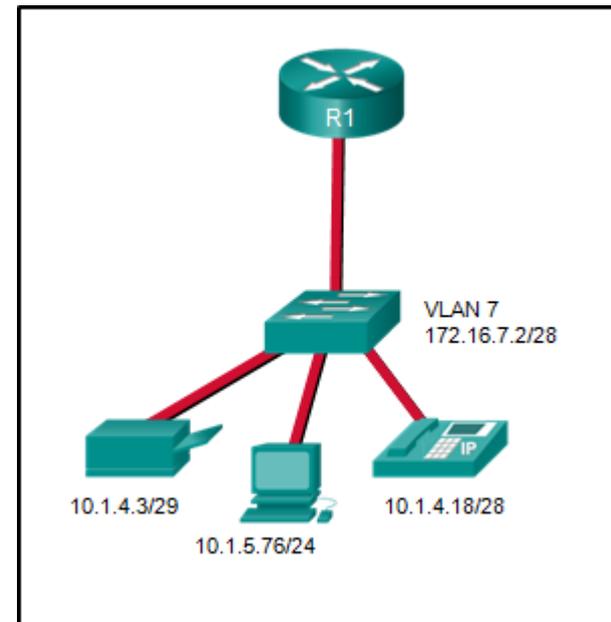
Multilayer Switch Inter-VLAN Routing

- Multilayer switches can perform Layer 2 and Layer 3 functions, replacing the need for dedicated routers.
- Multilayer switches support dynamic routing and inter-VLAN routing.
- The multilayer switch must have IP routing enabled.
- A switch virtual interface (SVI) exists for VLAN 1 by default. On a multilayer switch, a logical (layer 3) interface can be configured for any VLAN.
- The switch understands network-layer PDUs; therefore, can route between its SVIs, just as a router routes between its interfaces.
- With a multilayer switch, traffic is routed internal to the switch device.
- This routing process is a suitable and scalable solution.

Configure Router-on-a-Stick

- An alternative to legacy inter-VLAN routing is to use VLAN trunking and subinterfaces.

- VLAN trunking allows a single physical router interface to route traffic for multiple VLANs.

- The physical interface of the router must be connected to a trunk link on the adjacent switch.

- On the router, subinterfaces are created for each unique VLAN.

- Each subinterface is assigned an IP address specific to its subnet or VLAN and is also configured to tag frames for that VLAN.

Switch Configuration
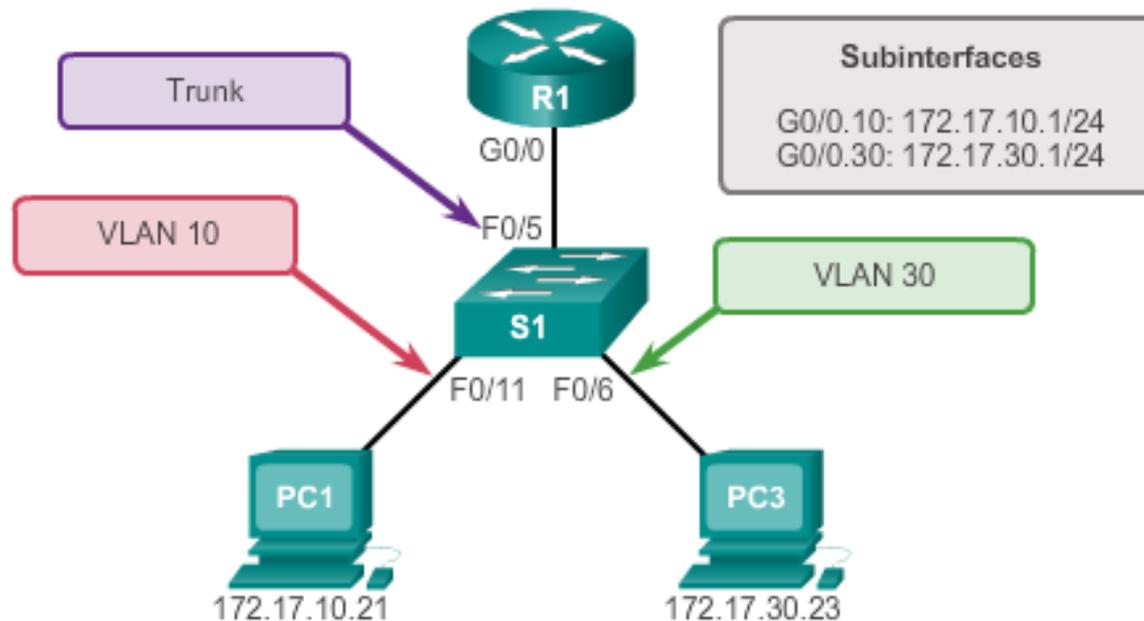

```
S1(config)# vlan 10
S1(config-vlan)# vlan 30
S1(config-vlan)# interface f0/5
S1(config-if)# switchport mode trunk
S1(config-if)# end
S1#
```

Router Subinterface Configuration

```
R1(config)# interface g0/0.10
R1(config-subif)# encapsulation dot1q 10
R1(config-subif)# ip address 172.17.10.1 255.255.255.0
R1(config-subif)# interface g0/0.30
R1(config-subif)# encapsulation dot1q 30
R1(config-subif)# ip address 172.17.30.1 255.255.255.0
R1(config)# interface g0/0
R1(config-if)# no shutdown
*Mar 20 00:20:59.299: %LINK-3-UPDOWN: Interface GigabitEthernet0/0,
 changed state to down
*Mar 20 00:21:02.919: %LINK-3-UPDOWN: Interface GigabitEthernet0/0,
 changed state to up
*Mar 20 00:21:03.919: %LINEPROTO-5-UPDOWN: Line protocol on
 changed state to down
*Mar 20 00:21:02.919: %LINK-3-UPDOWN: Interface GigabitEthernet0/0,
 changed state to up
*Mar 20 00:21:03.919: %LINEPROTO-5-UPDOWN: Line protocol on
 Interface GigabitEthernet0/0, changed state to up
```

Verifying Subinterfaces

```
R1# show vlans
<output omitted>
Virtual LAN ID:  10 (IEEE 802.1Q Encapsulation)

  vLAN Trunk Interface:     GigabitEthernet0/0.10

  Protocols Configured:  Address:        Received:    Transmitted:
          IP              172.17.10.1          11              18
<output omitted>
Virtual LAN ID:  30 (IEEE 802.1Q Encapsulation)

  vLAN Trunk Interface:     GigabitEthernet0/0.30

  Protocols Configured:  Address:        Received:    Transmitted:
          IP              172.17.30.1          11               8
<output omitted>
```

Verifying Subinterfaces

```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile,
       B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF,
       IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external
            type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1,
       L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default,
       U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP,
       l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

   172.17.0.0/16 is variably subnetted, 4 subnets, 2 masks
C     172.17.10.0/24 is directly connected, GigabitEthernet0/0.10
L     172.17.10.1/32 is directly connected, GigabitEthernet0/0.10
C     172.17.30.0/24 is directly connected, GigabitEthernet0/0.30
L     172.17.30.1/32 is directly connected, GigabitEthernet0/0.30
```

Inter-VLAN Configuration Issues

- Inter-VLAN communication is not occurring in a particular building of a school. Which two commands could the network administrator use to verify that inter-VLAN communication was working properly between a router and a Layer 2 switch when the router-on-a-stick design method is implemented?

From the router:

issue the show ip route command

From the switch:

issue the show interfaces trunk command

Router-on-a-Stick

```
CiscoVille# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
CiscoVille(config)# interface gigabitethernet 0/0
CiscoVille(config-if)# no ip address
CiscoVille(config-if)# interface gigabitethernet 0/0.10
CiscoVille(config-subif)# encapsulation dot1Q 10
CiscoVille(config-subif)# ip address 192.168.10.254 255.255.255.0
CiscoVille(config-subif)# interface gigabitethernet 0/0.20
CiscoVille(config-subif)# encapsulation dot1Q 20
CiscoVille(config-subif)# ip address 192.168.20.254 255.255.255.0
CiscoVille(config-subif)# exit
CiscoVille(config)# interface gigabitethernet 0/0
CiscoVille(config-if)# no shutdown
```

- A network administrator has configured a router with the above commands to provide inter-VLAN routing. What command will be required on a switch that is connected to the Gi0/0 interface on the router to allow inter-VLAN routing?

  switchport mode trunk
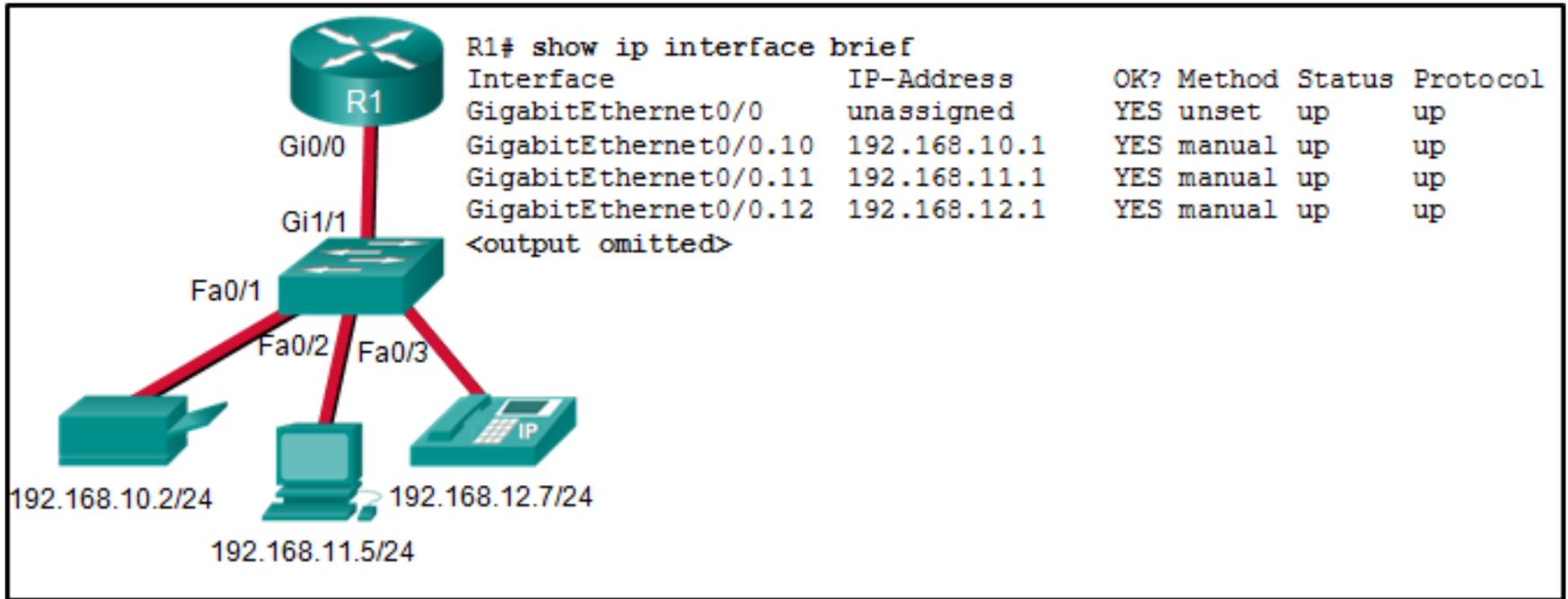
Router-on-a-Stick

```
RA(config)# interface fastethernet 0/1
RA(config-if)# no shutdown
RA(config-if)# interface fastethernet 0/1.1
RA(config-subif)# encapsulation dot1q 1
RA(config-subif)# ip address 192.168.1.62 255.255.255.224
RA(config-subif)# interface fastethernet 0/1.2
RA(config-subif)#  encapsulation dot1q 2
RA(config-subif)# ip address 192.168.1.94 255.255.255.224
RA(config-subif)#   interface fastethernet 0/1.3
RA(config-subif)#   encapsulation dot1q 3
RA(config-subif)# ip address 192.168.1.126 255.255.255.224
RA(config-subif)#  end
```

- A router receives a packet with a source address of 192.168.1.35 and a destination address of 192.168.1.85. What will the router do with this packet?

  The router will forward the packet out interface FastEthernet 0/1.2

Router-on-a-Stick

```
R1# show ip interface brief
Interface              IP-Address       OK? Method Status Protocol
GigabitEthernet0/0     unassigned       YES unset  up     up
GigabitEthernet0/0.10  192.168.10.1     YES manual up     up
GigabitEthernet0/0.11  192.168.11.1     YES manual up     up
GigabitEthernet0/0.12  192.168.12.1     YES manual up     up
<output omitted>
```

R1
Gi0/0
Gi1/1
Fa0/1
Fa0/2 Fa0/3
192.168.10.2/24   192.168.12.7/24
192.168.11.5/24

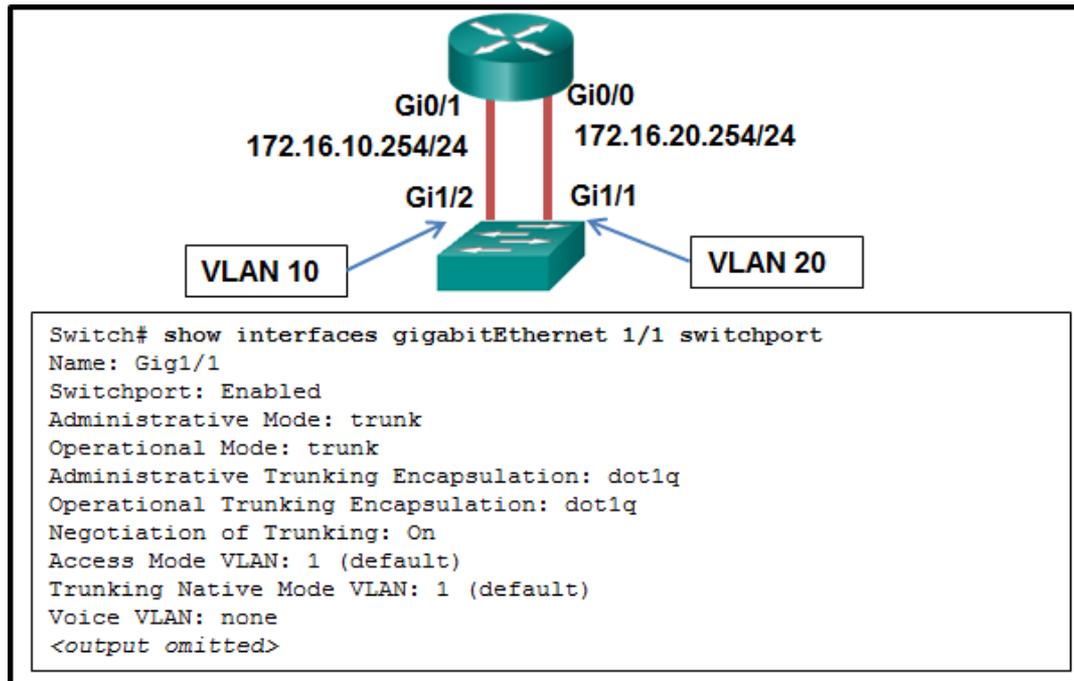- Communication between the VLANs is not occurring. What could be the issue?

    The Gi1/1 switch port is not in trunking mode

Inter-VLAN Configuration Switch Port Issues

- When using the legacy routing model, ensure that the switch ports connect to the router interfaces and are configured with the correct VLANs.

- Use the `switchport access vlan [appropriate vlan#]` command to correct any erroneous VLAN port assignment.

- Ensure that the router is connected to the correct switch port.

- When using router-on-a-stick, ensure that the switch port connected to the router is configured as a trunk link.

- Use the `switchport mode trunk` command to make the switch port a trunk.

Inter-VLAN Configuration Issues


```
Switch# show interfaces gigabitEthernet 1/1 switchport
Name: Gig1/1
Switchport: Enabled
Administrative Mode: trunk
Operational Mode: trunk
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: dot1q
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Voice VLAN: none
<output omitted>
```
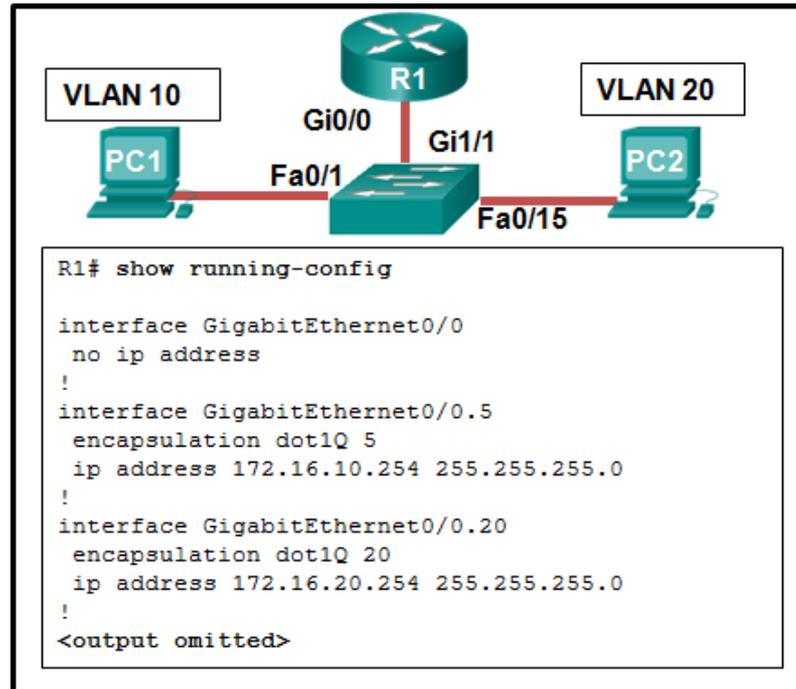
- A network administrator is verifying the configuration of inter-VLAN routing. Users complain that PCs on different VLANs cannot communicate. Based on the output, what are two configuration errors on switch interface Gi1/1?

    Gi1/1 is in the default VLAN

    Gi1/1 is configured as trunk mode

Inter-VLAN Configuration Issues


```
R1# show running-config

interface GigabitEthernet0/0
 no ip address
!
interface GigabitEthernet0/0.5
 encapsulation dot1Q 5
 ip address 172.16.10.254 255.255.255.0
!
interface GigabitEthernet0/0.20
 encapsulation dot1Q 20
 ip address 172.16.20.254 255.255.255.0
!
<output omitted>
```

- A network administrator is verifying the configuration of inter-VLAN routing. Users complain that PC2 cannot communicate with PC1. Based on the output, what is the possible cause of the problem?

  The encapsulation dot1Q 5 command contains the wrong VLAN

Inter-VLAN Configuration Issues

```
RTA# configure terminal
RTA(config)# interface Fa0/0
RTA(config-if)# no shutdown
RTA(config-if)# interface Fa0/0.10
RTA(config-subif)# encapsulation dot1q  10
RTA(config-subif)# ip address 192.168.3.30 255.255.255.224
RTA(config-subif)# interface Fa0/0.20
RTA(config-subif)# encapsulation dot1q  20
RTA(config-subif)# ip address 192.168.3.49 255.255.255.224
RTA(config-subif)# interface Fa0/0.30
RTA(config-subif)# encapsulation dot1q  30
RTA(config-subif)# ip address 192.168.3.62 255.255.255.224
```

- After attempting to enter the configuration that is shown in router RTA, an administrator receives an error and users on VLAN 20 report that they are unable to reach users on VLAN 30. What is causing the problem?

  RTA is using the same subnet for VLAN 20 and VLAN 30

Inter-VLAN Configuration Issues

```
<output omitted>
!
interface GigabitEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface GigabitEthernet0/0.15
 encapsulation dot1Q 15
 ip address 172.16.15.254 255.255.255.0
!
interface GigabitEthernet0/0.30
 encapsulation dot1Q 30
 ip address 172.16.3.254 255.255.255.0
!
interface GigabitEthernet0/0.45
 encapsulation dot1Q 45
 ip address 172.16.45.254 255.255.255.0
!
<output omitted>
```

- A router-on-a-stick configuration was implemented for VLANs 15, 30, and 45, according to the show running-config command output. PCs on VLAN 45 that are using the 172.16.45.0 /24 network are having trouble connecting to PCs on VLAN 30 in the 172.16.30.0 /24 network. Which error is most likely causing this problem?

  There is an incorrect IP address configured on GigabitEthernet 0/0.30

Inter-VLAN Configuration Issues
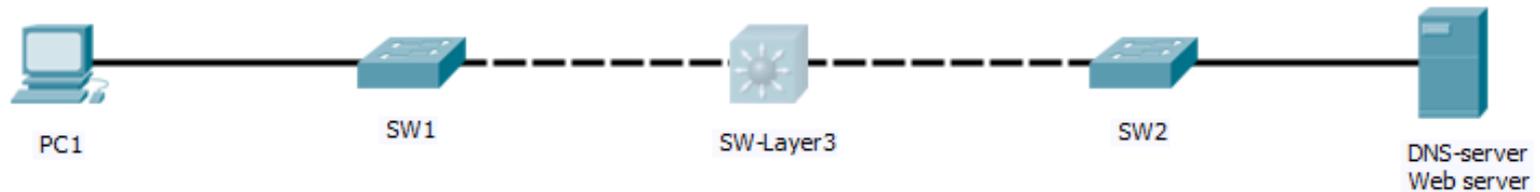

```
Switch-Layer3#sh run
Building configuration...

interface FastEthernet0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface FastEthernet0/2
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface Vlan1
 no ip address
 shutdown
!
interface Vlan10
 ip address 192.168.10.1 255.255.255.0
!
interface Vlan20
 no ip address
!
```
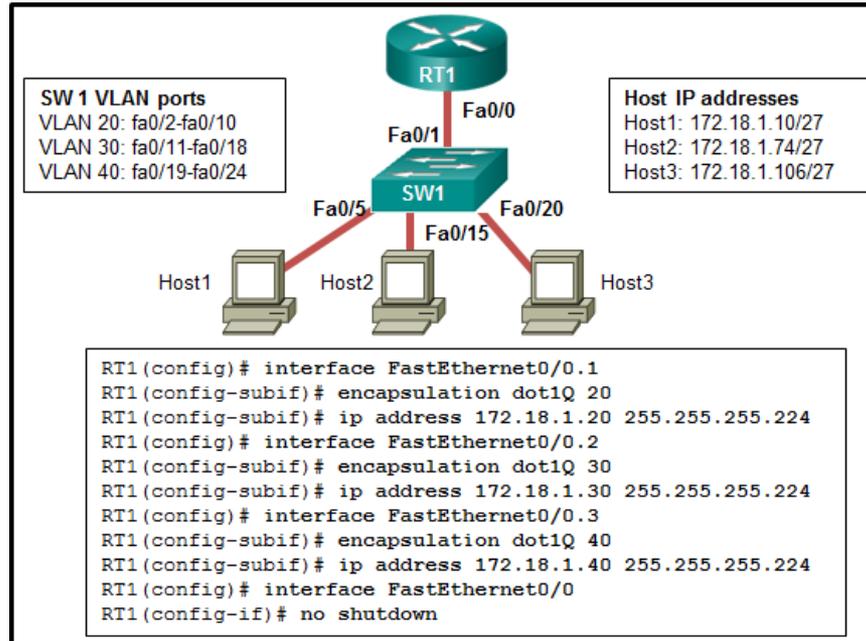
- Which command is missing on the Layer 3 switch to restore the full connectivity between PC1 and the web server?

  ip address 192.168.20.1 255.255.255.0

Inter-VLAN Configuration Issues

SW 1 VLAN ports
VLAN 20: fa0/2-fa0/10
VLAN 30: fa0/11-fa0/18
VLAN 40: fa0/19-fa0/24

Host IP addresses
Host1: 172.18.1.10/27
Host2: 172.18.1.74/27
Host3: 172.18.1.106/27

```
RT1(config)# interface FastEthernet0/0.1
RT1(config-subif)# encapsulation dot1Q 20
RT1(config-subif)# ip address 172.18.1.20 255.255.255.224
RT1(config)# interface FastEthernet0/0.2
RT1(config-subif)# encapsulation dot1Q 30
RT1(config-subif)# ip address 172.18.1.30 255.255.255.224
RT1(config)# interface FastEthernet0/0.3
RT1(config-subif)# encapsulation dot1Q 40
RT1(config-subif)# ip address 172.18.1.40 255.255.255.224
RT1(config)# interface FastEthernet0/0
RT1(config-if)# no shutdown
```

▪ A network administrator is configuring RT1 for inter-VLAN routing. The switch is configured correctly and is functional. Host1, Host2, and Host3 cannot communicate with each other. Based on the router configuration, what is causing the problem?

   IP addresses on the subinterfaces are incorrectly matched to the VLANs

Verify Switch Configuration

```
S1# show interfaces fastEthernet 0/4 switchport
Name: Fa0/4
Switchport: Enabled
Administrative Mode: static access
Operational Mode: up
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
 <output omitted>
S1#
```
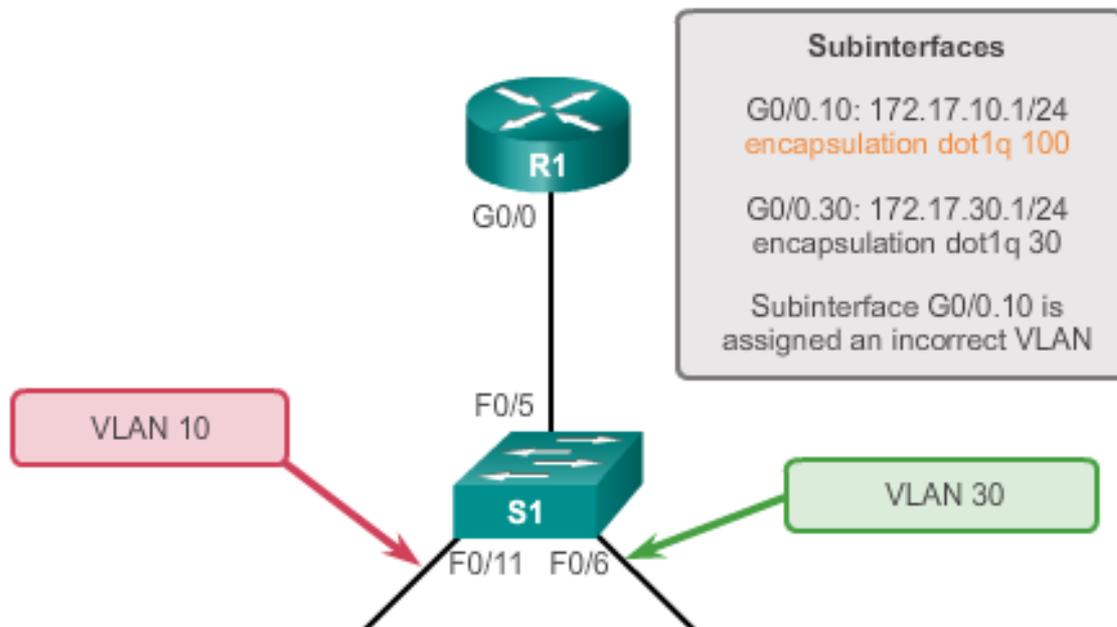
Verify Router Configuration

- With router-on-a-stick configurations, a common problem is assigning the wrong VLAN ID to the subinterface.

- The show interface command can help detect this problem.

- If this is the case, use the `encapsulation dot1q <vlan_id> interface` command to fix the problem.

Subinterfaces

G0/0.10: 172.17.10.1/24
encapsulation dot1q 100

G0/0.30: 172.17.30.1/24
encapsulation dot1q 30

Subinterface G0/0.10 is
assigned an incorrect VLAN

R1

G0/0

F0/5

VLAN 10

S1

VLAN 30

F0/11 F0/6

Verify Router Configuration

```
R1# show interface

<output omitted>

GigabitEthernet0/0.10 is up,line protocol is down (disabled)
 Encapsulation 802.1Q Virtual Lan,Vlan ID 100
 ARP type :ARPA,ARP Timeout 04:00:00,
 Last clearing of "show interface" counters never

<output omitted>

R1#
R1# show run
Building configuration...
Current configuration : 505 bytes

<output omitted>

!
interface GigabitEthernet0/0.10
 encapsulation dot1Q 100
 ip address 172.17.10.1 255.255.255.0
!
interface GigabitEthernet0/0.30
```

Errors with IP Address and Subnet Masks

- When using legacy inter-VLAN routing, ensure that the router has the correct IP address and mask on the interfaces connecting to the switch.

- Ensure that the network devices are configured with the correct IP address and mask.

- In the router, use the `ip address` command to fix any erroneous IP assignments.

- In the PCs, refer to the installed operating system documentation to properly change IP information.

Verifying IP Address and Subnet Mask Configuration Issues

- Use the **`show ip interface`** command to verify if the correct IP address is configured in the router.

- Use the **`show running-config`** when troubleshooting router-related problems.

- When troubleshooting addressing issues, ensure that the subinterface is configured with the correct address for that VLAN.

- Subinterface IDs are often configured to match the VLAN number, which makes it easier to manage inter-VLAN configuration, but this is not a requirement.

Introduction to Layer 3 Switching

- Layer 3 switches usually have packet-switching throughputs in the millions of packets per second (pps).

- All Catalyst multilayer switches support the following types of Layer 3 interfaces:
    - Routed port
    - Switch virtual interface (SVI)

- High-performance switches, such as the Catalyst 6500 and Catalyst 4500, are able to perform most of the router's functions.

- Several models of Catalyst switches require enhanced software for specific routing protocol features.

- Disadvantage: Multilayer switches are more expensive than router-on-a-stick implementations.

Inter-VLAN Routing with Switch Virtual Interfaces

- Today's routing has become faster and cheaper and can be performed at hardware speed.

- Routing can be transferred to core and distribution devices with little to no impact on network performance.

- Many users are in separate VLANs, and each VLAN is usually a separate subnet. This implies that each distribution switch must have IP addresses matching each access switch VLAN.

- Layer 3 (routed) ports are normally implemented between the distribution and the core layer. This model is less dependent on spanning tree, because there are no loops in the Layer 2 portion of the topology.

Inter-VLAN Routing with SVIs

- By default, an SVI is created for the default VLAN (VLAN 1). This allows for remote switch administration.

- An SVI is used as a vitrual-routed VLAN interface.

- Any additional SVIs must be created by the administrator.

- SVIs are created the first time the VLAN interface configuration mode is entered for a particular VLAN SVI.

- Enter the `interface vlan 10` command to create an SVI named VLAN 10.

- The VLAN number used corresponds to the VLAN tag associated with data frames on an 802.1Q encapsulated trunk.

- When the SVI is created, ensure that the specific VLAN is present in the VLAN database.

Inter-VLAN Routing with SVIs

- SVIs advantages include:
  - Much faster than router-on-a-stick, because everything is hardware-switched and routed.
  - No need for external links from the switch to the router for routing.
  - Not limited to one link. Layer 2 EtherChannels can be used between the switches to get more bandwidth.
  - Latency is much lower, because it does not need to leave the switch.

Inter-VLAN Routing with Routed Ports

- A routed port is a physical port that acts similarly to an interface on a router.

- Routed ports are not associated with any VLANs.

- Layer 2 protocols, such as STP, do not function on a routed interface.

- Routed ports on a Cisco IOS switch do not support subinterfaces.

- To configure routed ports, use the `no switchport` interface configuration mode command.

- Note: Routed ports are not supported on Catalyst 2960 Series switches.

Configuring Static Routes on a Catalyst 2960

- The Cisco Switch Database Manager (SDM) provides multiple templates for the Cisco Catalyst 2960 switch.

- The SDM *lanbase-routing* template can be enabled to allow the switch to route between VLANs and to support static routing.

- Use the `show sdm prefer` command to verify which template is in use.

- The SDM template can be changed in global configuration mode with the `sdm prefer` command.

Layer 3 Switch Configuration Issues

To troubleshoot Layer 3 switching issues, verify the following for accuracy:

- **VLANs**
  - VLANs must be defined across all the switches.
  - VLANs must be enabled on the trunk ports.
  - Ports must be in the right VLANs.
- **SVIs**
  - SVIs must have the correct IP address or subnet mask.
  - SVIs must be up.
  - SVIs must match with the VLAN number.

Layer 3 Switching Configuration Issues

To troubleshoot Layer 3 switching issues, verify the following for accuracy:

- **Routing**
  - IP Routing must be enabled.
  - Each interface or network should be added to the routing protocol.
- **Hosts**
  - Hosts must have the correct IP address or subnet mask.
  - Hosts must have a default gateway associated with an SVI or routed port.

Layer 3 Switching Configuration Issues

- The switch does the routing for the hosts that connect to VLAN 5. If the PC accesses a web server from the Internet, at what point will a VLAN number be added to the frame?

  No VLAN number is added to the frame in this design.