

Chapter 5: Inter-VLAN Routing



CCNP SWITCH: Implementing Cisco IP Switched Networks

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Chapter 5 Objectives

- Given an enterprise network, design, implement, and verify **inter-VLAN routing** using an external router or a multilayer switch, using either switch virtual interfaces or routed interfaces

- Understand **Layer 3 EtherChannel** and its configuration

- Understand **DHCP** operation and its implementation and verification in a given enterprise network

Describing Inter-VLAN Routing





Describing Inter-VLAN Routing

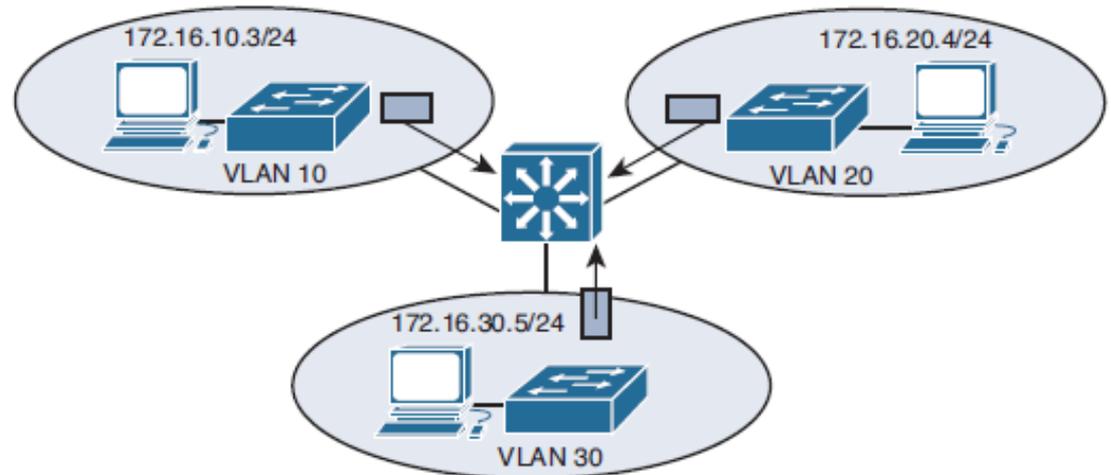
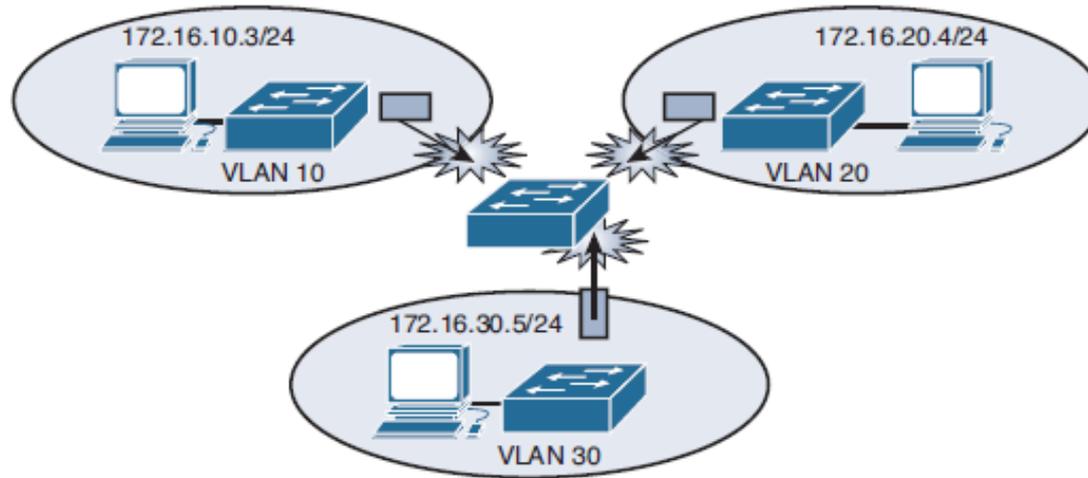
- Introduction to inter-VLAN routing
 - Inter-VLAN routing using an **external router**
 - Inter-VLAN routing with **switch virtual interfaces (SVI)**
 - Routing with **routed ports**
- Configuring inter-VLAN routing using **SVI** and **routed ports**
- Troubleshooting inter-VLAN routing



Introduction to Inter-VLAN Routing

- Because VLANs isolate traffic to a defined broadcast domain and subnet, network devices in **different VLANs cannot communicate with each other natively**.
- The devices in each VLAN can communicate to the network devices in another VLAN **only through a Layer 3 routing device**
- The following devices can provide inter-VLAN routing:
 - Any **Layer 3 multilayer Catalyst switch**
 - Any **external router with an interface that supports trunking (router-on-a-stick)**
 - Any external router or group of **routers with a separate interface** in each VLAN (**Legacy**)

Introduction to Inter-VLAN Routing





Router vs. MLS for I-VR

- **Router-on-a-stick** is simple to implement because routers are usually available in every network, but most enterprise networks use multilayer switches to **achieve high packet processing rates using hardware switching**.
- Layer 3 switches usually have **packet-switching throughputs in the millions of packets per second (pps)**, whereas traditional general-purpose routers provide packet-switching in the range of 100,000 pps to more than 1 million pps.

All the Catalyst multilayer switches support three different types of Layer 3 interfaces:

- **Routed port:** A pure Layer 3 interface similar to a routed port on a Cisco IOS router.
- **Switch virtual interface (SVI):** A virtual VLAN interface for inter-VLAN routing. In other words, switch virtual interfaces (SVIs) are the **virtual routed VLAN interfaces**.
- **Bridge virtual interface (BVI):** A Layer 3 virtual bridging interface.



Routing with an **External Router** Configuration

Configure router **subinterface** for routing of VLAN10-VLAN20 traffic:

- R1(config)# **interface ethernet 0/0.10**
- R1(config-subif)# **encapsulation dot1q 10**
- R1(config-subif)# **ip address 10.0.10.1 255.255.255.0**
- R1(config)# **interface ethernet 0/0.20**
- R1(config-subif)# **encapsulation dot1q 20**
- R1(config-subif)# **ip address 10.0.20.1 255.255.255.0**

Configure a subinterface for native VLAN traffic:

- R1(config)# **interface ethernet 0/0.1**
- R1(config-subif)# **encapsulation dot1q 1 native**
- R1(config-subif)# **ip address 10.0.1.1 255.255.255.0**



Verify configuration

```
R1# show ip interface brief
```

Interface	IP-Address	OK?	Method	Status	Protocol
Ethernet0/0	unassigned	YES	NVRAM	up	up
Ethernet0/0.1	10.0.1.1	YES	manual	up	up
Ethernet0/0.10	10.0.10.1	YES	manual	up	up
Ethernet0/0.20	10.0.20.1	YES	manual	up	up
Ethernet0/1	unassigned	YES	NVRAM	administratively down	down
Ethernet0/2	unassigned	YES	NVRAM	administratively down	down
Ethernet0/3	unassigned	YES	NVRAM	administratively down	down



Routing with an External Router Configuration

Configure switch trunk port. Allow only VLAN 1, 10, and 20 traffic:

- **SW1(config)# interface ethernet 0/0**
- **SW1(config-if)# switchport trunk encapsulation dot1q**
- **SW1(config-if)# switchport mode trunk**
- **SW1(config-if)# switchport trunk allowed vlan 1,10,20**



External Routers: Advantages & Disadvantages

The following are **advantages** of external router usage:

- An external router works with any switch because **Layer 3 services are not required on the switch**. Many switches do not contain Layer 3 forwarding capability, especially switches that are used at the access layer of a hierarchical network.
- The implementation is simple. **Only one switch port and one router interface require configuration**.
- If the network design includes only Layer 2 switches, the design and also the process for **troubleshooting traffic flow become very simple** because there is only one place in the network where VLANs interconnect.



External Routers: Advantages & Disadvantages

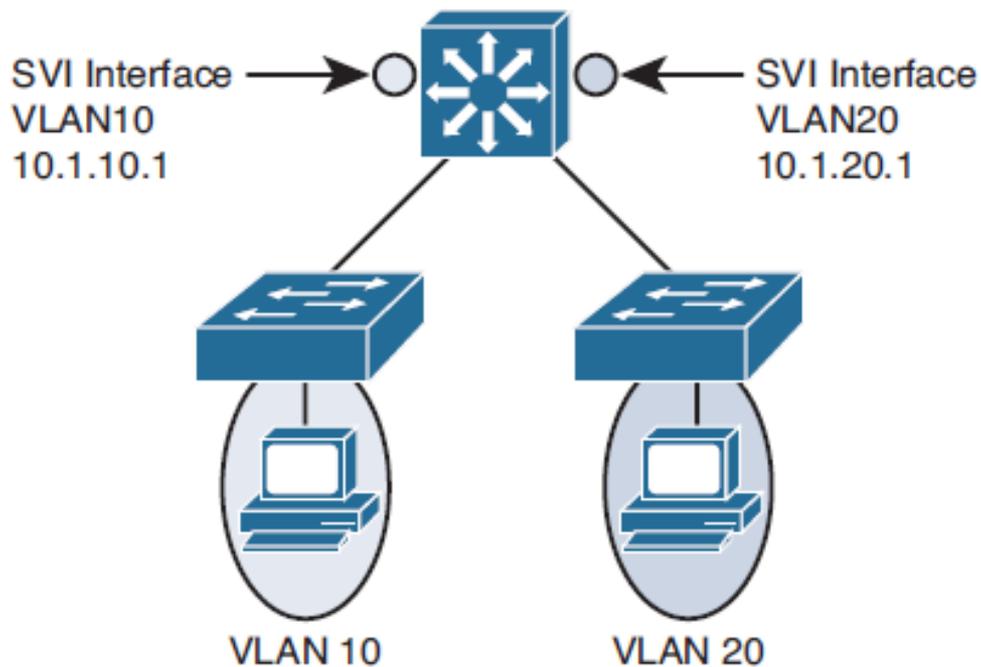
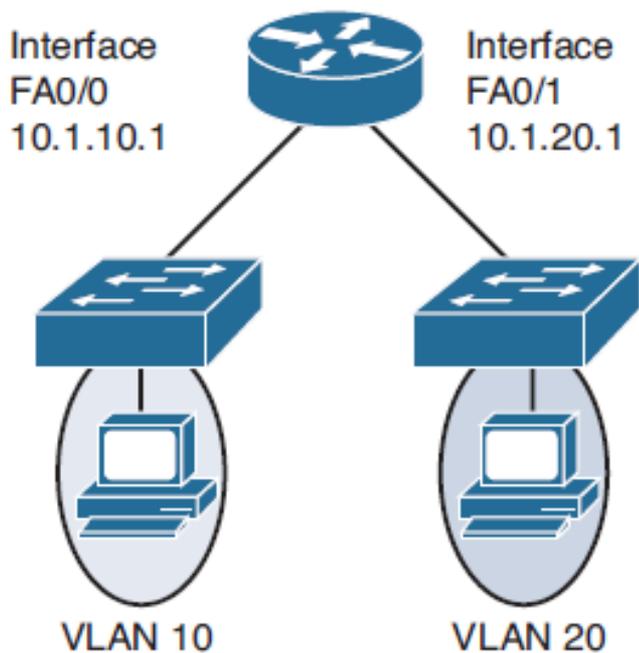
The following are **disadvantages** of external router usage:

- The router is a **single point of failure**.
- A single traffic path may become **congested**. With a router-on-a-stick model, the trunk link is **limited by the speed of the router interface** being shared across all trunked VLANs
- Latency may be introduced as frames leave and reenter the switch chassis multiple times and as the **router makes software-based routing decisions**.



Inter-VLAN Routing Using Switch Virtual Interfaces

- An **SVI is a virtual interface** configured within a **multilayer switch**, as compared to external router configuration
- An SVI can be created for any VLAN **that exists on the switch**. Only one VLAN associates with one SVI.





Switch Virtual Interfaces

- An SVI is “virtual” in that there is **no physical port** dedicated to the interface yet, it can perform the **same functions for the VLAN** as a router interface would.
- Can be configured in much the same way as a router interface (IP address, inbound/outbound access control lists [ACLs], and ...).
- The SVI for the VLAN provides Layer 3 processing for packets to or from all switch ports associated with that VLAN.
- By default, an SVI is created for the **default VLAN (VLAN1)** to permit remote switch administration.
- Additional SVIs must be explicitly created and the number used corresponds to the VLAN tag associated.
- **Whenever the SVI is created, make sure that particular VLAN is present in the VLAN database manually or learned via VTP; otherwise, the SVI interface will stay down**



Reasons to configure SVI

- **To provide a gateway for a VLAN** so that traffic can be routed into or out of that VLAN
- To provide fallback bridging if it is required for non-routable protocols
- To provide Layer 3 IP connectivity to the switch
- To support routing protocol and bridging configurations



SVI: Advantages & Disadvantages

The following are some of the advantages of SVI:

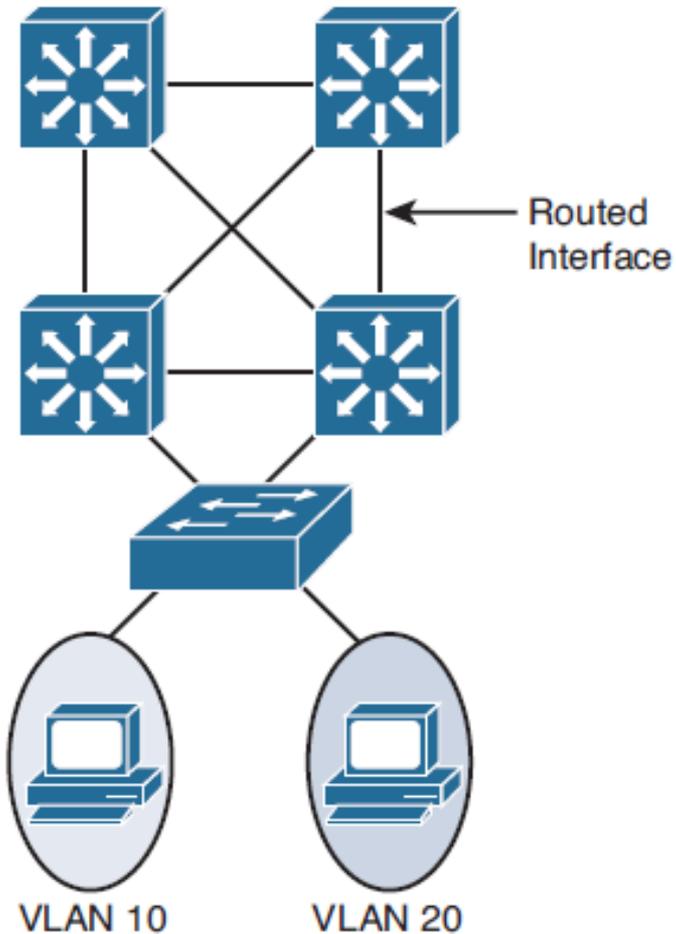
- It is **much faster than router-on-a-stick** because everything is **hardware switched** and routed.
- **No need for external links from the switch to the router** for routing.
- **Not limited to one link**. Layer 2 EtherChannels can be used between the switches to get more bandwidth.
- **Latency is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

The following are some of the disadvantages:

- It needs a **Layer 3 switch to perform inter-VLAN routing, which is more expensive**



Routing with Routed Ports



- A routed port is a physical port that acts similarly to a port on a traditional router with Layer 3 addresses configured.
- Unlike an access port, a **routed port is not associated with a particular VLAN**. A routed port behaves like a regular router interface.
- Also, because Layer 2 functionality has been removed, Layer 2 protocols (STP and VTP) do not function on a routed interface.
- Link Aggregation Control Protocol (LACP), which can be used to build either Layer 2 or Layer 3 EtherChannel bundles, would still function at Layer 3.
- Routed ports are used for point-to-point links
- **Routed interfaces do not support sub-interfaces as with Cisco IOS routers.**
- To configure routed ports, make sure to configure the respective interface as a Layer 3 interface using the **no switchport** interface command

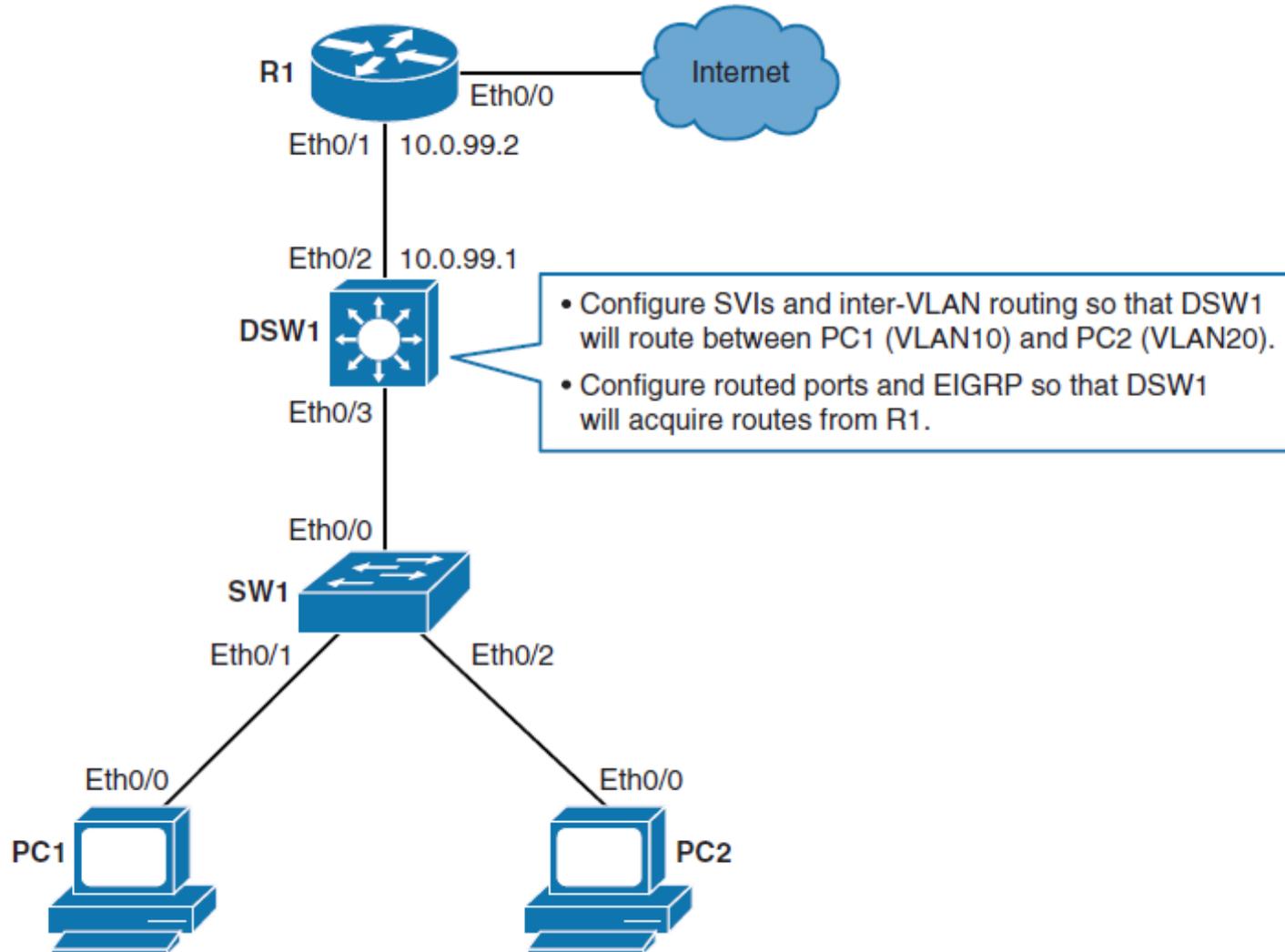


Routed Ports: Advantages

Following are some of the advantages of routed ports:

- A multilayer switch can have SVI and routed ports in a single switch.
- Multilayer switches forward either Layer 2 or Layer 3 traffic in hardware, so it **helps to do routing faster**.

Configuring Inter-VLAN Routing Using SVI and Routed Ports





Configuring Routing on a Multilayer Switch

Step 1. Create VLANs 10 and 20:

- `DSW1(config)# vlan 10`
- `DSW1(config-vlan)# vlan 20`

Step 2. On DSW1, enable IPv4 routing:

- `DSW1(config)# ip routing`

Step 3. Configure SVI for VLANs with IP address

- `DSW1(config)# interface vlan 10`
- `DSW1(config-if)# ip address 10.0.10.1 255.255.255.0`
- `DSW1(config-if)# no shutdown`
- `DSW1(config)# interface vlan 20`
- `DSW1(config-if)# ip address 10.0.20.1 255.255.255.0`
- `DSW1(config-if)# no shutdown`



Configuring Routing on a Multilayer Switch

Step 4. Turn the interface that connects to R1 (Ethernet 0/0) into a routed interface and configure it with IP address.

- **DSW1(config)# interface ethernet 0/2**
- **DSW1(config-if)# no switchport**

```
*Nov 28 15:03:55.138: %LINK-3-UPDOWN: Interface Ethernet0/2, changed state to up
*Nov 28 15:03:56.142: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/2, changed state to up
```
- **DSW1(config-if)# ip address 10.0.99.1 255.255.255.0**

Step 5. Configure a Routing Protocol

- **DSW1(config)# router eigrp 1**
- **DSW1(config-router)# network 10.0.0.0**

```
*Nov 28 15:12:22.448: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 10.0.99.2 (Ethernet0/2) is up: new adjacency
```



Using the SVI autostate exclude Command

- The SVI interface is brought up when one **Layer 2 port in the VLAN has had time to converge** (transition from STP listening-learning state to forwarding state).
- The default action when a VLAN has multiple ports is that the **SVI goes down when all ports in the VLAN go down**.
- This action prevents features such as routing protocols from using the VLAN interface as if it were fully operational and minimizes other problems, such as routing black holes.
- You can use the **SVI autostate exclude** command to configure **a port so that it is not included in the SVI line-state up-and-down calculation**.



Configuring autostate exclude

- Switch(config)# **interface** *slot/number*
- Switch(config-if)# **switchport autostate exclude**

- This disables the SVI autostate and makes the SVI interface **permanently active**.



SVI Configuration Checklist

1. Identify which VLANs require a Layer 3 gateway.
2. Create a VLAN on a L3 switch if it does not already exist.
3. Create an SVI interface for each VLAN.
4. Configure the SVI interface with an IP address.
5. Enable the SVI interface.
6. Enable IP routing on the multilayer switch.
7. Determine whether a dynamic routing protocol is needed.
8. Configure a dynamic routing protocol if needed.
9. Identify any switch ports that require autostate exclude.
10. Configure autostate exclude on identified switch ports.



Common Inter-VLAN Routing Problems

Problem	Possible Cause
Missing VLAN	VLAN might not be defined across all the switches. VLAN might not be enabled on the trunk ports. Ports might not be in the right VLANs.
Layer 3 interface mis-configuration	Virtual interface might have the wrong IP address or subnet mask. Virtual interface might not be up. Virtual interface number might not match with the VLAN number. Routing has to be enabled to route frames between VLAN. Routing might not be enabled.
Routing protocol mis-configuration	Every interface or network needs to be added in the routing protocol. The new interface might not be added to the routing protocol. Routing protocol configuration is needed only if VLAN subnets need to communicate to the other routers, as previously mentioned in this chapter.
Host misconfiguration	Host might not have the right IP address or subnet mask. Each host has to have the default gateway that is the SVI or Layer 3 interface to communicate with other networks and VLAN. Host might not be configured with the default gateway.



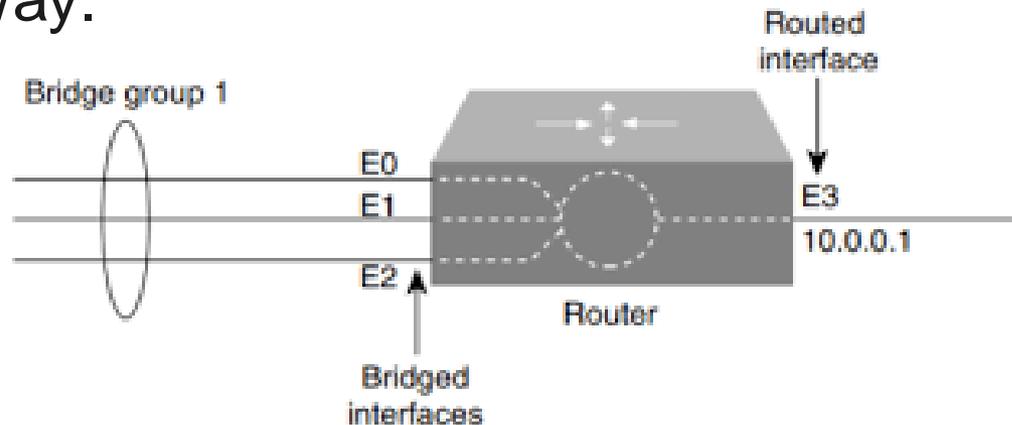
Troubleshooting Inter-VLAN Problems

- Correct VLANs on all switches and trunks.
- Correct routes.
- Correct primary and secondary root bridges.
- Correct IP address and subnet masks.



BVI - What is it and what are its uses?

- A BVI is in fact quite similar to an SVI (**interface Vlan**).
- A **software bridging** can be defined between various interfaces of a router, similar to switching between various ports on a switch.
- If the ports on a switch belong to the same VLAN and the switch is capable of multilayer switching, you can create an **interface Vlan** for that VLAN and allow the hosts in that VLAN to use the IP address of the interface Vlan as their default gateway.





BVI - What is it and what are its uses?

- The same goes for interface BVI - **Bridged Virtual Interface**.
- When configuring software bridging, you define a group of interfaces that are bridged.
- The router performs bridging (i.e. software-based switching) of frames between all member ports of a bridge group, in essence forming a single broadcast domain - an IP subnet.
- If the devices in the common bridge group want to access other IP networks, they need a gateway, so you create an associated **interface BVI** that is also a part of the bridge group, and devices in the bridge group then use the IP address of the BVI interface as their gateway.



BVI - What is it and what are its uses?

- For example, imagine a router with two FastEthernet interfaces:

```

bridge irb
!
interface FastEthernet0/0
  no ip address
  no shutdown
  bridge-group 1
!
interface FastEthernet0/1
  no ip address
  no shutdown
  bridge-group 1
!
interface BVI1
  ip address 10.0.0.1 255.255.255.0
  no shutdown
!
bridge 1 route ip

```



BVI - What is it and what are its uses?

- This configuration would make your router to basically behave as a 2-port "switch" on its Fa0/0 and Fa0/1 interfaces, and devices connected to these ports would use the 10.0.0.1 as their default gateway to other networks.
- You rarely configure bridging exactly this way these days, as switches are orders of magnitude faster and have way more ports. Still, there are situations where you need to bridge two interfaces, taking packets out of frames of one technology and putting them into frames of a different technology, **without routing them, just repackaging** but still carrying them between interfaces. This is often done in, say, DSL if the router is configured to act in bridge mode - take IP packets coming to Ethernet interface and simply repackage them into PPP or ATM+AAL5 cells on the DSL WAN port (and vice versa).

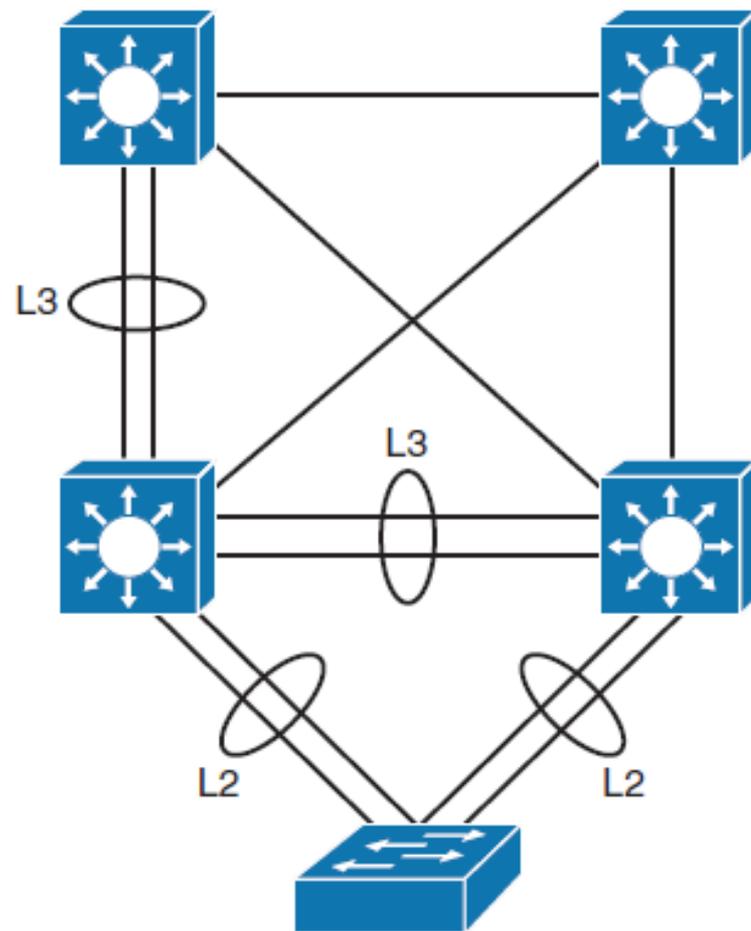
Layer 2 vs. Layer 3 EtherChannel





Layer 2 vs. Layer 3 EtherChannel

- On a multilayer switch, you can configure Layer 2 or Layer 3 EtherChannels, depending on what type of devices that will be connected, and depending on their position in the network.





Layer 3 EtherChannel Configuration

Step 1. Create a virtual Layer 2 port-channel interface:

- `Switch(config)# interface port-channel 1`

Step 2. Change interface to Layer 3 and enable the use of the **ip address** command:

- `Switch(config-if)# no switchport`

Step 3. Assign an IP address to the port channel interface because this will now be a Layer 3 interface:

- `Switch(config-if)# ip address 172.32.52.10 255.255.255.0`

Step 4. Navigate to the interfaces that is to be associated with the EtherChannel bundle.

- `Switch(config)# interface range fastethernet 5/4 - 5`



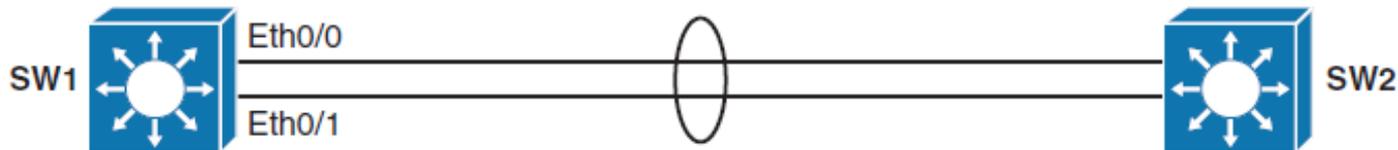
Layer 3 EtherChannel Configuration

Step 5. Remove the independent Layer 2 and Layer 3 functionality of the port so that the port can function as part of a group:

- `Switch(config-if-range)# no switchport`
- `Switch(config-if-range)# channel-protocol pagp`

Step 6. Assign all of the physical interfaces in the range to the EtherChannel group:

- `Switch(config-if-range)# channel-group 1 mode desirable`



```
SW1(config)# interface range ethernet 0/0 - 1
SW1(config-if)# no switchport
SW1(config-if)# channel-group 1 mode on
SW1(config-if)# exit
SW1(config)# interface port-channel 1
SW1(config-if)# no switchport
SW1(config-if)# ip address 10.1.20.1 255.255.255.0
```



L3 EtherChannel Configuration Guidelines

The following are the guidelines for configuration for EtherChannel:

- **Speed and duplex:** Configure all interfaces in an EtherChannel to operate at the **same speed** and in the **same duplex mode**.
- **Interface mode:** Because the port channel interface is a routed port, **the no switchport the same command must also be applied to the physical ports**
- **Verifying the EtherChannel configuration:** After EtherChannel is configured, use the following commands to verify and troubleshoot EtherChannel:
 - **show interface port-channel *channel-group-number***
 - **show etherchannel *channel-group-number* summary**
 - **show spanning-tree vlan *vlan-number* detail**

Implementing DHCP





Implementing DHCP

- Explain the idea behind DHCP
- Configure a DHCP server
- Configure manual DHCP bindings
- Configure a DHCP relay
- Configure DHCP options



DHCP Overview

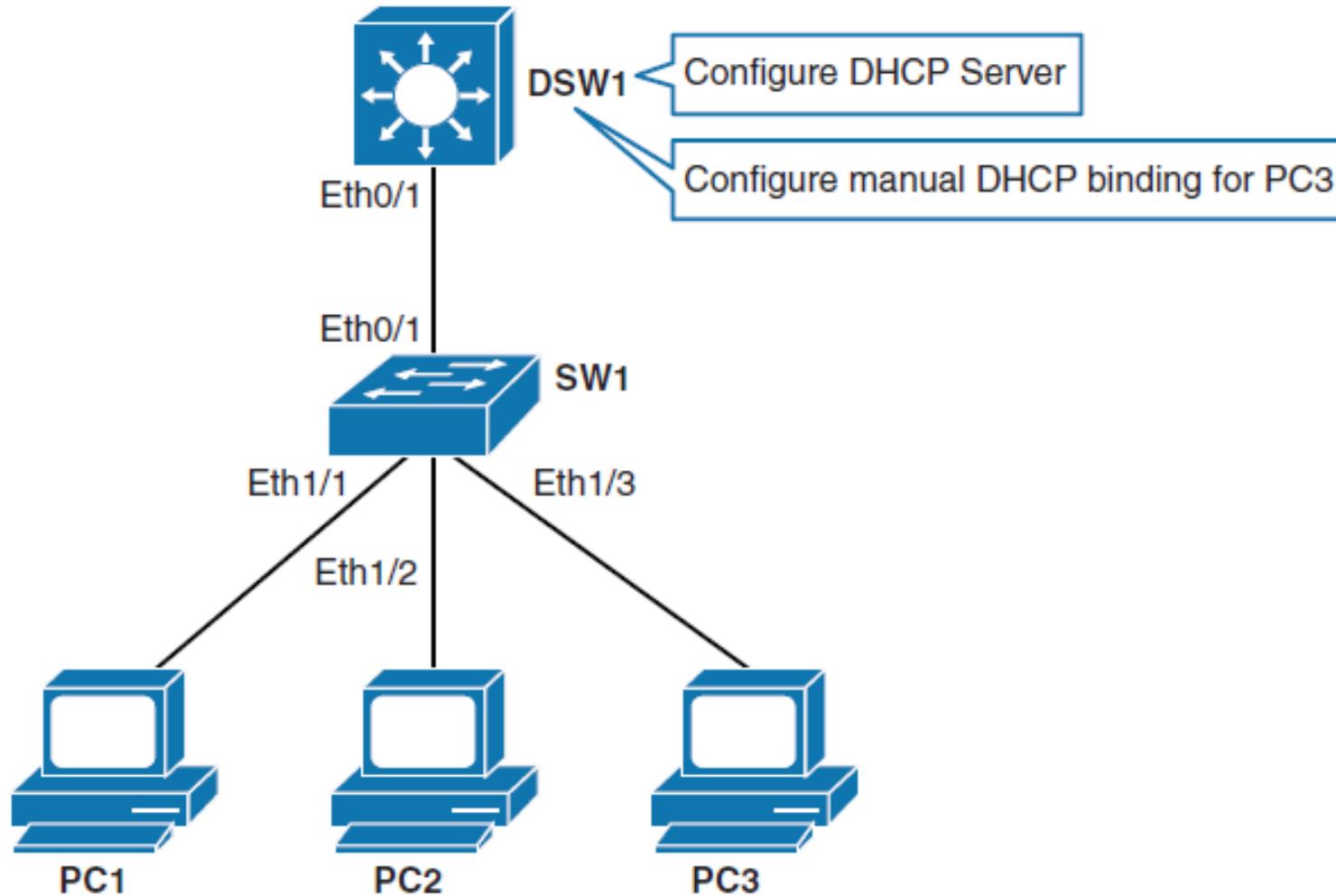
- DHCP provides configuration parameters to Internet hosts.
- DHCP consists of two components:
 1. a protocol for delivering host-specific configuration parameters from a DHCP server to a host, and
 2. a mechanism for allocating network addresses to hosts.
- DHCP is built on a client/server model in which designated DHCP server hosts allocate network addresses and deliver configuration parameters to dynamically configured hosts.
- Clients in access VLANs need DHCP services, and not only external servers but also routers can be used for DHCP services.



DHCP on MLS

- Cisco multilayer switches running Cisco IOS Software include **DHCP server** and **relay agent software**.
- Distribution multilayer switches often act as Layer 3 **gateways for clients** connecting to the access switches on various VLANs.
- Therefore, the DHCP service can be provided directly by the distribution switches.
- Alternatively, DHCP services can be concentrated in an external, dedicated DHCP server.
- In that case, distribution switches need to redirect the incoming clients' DHCP requests to the external DHCP server.

Configuring DHCP in Multilayer Switched Network





Configuring **Dynamic** DHCP in Multilayer Switched Network

- DSW1(config)# **ip dhcp excluded-address 10.0.10.1 10.0.10.10**
- DSW1(config)# **ip dhcp pool VLAN73POOL**
- DSW1(dhcp-config)# **network 10.0.73.0 255.255.255.0**
- DSW1(dhcp-config)# **default-router 10.0.73.1**
- DSW1(dhcp-config)# **next-server 10.0.73.8**
- DSW1(dhcp-config)# **domain-name cisco.com**
- DSW1(dhcp-config)# **dns-server 147.232.4.4**
- DSW1(dhcp-config)# **lease 2**



Configuring **Dynamic** DHCP in Multilayer Switched Network

- DSW1# **show run | begin excluded**

```
ip dhcp excluded-address 10.0.10.1
10.0.10.10
```

```
!
```

```
ip dhcp pool VLAN73POOL
```

```
network 10.0.10.0 255.255.255.0
```

```
next-server 10.0.10.8
```

```
domain-name cisco.com
```

```
default-router 10.0.10.1
```

```
dns-server 192.168.28.10
```

```
lease 2
```



Configuring DHCP in Multilayer Switched Network

Command	Description
<code>ip dhcp excluded-address <i>start-ip end-ip</i></code>	If there are addresses within the IP subnet that should not be offered to DHCP clients, this command will make sure that the specified addresses are not offered. In the example, 10.0.10.1 was excluded from the DHCP pool because this is the IP address of the Layer 3 interface on DSW1.
<code>ip dhcp pool <i>pool-name</i></code>	The <i>pool-name</i> parameter defines a DHCP pool. Using this command, you enter the DHCP pool configuration mode.
<code>network <i>ip-address subnet-mask</i></code>	Specifies the address range through IP subnet and subnet mask. The network command will bind the DHCP server to matching Layer 3 interface. In the example, DHCP server VLAN10POOL is bound to VLAN 10 interface. Broadcast and network IPs are not offered to clients. You can assign multiple subnets per pool.
<code>default-router ip-address [<i>ip-address2</i>] [<i>ip-address3</i>] ...</code>	Sets the default router address that will be offered to clients. In the example, this is the IP address of the Layer 3 interface on the switch.
<code>lease (infinite {days [hours [minutes]]})</code>	Sets IP address lease duration. By default, the IP address is leased to a client for 1 day. In the example, it is set to 2 days.



Configuring **Static#1** DHCP in Multilayer Switched Network

- DSW1(config)# ip dhcp excluded-address 10.0.10.1
- DSW1(config)# ip dhcp pool STATIC_HOST1
- DSW1(dhcp-config)# host 10.0.10.200 255.255.255.0
- DSW1(dhcp-config)# client-identifier
0063.6973.636f.2d61.6162.622e.6363.3030.2e30.3630.302d.457
4.302f.30
- DSW1(dhcp-config)# client-identifier 1cca.e371.06fd
- DSW1(dhcp-config)# client-identifier 011c.cae3.7106.fd

Or deprecated way:

- DSW1(dhcp-config)# hardware-address *MAC-address*



Configuring **Static#2** DHCP in Multilayer Switched Network

- DSW1(config)# ip dhcp pool STATIC
- DSW1(dhcp-config)# **origin file**
tftp://192.168.73.10/DHCP_database.txt
- DSW1(dhcp-config)# default-router 192.168.73.1
- DSW1(dhcp-config)# dns-server 8.8.8.8 8.8.4.4
- DSW1(dhcp-config)# lease 0 1

or

- DSW1(config)# ip dhcp pool STATIC
- DSW1(dhcp-config)# **origin file**
flash:DHCP_database.txt



Configuring **Static#2** DHCP in Multilayer Switched Network

■ **WIFI_ROUTER# more flash:DHCP_database.txt**

```
*time* Feb 02 2023 10:49 AM
```

```
*version* 5
```

```
!type 1 = ethernet vid RFC
```

```
!id je vo formate 01xx.xxxx.xxxx.xx, kde xx.. je MAC adresa
```

```
!IP address.mask          Type          Hardware address          Lease
```

```
!notebook
```

```
192.168.73.99 /24          id           01c4.910c.ae30.89         5
```

```
!nb1_wifi
```

```
192.168.73.21 /24          id           0154.271e.4502.d3         5
```

```
!nb2_wifi
```

```
192.168.73.22 /24          id           0154.271e.4502.56         5
```

```
!nb3_wifi
```

```
192.168.73.23 /24          id           0154.271e.4502.cc         5
```

```
!nb4_wifi
```



Configuring DHCP in Multilayer Switched Network

- To view information about the currently leased addresses, you can use:

```
DSW1# show ip dhcp binding
```

Bindings from all pools not associated with VRF:

<i>IP address</i>	<i>Client-ID/ Hardware address/ User name</i>	<i>Lease expiration</i>	<i>Type</i>
192.168.73.11/24	01ec.f4bb.0fa3.1f	Infinite	Static
192.168.73.12/24	0100.1132.f58d.e4	Infinite	Static
192.168.73.21/24	0154.271e.4502.d3	Infinite	Static
192.168.73.28/24	0154.271e.4502.e1	Infinite	Static
192.168.73.29/24	0154.271e.4501.d5	Infinite	Static
192.168.73.30/24	0154.271e.4502.d9	Infinite	Static
192.168.73.31/24	0154.271e.4502.c6	Infinite	Static
192.168.73.32/24	0154.271e.4502.5d	Infinite	Static
192.168.73.99/24	01c4.910c.ae30.89	Infinite	Static
192.168.73.149	0100.089b.bdac.37	Mar 19 2023 04:34 PM	Automatic



Configuring DHCP in Multilayer Switched Network

- To view information about the currently leased addresses, you can use:

```
DSW1# show ip dhcp pool LAN73
```

```
Dynamic updates will be performed
```

```
Pool LAN73 :
```

```
Utilization mark (high/low)      : 100 / 0
```

```
Subnet size (first/next)         : 0 / 0
```

```
Total addresses                  : 254
```

```
Leased addresses                 : 1
```

```
Pending event                    : none
```

```
1 subnet is currently in the pool :
```

```
Current index                    IP address range
```

```
Leased addresses
```

```
192.168.73.225                  192.168.73.1      - 192.168.73.254
```



Configuring DHCP in Multilayer Switched Network

- To view information about the currently leased addresses, you can use:

```
DSW1# show ip dhcp pool STATIC
```

```
Dynamic updates will be performed
```

```
Pool STATIC :
```

```
Utilization mark (high/low)      : 100 / 0
```

```
Subnet size (first/next)         : 0 / 0
```

```
Total addresses                  : 15
```

```
Leased addresses                  : 15
```

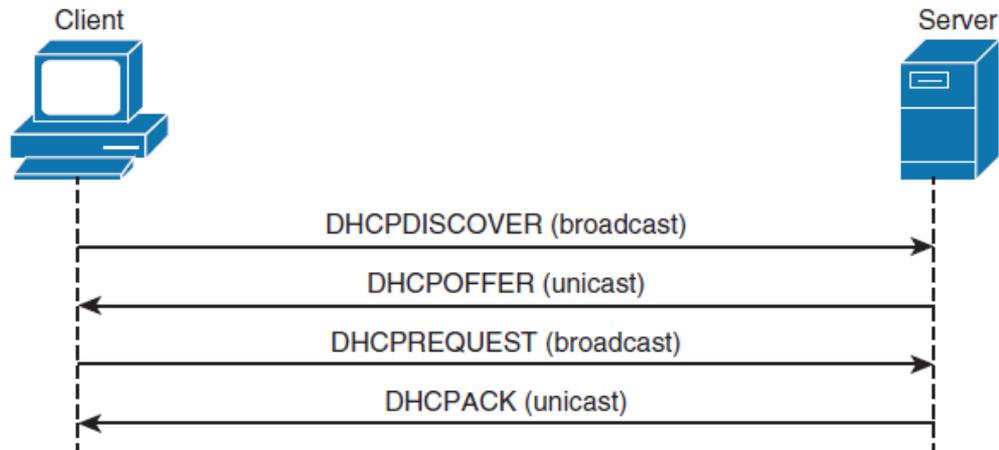
```
Pending event                     : none
```

```
0 subnet is currently in the pool :
```

Current index addresses	IP address range	Leased
192.168.73.99	192.168.73.99 - 192.168.73.99	1
192.168.73.21	192.168.73.21 - 192.168.73.21	1
192.168.73.22	192.168.73.22 - 192.168.73.22	1
192.168.73.23	192.168.73.23 - 192.168.73.23	1
192.168.73.24	192.168.73.24 - 192.168.73.24	1



DHCP Discovery Process

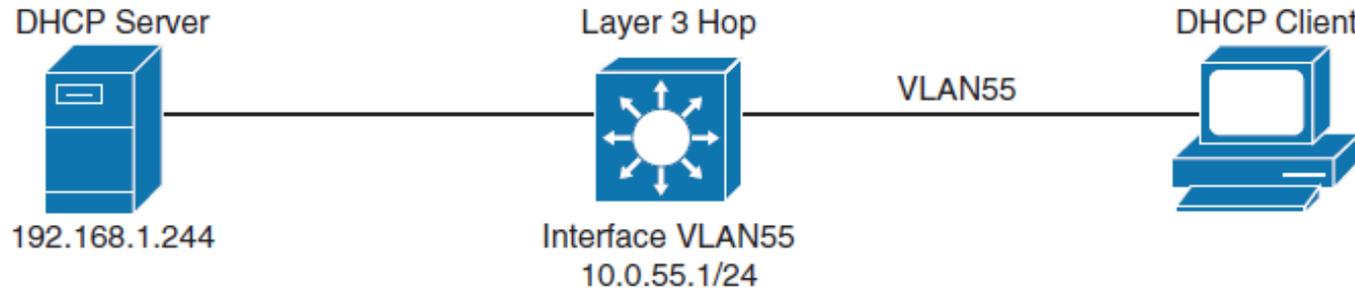


In addition to these four messages, the following DHCP messages are displayed with debug output:

- **DHCPDECLINE:** Message sent from the client to the server that the address is already in use.
- **DHCPNAK:** The server sends a refusal to the client for request for configuration.
- **DHCPRELEASE:** Client tells a server that it is giving up a lease.
- **DHCPINFORM:** A client already has an IP address but is requesting other configuration parameters that the DHCP server is configured to deliver such as DNS address.



Configuring a DHCP Relay



A client that resides in VLAN 55 needs to have the following two configurations to forward the DHCP broadcast to the centralized server 192.168.1.244:

1. The multilayer switch must have a **Layer 3 IP address** (it is 10.0.55.1/24 in this example) that will receive the client DHCP request. This address **may be a routed port or an SVI**.
2. The **ip helper-address** command must be configured on the multilayer switch Layer 3 interface. With the DHCP relay address, when the switch receives a DHCP request in the form of a broadcast message from a client, the switch forwards this request, as a unicast message, to the IP address that is specified in the **ip helper-address** command.

The **ip helper-address** command not only forwards DHCP UDP packets but also forwards TFTP, DNS, time, NetBIOS, name server, and BOOTP packets by default.



DHCP Options

- Supplying DHCP options is a smart way to configure network clients during the early phase of network access deployment.
- In addition to providing the IP address, the DHCP protocol is able to set a **large bunch of options** that are very useful for device configuration.
- Each option has a name and a numerical identifier to be transported in the protocol frames.
- DHCP server configuration can handle providing options to all devices asking for an IP address and also bound to a specific client identifier or mac address family.



Configuring DHCP Options

- Use DHCP options to “expand” the basic DHCP commands:
 - DHCP option **1**: subnet mask to be applied on the interface asking for an IP address
 - DHCP option **2**: time offset in seconds from UTC to be applied on the current time (note: deprecated by RFC4833 – options 100 and 101)
 - DHCP option **3**: default router or last resort gateway for this interface
 - DHCP option **4**: list of time server as stated in the RFC868 (Time Protocol)
 - DHCP option **6**: which DNS (Domain Name Server) to include in the IP configuration for name resolution
 - DHCP option **51**: lease time for this IP address
 - DHCP option **12**: host name of the client, very useful for IoT and any device without user
 - DHCP option **15**: specifies the domain name that client should use as suffix when resolving hostnames via the Domain Name System



Configuring DHCP Options

- Use DHCP options to “expand” the basic DHCP commands:
 - DHCP options **69** and **70**: respectively for SMTP and POP3 servers for sending and receiving email. We do see these options often on printers and scanners
 - DHCP option **81**: Client Fully Qualified Domain Name – this option allows to perform automatic update of the DNS records associated to the client, mainly the A and PTR. In the option we can specify whether the client or the server will update the records and the FQDN associated to the client. It is defined in the RFC4702
 - DHCP option **100**: time zone POSIX string as in IEEE 1003.1
 - DHCP option **101**: time zone as a string like in the TZ database (eg: Europe/Paris)
 - DHCP option **119**: DNS domain search list that will be used to perform DNS requests based on short name using the suffixes provided in this list.
 - DHCP option **150** (RFC 5859) is used by VoIP phones to obtain the VoIP Configuration Server Address, usually from a TFTP Server.



Configuring DHCP Options

■ Client Behavior:

In the **DHCPDISCOVER** (broadcast) or **DHCPREQUEST** messages, the client can include a field called **Parameter Request List** (Option 55).

- This list contains **option numbers** the client wants to receive from the server - **Option 55: 1, 3, 6, 15, 51**

This tells the server:

“Please include subnet mask (1), default gateway (3), DNS (6), domain name (15), and lease time (51) in your DHCPOFFER.”

- It **responds with matching options** in the **DHCPOFFER** and **DHCPACK** messages — including any **required or configured options** like Option 150, even if not explicitly requested (depending on the server config).



Chapter 5 Summary

- Inter-VLAN routing provides communication between the devices in different VLANs. Recall that a VLAN is a single broadcast domain, and the devices within a VLAN cannot communicate beyond VLAN boundaries unless through a Layer 3 device. Multilayer switches support two types of Layer 3 interfaces: routed ports and SVIs (VLAN interfaces).
- Routed ports are point-to-point connections such as those that interconnect the building distribution submodules and the campus backbone submodules when using Layer 3 in the distribution layer.
- SVIs are VLAN interfaces that route traffic between VLANs and VLAN group ports. In multilayer switched networks with Layer 3 in the distribution layer and Layer 2 in the access layer, SVIs can route traffic from VLANs on the access layer switches.



Chapter 5 Summary

- Using router-on-a-stick is an alternative and legacy method of implementing inter- VLAN routing for low-throughput and latency-tolerant applications.
- On multilayer switches, Layer 3 links can be aggregated using Layer 3 EtherChannels.
- When a Layer 3 interface is configured, routing can be enabled.
- DHCP server function can be configured on the Cisco switches and routers.
- If the network uses a centralized DHCP server, a DHCP relay agent feature can be configured on the switches by using the **ip helper-address** command.



Chapter 5 Labs

- **CCNPv7.1 SWITCH Lab5.1 IVL-ROUTING**
- **CCNPv7.1 SWITCH Lab5.2 DHCP4/6**

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