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CISCO CCNA

LAB GUIDE



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Introduction

Thanks very much for taking the time to download this free eBook. It contains complete configuration lab exercises and solutions to help you pass the Cisco CCNA Routing and Switching 200-125 exam. You can also use it as a configuration reference for Cisco routers and switches. I hope you can make use of it to expand your networking knowledge and further your career.

How the Lab Works

I wanted to make this a completely free resource and as simple to use as possible so the free software GNS3 and Packet Tracer is used for the labs.

I've used two different software programs because GNS3 is best for the routing labs, and Packet Tracer is best for the switching labs.

I've provided a lab startup file for each exercise which loads in either GNS3 or Packet Tracer so you can get up and running with the labs immediately. A download link is provided at the start of each exercise.

(You can alternatively use your own physical lab if you have one by cabling it as shown in the lab topology diagram for each exercise.)

Please watch my short free course showing how to install and use Packet Tracer and GNS3 first if you haven't used the software before:

GNS3 and Packet Tracer Installation course

Please note that I don't provide support for GNS or Packet Tracer, they have their own dedicated teams which are available through their support forums:

GNS3 Support | Cisco Support

If you find any errors in the book, please let me know so I can correct them. You can email me at neil@flackbox.com

Get the Complete Course

The lab exercises here can be used on their own or as a complement to my Cisco CCNA 200-125 Complete course. It has the highest review ratings of any CCNA course online and includes over 30 hours of video tutorials, flashcards and hands-on lab exercises. You can shortcut your path to getting CCNA certified by getting the course for only $10 USD (that's a massive 97% discount) with this link:

https://www.udemy.com/ccna-complete/?couponCode=DISCOUNTCEB

For practice tests I recommend AlphaPrep. They partner with Cisco and the CCNA test provider Pearson to bring you the most accurate preparation tests, and their advanced test engine lets you know when you're ready for the exam. Click here for a 10 day trial.

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About the Author



I'm Neil Anderson, you can visit my blog at https://www.flackbox.com to learn about Cloud and Data Center technologies.

The main focus of my current role is delivery of technical training and development of course content for large enterprise and service provider customers such as Cisco, NetApp, Verizon and IBM.

I dropped out of school with no qualifications or future plans at the age of 15. When I got a little bit older and wiser I realised I should make a career for myself so I learned about IT technologies through books and online resources. It's my passion now to help others do the same.

Connect with me on social media:

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04 The IOS Operating System - Lab Exercise

This lab explores basic navigation of the Cisco IOS operating system CLI (Command Line Interface). Only a single device is required.

This lab is a guided walkthrough of the IOS command line interface. Exercises for later sections will be split into two parts - first the tasks for you to complete on your own (without step by step instructions), and then an answer key showing you the solution.

Load the Startup Configuration

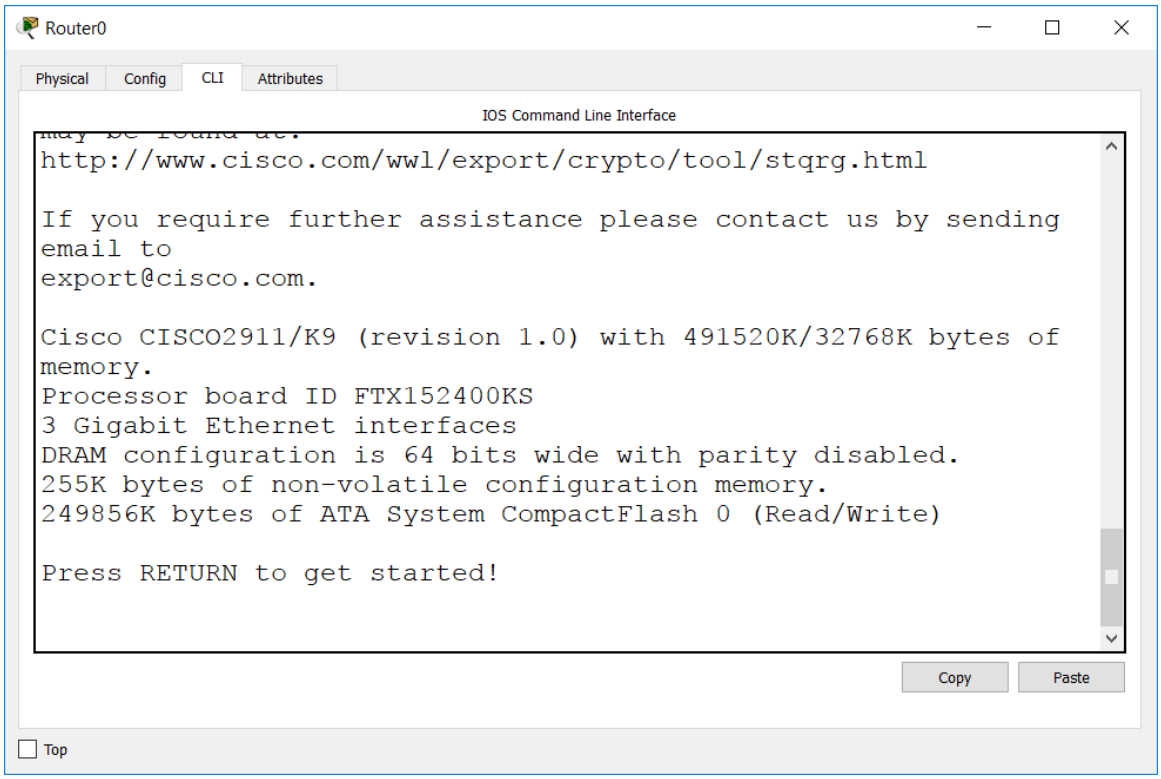
Download the '04 The IOS Operating System.pkt' file here. Open in Packet Tracer to load the lab.

Please watch my short free course showing how to install and use Packet Tracer and GNS3 first if you haven't used the software before:

GNS3 and Packet Tracer Installation course

Connect To Your Device

Click on Router0 and then the CLI tab to access the console.



Press Return to get started, then enter Privileged Exec mode.

```
Router>enable
Router#
```

Reboot the device.

```
Router#reload
Proceed with reload? [confirm]
```

Observe the device going through the bootup process in the command line output. This is possible because we are using a console connection (we could not see this if we connected to an IP address on the device.)

If prompted to enter the initial configuration dialog after the device has booted up, enter ‘no’.

```
Would you like to enter the initial configuration dialog? [yes/no]:
no
```

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Explore User Exec Mode and CLI command help

Notice that you are in User Exec mode as indicated by the ‘Router>’ prompt. (‘Router’ will be replaced with the device hostname after you configure one.)

```
Router>
```

Enter a question mark to explore the commands that are available in User Exec mode.

```
Router>?
Exec commands:
<1-99> Session number to resume
connect Open a terminal connection
disable Turn off privileged commands
disconnect Disconnect an existing network connection
enable Turn on privileged commands
exit Exit from the EXEC
logout Exit from the EXEC
ping Send echo messages
resume Resume an active network connection
show Show running system information
ssh Open a secure shell client connection
telnet Open a telnet connection
terminal Set terminal line parameters
traceroute Trace route to destination
```

Only a very limited set of informational commands are available in User Exec mode and we won’t typically be working here.

Enter the ‘show run’ command.

```
RouterX>show run
^
% Invalid input detected at '^' marker.
```

‘show run’ is a valid command but should be run at Privileged Exec mode, not User Exec, so the command fails.

This is the most common issue to trip up beginners at the IOS command line. If you see the ‘invalid input’ error then check you are at the correct level for the command you are trying to run.

Exploring Privileged Exec (Enable) Mode and Context Sensitive Help

Enter Privileged Exec mode. This mode is often commonly known as Enable mode. Notice that the prompt changes to ‘Router#’

```
Router>enable
Router#
```

Drop back to User Exec mode.

```
Router#disable
Router>
```

Go back to Privileged Exec mode by using shortened command abbreviation.

```
Router>en
Router#
```

Command abbreviation only works when you enter letters which could only match one unique command. Attempt to return to User Exec mode by entering the command ‘di’

```
Router#di
% Ambiguous command:  "di"
```

Check to see all the possible commands which begin with the letters ‘di’

```
Router#di?
dir  disable  disconnect
```

We can see that the shortest combination we could use for Disable would be ‘disa’

We can access detailed informational and debug output in Privileged Exec mode.

Check to see all commands that begin with ‘sh’

```
Router#sh?
Show
```

‘show’ is the only command that begins with ‘sh’ so we can use that as the abbreviation.

Enter ‘sh ?’ to see all available show commands. Notice that we have now included a space before the question mark. This enters context sensitive help for the ‘show’ command.

```
Router#sh ?
aaa Show AAA values
access-lists List access lists
arp Arp table
cdp CDP information
class-map Show QoS Class Map
clock Display the system clock
controllers Interface controllers status
crypto Encryption module
debugging State of each debugging option
dhcp Dynamic Host Configuration Protocol status
dot11 IEEE 802.11 show information
file Show filesystem information
flash: display information about flash: file system
flow Flow information
frame-relay Frame-Relay information
history Display the session command history
hosts IP domain-name, lookup style, nameservers, and host
table
interfaces Interface status and configuration
ip IP information
ipv6 IPv6 information
license Show license information
line TTY line information
--More—
```

Press the Enter key when you see ‘—More—‘ to cycle through the additional output one line at a time.

```
 -  Output truncated -
history Display the session command history
hosts IP domain-name, lookup style, nameservers, and host
table
interfaces Interface status and configuration
```

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```
ip IP information
ipv6 IPv6 information
license Show license information
line TTY line information
lldp LLDP information
--More—
```

One line at a time is a very slow way to view additional output so press the Space Bar to cycle through it one page at a time instead.

```
  -  Output truncated -
sessions Information about Telnet connections
snmp snmp statistics
spanning-tree Spanning tree topology
ssh Status of SSH server connections
standby standby configuration
startup-config Contents of startup configuration
storm-control Show storm control configuration
tcp Status of TCP connections
tech-support Show system information for Tech-Support
--More—
```

Keep hitting the Space Bar until you reach the end of the output.

```
  -  Output truncated -
standby standby configuration
startup-config Contents of startup configuration
storm-control Show storm control configuration
tcp Status of TCP connections
tech-support Show system information for Tech-Support
terminal Display terminal configuration parameters
users Display information about terminal lines
version System hardware and software status
vlan-switch VTP VLAN status
vtp Configure VLAN database
Router#sh
```

Check the possible options for the ‘show aaa’ command. (We’re using aaa for illustrative purposes here. Don’t worry about the meaning of the individual aaa commands, they’re not important for this exercise.)

```
Router#sh aaa ?
local Show AAA local method options
sessions Show AAA sessions as seen by AAA Session MIB
user Show users active in AAA subsystem
```

Context sensitive help can be very useful if you're not sure about the exact command you need to use. Unfortunately its use may be disabled in the simulator questions on the CCNA exam so you'll need to actually know the commands.

Enter 'sh aaa us' and then hit the Tab key to see Tab completion in action.

```
Router#sh aaa user
```

The Tab key will complete a partially entered command for you. Again this will only work if you've entered enough letters to be a unique match.

Enter the command 'sh aaa user all'.

```
Router#sh aaa user all
Router#
```

Notice that you do not get any output when you enter the command. This is not an error - AAA has not been configured. The CLI simply returns to the Enable prompt because there is nothing to show.

Enter the command 'sh aaa usor all'

```
Router#sh aaa usor all
                  ^
% Invalid input detected at '^' marker.
```

If you enter an illegal command you will get an error message.

Here we made a typo. The CLI warns us that invalid input was detected and shows us the location of the typo is at the 'o' of usor. We typed usor instead of user.

Enter the command 'sh aaa' and hit Enter.

```
Router#sh aaa
% Incomplete command.
```

The router warns us that we've entered an incomplete command, we need to enter additional input. We could enter 'sh aaa ?' again to see the available options.

Explore Global Configuration Mode

Enter Global Configuration mode. (The command can be abbreviated to ‘conf t’.)

```
Router#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#
```

Notice that the prompt changes to ‘Router(config)#’

Global Configuration mode is where we can enter configuration which affects the device as a whole (as opposed to configuring a particular interface for example).

Add a couple of host entries. (Don’t worry what this command does for now, we’re going to use it to illustrate command history in a second.)

```
Router(config)#ip host Server1 1.1.1.1
Router(config)#ip host Server2 2.2.2.2
```

Attempt to change the hostname of the device to R1 by entering the command ‘R1’.

```
Router(config)#R1
                     ^
% Invalid input detected at '^' marker.
```

Oops we forgot to enter the ‘hostname’ keyword at the start of the command.

Hit the Up Arrow on your keyboard to cycle back to the previous command.

```
Router(config)#R1
```

Enter Ctrl-A to bring the cursor to the beginning of the line and change the entry to ‘hostname R1’. This is quicker than typing the command again.

(We can also use ‘Ctrl-E’ to bring the cursor to the end of the line, and the left and right arrows to move the cursor one character at a time.)

```
Router(config)#hostname R1
R1(config)#
```

Notice that the command prompt changes to show the router’s hostname.

Hit the Up Arrow repeatedly to cycle back through your previous command history, and then the Down Arrow to cycle back again. Notice that command history is specific to your current level in the command hierarchy - only the commands you previously entered in Global Configuration mode are shown.

Enter the command ‘show ip interface brief’ to check which interfaces are available in the router.

```
R1(config)#show ip interface brief
                  ^
% Invalid input detected at '^' marker.
```

You receive the ‘invalid input detected’ error message but we haven’t made a typo. We’re getting the error because you have to be at the correct level whenever you enter a command. We’re in Global Configuration mode but ‘show’ commands are run in Privileged Exec mode.

We can override this for ‘show’ commands by entering ‘do’ at the start of the command. This works from any level in the command hierarchy.

Enter the correct command to check what interfaces are available from Global Configuration mode.

```
R1(config)#do show ip interface brief
Interface IP-Address OK? Method Status Protocol
GigabitEthernet0/0 unassigned YES NVRAM administratively down down
GigabitEthernet0/1 unassigned YES NVRAM administratively down down
GigabitEthernet0/2 unassigned YES NVRAM administratively down down
Vlan1 unassigned YES NVRAM administratively down down
```

Enter Interface Configuration mode for one of your interfaces.

```
R1(config)#interface gigabitEthernet 0/0
R1(config-if)#
```

Notice that the prompt changes to indicate you are in Interface Configuration mode.

Drop back down to Global Configuration mode.

```
R1(config-if)#exit
R1(config)#
```

The ‘exit’ command drops back down one level.

Hit the Up Arrow and go back to Interface Configuration mode.

```
R1(config)#interface gigabitEthernet 0/0
R1(config-if)#
```

Drop all the way back down to Privilege Exec mode with a single command.

```
R1(config-if)#end
R1#
```

The ‘end’ command drops back down to Privilege Exec mode from any level. You can also achieve this by entering ‘Ctrl-C’

View the entire device configuration.

```
R1#show running-config
Building configuration...

Current configuration : 737 bytes
!
version 15.1
no service timestamps log datetime msec
```

```
no service timestamps debug datetime msec
no service password-encryption
!
hostname R1
!
Output truncated –
```

View the entire configuration, starting from the hostname.

```
R1#sh run | begin hostname
hostname R1
!
no ip cef
no ipv6 cef
!
Output truncated –
```

Note that the IOS command line is not case sensitive, except when we pipe commands.

```
R1#sh run | begin Hostname
R1#
```

Here we entered ‘Hostname’ with a capital letter at the start, but this is not how it is shown in the configuration. The router could find no instance of ‘Hostname’ so it returns no output.

View configuration lines which include the word ‘interface’.

```
R1#show run | include interface
interface GigabitEthernet0/0
interface GigabitEthernet0/1
interface GigabitEthernet0/2
interface Vlan1
```

View all configuration lines which do not include the word ‘interface’.

```
R1#show run | exclude interface
Building configuration...

Current configuration : 737 bytes
!
```

```
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname R1
!
```

Output truncated –

IOS Configuration Management

Copy the running configuration to the startup configuration.

```
R1#copy run start
Destination filename [startup-config]?
Building configuration...
[OK]
```

Change the hostname of the router to RouterX

```
R1#config t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#hostname RouterX
RouterX(config)#
```

Notice that when you enter a command in IOS it takes effect immediately, we can see the command prompt changes to show the new hostname.

Check what hostname will be used when the system reboots.

```
RouterX(config)#do show startup-config
Using 737 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname R1
!
```

Commands take effect immediately but are not persistent across a reboot until we save them.

Save the current running configuration so it will be applied next time the router is reloaded.

```
RouterX#copy run start
Destination filename [startup-config]?
Building configuration...

[OK]
```

Verify the new hostname will be applied following a reboot.

```
RouterX#show start
Using 742 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname RouterX
!
```

Backup the current running configuration to flash memory in the router.

```
RouterX#copy run flash:
Destination filename [running-config]? config-backup
Building configuration...
[OK]
```

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It’s not a good idea to back up a device to the device itself, so enter the command to back the running configuration up to an external TFTP server.

```
RouterX#copy run tftp
Address or name of remote host []? 10.10.10.10
Destination filename [RouterX-confg]?

Writing running-config........
%Error opening tftp://10.10.10.10/RouterX-confg (Timed out)
```

(The command will try to run for a while and then time out and fail because we didn’t set up connectivity to a TFTP server in the lab.)

Reload the device and check it comes back up with the expected configuration with hostname RouterX.

```
RouterX#reload

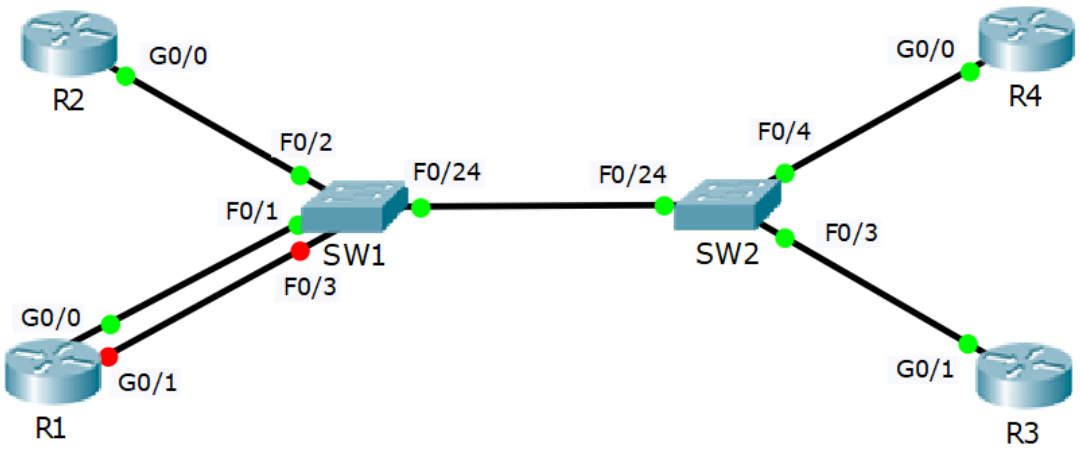
Proceed with reload? [confirm]
```

11 Cisco Device Functions – Lab Exercise

This lab explores the MAC address table on Cisco IOS switches and routing table on Cisco IOS routers.

This lab is a guided walkthrough of Cisco device functions. You will explore the commands used here in much more detail as you go through the rest of the course.

Lab Topology



Load the Startup Configurations

Download the '11 Cisco Device Functions.pkt' file here. Open in Packet Tracer to load the lab.

This preconfigures each router with an IP address in the 10.10.10.0/24 network.

Verify the Switch MAC Address Tables

1) Log into routers R1 to R4 and verify which interface is configured on the 10.10.10.0/24 network.

```
R1#show ip interface brief
Interface IP-Address OK? Method Status Protocol
GigabitEthernet0/0 10.10.10.1 YES manual up up
GigabitEthernet0/1 unassigned YES unset administratively down down
GigabitEthernet0/2 unassigned YES unset administratively down down
Vlan1 unassigned YES unset administratively down down
```

```
R2#show ip interface brief
Interface IP-Address OK? Method Status Protocol
GigabitEthernet0/0 10.10.10.2 YES manual up up
GigabitEthernet0/1 unassigned YES unset administratively down down
GigabitEthernet0/2 unassigned YES unset administratively down down
Vlan1 unassigned YES unset administratively down down
```

```
R3#show ip interface brief
Interface IP-Address OK? Method Status Protocol
GigabitEthernet0/0 unassigned YES unset administratively down down
GigabitEthernet0/1 10.10.10.3 YES manual up up
GigabitEthernet0/2 unassigned YES unset administratively down down
Vlan1 unassigned YES unset administratively down down
```

```
R4#show ip interface brief
Interface IP-Address OK? Method Status Protocol
GigabitEthernet0/0 10.10.10.4 YES manual up up
GigabitEthernet0/1 unassigned YES unset administratively down down
GigabitEthernet0/2 unassigned YES unset administratively down down
Vlan1 unassigned YES unset administratively down down
```

R1, R2 and R4 are using GigabitEthernet0/0, R3 is using GigabitEthernet0/1.

2) Note down the MAC addresses of these interfaces.

```
R1#show interface gig0/0
GigabitEthernet0/0 is up, line protocol is up (connected)
Hardware is CN Gigabit Ethernet, address is 0090.2b82.ab01 (bia
0090.2b82.ab01)
```

```
R2#show interface gig0/0
GigabitEthernet0/0 is up, line protocol is up (connected)
Hardware is CN Gigabit Ethernet, address is 0060.2fb3.9152 (bia
0060.2fb3.9152)
```

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```
R3#show interface gig0/1
GigabitEthernet0/1 is up, line protocol is up (connected)
Hardware is CN Gigabit Ethernet, address is 0001.9626.8970 (bia
0001.9626.8970)
```

```
R4#show interface gig0/0
GigabitEthernet0/0 is up, line protocol is up (connected)
Hardware is CN Gigabit Ethernet, address is 00d0.9701.02a9 (bia
00d0.9701.02a9)
```

Note: the MAC addresses in your lab may be different.

3) Verify connectivity between the routers by pinging R2, R3 and R4 from R1.

```
R1#ping 10.10.10.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.2, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/3 ms

R1#ping 10.10.10.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.3, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/1 ms

R1#ping 10.10.10.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.4, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/1 ms
```

4) Ping R3 and R4 from R2.

```
R2#ping 10.10.10.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.3, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/1 ms

R2#ping 10.10.10.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.4, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 0/0/1 ms
```

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5) View the dynamically learned MAC addresses on SW1 and verify that the router's MAC addresses are reachable via the expected ports. Ignore any other MAC addresses in the table.

```
SW1#show mac address-table dynamic
Mac Address Table
-------------------------------------------

Vlan Mac Address Type Ports
---- ----------- -------- -----

1 0001.9626.8970 DYNAMIC Fa0/24
1 000c.cf84.8418 DYNAMIC Fa0/24
1 0060.2fb3.9152 DYNAMIC Fa0/2
1 0090.2b82.ab01 DYNAMIC Fa0/1
1 00d0.9701.02a9 DYNAMIC Fa0/24
```

6) Repeat on SW2.

```
SW2#show mac address-table dynamic
Mac Address Table
-------------------------------------------

Vlan Mac Address Type Ports
---- ----------- -------- -----

1 0001.9626.8970 DYNAMIC Fa0/3
1 000b.be53.6418 DYNAMIC Fa0/24
1 0060.2fb3.9152 DYNAMIC Fa0/24
1 0090.2b82.ab01 DYNAMIC Fa0/24
1 00d0.9701.02a9 DYNAMIC Fa0/4
```

7) Clear the dynamic MAC Address Table on SW1.

```
SW1#clear mac address-table dynamic
```

8) Show the dynamic MAC Address Table on SW1. Do you see any MAC addresses? Why or why not?

```
SW1#show mac address-table dynamic
Mac Address Table
-------------------------------------------

Vlan Mac Address Type Ports
---- ----------- -------- -----

1 0001.9626.8970 DYNAMIC Fa0/24
1 000c.cf84.8418 DYNAMIC Fa0/24
1 0060.2fb3.9152 DYNAMIC Fa0/2
1 0090.2b82.ab01 DYNAMIC Fa0/1
1 00d0.9701.02a9 DYNAMIC Fa0/24
```

Devices in a real world network tend to be chatty and send traffic frequently, this causes the MAC address table to update (you may see less entries in Packet Tracer).

The switch will periodically flush old entries.

Examine a Routing Table

9) View the routing table on R1. What routes are present and why?

```
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, E - EGP
i - IS-IS, 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

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C 10.10.10.0/24 is directly connected, GigabitEthernet0/0
L 10.10.10.1/32 is directly connected, GigabitEthernet0/0
```

The router has a connected route for the 10.10.10.0/24 network and a local route for 10.10.10.1/32. These routes were automatically created when the IP address 10.10.10.1/24 was configured on interface GigabitEthernet0/0

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10) Configure IP address 10.10.20.1/24 on interface GigabitEthernet0/1

```
R1(config)#interface GigabitEthernet 0/1
R1(config-if)#ip address 10.10.20.1 255.255.255.0
R1(config-if)#no shutdown
```

11) What routes are in the routing table now?

```
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, E - EGP
i - IS-IS, 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

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C 10.10.10.0/24 is directly connected, GigabitEthernet0/0
L 10.10.10.1/32 is directly connected, GigabitEthernet0/0
C 10.10.20.0/24 is directly connected, GigabitEthernet0/1
L 10.10.20.1/32 is directly connected, GigabitEthernet0/1
```

The router has routes for both interfaces and can route traffic between hosts on the 10.10.10.0/24 and 10.10.20.0/24 networks.

12) Configure a static route to 10.10.30.0/24 with a next hop address of 10.10.10.2

```
R1(config)#ip route 10.10.30.0 255.255.255.0 10.10.10.2
```

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13) What routes are in the routing table now?

```
R1(config)#do 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, E - EGP
i - IS-IS, 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

Gateway of last resort is not set

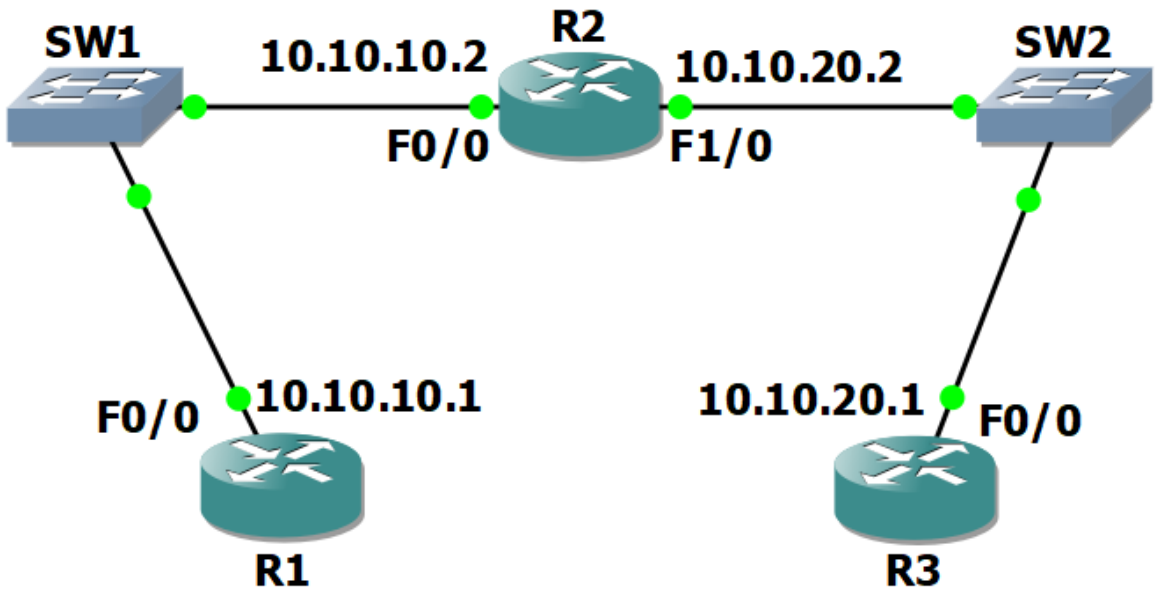
10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C 10.10.10.0/24 is directly connected, GigabitEthernet0/0
L 10.10.10.1/32 is directly connected, GigabitEthernet0/0
C 10.10.20.0/24 is directly connected, GigabitEthernet0/1
L 10.10.20.1/32 is directly connected, GigabitEthernet0/1
S 10.10.30.0/24 [1/0] via 10.10.10.2
```

The router has routes to its locally connected networks, and also to 10.10.30.0/24 which is available via 10.10.10.2

12 The Life of a Packet - Lab Exercise

This lab explores DNS configuration on Cisco routers and the ARP cache.

Lab Topology



Load the Startup Configurations

Download the '12 The Life of a Packet.gns3project' file here. Open in GNS3 to load the lab.

This configures the lab topology as shown above and adds static routes between R1 and R3.

You can learn the theory for this section and shortcut your path to CCNA certification by getting my CCNA Complete course. Get the course for only $10 USD (that's a massive 97% discount) with this link:

https://www.udemy.com/ccna-complete/?couponCode=DISCOUNTCEB

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Configure R3 as a DNS Server

1) Configure R3 as a DNS server for the flackbox.lab domain

2) Add host entries for R1, R2 and R3 using the IP addresses shown in the topology diagram. Use 10.10.10.2 as R2's IP address.

Configure R1 as a DNS Client

3) Configure R1 to use R3 as its DNS server.

4) Verify that you can ping R2 and R3 from R1 using their hostnames.

Examine the ARP Cache on the Routers

5) Do you expect to see an entry for R3 in the ARP cache of R1? Why or why not?

6) Verify the ARP cache on R1, R2 and R3.

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12 The Life of a Packet – Answer Key

This lab explores DNS configuration on Cisco routers and the ARP cache.

Configure R3 as a DNS Server

1) Configure R3 as a DNS server for the flackbox.lab domain

```
R3(config)#ip domain-lookup
R3(config)#ip name-server 10.10.20.1
R3(config)#ip domain-name flackbox.lab
R3(config)#ip dns server
```

2) Add host entries for R1, R2 and R3. Use 10.10.10.2 as R2's IP address.

```
R3(config)#ip host R1 10.10.10.1
R3(config)#ip host R2 10.10.10.2
R3(config)#ip host R3 10.10.20.1
R3(config)#ip host R1.flackbox.lab 10.10.10.1
R3(config)#ip host R2.flackbox.lab 10.10.10.2
R3(config)#ip host R3.flackbox.lab 10.10.20.1
```

Configure R1 as a DNS Client

3) Configure R1 to use R3 as its DNS server.

```
R1(config)#ip domain-lookup
R1(config)#ip name-server 10.10.20.1
R1(config)#ip domain-list flackbox.lab
```

4) Verify that you can ping R2 and R3 from R1 using their hostnames.

```
R1#ping R2
Translating "R2"...domain server (10.10.20.1) [OK]
```

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```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms

R1#ping R3
Translating "R3"...domain server (10.10.20.1) [OK]

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.20.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```

Examine the ARP Cache on the Routers

5) Do you expect to see an entry for R3 in the ARP cache of R1? Why or why not?

ARP requests use broadcast traffic so they are not forwarded by a router. R1 will have entries in its ARP cache for all hosts it has seen ***on its directly connected networks*** (10.10.10.0/24).

R1 is not directly connected to the 10.10.20.0/24 network so it will not have an entry in the ARP cache for R3 at 10.10.20.1.

R1 can reach R3 via R2's IP address 10.10.10.2 – this IP address is included in the ARP cache.

6) Verify the ARP cache on R1, R2 and R3.

```
R1#sh arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  10.10.10.2              1   c402.185c.0000  ARPA   FastEthernet0/0
Internet  10.10.10.1              -   c401.322c.0000  ARPA   FastEthernet0/0
```

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```
R2#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  10.10.10.2              -   c402.185c.0000  ARPA   FastEthernet0/0
Internet  10.10.10.1              1   c401.322c.0000  ARPA   FastEthernet0/0
Internet  10.10.20.1              1   c403.1f98.0000  ARPA   FastEthernet1/0
Internet  10.10.20.2              -   c402.185c.0010  ARPA   FastEthernet1/0

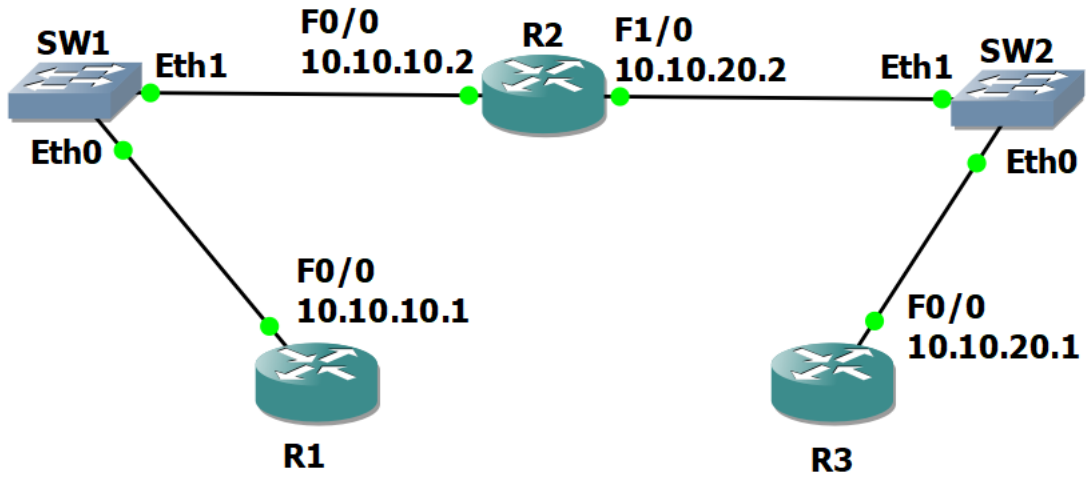
R3#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  10.10.20.1              -   c403.1f98.0000  ARPA   FastEthernet0/0
Internet  10.10.20.2              2   c402.185c.0010  ARPA   FastEthernet0/0
```

R2 is directly connected to 10.10.10.0/24 and 10.10.20.0/24 so it has entries in its ARP cache for both networks.

13 The Cisco Troubleshooting Methodology - Lab Exercise

This lab tests your network connectivity troubleshooting skills.

Lab Topology



Load the Startup Configurations

Download the '13 The Cisco Troubleshooting Methodology.gns3project' file here. Open in GNS3 to load the lab.

This configures the lab topology as shown above with R3 as a DNS server and adds static routes between R1 and R3.

Troubleshoot Connectivity to DNS Server

1) R3 has just been configured as a DNS server for the Flackbox.lab domain. Members of staff have complained that DNS is not working.

2) From R1, use Telnet to check if the DNS service appears operational on R3

3) When you have verified that DNS is not working, troubleshoot and fix the problem. Note that there may be more than one issue causing the problem.

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13 The Cisco Troubleshooting Methodology – Answer Key

This lab tests your network troubleshooting skills.

Troubleshoot Connectivity to DNS Server

1) R3 has just been configured as a server for the Flackbox.lab domain. Members of staff have complained that DNS is not working.

2) From R1, use Telnet to check if the DNS service appears operational on R3

```
R1#telnet 10.10.20.1 53
Trying 10.10.20.1, 53 ...
% Destination unreachable; gateway or host down
```

3) When you have verified that DNS is not working, troubleshoot and fix the problem. Note that there may be more than one issue causing the problem.

There is more than one way to troubleshoot the issue. A suggested workflow is shown below.

The first two questions to ask when troubleshooting a problem are:

1. Was it working before? If so, has something changed which could cause the problem? This will usually direct you to the cause.

This question is not particularly useful for our example as the DNS server has just been brought online for the first time.

2. Is the problem affecting everybody or just one particular user? If it's affecting just one user, the likelihood is that the problem is at their end.

In this case the problem is affecting all users, so the problem is likely on the server end or with the network.

The error message when we tried to Telnet was 'Destination unreachable', so it looks like a connectivity issue.

Ping from R1 to R3.

```
R1#ping 10.10.20.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.20.1, timeout is 2 seconds:
UUUUU
Success rate is 0 percent (0/5)
```

The ping fails at the network layer so there is little point in checking the DNS service at higher layers until we fix this problem.

Rather than checking connectivity hop by hop, we can possibly save a little time by using traceroute.

```
R1#traceroute 10.10.20.1

Type escape sequence to abort.
Tracing the route to 10.10.20.1

  1 10.10.10.2 64 msec 60 msec 60 msec
  2 10.10.10.2 !H  !H  !H
```

The traceroute got as far as R2, which lets us know that R1 has the correct route to get to R3, and the problem is probably between R2 and R3.

R2 has an interface connected to the 10.10.20.0/24 network, so we don't need to check it has a route to R3. We do need to check that the interface is up though.

```
R2#sh ip int brief
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            10.10.10.2      YES NVRAM  up                    up
FastEthernet0/1            unassigned      YES NVRAM  administratively down down
FastEthernet1/0            10.10.20.2      YES NVRAM  administratively down down
FastEthernet2/0            unassigned      YES NVRAM  administratively down down
FastEthernet3/0            unassigned      YES NVRAM  administratively down down
```

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There's the problem – FastEthernet1/0 facing R3 is administratively shutdown. Let's fix it.

```
R2(config)#interface f1/0
R2(config-if)#no shut
```

Next we'll try pinging from R1 to R3 again to verify we fixed connectivity.

```
R1#ping 10.10.20.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.20.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 1/1/1 ms
```

That looks better. Next we'll verify DNS is working.

```
R1#ping R3.flackbox.lab

Translating "R3.flackbox.lab"...domain server (10.10.10.1)
% Unrecognized host or address, or protocol not running.
```

The error message tells us the problem if we take the time to really read it – R1 is using 10.10.10.1 as its DNS server, but the correct address is 10.10.20.1.

We fix that next.

```
R1(config)#ip name-server 10.10.20.1
```

Then test again.

```
R1#ping R3.flackbox.lab

Translating "R3.flackbox.lab"...domain server (10.10.10.1)
(10.10.20.1)
% Unrecognized host or address, or protocol not running.
```

The error message helps us again. First, we forgot to remove the incorrect DNS server entry. Fix that first.

```
R1(config)#no ip name-server 10.10.10.1
```

We know we have connectivity and the DNS server configured correctly on R1, so the problem looks like it's on R3.

From R1, let's see if the DNS service is running on it.

```
R1#telnet 10.10.20.1 53
Trying 10.10.20.1, 53 ...
% Connection refused by remote host
```

It looks like DNS isn't running on R3. Let's check on R3.

```
R3#sh run | include dns
R3#
```

The DNS server command is missing. We fix that next.

```
R3(config)#ip dns server
```

And then check the rest of the DNS configuration.

```
R3#sh run
Building configuration...
ip domain name flackbox.lab
ip host R1 10.10.10.1
ip host R2 10.10.10.2
ip host R3 10.10.20.1
ip host R1.flackbox.lab 10.10.10.1
ip host R2.flackbox.lab 10.10.10.2
ip host R3.flackbox.lab 10.10.20.1
ip name-server 10.10.20.1
!
ip dns server
!
truncated
```

That looks better. Time to test it from R1 again. We try telnet to port 53 first.

```
R1#telnet 10.10.20.1 53
Trying 10.10.20.1, 53 ... Open

[Connection to 10.10.20.1 closed by foreign host]
```

'Open' shows that R3 is listening on port 53. The final check is to verify by pinging by FQDN.

```
R1#ping R3.flackbox.lab
Translating "R3.flackbox.lab"...domain server (10.10.20.1) [OK]

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.20.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
```

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That’s the problem solved.

To summarise the issues: port FastEthernet1/0 was shut down on R2, R1 was using the wrong IP address for the DNS server, and the DNS service was not running on R3.

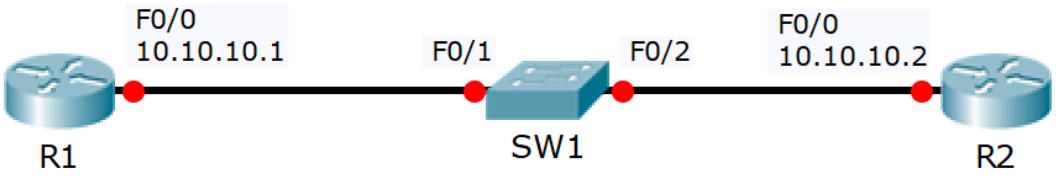
Problems in the real world are usually caused by just one error rather than three as in this case. This can still occur though, particularly when a new service is being deployed.

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14 Cisco Router and Switch Basics - Lab Exercise

In this lab you will complete a basic configuration on a switch, verify Cisco Discovery Protocol CDP and analyse the effects of interface speed and duplex configuration.

Lab Topology



Load the Startup Configurations

Download the '14 Cisco Router and Switch Basics.pkt' file here. Open in Packet Tracer to load the lab.

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Cisco Router and Switch Initial Configuration

1) Configure Router 1 with the hostname ‘R1’

2) Configure Router 2 with the hostname ‘R2’

3) Configure Switch 1 with the hostname ‘SW1’

4) Configure the IP address on R1 according to the topology diagram

5) Configure the IP address on R2 according to the topology diagram

6) Give SW1 the management IP address 10.10.10.10/24

7) The switch should have connectivity to other IP subnets via R2

8) Verify the switch can ping its default gateway

9) Enter suitable descriptions on the interfaces connecting the devices

10) On SW1, verify that speed and duplex are automatically negotiated to 100 Mbps full duplex on the link to R1

11) Manually configure full duplex and FastEthernet speed on the link to R2

12) What version of IOS is the switch running?

CDP Configuration

13) Verify the directly attached Cisco neighbors using Cisco Discovery Protocol

14) Prevent R1 from discovering information about Switch 1 via CDP

15) Flush the CDP cache on R1 by entering the ‘no cdp run’ then ‘cdp run’ commands in global configuration mode

16) Verify that R1 cannot see SW1 via CDP

Switch Troubleshooting

17) Verify the status of the switch port connected to R2 with the `show ip interface brief` command. It should show status and protocol up/up.

18) Shut down the interface connected to R2 and issue a `show ip interface brief` command again. The status and protocol should show administratively down/down.

19) Bring the interface up again. Verify the speed and duplex setting.

20) Set the duplex to half on Switch 1. Leave the settings as they are on R2.

21) Verify the state of the interface.

22) Set the duplex back to full duplex.

23) Set the speed to 10 Mbps.

24) Check if the interface is still operational.

25) Check if the interface is operational on R2. What is the status of the interface?

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14 Cisco Router and Switch Basics - Answer Key

In this lab you will complete a basic configuration on a switch, verify Cisco Discovery Protocol CDP and analyse the effects of interface speed and duplex configuration.

Cisco Router and Switch Initial Configuration

1) Configure Router 1 with the hostname ‘R1’

```
Router(config)#hostname R1
R1(config)#
```

2) Configure Router 2 with the hostname ‘R2’

```
Router(config)#hostname R2
R2(config)#
```

3) Configure Switch 1 with the hostname ‘SW1’

```
Switch(config)#hostname SW1
SW1(config)#
```

4) Configure the IP address on R1 according to the topology diagram

```
R1(config)#interface FastEthernet0/0
R1(config-if)#ip address 10.10.10.1 255.255.255.0
R1(config-if)#no shutdown
```

5) Configure the IP address on R2 according to the topology diagram

```
R2(config)#interface FastEthernet0/0
R2(config-if)#ip address 10.10.10.2 255.255.255.0
R1(config-if)#no shutdown
```

6) Give SW1 the management IP address 10.10.10.10/24

```
SW1(config)#interface vlan1
SW1(config-if)#ip address 10.10.10.10 255.255.255.0
R1(config-if)#no shutdown
```

7) The switch should have connectivity to other IP subnets via R2

```
SW1(config)#ip default-gateway 10.10.10.2
```

8) Verify the switch can ping its default gateway

```
SW1#ping 10.10.10.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.10.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/8 ms
```

9) Enter suitable descriptions on the interfaces connecting the devices

```
R1(config)#interface FastEthernet 0/0
R1(config-if)#description Link to SW1

R2(config-if)#interface FastEthernet 0/0
R2(config-if)#description Link to SW1

SW1(config)#interface FastEthernet 0/1
SW1(config-if)#description Link to R1
SW1(config-if)#interface FastEthernet 0/2
SW1(config-if)#description Link to R2
```

10) On SW1, verify that speed and duplex are automatically negotiated to 100 Mbps full duplex on the link to R1

```
SW1#show interface f0/1
FastEthernet0/1 is up, line protocol is up (connected)
Hardware is Lance, address is 00e0.8fd6.8901 (bia
00e0.8fd6.8901)
Description: Link to R2
BW 100000 Kbit, DLY 1000 usec,
reliability 255/255, txload 1/255, rxload 1/255
Encapsulation ARPA, loopback not set
Keepalive set (10 sec)
Full-duplex, 100Mb/s
```

11) Manually configure full duplex and FastEthernet speed on the link to R2

```
SW1(config)#interface FastEthernet 0/2
SW1(config-if)#speed 100
SW1(config-if)#duplex full
```

Don't forget to configure matching settings on R2!

```
R2(config)#interface FastEthernet 0/0
R2(config-if)#speed 100
R2(config-if)#duplex full
```

12) What version of IOS is the switch running?

```
SW1#show version
Cisco IOS Software, C2960 Software (C2960-LANBASE-M), Version
12.2(25)FX, RELEASE SOFTWARE (fc1)
```

CDP Configuration

13) Verify the directly attached Cisco neighbors using Cisco Discovery Protocol

```
SW1#show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone
Device ID Local Intrfce Holdtme Capability Platform Port ID
R1        Fas 0/1       170      R          C2800    Fas 0/0
R2        Fas 0/2       134      R          C2800    Fas 0/0
```

14) Prevent R1 from discovering information about Switch 1 via CDP

```
SW1(config)#interface FastEthernet 0/1
SW1(config-if)#no cdp enable
```

15) Flush the CDP cache on R1 by entering the 'no cdp run' then 'cdp run' commands in global configuration mode

```
R1(config)#no cdp run
R1(config)#cdp run
```

16) Verify that R1 cannot see SW1 via CDP

```
R1#show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone,
                  D - Remote, C - CVTA, M - Two-port Mac Relay

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
R1#
```

Switch Troubleshooting

17) Verify the status of the switch port connected to R2 with the `show ip interface brief` command. It should show status and protocol up/up.

```
SW1#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Vlan1                  10.10.10.10     YES manual up                    up
FastEthernet0/1        unassigned      YES unset  up                    up
FastEthernet0/2        unassigned      YES unset  up                    up
```

18) Shut down the interface connected to R2 and issue a `show ip interface brief` command again. The status and protocol should show administratively down/down.

```
SW1(config)#interface FastEthernet 0/2
SW1(config-if)#shutdown
*Mar  1 00:44:34.212: %LINK-5-CHANGED: Interface FastEthernet0/2,
changed state to administratively down
*Mar  1 00:44:35.219: %LINEPROTO-5-UPDOWN: Line protocol on
Interface FastEthernet0/2, changed state to down
```

```
SW1(config-if)#do show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Vlan1                  10.10.10.10     YES manual up                    up
FastEthernet0/1        unassigned      YES unset  up                    up
FastEthernet0/2        unassigned      YES unset  administratively down down
```

19) Bring the interface up again. Verify the speed and duplex setting.

```
SW1(config)#interface FastEthernet 0/2
SW1(config-if)#no shutdown
SW1(config-if)#
*Mar  1 00:45:52.637: %LINK-3-UPDOWN: Interface FastEthernet0/2,
changed state to up
*Mar  1 00:45:53.644: %LINEPROTO-5-UPDOWN: Line protocol on
Interface FastEthernet0/2, changed state to up
```

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```
SW1#sh interface f0/2
FastEthernet0/2 is up, line protocol is up (connected)
Hardware is Lance, address is 00e0.8fd6.8902 (bia
00e0.8fd6.8902)
BW 100000 Kbit, DLY 1000 usec,
reliability 255/255, txload 1/255, rxload 1/255
Encapsulation ARPA, loopback not set
Keepalive set (10 sec)
Full-duplex, 100Mb/s
```

20) Set the duplex to half on Switch 1. Leave the settings as they are on R2.

```
SW1(config-if)#duplex half
SW1(config-if)#
%LINK-5-CHANGED: Interface FastEthernet0/2, changed state to
down

    %LINEPROTO-5-UPDOWN: Line protocol on Interface
    FastEthernet0/2, changed state to down
```

21) Verify the state of the interface.

The interface is down/down. It will not forward traffic.

```
SW1#show ip interface brief
Interface      IP-Address OK? Method Status Protocol
FastEthernet0/1 unassigned YES manual up up
FastEthernet0/2 unassigned YES manual down down
```

22) Set the duplex back to full duplex.

```
SW1(config)#int f0/2
SW1(config-if)#duplex full
SW1(config-if)#
%LINK-5-CHANGED: Interface FastEthernet0/2, changed state to
up

%LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/2,
changed state to up
```

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23) Set the speed to 10 Mbps.

```
SW1(config)#int f0/2
SW1(config-if)#speed 10
SW1(config-if)#
%LINK-5-CHANGED: Interface FastEthernet0/2, changed state to
down

%LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/2,
changed state to down
```

24) Check if the interface is still operational.

```
SW1#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Vlan1                  10.10.10.10     YES manual up                    up
FastEthernet0/1        unassigned      YES unset  up                    up
FastEthernet0/2        unassigned      YES unset  down                  down
```

The interface status is down/down.

25) Check if the interface is operational on R2. What is the status of the interface?

```
R2#show ip interface brief
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            10.10.10.2      YES manual up                    down
```

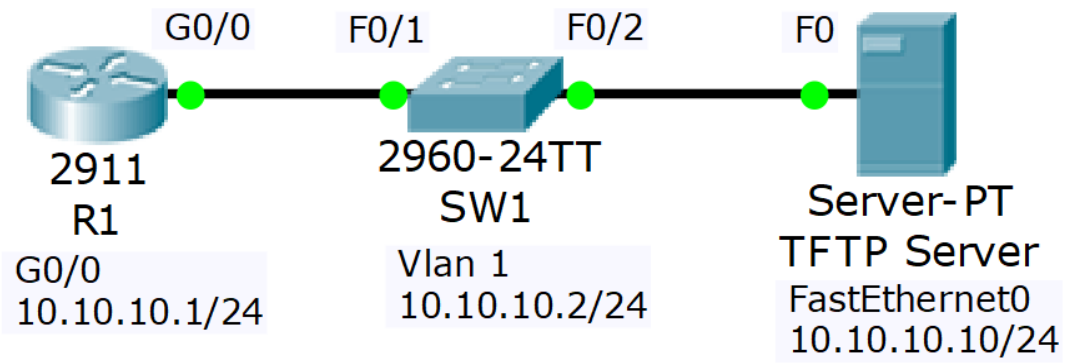
The interface status is up/down on R2.

15 Cisco Device Management - Lab Exercise

In this lab you will perform a factory reset, password recovery, configuration backup, and system image backup and recovery on a Cisco router. You will also perform an IOS upgrade on a Cisco switch.

Use Cisco Packet Tracer for this exercise. The generic server in Packet Tracer (as shown in the topology diagram below) has built-in TFTP server software.

Lab Topology



Load the Startup Configurations

Download the '15 Cisco Device Management.pkt' file here. Open in Packet Tracer to load the lab.

Factory Reset

1) View the running configuration on R1. Note that the hostname and interface have been configured

2) Factory reset R1 and reboot

3) Watch the boot up process as the router boots

4) The router should boot into the Setup Wizard. Exit out of the wizard and then confirm the startup and running configurations are empty.

5) Paste the configuration for R1 from the '15 Cisco Device Management.zip' file back into the configuration and save

Password Recovery

6) Set the enable secret 'Flackbox1' on R1

7) Configure the router to boot into the rommon prompt on next reload, and reboot the router. In a real world scenario you would enter the Break sequence on the keyboard when first powering up the router to access the rommon prompt

8) Configure the router to ignore the startup-config when booting up, and reload the router

9) The router should boot into the Setup Wizard. Exit out of the wizard

10) What do you expect to see if you view the running and startup configurations? Confirm this.

11) Copy the startup config to the running config. Do not miss this step or you will factory reset the router!

12) Remove the enable secret

13) Ensure the router will reboot normally on the next reload and you will be able to access the router

14) Reboot the router to confirm

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Configuration Backup

15) Backup the running configuration to Flash on R1. Use a suitable name for the backup file. Verify the configuration has been backed up.

16) Backup the R1 startup configuration to the TFTP server. Use a suitable name for the backup file. Verify the configuration has been backed up.

IOS System Image Backup and Recovery

17) Backup the IOS system image on R1 to the TFTP server. Verify the configuration has been backed up.

18) Delete the system image from Flash and reload.

19) Use Internet search to find system recovery instructions for your model of router. Recover the system image using the TFTP server.

20) If you are using the latest version of Packet Tracer the download will time out because the GigabitEthernet interface stays down in rommon mode. You have completed this part of the lab once you have entered the `tftpdnld` command.

IOS Image Upgrade

21) Verify SW1 is running C2960 Software (C2960-LANBASE-M), Version 12.2(25)FX

22) Use the TFTP server to upgrade to C2960-lanbasek9-mz.150-2.SE4.bin

23) Reboot and verify the switch is running the new software version

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15 Cisco Device Management - Answer Key

In this lab you will perform a factory reset, password recovery, configuration backup, and system image backup and recovery on a Cisco router. You will also perform an IOS upgrade on a Cisco switch.

Factory Reset

1) View the running configuration on R1. Note that the hostname and interface have been configured.

```
R1#sh run
Building configuration...

Current configuration : 696 bytes
!
hostname R1

!
interface GigabitEthernet0/0
ip address 10.10.10.1 255.255.255.0
duplex auto
speed auto
```

2) Factory reset R1 and reboot

```
R1#write erase
Erasing the nvram filesystem will remove all configuration
files! Continue? [confirm]
[OK]
Erase of nvram: complete
%SYS-7-NV_BLOCK_INIT: Initialized the geometry of nvram
R1#reload

Proceed with reload? [confirm]
```

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3) Watch the boot up process as the router boots

```
System Bootstrap, Version 15.1(4)M4, RELEASE SOFTWARE (fc1)

Readonly ROMMON initialized

IOS Image Load Test
_____________________
Digitally Signed Release Software

Self decompressing the image :
################################################################################
###### [OK]
```

4) The router should boot into the Setup Wizard. Exit out of the wizard and then confirm the startup and running configurations are empty.

```
--- System Configuration Dialog ---

Continue with configuration dialog? [yes/no]: no


Router>enable
Router#show run
Building configuration...
hostname Router
!

interface GigabitEthernet0/0
no ip address
duplex auto
speed auto
shutdown


Router#show start
startup-config is not present
```

5) Paste the configuration for R1 from the '15 Cisco Device Management.zip' file back into the configuration and save

```
Router#configure terminal
Router(config)#hostname R1
R1(config)#!
R1(config)#interface GigabitEthernet0/0
R1(config-if)# ip address 10.10.10.1 255.255.255.0
R1(config-if)# duplex auto
R1(config-if)# speed auto
R1(config-if)# no shutdown
R1(config-if)#!
R1(config-if)#line con 0
R1(config-line)# exec-timeout 30 0
R1(config-line)#end
R1#copy run start
Destination filename [startup-config]?
Building configuration...
[OK]
```

Password Recovery

6) Set the enable secret 'Flackbox1' on R1

```
R1(config)#enable secret Flackbox1
```

7) Configure the router to boot into the rommon prompt on next reload, and reboot the router. (In a real world scenario you would enter the Break sequence on the keyboard when first powering up the router to access the rommon prompt)

```
R1(config)#config-register 0x2120
R1(config)#end
Router#copy start run
R1#reload
Proceed with reload? [confirm]
```

8) Configure the router to ignore the startup-config when booting up, and reload the router

```
rommon 1 > confreg 0x2142
rommon 2 > reset
```

9) The router should boot into the Setup Wizard. Exit out of the wizard

```
--- System Configuration Dialog ---
Continue with configuration dialog? [yes/no]: no
```

10) What do you expect to see if you view the running and startup configurations? Confirm this.

The running configuration should be empty because the router bypassed loading the startup config on boot up. The startup config should remain unchanged and all previous configuration should still be there.

```
Router#sh run
Building configuration...

hostname Router

!

interface GigabitEthernet0/0
no ip address
duplex auto
speed auto


Router#sh start
!
hostname R1
!
enable secret 5 $1$mERr$J2XZHMOgpVVXdLjC9lYtE1
!
interface GigabitEthernet0/0
ip address 10.10.10.1 255.255.255.0
duplex auto
speed auto
```

11) Copy the startup config to the running config. Do not miss this step or you will factory reset the router!

```
Router#copy start run
Destination filename [running-config]?
```

12) Remove the enable secret

```
Router(config)#no enable secret
```

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13) Ensure the router will reboot normally on the next reload and you will be able to access the router

```
Router(config)#config-register 0x2102
Router(config)#end
Router#copy run start
Destination filename [startup-config]?
Building configuration...
[OK]
```

14) Reboot the router to confirm

```
Router#reload
Proceed with reload? [confirm]
```

```
R1>en
R1#sh run
Building configuration...
hostname R1
!
interface GigabitEthernet0/0
ip address 10.10.10.1 255.255.255.0
duplex auto
speed auto
```

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Configuration Backup

15) Backup the running configuration to Flash on R1. Use a suitable name for the backup file. Verify the configuration has been backed up.

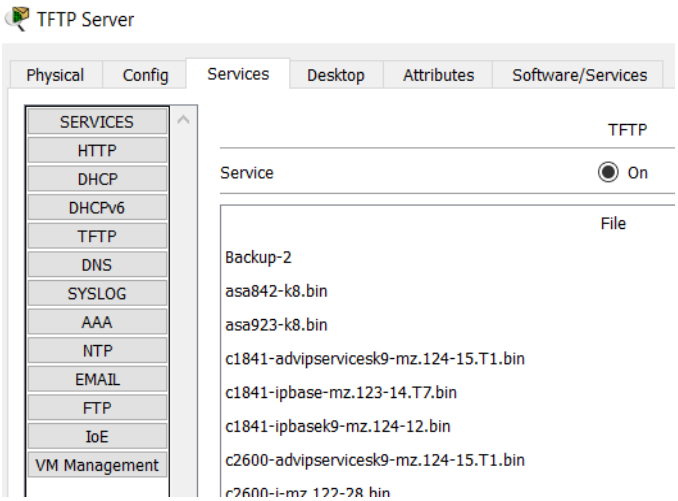
```
R1#copy run flash
Destination filename [running-config]? Backup-1
Building configuration...
[OK]


R1#show flash

System flash directory:
File Length Name/status
5 728 Backup-1
3 33591768 c2900-universalk9-mz.SPA.151-4.M4.bin
2 28282 sigdef-category.xml
1 227537 sigdef-default.xml
[33848315 bytes used, 221895685 available, 255744000 total]
249856K bytes of processor board System flash (Read/Write)
```

16) Backup the R1 startup configuration to the TFTP server. Use a suitable name for the backup file. Verify the configuration has been backed up.

```
R1#copy start tftp
Address or name of remote host []? 10.10.10.10
Destination filename [R1-confg]? Backup-2
Writing startup-config....!!
[OK - 728 bytes]
728 bytes copied in 3.007 secs (242 bytes/sec)
```



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IOS System Image Backup and Recovery

17) Backup the IOS system image on R1 to the TFTP server. Verify the configuration has been backed up.

```
R1#show flash

System flash directory:
File Length Name/status
5 728 Backup-1
3 33591768 c2900-universalk9-mz.SPA.151-4.M4.bin
2 28282 sigdef-category.xml
1 227537 sigdef-default.xml
[33848315 bytes used, 221895685 available, 255744000 total]
249856K bytes of processor board System flash (Read/Write)


R1#copy flash tftp
Source filename []? c2900-universalk9-mz.SPA.151-4.M4.bin
Address or name of remote host []? 10.10.10.10
Destination filename [c2900-universalk9-mz.SPA.151-4.M4.bin]?

Writing c2900-universalk9-mz.SPA.151-
4.M4.bin...!!!
```

18) Delete the system image from Flash and reload.

```
R1#delete flash:c2900-universalk9-mz.SPA.151-4.M4.bin
Delete filename [c2900-universalk9-mz.SPA.151-4.M4.bin]?
Delete flash:/c2900-universalk9-mz.SPA.151-4.M4.bin? [confirm]

R1#reload
Proceed with reload? [confirm]


Boot process failed...

The system is unable to boot automatically. The BOOT
environment variable needs to be set to a bootable
image.
rommon 1 >
```

19) Use Internet search to find system recovery instructions for your model of router. Recover the system image using the TFTP server.

http://www.cisco.com/c/en/us/td/docs/routers/access/1900/software/configuration/guide/Software_Configuration/appendixCrommon.html is the first hit when searching for 'Cisco 2900 rommon recovery'.

Go to the "Recovering the System Image (tftpdnld)" section.

```
rommon 1 > IP_ADDRESS=10.10.10.1
rommon 2 > IP_SUBNET_MASK=255.255.255.0
rommon 3 > DEFAULT_GATEWAY=10.10.10.1
rommon 4 > TFTP_SERVER=10.10.10.10
rommon 5 > TFTP_FILE=c2900-universalk9-mz.SPA.151-4.M4.bin
rommon 6 > TFTP_DESTINATION=flash:
rommon 7 > TFTP_TIMEOUT=120
rommon 8 > tftpdnld

IP_ADDRESS: 10.10.10.1
IP_SUBNET_MASK: 255.255.255.0
DEFAULT_GATEWAY: 10.10.10.1
TFTP_SERVER: 10.10.10.10
TFTP_FILE: c2900-universalk9-mz.SPA.151-4.M4.bin
Invoke this command for disaster recovery only.
WARNING: all existing data in all partitions on flash will be
lost!

Do you wish to continue? y/n: [n]: y


.....[TIMED OUT]
TFTP: Operation terminated.
```

20) If you are using the latest version of Packet Tracer the download will time out because the GigabitEthernet interface stays down in rommon mode. You have completed this part of the lab once you have entered the `tftpdnld` command.

This is as far as we can go with this part of the lab. You've seen how to recover the system image, the only thing left to do in a real world scenario after the download has completed is:

```
rommon 9 > reset
```

IOS Image Upgrade

21) Verify SW1 is running C2960 Software (C2960-LANBASE-M), Version 12.2(25)FX

```
SW1#sh version
Cisco IOS Software, C2960 Software (C2960-LANBASE-M), Version
12.2(25)FX
```

22) Use the TFTP server to upgrade to c2960-lanbasek9-mz.150-2.SE4.bin

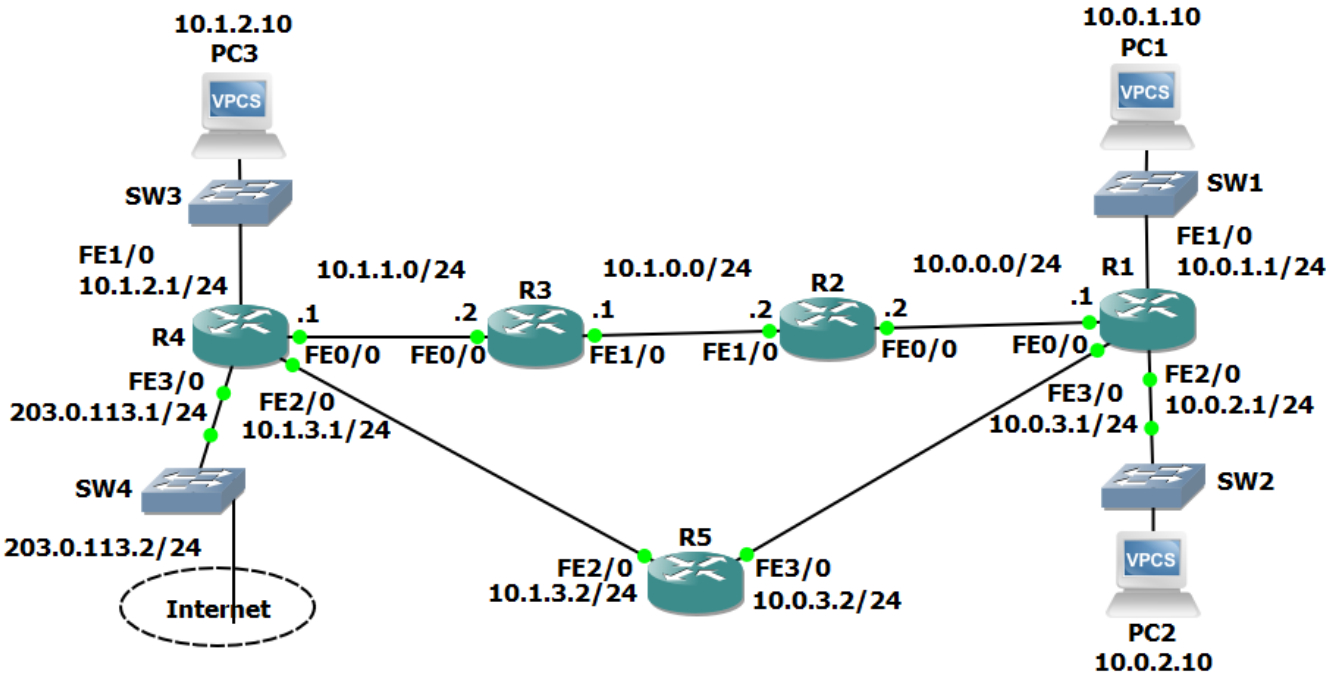
```
SW1#copy tftp flash
Address or name of remote host []? 10.10.10.10
Source filename []? c2960-lanbasek9-mz.150-2.SE4.bin
Destination filename [c2960-lanbasek9-mz.150-2.SE4.bin]?

Accessing tftp://10.10.10.10/c2960-lanbasek9-mz.150-
2.SE4.bin....
Loading c2960-lanbasek9-mz.150-2.SE4.bin from 10.10.10.10:
!!!
```

16 Routing Fundamentals - Lab Exercise

In this lab you will configure and verify connected, local, static, summary and default routes. You will also examine the effect of longest prefix match routing.

Lab Topology



Load the Startup Configurations

Download the '16 Routing Fundamentals.gns3project' file here. Open in GNS3 to load the lab.

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https://www.udemy.com/ccna-complete/?couponCode=DISCOUNTCEB

Connected and Local Routes

1) Configure the PCs with an IP address and default gateway according to the Lab Topology diagram

2) Configure IP addresses on R1 according to the Lab Topology diagram

3) Verify routes have been automatically added for the connected and local networks (note that local routes only appear from IOS 15)

4) Should you be able to ping from PC1 to PC2? Verify this.

5) Verify the traffic path from PC1 to PC2.

6) Should you be able to ping from PC1 to PC3? Verify this.

Static Routes

7) Configure IP addresses on R2, R3 and R4 according to the Lab Topology diagram. Do not configure the Internet FastEthernet 3/0 interface on R4. Do not configure R5.

8) Configure static routes on R1, R2, R3 and R4 to allow connectivity between all their subnets. Use /24 prefixes for each network.

9) Verify connectivity between PC1, PC2 and PC3.

10) Verify the path traffic takes from PC1 to PC3.

Summary Routes

11) Remove all the static routes on R1

12) Verify that PC1 loses connectivity to PC3

13) Restore connectivity to all subnets with a single command on R1.

14) Verify the routing table on R1 does not contain /24 routes to remote subnets.

15) Ensure that connectivity is restored between PC1 and PC3.

Longest Prefix Match

16) Configure IP addresses on R5 according to the Lab Topology diagram

17) Do not add any additional routes. Does PC1 have reachability to the FastEthernet 2/0 interface on R5? If so, which path will the traffic take?

18) Ensure reachability over the shortest possible path from R5 to all directly connected networks on R1. Achieve this with a single command.

19) Verify the path traffic takes from PC1 to the FastEthernet 2/0 interface on R5.

20) Verify the path the return traffic takes from R5 to PC1.

21) Ensure that traffic between PC1 and the FastEthernet 2/0 interface on R5 takes the most direct path in both directions.

22) Verify that traffic between PC1 and the FastEthernet 2/0 interface on R5 takes the most direct path in both directions.

Default Route and Load Balancing

23) Configure an IP address on the Internet FastEthernet 3/0 interface on R4 according to the lab topology diagram.

24) Ensure that all PCs have a route out to the internet through the Internet Service Provider connection on R4. (Note that the lab does not actually have Internet connectivity.)

25) Traffic between PC1 and the internet should be load balanced over R2 and R5.

16 Routing Fundamentals - Answer Key

In this lab you will configure and verify connected, local, static, summary and default routes. You will also examine the effect of longest prefix match routing.

Connected and Local Routes

1) Configure the PCs with an IP address and default gateway according to the Lab Topology diagram

```
PC1> ip 10.0.1.10 /24 10.0.1.1


PC2> ip 10.0.2.10 /24 10.0.2.1


PC3> ip 10.1.2.10 /24 10.1.2.1
```

2) Configure IP addresses on R1 according to the Lab Topology diagram

```
R1(config)#int f0/0
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#int f1/0
R1(config-if)#ip address 10.0.1.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#int f2/0
R1(config-if)#ip address 10.0.2.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#int f3/0
R1(config-if)#ip address 10.0.3.1 255.255.255.0
R1(config-if)#no shut
```

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3) Verify routes have been automatically added for the connected and local networks (note that local routes only appear from IOS 15)

```
R1#sh ip route
Codes: 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

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
```

4) Should you be able to ping from PC1 to PC2? Verify this.

Ping from PC1 to PC2 should be successful as both PCs are in networks which R1 is directly connected to.

```
PC1> ping 10.0.2.10
84 bytes from 10.0.2.10 icmp_seq=1 ttl=63 time=58.045 ms
```

5) Verify the traffic path from PC1 to PC2.

The ping went via R1 at 10.0.1.1

```
PC1> trace 10.0.2.10
trace to 10.0.2.10, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   19.013 ms  9.007 ms  9.007 ms
 2     *  *  *
 3   *10.0.2.10   14.009 ms (ICMP type:3, code:3, Destination port
unreachable)
```

6) Should you be able to ping from PC1 to PC3? Verify this.

Ping from PC1 to PC3 should fail as R1 does not have a route to the 10.1.2.0 network.

```
PC1> ping 10.1.2.10
*10.0.1.1 icmp_seq=1 ttl=255 time=20.013 ms (ICMP type:3, code:1,
Destination host unreachable)
```

Static Routes

7) Configure IP addresses on R2, R3 and R4 according to the Lab Topology diagram. Do not configure the Internet FastEthernet 3/0 interface on R4. Do not configure R5.

```
R2(config)#int f0/0
R2(config-if)#ip add 10.0.0.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#int f1/0
R2(config-if)#ip add 10.1.0.2 255.255.255.0
R2(config-if)#no shut
```

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```
R3(config)#int f1/0
R3(config-if)#ip add 10.1.0.1 255.255.255.0
R3(config-if)#no shut
R3(config-if)#int f0/0
R3(config-if)#ip add 10.1.1.2 255.255.255.0
R3(config-if)#no shut

R4(config)#int f0/0
R4(config-if)#ip add 10.1.1.1 255.255.255.0
R4(config-if)#no shut
R4(config-if)#int f1/0
R4(config-if)#ip add 10.1.2.1 255.255.255.0
R4(config-if)#no shut
R4(config-if)#int f2/0
R4(config-if)#ip add 10.1.3.1 255.255.255.0
R4(config-if)#no shut
```

8) Configure static routes on R1, R2, R3 and R4 to allow connectivity between all their subnets. Use /24 prefixes for each network.

```
R1(config)#ip route 10.1.0.0 255.255.255.0 10.0.0.2
R1(config)#ip route 10.1.1.0 255.255.255.0 10.0.0.2
R1(config)#ip route 10.1.2.0 255.255.255.0 10.0.0.2
R1(config)#ip route 10.1.3.0 255.255.255.0 10.0.0.2

R2(config)#ip route 10.0.1.0 255.255.255.0 10.0.0.1
R2(config)#ip route 10.0.2.0 255.255.255.0 10.0.0.1
R2(config)#ip route 10.0.3.0 255.255.255.0 10.0.0.1
R2(config)#ip route 10.1.1.0 255.255.255.0 10.1.0.1
R2(config)#ip route 10.1.2.0 255.255.255.0 10.1.0.1
R2(config)#ip route 10.1.3.0 255.255.255.0 10.1.0.1
```

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```
R3(config)#ip route 10.0.0.0 255.255.255.0 10.1.0.2
R3(config)#ip route 10.0.1.0 255.255.255.0 10.1.0.2
R3(config)#ip route 10.0.2.0 255.255.255.0 10.1.0.2
R3(config)#ip route 10.0.3.0 255.255.255.0 10.1.0.2
R3(config)#ip route 10.1.2.0 255.255.255.0 10.1.1.1
R3(config)#ip route 10.1.3.0 255.255.255.0 10.1.1.1

R4(config)#ip route 10.1.0.0 255.255.255.0 10.1.1.2
R4(config)#ip route 10.0.0.0 255.255.255.0 10.1.1.2
R4(config)#ip route 10.0.1.0 255.255.255.0 10.1.1.2
R4(config)#ip route 10.0.2.0 255.255.255.0 10.1.1.2
R4(config)#ip route 10.0.3.0 255.255.255.0 10.1.1.2
```

9) Verify connectivity between PC1, PC2 and PC3.

Ping PC2 and PC3 from PC1.

```
PC1> ping 10.0.2.10
84 bytes from 10.0.2.10 icmp_seq=1 ttl=63 time=25.018 ms

PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=60 time=114.081 ms
```

Ping PC3 from PC2.

```
PC2> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=60 time=77.868 ms
```

Ping verifies two way reachability so we have now verified full connectivity.

10) Verify the path traffic takes from PC1 to PC3.

```
PC1> trace 10.1.2.10
trace to 10.1.2.10, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   9.006 ms  8.007 ms  8.005 ms
 2   10.0.0.2   39.026 ms  30.026 ms  28.020 ms
 3   10.1.0.1   58.039 ms  48.537 ms  48.040 ms
 4   10.1.1.1   79.640 ms  69.557 ms  69.052 ms
 5     *  *  *
 6   *10.1.2.10   76.558 ms (ICMP type:3, code:3, Destination port
unreachable)
```

The traffic goes via the path R1 > R2 > R3 > R4

Note that IP return traffic (PC3 to PC1 in this case) does not necessarily have to come back along the same path, although it typically will.

Summary Routes

11) Remove all the static routes on R1

```
R1(config)#no ip route 10.1.0.0 255.255.255.0 10.0.0.2
R1(config)#no ip route 10.1.1.0 255.255.255.0 10.0.0.2
R1(config)#no ip route 10.1.2.0 255.255.255.0 10.0.0.2
R1(config)#no ip route 10.1.3.0 255.255.255.0 10.0.0.2
```

12) Verify that PC1 loses connectivity to PC3

```
PC1> ping 10.1.2.10
*10.0.1.1 icmp_seq=1 ttl=255 time=19.012 ms (ICMP type:3, code:1,
Destination host unreachable)
```

13) Restore connectivity to all subnets with a single command on R1.

A summary route to 10.1.0.0/16 will add all remote subnets with one command.

```
R1(config)#ip route 10.1.0.0 255.255.0.0 10.0.0.2
```

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14) Verify the routing table on R1 does not contain /24 routes to remote subnets.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [1/0] via 10.0.0.2
```

15) Ensure that connectivity is restored between PC1 and PC3.

```
PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=60 time=77.055 ms
```

Longest Prefix Match

16) Configure IP addresses on R5 according to the Lab Topology diagram

```
R5(config)#int f2/0
R5(config-if)#ip add 10.1.3.2 255.255.255.0
R5(config-if)#no shut
R5(config-if)#int f3/0
R5(config-if)#ip add 10.0.3.2 255.255.255.0
R5(config-if)#no shut
```

17) Do not add any additional routes. Does PC1 have reachability to the FastEthernet 2/0 interface on R5? If so, which path will the traffic take?

The summary route on R1 to 10.1.0.0/16 will provide a route to R5 over the path R1 > R2 > R3 > R4 > R5, but R5 does not have a route back to R1.

A ping from PC1 to 10.1.3.2 on R5 will fail.

```
PC1> ping 10.1.3.2
10.1.3.2 icmp_seq=1 timeout
```

Traceroute will show replies from R1 > R2 > R3 > R4 before failing.

```
PC1> trace 10.1.3.2
trace to 10.1.3.2, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   29.020 ms  9.004 ms  9.008 ms
 2   10.0.0.2   29.524 ms  19.123 ms  18.012 ms
 3   10.1.0.1   48.034 ms  39.157 ms  38.025 ms
 4   10.1.1.1   59.550 ms  48.029 ms  50.042 ms
 5     *  *  *
 6     *  *  *
 7     *  *  *
 8     *  *  *
```

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18) Ensure reachability over the shortest possible path from R5 to all directly connected networks on R1. Achieve this with a single command.

Add a summary route on R5 for all the directly connected networks on R1.

```
R5(config)#ip route 10.0.0.0 255.255.0.0 10.0.3.1
```

19) Verify the path traffic takes from PC1 to the FastEthernet 2/0 interface on R5.

```
PC1> trace 10.1.3.2
trace to 10.1.3.2, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   9.006 ms  9.007 ms  8.007 ms
 2   10.0.0.2   28.530 ms  28.017 ms  29.020 ms
 3   10.1.0.1   49.038 ms  49.033 ms  49.040 ms
 4   10.1.1.1   69.548 ms  69.565 ms  68.644 ms
 5   *10.1.3.2   60.047 ms (ICMP type:3, code:3, Destination port
unreachable)
```

Traffic takes the path R1 > R2 > R3 > R4 > R5

20) Verify the path the return traffic takes from R5 to PC1.

```
R5#traceroute 10.0.1.10
Type escape sequence to abort.
Tracing the route to 10.0.1.10
VRF info: (vrf in name/id, vrf out name/id)
  1 10.0.3.1 16 msec 20 msec 20 msec
  2 10.0.1.10 32 msec 28 msec 32 msec
```

Traffic takes the path R5 > R1. This shows that routers make independent decisions based on their routing table and it is possible (though not common) for return traffic to take an asynchronous path.

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21) Ensure that traffic between PC1 and the FastEthernet 2/0 interface on R5 takes the most direct path in both directions.

A route from R1 to the 10.1.3.0/24 network on R5 will achieve this.

```
R1(config)#ip route 10.1.3.0 255.255.255.0 10.0.3.2
```

Traffic to 10.1.3.0/24 will now match two routes in the routing table.

```
S        10.1.0.0/16 [1/0] via 10.0.0.2
S        10.1.3.0/24 [1/0] via 10.0.3.2
```

The new route has a longer prefix match so will be preferred.

22) Verify that traffic between PC1 and the FastEthernet 2/0 interface on R5 takes the most direct path in both directions.

```
PC1> ping 10.1.3.2
84 bytes from 10.1.3.2 icmp_seq=1 ttl=254 time=21.020 ms
84 bytes from 10.1.3.2 icmp_seq=2 ttl=254 time=28.131 ms
84 bytes from 10.1.3.2 icmp_seq=3 ttl=254 time=26.017 ms
84 bytes from 10.1.3.2 icmp_seq=4 ttl=254 time=28.018 ms
84 bytes from 10.1.3.2 icmp_seq=5 ttl=254 time=27.525 ms

PC1> trace 10.1.3.2
trace to 10.1.3.2, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   9.008 ms  10.009 ms  9.008 ms
 2   *10.0.3.2   28.019 ms (ICMP type:3, code:3, Destination port
unreachable)

R5#traceroute 10.0.1.10
Type escape sequence to abort.
Tracing the route to 10.0.1.10
VRF info: (vrf in name/id, vrf out name/id)
  1 10.0.3.1 20 msec 16 msec 20 msec
  2 10.0.1.10 32 msec 28 msec 32 msec
```

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Default Route and Load Balancing

23) Configure an IP address on the Internet FastEthernet 3/0 interface on R4 according to the lab topology diagram.

```
R4(config)#int f3/0
R4(config-if)#ip add 203.0.113.1 255.255.255.0
R4(config-if)#no shut
```

24) Ensure that all PCs have a route out to the internet through the Internet Service Provider connection on R4. (Note that the lab does not actually have Internet connectivity.)

```
R1(config)#ip route 0.0.0.0 0.0.0.0 10.0.0.2

R2(config)#ip route 0.0.0.0 0.0.0.0 10.1.0.1

R3(config)#ip route 0.0.0.0 0.0.0.0 10.1.1.1

R4(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2

R5(config)#ip route 0.0.0.0 0.0.0.0 10.1.3.1
```

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All routers should have a default route to the next hop IP on the path to the Internet.

```
R4#sh 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 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
S        10.0.0.0/24 [1/0] via 10.1.1.2
S        10.0.1.0/24 [1/0] via 10.1.1.2
S        10.0.2.0/24 [1/0] via 10.1.1.2
S        10.0.3.0/24 [1/0] via 10.1.1.2
S        10.1.0.0/24 [1/0] via 10.1.1.2
C        10.1.1.0/24 is directly connected, FastEthernet0/0
L        10.1.1.1/32 is directly connected, FastEthernet0/0
C        10.1.2.0/24 is directly connected, FastEthernet1/0
L        10.1.2.1/32 is directly connected, FastEthernet1/0
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.1/32 is directly connected, FastEthernet2/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/24 is directly connected, FastEthernet3/0
L        203.0.113.1/32 is directly connected, FastEthernet3/0
```

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25) Traffic from PC1 and PC2 going to the internet should be load balanced over R2 and R5.

Add an additional default route on R1 to send Internet traffic via R5.

```
R1(config)#ip route 0.0.0.0 0.0.0.0 10.0.3.2
```

The routing table will show that R1 will load balance traffic over both paths.

```
R1#sh 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 10.0.3.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.0.3.2
                [1/0] via 10.0.0.2
      10.0.0.0/8 is variably subnetted, 10 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [1/0] via 10.0.0.2
S        10.1.3.0/24 [1/0] via 10.0.3.2
```

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Add additional routes on R4 to load balance the return traffic to PC1 and PC2 from the Internet.

```
R4(config)#ip route 10.0.1.0 255.255.255.0 10.1.3.2
R4(config)#ip route 10.0.2.0 255.255.255.0 10.1.3.2
```

R4's routing table should show both paths back to 10.0.1.0/24 and 10.0.2.0/24

```
R4#sh 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 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
S        10.0.0.0/24 [1/0] via 10.1.1.2
S        10.0.1.0/24 [1/0] via 10.1.3.2
                     [1/0] via 10.1.1.2
S        10.0.2.0/24 [1/0] via 10.1.3.2
                     [1/0] via 10.1.1.2
S        10.0.3.0/24 [1/0] via 10.1.1.2
S        10.1.0.0/24 [1/0] via 10.1.1.2
C        10.1.1.0/24 is directly connected, FastEthernet0/0
L        10.1.1.1/32 is directly connected, FastEthernet0/0
C        10.1.2.0/24 is directly connected, FastEthernet1/0
L        10.1.2.1/32 is directly connected, FastEthernet1/0
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.1/32 is directly connected, FastEthernet2/0
```

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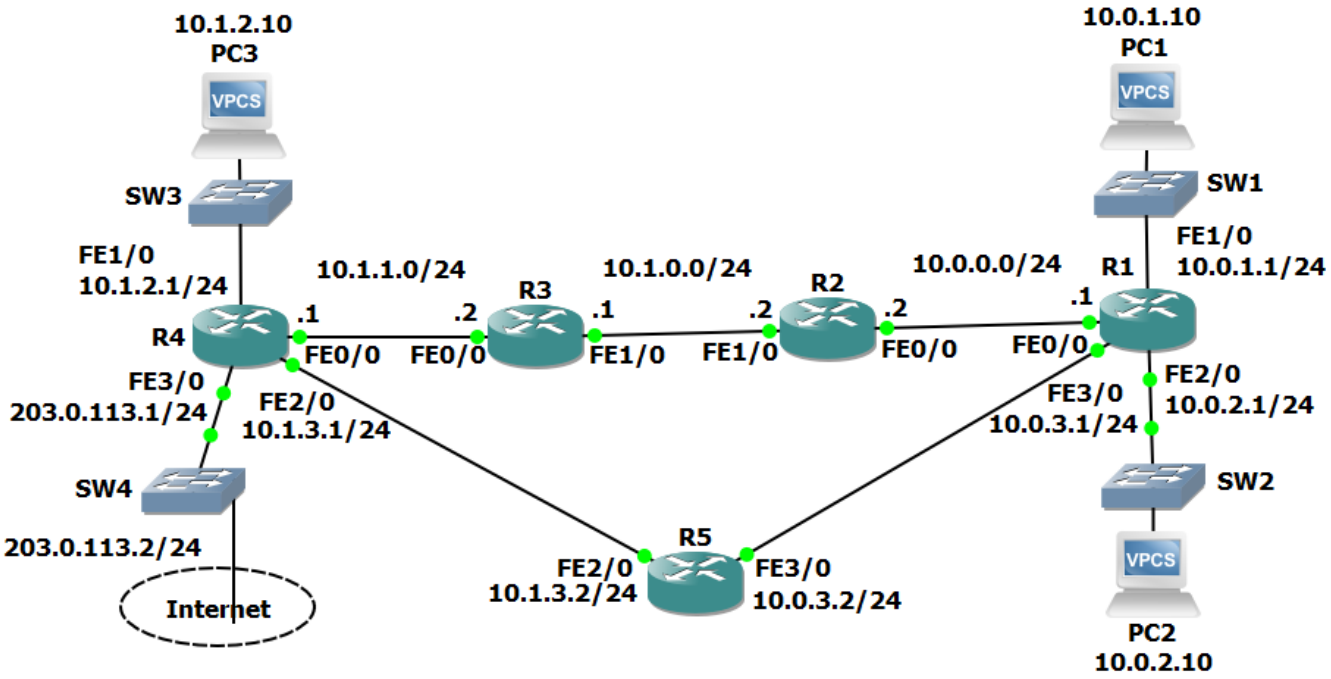
```
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/24 is directly connected, FastEthernet3/0
L        203.0.113.1/32 is directly connected, FastEthernet3/0
```

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17 Dynamic Routing Protocols – Lab Exercise

In this lab you will examine features which are common to all Interior Gateway Protocols. Basic configuration for various IGPs is included but is not the focus of this lab exercise. Configuration for each of the IGPs will be covered in detail later.

Lab Topology



Load the Startup Configurations

Download the '17 Dynamic Routing Protocols.gns3project' file here. Open in GNS3 to load the lab.

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Routing Protocol Updates

1) Enter the commands below on each router to provision a basic RIPv1 configuration and enable RIP on every interface.

```
router rip
network 10.0.0.0
no auto-summary
```

2) Debug the routing protocol updates on R1. Observe the updates being sent and received. What kind of traffic is used (unicast, broadcast or multicast)?

3) Enter the commands below to enable RIPv2 on every router.

```
router rip
version 2
```

4) What kind of traffic is used for the updates now?

5) Turn off all debugging on R1.

6) Check that RIP routes have been added to R1 and it has a route to every subnet in the lab.

7) Why are there two routes to the 10.1.1.0/24 network in the routing table?

Comparing Routing Protocols

8) View the RIP database on R1.

9) Enter the commands below on each router to provision a basic OSPF configuration and enable OSPF on every interface.

```
router ospf 1
network 10.0.0.0 0.255.255.255 area 0
```

10) Are RIP routes included in the routing table on R1? Why or why not?

11) Why is there now only one route to the 10.1.1.0/24 network?

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12) Disable interface FastEthernet 0/0 on R2. What do you expect to happen to R1's routing table?

13) Verify your expected changes to R1's routing table.

14) Aside from the next hop address, what else has changed on the routing table?

15) View the OSPF database on R1. What is different between it and the RIP database? Why?

Routing Protocol Metrics and Administrative Distance

16) Enter the command below to remove OSPF on every router

```
no router ospf 1
```

17) Will R1 still have connectivity to R4?

18) What is the metric to the 10.1.1.0/24 network on R1?

19) Why is there only one route on R1 to the 10.1.1.0/24 network now?

20) Make the required change so that there are two routes to the 10.1.1.0/24 network in the routing table on R1.

21) Enter the commands below on each router to provision a basic EIGRP configuration and enable EIGRP on every interface.

```
router eigrp 100
no auto-summary
network 10.0.0.0 0.255.255.255
```

22) What changes do you expect to see in the routing tables? Why?

23) Verify the changes to the routing table on R1.

24) What is the metric to the 10.1.1.0/24 network on R1?

25) Why is there only one route to the 10.1.1.0/24 network on R1?

26) Disable RIP and EIGRP on R5 with the commands below.

```
R5(config)#no router rip
R5(config)#no router eigrp 100
```

27) Configure the network so that there is still connectivity between all subnets if the link between R1 and R2 goes down. Accomplish this with six commands. Do not enable EIGRP on R5 but note that the routing protocol is expected to be enabled there in the future.

28) What changes do you expect to see to the routing table on R1?

29) Verify the changes to the routing table on R1.

30) Verify that traffic from PC1 to PC3 still goes via R2.

31) Shut down interface FastEthernet 0/0 on R2.

32) What changes do you expect to see on R1's routing table?

33) Verify the changes to the routing table on R1.

34) Verify connectivity between PC1 and PC3.

35) Verify the traffic goes via R5.

36) Bring interface FastEthernet 0/0 on R2 back up.

37) Enter the commands below on R5 to provision a basic EIGRP configuration and enable EIGRP on every interface.

```
R5(config)#router eigrp 100
R5(config-router)#no auto-summary
R5(config-router)#network 10.0.0.0 0.255.255.255
```

Loopback Interfaces

38) Configure loopback interface 0 on each router. Assign the IP address 192.168.0.x/32, where 'x' is the router number (for example 192.168.0.3/32 on R3.)

39) Is there connectivity to the loopback interfaces from the PCs? Why or why not?

40) Enter the commands below on each router to include the loopback interfaces in EIGRP.

```
R1(config)#router eigrp 100
R1(config-router)#network 192.168.0.0 0.0.0.255
```

41) Verify the loopback interfaces are in the routing table on R1.

42) Verify connectivity from PC1 to the loopback interface on R5.

Adjacencies and Passive Interfaces

43) Enter the command below to verify that R1 has established EIGRP adjacencies with R2 and R5.

```
R1#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   10.0.3.2                Fa3/0                    14 00:17:21   33   198  0  16
0   10.0.0.2                Fa0/0                    11 00:19:21   36   216  0  32
```

44) Verify that traffic from R5 to the directly connected interfaces on R1 goes via the FastEthernet 3/0 interface.

45) Enter the commands below to configure the loopback interface and the link to R5 as passive interfaces on R1.

```
R1(config-if)#router eigrp 100
R1(config-router)#passive-interface loopback0
R1(config-router)#passive-interface fastethernet3/0
```

46) What changes do you expect to see in the routing table on R5 and why?

47) Verify the expected changes to the routing table on R5.

17 Dynamic Routing Protocols - Answer Key

In this lab you will examine features which are common to all Interior Gateway Protocols. Basic configuration for various IGPs is included but is not the focus of this lab exercise. Configuration for each of the IGPs will be covered in detail later.

Routing Protocol Updates

1) Enter the commands below on each router to provision a basic RIPv1 configuration and enable RIP on every interface.

```
router rip
network 10.0.0.0
no auto-summary
```

2) Debug the routing protocol updates on R1. Observe the updates being sent and received. What kind of traffic is used (unicast, broadcast or multicast)?

The updates are being sent on the broadcast address 255.255.255.255. All hosts on the subnet must process the packets.

```
R1#debug ip rip
RIP protocol debugging is on
R1#
*Jul  4 03:43:55.455: RIP: sending v1 update to 255.255.255.255 via
FastEthernet3/0 (10.0.3.1)
```

3) Enter the commands below to enable RIPv2 on every router.

```
router rip
version 2
```

4) What kind of traffic is used for the updates now?

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The updates are being sent on the RIPv2 multicast address 224.0.0.9. Only RIPv2 routers will process the packets beyond layer 3.

```
*Jul  4 03:48:09.175: RIP: sending v2 update to 224.0.0.9 via
FastEthernet3/0 (10.0.3.1)
```

5) Turn off all debugging on R1.

```
R1#undebug all
All possible debugging has been turned off
```

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6) Check that RIP routes have been added to R1 and it has a route to every subnet in the lab.

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/24 [120/1] via 10.0.0.2, 00:00:22, FastEthernet0/0
R        10.1.1.0/24 [120/2] via 10.0.3.2, 00:00:06, FastEthernet3/0
                     [120/2] via 10.0.0.2, 00:00:22, FastEthernet0/0
R        10.1.2.0/24 [120/2] via 10.0.3.2, 00:00:06, FastEthernet3/0
R        10.1.3.0/24 [120/1] via 10.0.3.2, 00:00:06, FastEthernet3/0
```

7) Why are there two routes to the 10.1.1.0/24 network in the routing table?

Two paths to 10.1.1.0/24 have an equal metric – a hop count of 2. Both routes are installed in the routing table and the router will perform Equal Cost Load Balancing between the next hops of 10.0.3.2 and 10.0.0.2.

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Comparing Routing Protocols

8) View the RIP database on R1.

```
R1#show ip rip database
10.0.0.0/8    auto-summary
10.0.0.0/24    directly connected, FastEthernet0/0
10.0.1.0/24    directly connected, FastEthernet1/0
10.0.2.0/24    directly connected, FastEthernet2/0
10.0.3.0/24    directly connected, FastEthernet3/0
10.1.0.0/24
    [1] via 10.0.0.2, 00:00:01, FastEthernet0/0
10.1.1.0/24
    [2] via 10.0.3.2, 00:00:15, FastEthernet3/0
    [2] via 10.0.0.2, 00:00:01, FastEthernet0/0
10.1.2.0/24
    [2] via 10.0.3.2, 00:00:15, FastEthernet3/0
10.1.3.0/24
    [1] via 10.0.3.2, 00:00:15, FastEthernet3/0
```

9) Enter the commands below on each router to provision a basic OSPF configuration and enable OSPF on every interface.

```
router ospf 1
network 10.0.0.0 0.255.255.255 area 0
```

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10) Are RIP routes included in the routing table on R1? Why or why not?

The RIP routes are replaced by OSPF because its Administrative Distance of 110 is preferred to RIP's AD of 120.

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2] via 10.0.0.2, 00:00:41, FastEthernet0/0
O        10.1.1.0/24 [110/3] via 10.0.0.2, 00:00:31, FastEthernet0/0
O        10.1.2.0/24 [110/4] via 10.0.0.2, 00:00:31, FastEthernet0/0
O        10.1.3.0/24 [110/13] via 10.0.0.2, 00:00:31, FastEthernet0/0
```

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11) Why is there now only one route to the 10.1.1.0/24 network?

OSPF uses cost as its metric which takes into account interface bandwidth. The interfaces on R5 have a configured bandwidth of 10Mbps. The interfaces along the top path of the network topology all have the default FastEthernet bandwidth of 100Mbps so this route is preferred. All traffic will go via the next hop 10.0.0.2.

```
R5#show run interface f3/0
!
interface FastEthernet3/0
 bandwidth 10000
 ip address 10.0.3.2 255.255.255.0
 duplex full
end
```

12) Disable interface FastEthernet 0/0 on R2. What do you expect to happen to R1's routing table?

OSPF will reconverge. The routes to the 10.1.0.0 networks via R2 will be removed from the routing table and replaced with routes via R5.

```
R2(config)#interface fastEthernet 0/0
R2(config-if)#shutdown
```

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13) Verify your expected changes to R1's routing table.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/22] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.1.0/24 [110/21] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.2.0/24 [110/21] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.3.0/24 [110/20] via 10.0.3.2, 00:00:27, FastEthernet3/0
```

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14) Aside from the next hop address, what else has changed on the routing table?

The new routes have a higher metric. This is why they were not in the routing table when the path via R2 was up.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/22] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.1.0/24 [110/21] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.2.0/24 [110/21] via 10.0.3.2, 00:00:27, FastEthernet3/0
O        10.1.3.0/24 [110/20] via 10.0.3.2, 00:00:27, FastEthernet3/0
```

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15) View the OSPF database on R1. What is different between it and the RIP database? Why?

RIP is a Distance Vector routing protocol so it only knows its directly connected neighbors and the lists of networks those neighbors have advertised.

OSPF is a Link State routing protocol so it knows the state of every link on every router in its area.

```
R1#show ip ospf database

            OSPF Router with ID (10.0.3.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.3.1        10.0.3.1        577         0x80000004 0x009EFB 4
10.1.0.2        10.1.0.2        614         0x80000003 0x00C538 1
10.1.1.2        10.1.1.2        1820        0x80000003 0x00626F 2
10.1.3.2        10.1.3.2        1046        0x80000003 0x00882A 2
203.0.113.1     203.0.113.1     1815        0x80000003 0x00AA9A 3

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.3.1        10.0.3.1        1856        0x80000001 0x00A55A
10.1.0.1        10.1.1.2        1825        0x80000001 0x009371
10.1.1.1        203.0.113.1     1822        0x80000001 0x00EEB3
10.1.3.1        203.0.113.1     1816        0x80000001 0x00F2AB
```

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Routing Protocol Metrics and Administrative Distance

16) Enter the command below to remove OSPF on every router

```
no router ospf 1
```

17) Will R1 still have connectivity to R4?

Yes. RIP is still running so RIP routes will replace the removed OSPF routes in the routing table.

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/24 [120/3] via 10.0.3.2, 00:00:07, FastEthernet3/0
R        10.1.1.0/24 [120/2] via 10.0.3.2, 00:00:07, FastEthernet3/0
R        10.1.2.0/24 [120/2] via 10.0.3.2, 00:00:07, FastEthernet3/0
R        10.1.3.0/24 [120/1] via 10.0.3.2, 00:00:07, FastEthernet3/0
```

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18) What is the metric to the 10.1.1.0/24 network on R1?

A hop count of 2.

19) Why is there only one route on R1 to the 10.1.1.0/24 network now?

Interface FastEthernet 0/0 on R2 is still shut down so no routes go through it.

20) Make the required change so that there are two routes to the 10.1.1.0/24 network in the routing table on R1.

```
R2(config)#interface f0/0
R2(config-if)#no shut
```

21) Enter the commands below on each router to provision a basic EIGRP configuration and enable EIGRP on every interface.

```
router eigrp 100
no auto-summary
network 10.0.0.0 0.255.255.255
```

22) What changes do you expect to see in the routing tables? Why?

The RIP routes will be replaced by EIGRP because its Administrative Distance of 90 is preferred to RIP's AD of 120.

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23) Verify the changes to the routing table on R1.

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:03:44, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:03:33, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:03:33, FastEthernet0/0
D        10.1.3.0/24 [90/261120] via 10.0.3.2, 00:03:33, FastEthernet3/0
```

24) What is the metric to the 10.1.1.0/24 network on R1?

A composite metric of 33280.

25) Why is there only one route to the 10.1.1.0/24 network on R1?

EIGRP uses a composite metric which takes into account interface bandwidth and delay. The interfaces on R5 have a configured bandwidth of 10Mbps. The interfaces along the top path of the network topology all have the default FastEthernet bandwidth of 100Mbps so this route is preferred. All traffic will go via the next hop 10.0.0.2.

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26) Disable RIP and EIGRP on R5 with the commands below.

```
R5(config)#no router rip
R5(config)#no router eigrp 100
```

27) Configure the network so that there is still connectivity between all subnets if the link between R1 and R2 goes down. Accomplish this with six commands. Do not enable EIGRP on R5 but note that the routing protocol is expected to be enabled there in the future.

Floating static routes need to be added as a backup to the EIGRP routes. These routes would normally be preferred to the route learned via EIGRP because static routes have a better Administrative Distance of 1 by default. Set the AD to be higher than EIGRP's AD of 90.

```
R1(config)#ip route 10.1.0.0 255.255.0.0 10.0.3.2 95

R2(config)#ip route 10.0.0.0 255.255.0.0 10.1.0.1 95

R3(config)#ip route 10.0.0.0 255.255.0.0 10.1.1.1 95

R4(config)#ip route 10.0.0.0 255.255.0.0 10.1.3.2 95

R5(config)#ip route 10.0.0.0 255.255.0.0 10.0.3.1 95
R5(config)#ip route 10.1.0.0 255.255.0.0 10.1.3.1 95
```

R5 is not running EIGRP so it is not currently necessary to set the Administrative Distance for its routes to 95. It is required to prevent the floating static routes from being preferred when EIGRP is enabled in the future however.

Summary routes need to be used to accomplish the task in six commands.

28) What changes do you expect to see to the routing table on R1?

The summary route will be added to the routing table but not used because it has a prefix length of /16, compared to the EIGRP routes which have a longer prefix length of /24.

If individual floating static routes had been added for each of the /24 destination networks then these would not have appeared in the routing table (unless a link went down) because EIGRP has a better Administrative Distance.

29) Verify the changes to the routing table on R1.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 13 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.0.3.2
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:35:41, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:35:30, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:35:30, FastEthernet0/0
D        10.1.3.0/24 [90/266240] via 10.0.0.2, 00:25:14, FastEthernet0/0
```

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30) Verify that traffic from PC1 to PC3 still goes via R2.

```
PC1> trace 10.1.2.10
trace to 10.1.2.10, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   29.169 ms  8.005 ms  9.006 ms
 2   10.0.0.2   28.020 ms  29.526 ms  28.522 ms
 3   10.1.0.1   49.034 ms  49.043 ms  49.030 ms
 4   10.1.1.1   80.063 ms  80.057 ms  68.046 ms
 5   *10.1.2.10   110.046 ms (ICMP type:3, code:3, Destination port
unreachable)
```

31) Shut down interface FastEthernet 0/0 on R2.

```
R2(config)#interface f0/0
R2(config-if)#shutdown
```

32) What changes do you expect to see on R1's routing table?

The EIGRP routes will be removed.

33) Verify the changes to the routing table on R1.

```
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

      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.0.3.2
```

34) Verify connectivity between PC1 and PC3.

```
PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=61 time=56.766 ms
84 bytes from 10.1.2.10 icmp_seq=2 ttl=61 time=54.036 ms
84 bytes from 10.1.2.10 icmp_seq=3 ttl=61 time=56.171 ms
84 bytes from 10.1.2.10 icmp_seq=4 ttl=61 time=57.038 ms
84 bytes from 10.1.2.10 icmp_seq=5 ttl=61 time=59.176 ms
```

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35) Verify the traffic goes via R5.

```
PC1> trace 10.1.2.10
trace to 10.1.2.10, 8 hops max, press Ctrl+C to stop
 1   10.0.1.1   9.005 ms  9.005 ms  9.008 ms
 2   10.0.3.2   28.018 ms  28.530 ms  29.184 ms
 3   10.1.3.1   49.033 ms  50.161 ms  49.036 ms
 4   *10.1.2.10   59.220 ms (ICMP type:3, code:3, Destination port
unreachable)
```

36) Bring interface FastEthernet 0/0 on R2 back up.

```
R2(config)#interface f0/0
R2(config-if)#no shutdown
```

37) Enter the commands below on R5 to provision a basic EIGRP configuration and enable EIGRP on every interface.

```
R5(config)#router eigrp 100
R5(config-router)#no auto-summary
R5(config-router)#network 10.0.0.0 0.255.255.255
```

Loopback Interfaces

38) Configure loopback interface 0 on each router. Assign the IP address 192.168.0.x/32, where 'x' is the router number (for example 192.168.0.3/32 on R3.)

```
R1(config)#interface loopback0
R1(config-if)#ip address 192.168.0.1 255.255.255.255

R2(config)#interface loopback0
R2(config-if)#ip address 192.168.0.2 255.255.255.255

R3(config)#interface loopback0
R3(config-if)#ip address 192.168.0.3 255.255.255.255
```

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```
R4(config)#interface loopback0
R4(config-if)#ip address 192.168.0.4 255.255.255.255

R5(config)#interface loopback0
R5(config-if)#ip address 192.168.0.5 255.255.255.255
```

39) Is there connectivity to the loopback interfaces from the PCs? Why or why not?

There is no connectivity from the PCs to the loopback interfaces because they are not in the routing tables of the routers (apart from the local loopback interface on each router). The loopback interfaces are not in the routing tables because they are in the 192.168.0.0/24 range which has not been included in the routing protocol.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 13 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.0.3.2
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:05:10, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:03:12, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:03:12, FastEthernet0/0
```

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```
D        10.1.3.0/24 [90/261120] via 10.0.3.2, 00:03:12, FastEthernet3/0
      192.168.0.0/32 is subnetted, 1 subnets
C        192.168.0.1 is directly connected, Loopback0
```

40) Enter the commands below on each router to include the loopback interfaces in EIGRP.

```
R1(config)#router eigrp 100
R1(config-router)#network 192.168.0.0 0.0.0.255
```

41) Verify the loopback interfaces are in the routing table on R1.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 13 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.0.3.2
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:11:46, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:09:48, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:09:48, FastEthernet0/0
D        10.1.3.0/24 [90/261120] via 10.0.3.2, 00:09:48, FastEthernet3/0
```

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```
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
D        192.168.0.2 [90/156160] via 10.0.0.2, 00:00:17, FastEthernet0/0
D        192.168.0.3 [90/158720] via 10.0.0.2, 00:00:12, FastEthernet0/0
D        192.168.0.4 [90/161280] via 10.0.0.2, 00:00:09, FastEthernet0/0
D        192.168.0.5 [90/386560] via 10.0.3.2, 00:00:05, FastEthernet3/0
```

42) Verify connectivity from PC1 to the loopback interface on R5.

```
PC1> ping 192.168.0.5
84 bytes from 192.168.0.5 icmp_seq=1 ttl=254 time=25.015 ms
84 bytes from 192.168.0.5 icmp_seq=2 ttl=254 time=24.032 ms
84 bytes from 192.168.0.5 icmp_seq=3 ttl=254 time=28.027 ms
84 bytes from 192.168.0.5 icmp_seq=4 ttl=254 time=29.023 ms
84 bytes from 192.168.0.5 icmp_seq=5 ttl=254 time=27.019 ms
```

Adjacencies and Passive Interfaces

43) Enter the command below to verify that R1 has established EIGRP adjacencies with R2 and R5.

```
R1#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   10.0.3.2                Fa3/0                    14 00:17:21   33   198  0  16
0   10.0.0.2                Fa0/0                    11 00:19:21   36   216  0  32
```

44) Verify that traffic from R5 to the directly connected interfaces on R1 goes via the FastEthernet 3/0 interface.

```
R5#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

      10.0.0.0/8 is variably subnetted, 12 subnets, 3 masks
S        10.0.0.0/16 [95/0] via 10.0.3.1
D        10.0.0.0/24 [90/261120] via 10.0.3.1, 00:23:01, FastEthernet3/0
D        10.0.1.0/24 [90/261120] via 10.0.3.1, 00:23:01, FastEthernet3/0
D        10.0.2.0/24 [90/261120] via 10.0.3.1, 00:23:01, FastEthernet3/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.2/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.1.3.1
D        10.1.0.0/24 [90/263680] via 10.1.3.1, 00:23:01, FastEthernet2/0
                     [90/263680] via 10.0.3.1, 00:23:01, FastEthernet3/0
D        10.1.1.0/24 [90/261120] via 10.1.3.1, 00:23:01, FastEthernet2/0
D        10.1.2.0/24 [90/261120] via 10.1.3.1, 00:23:01, FastEthernet2/0
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.2/32 is directly connected, FastEthernet2/0
      192.168.0.0/32 is subnetted, 5 subnets
D        192.168.0.1 [90/386560] via 10.0.3.1, 00:15:05, FastEthernet3/0
D        192.168.0.2 [90/389120] via 10.0.3.1, 00:13:29, FastEthernet3/0
D        192.168.0.3 [90/389120] via 10.1.3.1, 00:13:25, FastEthernet2/0
D        192.168.0.4 [90/386560] via 10.1.3.1, 00:13:22, FastEthernet2/0
C        192.168.0.5 is directly connected, Loopback0
```

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45) Enter the commands below to configure the loopback interface and the link to R5 as passive interfaces on R1.

```
R1(config-if)#router eigrp 100
R1(config-router)#passive-interface loopback0
R1(config-router)#passive-interface fastethernet3/0
```

46) What changes do you expect to see in the routing table on R5 and why?

The EIGRP adjacency between R1 and R5 will go down. All EIGRP routes via R1 will be removed from the routing table and replaced with routes via R4.

Configuring the loopback interface as a passive interface on R1 does not affect any routing tables but is a best practice.

47) Verify the expected changes to the routing table on R5.

```
R5#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

      10.0.0.0/8 is variably subnetted, 12 subnets, 3 masks
S        10.0.0.0/16 [95/0] via 10.0.3.1
D        10.0.0.0/24 [90/266240] via 10.1.3.1, 00:04:24, FastEthernet2/0
D        10.0.1.0/24 [90/268800] via 10.1.3.1, 00:04:24, FastEthernet2/0
D        10.0.2.0/24 [90/268800] via 10.1.3.1, 00:04:24, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.2/32 is directly connected, FastEthernet3/0
S        10.1.0.0/16 [95/0] via 10.1.3.1
D        10.1.0.0/24 [90/263680] via 10.1.3.1, 00:04:24, FastEthernet2/0
D        10.1.1.0/24 [90/261120] via 10.1.3.1, 00:33:20, FastEthernet2/0
D        10.1.2.0/24 [90/261120] via 10.1.3.1, 00:33:20, FastEthernet2/0
```

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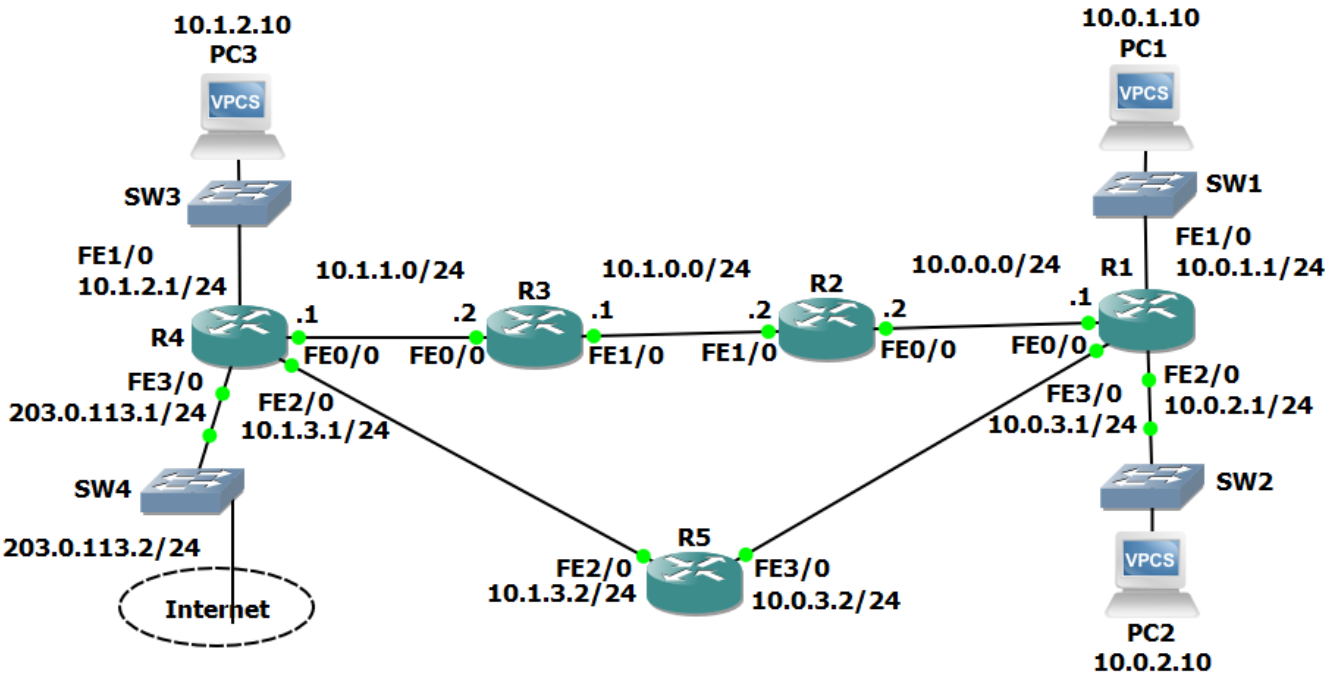
```
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.2/32 is directly connected, FastEthernet2/0
      192.168.0.0/32 is subnetted, 5 subnets
D        192.168.0.1 [90/394240] via 10.1.3.1, 00:04:24, FastEthernet2/0
D        192.168.0.2 [90/391680] via 10.1.3.1, 00:04:24, FastEthernet2/0
D        192.168.0.3 [90/389120] via 10.1.3.1, 00:23:44, FastEthernet2/0
D        192.168.0.4 [90/386560] via 10.1.3.1, 00:23:41, FastEthernet2/0
C        192.168.0.5 is directly connected, Loopback0
```

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18 Connectivity Troubleshooting – Lab Exercise

In this lab you will troubleshoot a connectivity issue and configure IP SLA.

Lab Topology



Load the Startup Configurations

Download the '18 Connectivity Troubleshooting.gns3project' file here. Open in GNS3 to load the lab.

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Troubleshoot Connectivity

1) Use ping to test connectivity from PC1 to PC3.

2) Use traceroute to determine where the problem is likely to be.

3) Determine the issue and fix it to restore connectivity between PC1 and PC3.

IP SLA Configuration

4) Configure IP SLA on R1 to verify that connectivity remains up from PC1's subnet to PC3. 10 pings should be sent every minute and the task should run indefinitely.

5) How long does PC3 have to respond to the ping before it is marked as failed.

6) Leave the task to run for around a minute and then check for any connectivity failures.

18 Connectivity Troubleshooting - Answer Key

In this lab you will troubleshoot a connectivity issue and configure IP SLA.

Troubleshoot Connectivity

1) Use ping to test connectivity from PC1 to PC3.

Connectivity is down.

```
PC1> ping 10.1.2.10

*10.1.0.1 icmp_seq=1 ttl=253 time=55.202 ms (ICMP type:3, code:1,
Destination host unreachable)

*10.1.0.1 icmp_seq=2 ttl=253 time=48.034 ms (ICMP type:3, code:1,
Destination host unreachable)

*10.1.0.1 icmp_seq=3 ttl=253 time=47.082 ms (ICMP type:3, code:1,
Destination host unreachable)

*10.1.0.1 icmp_seq=4 ttl=253 time=44.030 ms (ICMP type:3, code:1,
Destination host unreachable)

*10.1.0.1 icmp_seq=5 ttl=253 time=46.652 ms (ICMP type:3, code:1,
Destination host unreachable)
```

2) Use traceroute to determine where the problem is likely to be.

Traceroute is making it as far as 10.1.0.1 on R3 so that is a good place to continue troubleshooting.

```
PC1> trace 10.1.2.10

trace to 10.1.2.10, 8 hops max, press Ctrl+C to stop

 1   10.0.1.1   16.013 ms  8.007 ms  8.507 ms

 2   10.0.0.2   49.535 ms  30.019 ms  28.018 ms

 3   10.1.0.1   49.533 ms  50.032 ms  49.533 ms

 4   *10.1.0.1   49.532 ms (ICMP type:3, code:1, Destination host
unreachable)
```

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3) Determine the issue and fix it to restore connectivity between PC1 and PC3.

The first thing to do is check that R3 has a route to PC3's network 10.1.2.0/24

```
R3#sh 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

      10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
S        10.0.0.0/24 [1/0] via 10.1.0.2
S        10.0.1.0/24 [1/0] via 10.1.0.2
S        10.0.2.0/24 [1/0] via 10.1.0.2
S        10.0.3.0/24 [1/0] via 10.1.0.2
C        10.1.0.0/24 is directly connected, FastEthernet1/0
L        10.1.0.1/32 is directly connected, FastEthernet1/0
C        10.1.1.0/24 is directly connected, FastEthernet0/0
L        10.1.1.2/32 is directly connected, FastEthernet0/0
S        10.1.3.0/24 [1/0] via 10.1.1.1
```

The network is not in the routing table. From the 'show ip route' command we can also see that static routes are being used. We need to add a static route for the 10.1.2.0/24 network with R4 as the next hop.

```
R3(config)#ip route 10.1.2.0 255.255.255.0 10.1.1.1
```

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Lastly we need to verify connectivity is restored.

```
PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=60 time=149.841 ms
84 bytes from 10.1.2.10 icmp_seq=2 ttl=60 time=73.551 ms
84 bytes from 10.1.2.10 icmp_seq=3 ttl=60 time=73.058 ms
84 bytes from 10.1.2.10 icmp_seq=4 ttl=60 time=79.553 ms
84 bytes from 10.1.2.10 icmp_seq=5 ttl=60 time=79.551 ms
```

IP SLA Configuration

4) Configure IP SLA on R1 to verify that connectivity remains up from PC1's subnet to PC3. 10 pings should be sent every minute and the task should run indefinitely.

Use the interface on PC1's subnet as the source interface and set the ping to be sent every 6 seconds.

```
R1(config)#ip sla 1
R1(config-ip-sla)#icmp-echo 10.1.2.10 source-ip 10.0.1.1
R1(config-ip-sla-echo)#frequency 6
R1(config-ip-sla-echo)#exit
R1(config)#ip sla schedule 1 life forever start-time now
```

5) How long does PC3 have to respond to the ping before it is marked as failed.

5 seconds.

```
R1#show ip sla configuration
IP SLAs Infrastructure Engine-III
Entry number: 1
Owner:
Tag:
Operation timeout (milliseconds): 5000
Type of operation to perform: icmp-echo
Target address/Source address: 10.1.2.10/10.0.1.1
```

```
Type Of Service parameter: 0x0
Request size (ARR data portion): 28
Verify data: No
Vrf Name:
Schedule:
   Operation frequency (seconds): 6  (not considered if randomly
scheduled)
   Next Scheduled Start Time: Start Time already passed
   Group Scheduled : FALSE
   Randomly Scheduled : FALSE
   Life (seconds): Forever
   Entry Ageout (seconds): never
   Recurring (Starting Everyday): FALSE
   Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Distribution Statistics:
   Number of statistic hours kept: 2
   Number of statistic distribution buckets kept: 1
   Statistic distribution interval (milliseconds): 20
Enhanced History:
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
```

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6) Leave the task to run for around a minute and then check for any connectivity failures.

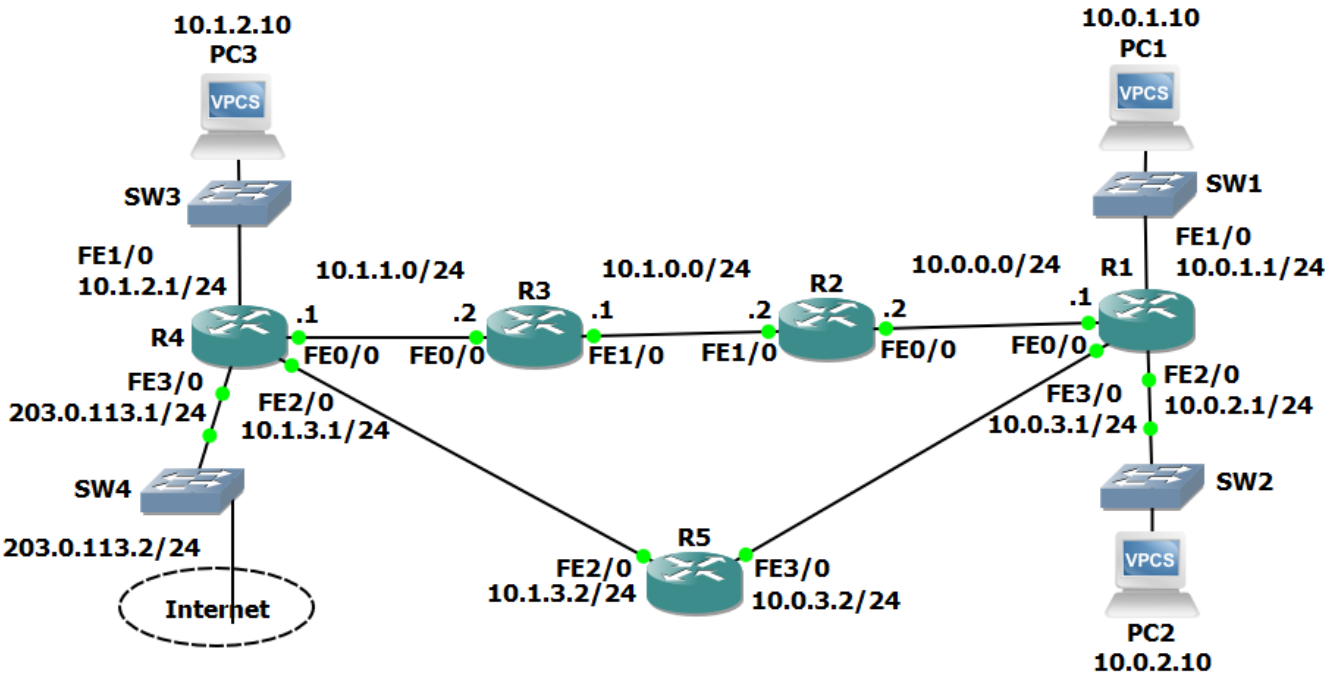
```
R1#show ip sla statistics
IPSLAs Latest Operation Statistics

IPSLA operation id: 1
        Latest RTT: 51 milliseconds
Latest operation start time: 07:50:01 UTC Tue Jul 11 2017
Latest operation return code: OK
Number of successes: 31
Number of failures: 0
Operation time to live: Forever
```

19-1 RIP Configuration – Lab Exercise

In this lab you will configure the RIPv2 routing protocol.

Lab Topology



Load the Startup Configurations

Download the '19-1 RIP Configuration.gns3project' file here. Open in GNS3 to load the lab.

RIP Configuration

1) Enable RIPv2 on every router. Ensure all networks except 203.0.113.0/24 are advertised. Do not perform any summarisation.

2) Verify all networks are in the router's routing tables.

3) Enable summarisation using a /16 mask on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

4) What change do you expect to see on R1's routing table? Verify this (give the routing table a couple of minutes to converge).

5) Will R4's routes to the 10.0.x.x networks mirror R1's routes to the 10.1.x.x networks? Verify this.

6) Verify that routing is working by checking that PC1 has connectivity to PC3.

7) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not advertised to the Service Provider at 203.0.113.2.

8) Verify that all routers have a path to the 203.0.113.0/24 network.

9) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

10) Ensure that all other routers learn via RIP how to reach the Internet.

11) Verify all routers have a route to the Internet.

12) Set the RIP timers to half their current settings on all routers.

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19-1 RIP Configuration - Answer Key

In this lab you will configure the RIPv2 routing protocol.

RIP Configuration

1) Enable RIPv2 on every router. Ensure all networks except 203.0.113.0/24 are advertised. Do not perform any summarisation.

On every router:

```
R1(config)#router rip
R1(config-router)#version 2
R1(config-router)#no auto-summary
R1(config-router)#network 10.0.0.0
```

2) Verify all networks are in the router's routing tables.

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
```

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```
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/24 [120/1] via 10.0.0.2, 00:00:21, FastEthernet0/0
R        10.1.1.0/24 [120/2] via 10.0.3.2, 00:00:20, FastEthernet3/0
                     [120/2] via 10.0.0.2, 00:00:21, FastEthernet0/0
R        10.1.2.0/24 [120/2] via 10.0.3.2, 00:00:20, FastEthernet3/0
R        10.1.3.0/24 [120/1] via 10.0.3.2, 00:00:20, FastEthernet3/0
```

3) Enable summarisation using a /16 mask on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

Configure summarisation in both directions on the R2 and R5 routers.

```
R2(config)#int f0/0
R2(config-if)#ip summary-address rip 10.1.0.0 255.255.0.0
R2(config)#int f1/0
R2(config-if)#ip summary-address rip 10.0.0.0 255.255.0.0

R5(config)#int f3/0
R5(config-if)#ip summary-address rip 10.1.0.0 255.255.0.0
R5(config)#int f2/0
R5(config-if)#ip summary-address rip 10.0.0.0 255.255.0.0
```

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4) What change do you expect to see on R1's routing table? Verify this (give the routing table a couple of minutes to converge).

R1 will have a single /16 summary route to the 10.1.0.0 networks rather than individual /24 routes. The routes will use Equal Cost Multi Path through routers R2 and R5.

Before summarisation with individual /24 routes:

```
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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/24 [120/1] via 10.0.0.2, 00:00:21, FastEthernet0/0
R        10.1.1.0/24 [120/2] via 10.0.3.2, 00:00:20, FastEthernet3/0
                     [120/2] via 10.0.0.2, 00:00:21, FastEthernet0/0
R        10.1.2.0/24 [120/2] via 10.0.3.2, 00:00:20, FastEthernet3/0
R        10.1.3.0/24 [120/1] via 10.0.3.2, 00:00:20, FastEthernet3/0
```

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After summarisation with ECMP /16 summarised routes:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/16 [120/1] via 10.0.3.2, 00:00:29, FastEthernet3/0
                     [120/1] via 10.0.0.2, 00:00:21, FastEthernet0/0
```

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5) Will R4's routes to the 10.0.x.x networks mirror R1's routes to the 10.1.x.x networks? Verify this.

No. R4 will have a 10.0.0.0/16 summary route with a single next hop of 10.1.3.2 on R5 and a hop count of 1. It will not load balance traffic through R2 as well because that path would have a hop count of 2. (R4 is not directly adjacent to R2 as R1 is, it is an extra hop away.)

```
R4#sh 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

      10.0.0.0/8 is variably subnetted, 8 subnets, 3 masks
R        10.0.0.0/16 [120/1] via 10.1.3.2, 00:00:03, FastEthernet2/0
R        10.1.0.0/24 [120/1] via 10.1.1.2, 00:00:23, FastEthernet0/0
C        10.1.1.0/24 is directly connected, FastEthernet0/0
L        10.1.1.1/32 is directly connected, FastEthernet0/0
C        10.1.2.0/24 is directly connected, FastEthernet1/0
L        10.1.2.1/32 is directly connected, FastEthernet1/0
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.1/32 is directly connected, FastEthernet2/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/24 is directly connected, FastEthernet3/0
L        203.0.113.1/32 is directly connected, FastEthernet3/0
```

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6) Verify that routing is working by checking that PC1 has connectivity to PC3.

```
PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=61 time=157.988 ms
84 bytes from 10.1.2.10 icmp_seq=2 ttl=61 time=108.570 ms
84 bytes from 10.1.2.10 icmp_seq=3 ttl=61 time=108.848 ms
84 bytes from 10.1.2.10 icmp_seq=4 ttl=61 time=108.576 ms
84 bytes from 10.1.2.10 icmp_seq=5 ttl=61 time=115.893 ms
```

7) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

The 203.0.113.0/24 network must be added to the RIP process on R4, and interface FastEthernet 3/0 facing the service provider configured as a passive interface to avoid sending out internal network information.

```
R4(config)#router rip
R4(config-router)#passive-interface f3/0
R4(config-router)#network 203.0.113.0
```

8) Verify that all routers have a path to the 203.0.113.0/24 network.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
```

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```
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/16 [120/1] via 10.0.3.2, 00:00:18, FastEthernet3/0
                     [120/1] via 10.0.0.2, 00:00:24, FastEthernet0/0
R     203.0.113.0/24 [120/2] via 10.0.3.2, 00:00:18, FastEthernet3/0
```

9) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

```
R4(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2
```

10) Ensure that all other routers learn via RIP how to reach the Internet.

Inject the default static route into RIP on R4.

```
R4(config)#router rip
R4(config-router)#default-information originate
```

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11) Verify all routers have a route to the Internet.

```
R1#sh 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 10.0.3.2 to network 0.0.0.0

R*    0.0.0.0/0 [120/2] via 10.0.3.2, 00:00:05, FastEthernet3/0
      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
R        10.1.0.0/16 [120/1] via 10.0.3.2, 00:00:05, FastEthernet3/0
                     [120/1] via 10.0.0.2, 00:00:08, FastEthernet0/0
R     203.0.113.0/24 [120/2] via 10.0.3.2, 00:00:05, FastEthernet3/0
```

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12) Set the RIP timers to half their current settings on all routers.

Check the current timers first.

```
R1#sh ip protocols | include seconds
  Sending updates every 30 seconds, next due in 14 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
```

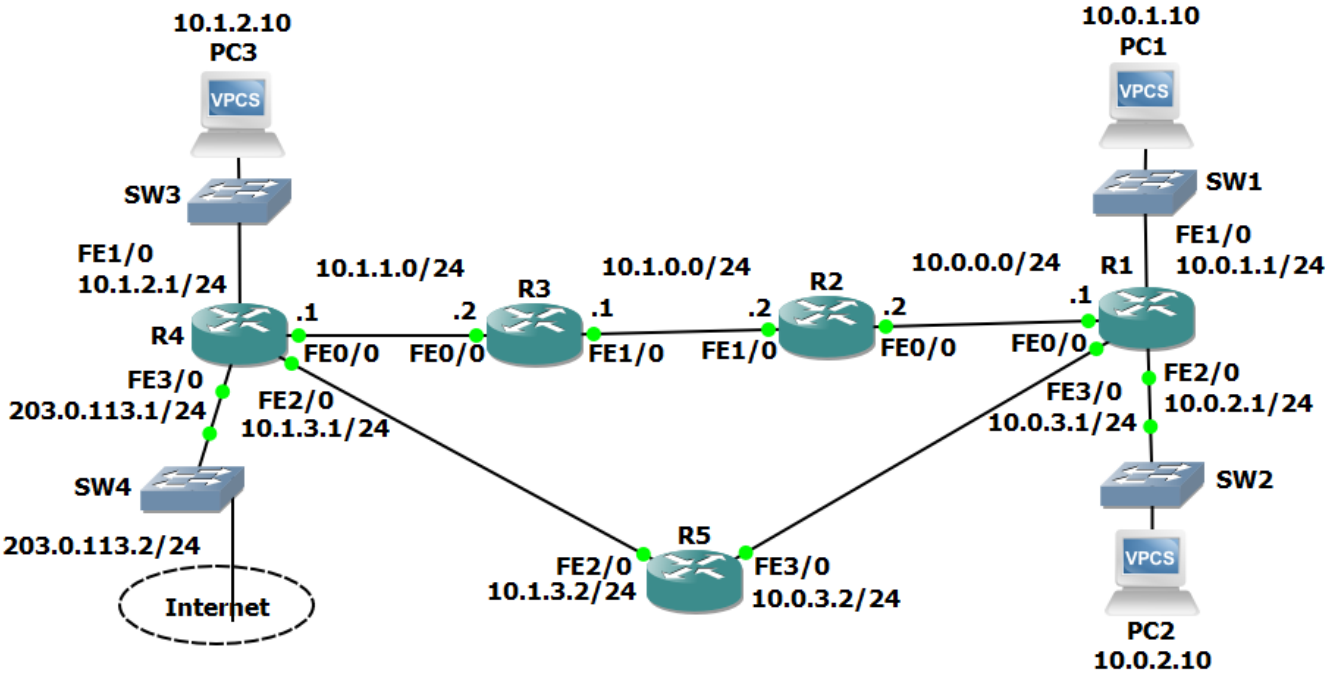
On all routers:

```
R1(config)#router rip
R1(config-router)#timers basic 15 90 90 120
```

20-1 EIGRP Configuration – Lab Exercise

In this lab you will configure the EIGRP routing protocol.

Lab Topology



Load the Startup Configurations

Download the '20-1 EIGRP Configuration.gns3project' file here. Open in GNS3 to load the lab.

EIGRP Basic Configuration

1) Enable EIGRP AS 100 on every router. Ensure all networks except 203.0.113.0/24 are advertised.

2) Enable a loopback interface on each router. Use the IP address 192.168.0.x/32, where ‘x’ is the router number. For example 192.168.0.3/32 on R3.

3) What do you expect the EIGRP Router ID to be on R1? Verify this.

4) Verify the routers have formed adjacencies with each other.

5) Verify all 10.x.x.x networks are in the router’s routing tables.

EIGRP Summarisation

6) Enable summarisation using a /16 mask on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

7) What change do you expect to see on R1’s routing table? Verify this (give the routing table a few seconds to converge).

8) Will R4’s routes to the 10.0.x.x networks mirror R1’s routes to the 10.1.x.x networks? Verify this.

9) Verify that routing is working by checking that PC1 has connectivity to PC3.

10) Remove the summary routes on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

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Successors and Feasible Successors

11) There are two possible paths which R1 could use to reach the 10.1.2.0/24 network – either through R2 or R5. Which route is in the routing table?

12) What are the Reported Distance and Feasible Distance of the path to 10.1.2.0/24?

13) Is the other path a feasible successor?

14) What are the Reported Distance and Feasible Distance of the other path?

EIGRP Metric

15) Traffic from R1 to the 10.1.2.0/24 network takes the path via R5. Change this to go via R2 instead. The path via R5 must be a Feasible Successor.

16) Verify that traffic to the 10.1.2.0/24 network from R1 goes via R2.

17) Verify that the path via R5 is a Feasible Successor.

Default Route Injection

18) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

19) Verify that all routers have a path to the 203.0.113.0/24 network.

20) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

21) Ensure that all other routers learn via EIGRP how to reach the Internet.

22) Verify all routers have a route to the Internet.

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20-1 EIGRP Configuration - Answer Key

In this lab you will configure the EIGRP routing protocol.

EIGRP Basic Configuration

1) Enable EIGRP AS 100 on every router. Ensure all networks except 203.0.113.0/24 are advertised.

On every router:

```
R1(config)#router eigrp 100
R1(config-router)#network 10.0.0.0
```

2) Enable a loopback interface on each router. Use the IP address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

```
R1(config)#interface loopback0
R1(config-if)#ip add 192.168.0.1 255.255.255.255
```

3) What do you expect the EIGRP Router ID to be on R1? Verify this.

The Router ID is 10.0.3.1. This was the highest IP address on the router when EIGRP was enabled. The Router ID will change to the Loopback address 192.168.0.1 when the EIGRP process restarts.

```
R1#sh ip proto
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
```

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```
NSF-aware route hold timer is 240
```
Router-ID: 10.0.3.1

4) Verify the routers have formed adjacencies with each other.

```
R1#sh ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   10.0.3.2                Fa3/0                    11 00:00:10   44   264  0  6
0   10.0.0.2                Fa0/0                    11 00:00:20   21   126  0  10
```

5) Verify all 10.x.x.x networks are in the router's routing tables.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:00:33, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.3.2, 00:00:18, FastEthernet3/0
```

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```
                    [90/33280] via 10.0.0.2, 00:00:18, FastEthernet0/0
D        10.1.2.0/24 [90/33280] via 10.0.3.2, 00:00:18, FastEthernet3/0
D        10.1.3.0/24 [90/30720] via 10.0.3.2, 00:00:23, FastEthernet3/0
```

EIGRP Summarisation

6) Enable summarisation using a /16 mask on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

Configure summarisation in both directions on the R2 and R5 routers.

```
R2(config)#int f0/0
R2(config-if)#ip summary-address eigrp 100 10.1.0.0 255.255.0.0
R2(config)#int f1/0
R2(config-if)#ip summary-address eigrp 100 10.0.0.0 255.255.0.0

R5(config)#int f3/0
R5(config-if)#ip summary-address eigrp 100 10.1.0.0 255.255.0.0
R5(config)#int f2/0
R5(config-if)#ip summary-address eigrp 100 10.0.0.0 255.255.0.0
```

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7) What change do you expect to see on R1's routing table? Verify this (give the routing table a few seconds to converge).

R1 will have a single /16 summary route to the 10.1.0.0 networks rather than individual /24 routes. The routes will use Equal Cost Multi Path through routers R2 and R5.

Before summarisation with individual /24 routes:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:00:33, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.3.2, 00:00:18, FastEthernet3/0
                     [90/33280] via 10.0.0.2, 00:00:18, FastEthernet0/0
D        10.1.2.0/24 [90/33280] via 10.0.3.2, 00:00:18, FastEthernet3/0
D        10.1.3.0/24 [90/30720] via 10.0.3.2, 00:00:23, FastEthernet3/0
```

After summarisation with ECMP /16 summarised route:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/16 [90/30720] via 10.0.3.2, 00:00:06, FastEthernet3/0
                     [90/30720] via 10.0.0.2, 00:00:06, FastEthernet0/0
```

8) Will R4's routes to the 10.0.x.x networks mirror R1's routes to the 10.1.x.x networks? Verify this.

No. R4 will have a 10.0.0.0/16 summary route with a single next hop of 10.1.3.2 on R5. It will not load balance traffic through R2 as well because that path would have a higher metric. (R4 is not directly adjacent to R2 as R1 is, it is an extra hop away.)

```
R4#sh 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

      10.0.0.0/8 is variably subnetted, 8 subnets, 3 masks
D        10.0.0.0/16 [90/30720] via 10.1.3.2, 00:02:17, FastEthernet2/0
D        10.1.0.0/24 [90/30720] via 10.1.1.2, 00:03:54, FastEthernet0/0
C        10.1.1.0/24 is directly connected, FastEthernet0/0
L        10.1.1.1/32 is directly connected, FastEthernet0/0
C        10.1.2.0/24 is directly connected, FastEthernet1/0
L        10.1.2.1/32 is directly connected, FastEthernet1/0
C        10.1.3.0/24 is directly connected, FastEthernet2/0
L        10.1.3.1/32 is directly connected, FastEthernet2/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/24 is directly connected, FastEthernet3/0
L        203.0.113.1/32 is directly connected, FastEthernet3/0
```

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9) Verify that routing is working by checking that PC1 has connectivity to PC3.

```
PC1> ping 10.1.2.10
84 bytes from 10.1.2.10 icmp_seq=1 ttl=61 time=157.988 ms
84 bytes from 10.1.2.10 icmp_seq=2 ttl=61 time=108.570 ms
84 bytes from 10.1.2.10 icmp_seq=3 ttl=61 time=108.848 ms
84 bytes from 10.1.2.10 icmp_seq=4 ttl=61 time=108.576 ms
84 bytes from 10.1.2.10 icmp_seq=5 ttl=61 time=115.893 ms
```

10) Remove the summary routes on the routers which are at the boundary of the 10.0.0.0/16 and 10.1.0.0/16 networks.

Individual routes for all networks will be restored in the routing tables.

```
R2(config-if)#int f0/0
R2(config-if)#no ip summary-address eigrp 100 10.1.0.0 255.255.0.0
R2(config-if)#int f1/0
R2(config-if)#no ip summary-address eigrp 100 10.0.0.0 255.255.0.0

R5(config-if)#int f3/0
R5(config-if)#no ip summary-address eigrp 100 10.1.0.0 255.255.0.0
R5(config-if)#int f2/0
R5(config-if)#no ip summary-address eigrp 100 10.0.0.0 255.255.0.0
```

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Successors and Feasible Successors

11) There are two possible paths which R1 could use to reach the 10.1.2.0/24 network – either through R2 or R5. Which route is in the routing table?

The path via R5 at 10.0.3.2.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:06:01, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.3.2, 00:05:46, FastEthernet3/0
                     [90/33280] via 10.0.0.2, 00:05:46, FastEthernet0/0
D        10.1.2.0/24 [90/33280] via 10.0.3.2, 00:05:46, FastEthernet3/0
D        10.1.3.0/24 [90/30720] via 10.0.3.2, 00:05:51, FastEthernet3/0
```

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12) What are the Reported Distance and Feasible Distance of the path to 10.1.2.0/24?

The Reported Distance is 30720, The Feasible Distance is 33280.

```
R1#sh ip eigrp topology
EIGRP-IPv4 Topology Table for AS(100)/ID(10.0.3.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 10.0.3.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet3/0
P 10.0.1.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet1/0
P 10.1.3.0/24, 1 successors, FD is 30720
        via 10.0.3.2 (30720/28160), FastEthernet3/0
P 10.1.0.0/24, 1 successors, FD is 30720
        via 10.0.0.2 (30720/28160), FastEthernet0/0
P 10.0.0.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet0/0
P 10.1.2.0/24, 1 successors, FD is 33280
        via 10.0.3.2 (33280/30720), FastEthernet3/0
P 10.0.2.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet2/0
P 10.1.1.0/24, 2 successors, FD is 33280
        via 10.0.0.2 (33280/30720), FastEthernet0/0
        via 10.0.3.2 (33280/30720), FastEthernet3/0
```

13) Is the other path a feasible successor?

No. ‘Show ip eigrp topology’ only shows the path via R5.

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14) What are the Reported Distance and Feasible Distance of the other path?

Use the ‘show ip eigrp topology all-links’ to see information on Non-Successor Routes.

The Reported Distance is 33280, The Feasible Distance is 35840.

The Reported Distance from R2 (33280) is not less than the Feasible Distance of the Successor Route via R5 (also 33280), so it is not a Feasible Successor.

```
R1#sh ip eigrp topology all-links
EIGRP-IPv4 Topology Table for AS(100)/ID(10.0.3.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 10.0.3.0/24, 1 successors, FD is 28160, serno 4
        via Connected, FastEthernet3/0
P 10.0.1.0/24, 1 successors, FD is 28160, serno 2
        via Connected, FastEthernet1/0
P 10.1.3.0/24, 1 successors, FD is 30720, serno 9
        via 10.0.3.2 (30720/28160), FastEthernet3/0
P 10.1.0.0/24, 1 successors, FD is 30720, serno 5
        via 10.0.0.2 (30720/28160), FastEthernet0/0
P 10.0.0.0/24, 1 successors, FD is 28160, serno 1
        via Connected, FastEthernet0/0
P 10.1.2.0/24, 1 successors, FD is 33280, serno 11
        via 10.0.3.2 (33280/30720), FastEthernet3/0
        via 10.0.0.2 (35840/33280), FastEthernet0/0
P 10.0.2.0/24, 1 successors, FD is 28160, serno 3
        via Connected, FastEthernet2/0
P 10.1.1.0/24, 2 successors, FD is 33280, serno 10
        via 10.0.0.2 (33280/30720), FastEthernet0/0
        via 10.0.3.2 (33280/30720), FastEthernet3/0
```

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EIGRP Metric

15) Traffic from R1 to the 10.1.2.0/24 network takes the path via R5. Change this to go via R2 instead. The path via R5 must be a Feasible Successor.

All interfaces have a delay of 100 usec.

```
R1#sh interface f3/0
FastEthernet3/0 is up, line protocol is up
  Hardware is DEC21140, address is ca01.2630.0054 (bia
ca01.2630.0054)
  Internet address is 10.0.3.1/24
  MTU 1500 bytes, BW 100000 Kbit/sec, DLY 100 usec,
```

Increasing the delay on the links via R5 will cause the route via R2 to be preferred. Note you could alternatively reduce the delay on the links via R2. You could also have changed the bandwidth configured on the links, but changing delay is the recommended method.

I double the delay to 200 usec (note the command is delay 20, not 200). You need to set the delay high enough that the path to R2 will have a better metric, but not too high because we need the path via R5 to have a low enough Reported Distance to be a Feasible Successor.

```
R1(config)#int f3/0
R1(config-if)#delay 20

R5(config)#int f2/0
R5(config-if)#delay 20
R5(config)#int f3/0
R5(config-if)#delay 20

R4(config)#int f2/0
R4(config-if)#delay 20
```

16) Verify that traffic to the 10.1.2.0/24 network from R1 goes via R2.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:00:49, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:00:18, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:00:18, FastEthernet0/0
D        10.1.3.0/24 [90/35840] via 10.0.3.2, 00:00:04, FastEthernet3/0
```

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17) Verify that the path via R5 is a Feasible Successor.

```
R1#show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(100)/ID(10.0.3.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 10.0.3.0/24, 1 successors, FD is 30720
        via Connected, FastEthernet3/0
P 10.0.1.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet1/0
P 10.1.3.0/24, 1 successors, FD is 33280
        via 10.0.3.2 (35840/30720), FastEthernet3/0
P 10.1.0.0/24, 1 successors, FD is 30720
        via 10.0.0.2 (30720/28160), FastEthernet0/0
P 10.0.0.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet0/0
P 10.1.2.0/24, 1 successors, FD is 35840
        via 10.0.0.2 (35840/33280), FastEthernet0/0
        via 10.0.3.2 (38400/33280), FastEthernet3/0
P 10.0.2.0/24, 1 successors, FD is 28160
        via Connected, FastEthernet2/0
P 10.1.1.0/24, 1 successors, FD is 33280
        via 10.0.0.2 (33280/30720), FastEthernet0/0
```

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Default Route Injection

18) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

The 203.0.113.0/24 network must be added to the EIGRP process on R4, and interface FastEthernet 3/0 facing the service provider configured as a passive interface to avoid sending out internal network information.

```
R4(config)#router eigrp 100
R4(config-router)#passive-interface f3/0
R4(config-router)#network 203.0.113.0
```

19) Verify that all routers have a path to the 203.0.113.0/24 network.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:31:56, FastEthernet0/0
```

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```
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:00:07, FastEthernet0/0
D        10.1.2.0/24 [90/35840] via 10.0.0.2, 00:00:07, FastEthernet0/0
D        10.1.3.0/24 [90/35840] via 10.0.3.2, 00:00:12, FastEthernet3/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/24 is directly connected, Loopback0
L        192.168.0.1/32 is directly connected, Loopback0
D     203.0.113.0/24 [90/35840] via 10.0.0.2, 00:00:07, FastEthernet0/0
```

20) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

```
R4(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2
```

21) Ensure that all other routers learn via EIGRP how to reach the Internet.

Configure EIGRP summary routes on R4 to inject the default static route into EIGRP. Summary routes should be configured on the interfaces facing R3 and R5.

```
R4(config-router)#int f0/0
R4(config-if)#ip summary-address eigrp 100 0.0.0.0 0.0.0.0
R4(config-router)#int f2/0
R4(config-if)#ip summary-address eigrp 100 0.0.0.0 0.0.0.0
```

22) Verify all routers have a route to the Internet.

```
R1#sh 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 10.0.0.2 to network 0.0.0.0

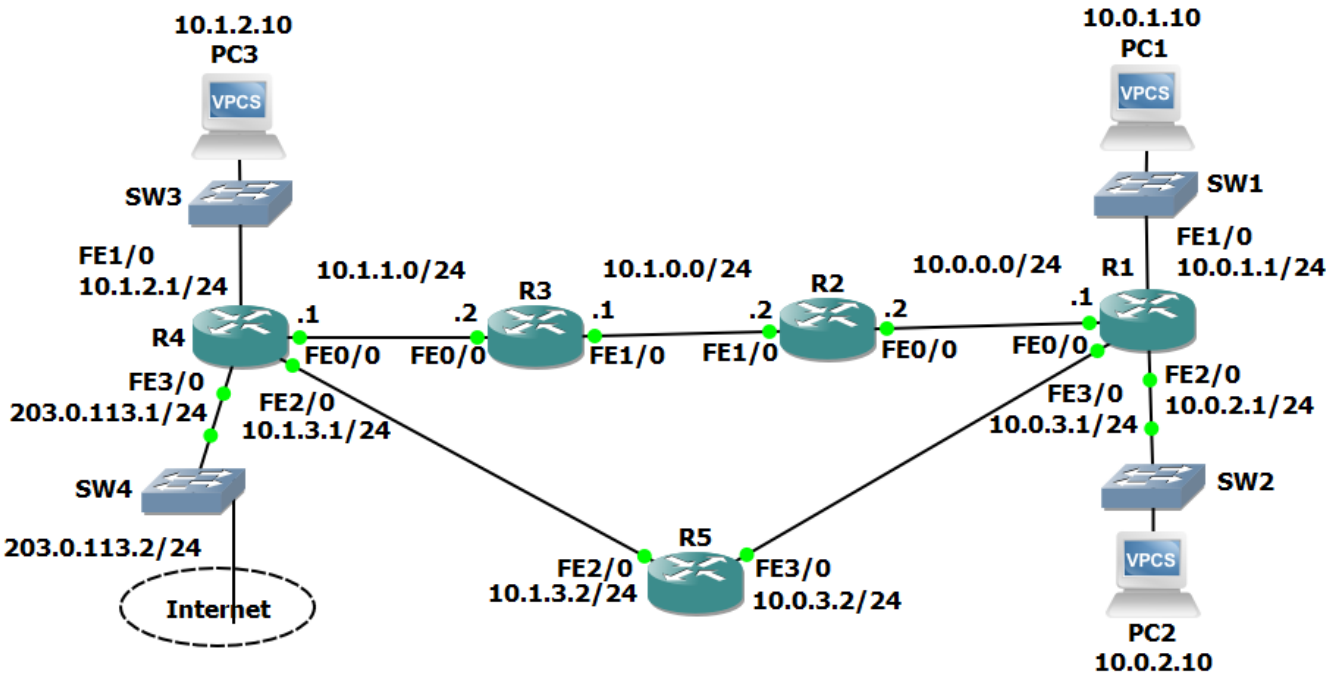
D*    0.0.0.0/0 [90/35840] via 10.0.0.2, 00:00:05, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
D        10.1.0.0/24 [90/30720] via 10.0.0.2, 00:34:12, FastEthernet0/0
D        10.1.1.0/24 [90/33280] via 10.0.0.2, 00:02:23, FastEthernet0/0
D        10.1.3.0/24 [90/35840] via 10.0.3.2, 00:02:28, FastEthernet3/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/24 is directly connected, Loopback0
L        192.168.0.1/32 is directly connected, Loopback0
```

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21-1 OSPF Configuration – Lab Exercise

In this lab you will configure the OSPF routing protocol.

Lab Topology



Load the Startup Configurations

Download the '21-1 OSPF Configuration.gns3project' file here. Open in GNS3 to load the lab.

You can learn the theory for this section and shortcut your path to CCNA certification by getting my CCNA Complete course. Get the course for only $10 USD (that's a massive 97% discount) with this link:

https://www.udemy.com/ccna-complete/?couponCode=DISCOUNTCEB

OSPF Basic Configuration

1) Enable a loopback interface on each router. Use the IP address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

2) Enable single area OSPF on every router. Ensure all networks except 203.0.113.0/24 are advertised.

3) What do you expect the OSPF Router ID to be on R1? Verify this.

4) Verify the routers have formed adjacencies with each other.

5) Verify all 10.x.x.x networks and loopbacks are in the router's routing tables.

6) Set the reference bandwidth so that a 100 Gbps interface will have a cost of 1.

7) What will the OSPF cost be on the FastEthernet links? Verify this.

8) What effect does this have on the cost to the 10.1.2.0/24 network from R1?

OSPF Cost

9) There are two possible paths which R1 could use to reach the 10.1.2.0/24 network – either through R2 or R5. Which route is in the routing table?

10) Change this so that traffic from R1 to 10.1.2.0/24 will be load balanced via both R2 and R5.

11) Verify that traffic to the 10.1.2.0/24 network from R1 is load balanced via both R2 and R5.

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Default Route Injection

12) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

13) Verify that all routers have a path to the 203.0.113.0/24 network.

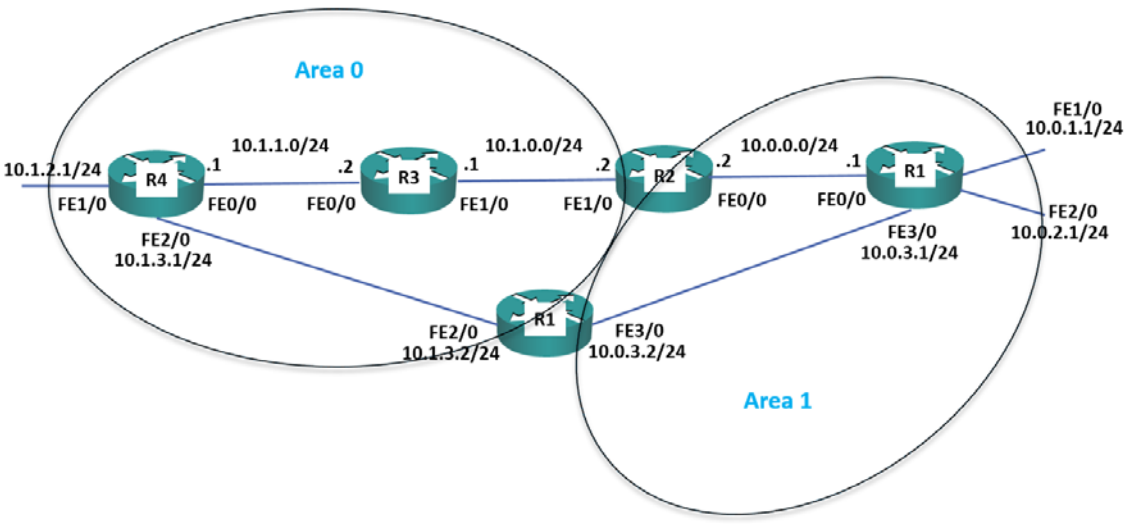
14) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

15) Ensure that all other routers learn via OSPF how to reach the Internet.

16) Verify all routers have a route to the Internet.

Multi-Area OSPF

17) Convert the network to use multi-area OSPF. R3 and R4 should be backbone routers, R1 a normal router in Area 1, and R2 and R5 ABRs as shown in the diagram below.



18) Verify the router's interfaces are in the correct areas.

19) Verify the routers have formed adjacencies with each other.

20) What change do you expect to see on R1's routing table? Verify this (give the routing table a few seconds to converge).

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21) Do you see less routes in R1's routing table? Why or why not?

22) Configure summary routes on the Area Border Routers for the 10.0.0.0/16 and 10.1.0.0/16 networks.

23) Verify R1 now sees a single summary route for 10.1.0.0/16 rather than individual routes for the 10.1.x.x networks.

24) Verify R1 is receiving a summary route for the 10.1.0.0/16 network from both R2 and R5.

25) R1 is routing traffic to 10.1.0.0/16 via R2 only. Why is it not load balancing the traffic through both R2 and R5?

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21-1 OSPF Configuration - Answer Key

In this lab you will configure the OSPF routing protocol.

OSPF Basic Configuration

1) Enable a loopback interface on each router. Use the IP address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

On every router:

```
R1(config)#interface loopback0
R1(config-if)#ip address 192.168.0.1 255.255.255.255
```

2) Enable single area OSPF on every router. Ensure all networks except 203.0.113.0/24 are advertised.

On every router:

```
R1(config)#router ospf 1
R1(config-router)#network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#network 192.168.0.0 0.0.0.255 area 0
```

You can use different network statements, as long as they cover the range of IP addresses configured on the router interfaces.

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3) What do you expect the OSPF Router ID to be on R1? Verify this.

The loopback address is used for the Router ID, 192.168.0.1

```
R1#sh ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.255.255.255 area 0
    192.168.0.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.1.1.2             110      00:00:25
    10.1.0.2             110      00:00:25
    10.1.3.2             110      00:00:25
    203.0.113.1          110      00:00:25
  Distance: (default is 110)
```

4) Verify the routers have formed adjacencies with each other.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.5       1   FULL/BDR        00:00:31    10.0.3.2        FastEthernet3/0
192.168.0.2       1   FULL/DR         00:00:39    10.0.0.2        FastEthernet0/0
```

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5) Verify all 10.x.x.x networks and loopbacks are in the router's routing tables.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        10.1.1.0/24 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
                     [110/3] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        10.1.2.0/24 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
O        10.1.3.0/24 [110/2] via 10.0.3.2, 00:03:16, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/2] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        192.168.0.3 [110/3] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        192.168.0.4 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
O        192.168.0.5 [110/2] via 10.0.3.2, 00:03:16, FastEthernet3/0
```

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6) Set the reference bandwidth so that a 100 Gbps interface will have a cost of 1.

Remember to do this on all routers.

```
R1(config)#router ospf 1
R1(config-router)#auto-cost reference-bandwidth 100000
```

7) What will the OSPF cost be on the FastEthernet links? Verify this.

OSPF Cost = Reference bandwidth / Interface bandwidth.

100000 / 100 = 1000

```
R1#show ip ospf interface FastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.0.0.1/24, Area 0, Attached via Network
Statement
  Process ID 1, Router ID 192.168.0.1, Network Type BROADCAST, Cost:
1000
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1000       no          no            Base
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 10.1.0.2, Interface address 10.0.0.2
  Backup Designated router (ID) 192.168.0.1, Interface address
10.0.0.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit
5
    oob-resync timeout 40
    Hello due in 00:00:02
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
```

```
    Adjacent with neighbor 10.1.0.2  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

8) What effect does this have on the cost to the 10.1.2.0/24 network from R1?

The cost changes from 3 to 3000.

Before reference bandwidth change:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        10.1.1.0/24 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
                     [110/3] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        10.1.2.0/24 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
O        10.1.3.0/24 [110/2] via 10.0.3.2, 00:03:16, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
```

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```
O        192.168.0.2 [110/2] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        192.168.0.3 [110/3] via 10.0.0.2, 00:03:16, FastEthernet0/0
O        192.168.0.4 [110/3] via 10.0.3.2, 00:03:16, FastEthernet3/0
O        192.168.0.5 [110/2] via 10.0.3.2, 00:03:16, FastEthernet3/0
```

After reference bandwidth change:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2000] via 10.0.0.2, 00:00:22, FastEthernet0/0
O        10.1.1.0/24 [110/3000] via 10.0.3.2, 00:00:38, FastEthernet3/0
                     [110/3000] via 10.0.0.2, 00:00:22, FastEthernet0/0
O        10.1.2.0/24 [110/3000] via 10.0.3.2, 00:00:39, FastEthernet3/0
O        10.1.3.0/24 [110/2000] via 10.0.3.2, 00:00:39, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/1001] via 10.0.0.2, 00:00:23, FastEthernet0/0
```

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```
O        192.168.0.3 [110/2001] via 10.0.0.2, 00:00:23, FastEthernet0/0
O        192.168.0.4 [110/2001] via 10.0.3.2, 00:00:39, FastEthernet3/0
O        192.168.0.5 [110/1001] via 10.0.3.2, 00:00:39, FastEthernet3/0
```

OSPF Cost

9) There are two possible paths which R1 could use to reach the 10.1.2.0/24 network – either through R2 or R5. Which route is in the routing table?

The path via R5 at 10.0.3.2.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2000] via 10.0.0.2, 00:00:22, FastEthernet0/0
O        10.1.1.0/24 [110/3000] via 10.0.3.2, 00:00:38, FastEthernet3/0
                     [110/3000] via 10.0.0.2, 00:00:22, FastEthernet0/0
O        10.1.2.0/24 [110/3000] via 10.0.3.2, 00:00:39, FastEthernet3/0
```

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```
O        10.1.3.0/24 [110/2000] via 10.0.3.2, 00:00:39, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/1001] via 10.0.0.2, 00:00:23, FastEthernet0/0
O        192.168.0.3 [110/2001] via 10.0.0.2, 00:00:23, FastEthernet0/0
O        192.168.0.4 [110/2001] via 10.0.3.2, 00:00:39, FastEthernet3/0
O        192.168.0.5 [110/1001] via 10.0.3.2, 00:00:39, FastEthernet3/0
```

10) Change this so that traffic from R1 to 10.1.2.0/24 will be load balanced via both R2 and R5.

Since we changed the reference bandwidth, all interfaces have a cost of 1000. The current path from R1 > R5 > R4 has a cost of 3000 (the cost of the destination interface itself is also counted in the total cost).

The path from R1 > R2 > R3 > R4 has a cost of 4000.

The easiest way to configure both paths to have the same cost is to configure the links from R1 > R5 and R5 > R4 to have a cost of 1500 each. (R1 > R5 = 1500, plus R5 > R4 = 1500, plus cost of 10.1.2.0/24 interface on R4 = 1000. Total = 4000).

```
R1(config)#int f3/0
R1(config-if)#ip ospf cost 1500

R5(config)#int f2/0
R5(config-if)# ip ospf cost 1500
R5(config)#int f3/0
R5(config-if)# ip ospf cost 1500

R4(config)#int f2/0
R4(config-if)# ip ospf cost 1500
```

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11) Verify that traffic to the 10.1.2.0/24 network from R1 is load balanced via both R2 and R5.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2000] via 10.0.0.2, 00:33:40, FastEthernet0/0
O        10.1.1.0/24 [110/3000] via 10.0.0.2, 00:33:40, FastEthernet0/0
O        10.1.2.0/24 [110/4000] via 10.0.3.2, 00:00:32, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:00:32, FastEthernet0/0
O        10.1.3.0/24 [110/3000] via 10.0.3.2, 00:00:32, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/1001] via 10.0.0.2, 00:33:40, FastEthernet0/0
O        192.168.0.3 [110/2001] via 10.0.0.2, 00:33:40, FastEthernet0/0
O        192.168.0.4 [110/3001] via 10.0.3.2, 00:00:32, FastEthernet3/0
                     [110/3001] via 10.0.0.2, 00:00:32, FastEthernet0/0
O        192.168.0.5 [110/1501] via 10.0.3.2, 00:26:30, FastEthernet3/0
```

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Default Route Injection

12) Ensure that all routers have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

The 203.0.113.0/24 network must be added to the OSPF process on R4, and interface FastEthernet 3/0 facing the service provider configured as a passive interface to avoid sending out internal network information.

```
R4(config)#router ospf 1
R4(config-router)#passive-interface f3/0
R4(config-router)#network 203.0.113.0 0.0.0.255 area 0
```

13) Verify that all routers have a path to the 203.0.113.0/24 network.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2000] via 10.0.0.2, 00:56:05, FastEthernet0/0
```

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```
O        10.1.1.0/24 [110/3000] via 10.0.0.2, 00:56:05, FastEthernet0/0
O        10.1.2.0/24 [110/4000] via 10.0.3.2, 00:22:57, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:22:57, FastEthernet0/0
O        10.1.3.0/24 [110/3000] via 10.0.3.2, 00:22:57, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/1001] via 10.0.0.2, 00:56:05, FastEthernet0/0
O        192.168.0.3 [110/2001] via 10.0.0.2, 00:56:05, FastEthernet0/0
O        192.168.0.4 [110/3001] via 10.0.3.2, 00:22:57, FastEthernet3/0
                     [110/3001] via 10.0.0.2, 00:22:57, FastEthernet0/0
O        192.168.0.5 [110/1501] via 10.0.3.2, 00:48:55, FastEthernet3/0
O     203.0.113.0/24 [110/4000] via 10.0.3.2, 00:01:46, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:01:46, FastEthernet0/0
```

14) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

```
R4(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2
```

15) Ensure that all other routers learn via OSPF how to reach the Internet.

```
R4(config)#router ospf 1
R4(config-router)#default-information originate
```

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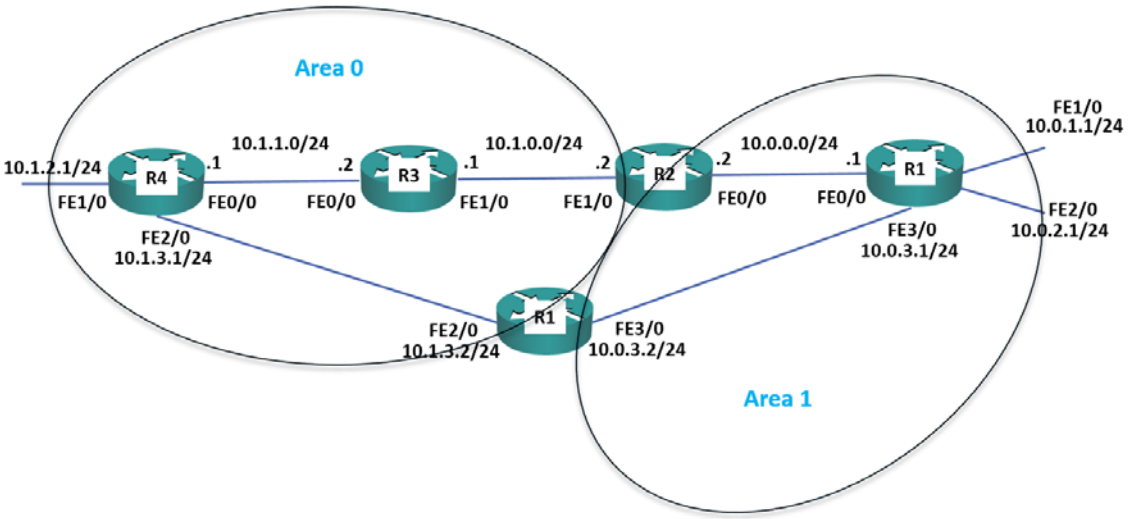
16) Verify all routers have a route to the Internet.

```
R1#sh 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 10.0.3.2 to network 0.0.0.0
O*E2  0.0.0.0/0 [110/1] via 10.0.3.2, 00:00:41, FastEthernet3/0
                [110/1] via 10.0.0.2, 00:00:41, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O        10.1.0.0/24 [110/2000] via 10.0.0.2, 00:59:13, FastEthernet0/0
O        10.1.1.0/24 [110/3000] via 10.0.0.2, 00:59:13, FastEthernet0/0
O        10.1.2.0/24 [110/4000] via 10.0.3.2, 00:26:05, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:26:05, FastEthernet0/0
O        10.1.3.0/24 [110/3000] via 10.0.3.2, 00:26:05, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/1001] via 10.0.0.2, 00:59:13, FastEthernet0/0
O        192.168.0.3 [110/2001] via 10.0.0.2, 00:59:13, FastEthernet0/0
O        192.168.0.4 [110/3001] via 10.0.3.2, 00:26:05, FastEthernet3/0
                     [110/3001] via 10.0.0.2, 00:26:05, FastEthernet0/0
O        192.168.0.5 [110/1501] via 10.0.3.2, 00:52:03, FastEthernet3/0
O     203.0.113.0/24 [110/4000] via 10.0.3.2, 00:04:54, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:04:54, FastEthernet0/0
```

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Multi-Area OSPF

17) Convert the network to use multi-area OSPF. R3 and R4 should be backbone routers, R1 a normal router in Area 1, and R2 and R5 ABRs as shown in the diagram below.



R3 and R4 require no change as all their interfaces are already in Area 0.

R1's interfaces need to be reconfigured to be in Area 1 rather than Area 0.

```
R1#show run | section ospf
 ip ospf cost 1500
router ospf 1
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R1(config)#router ospf 1
R1(config-router)#network 10.0.0.0 0.255.255.255 area 1
R1(config-router)#network 192.168.0.0 0.0.0.255 area 1
```

R2 interface FastEthernet 1/0 should remain in Area 0. FastEthernet 0/0 needs to be reconfigured to be in Area 1. I used a 10.0.0.0/8 network statement originally so I need to remove that and add more granular statements.

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```
R2#sh run | section ospf
router ospf 1
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R2(config)#router ospf 1
R2(config-router)#no network 10.0.0.0 0.255.255.255 area 0
R2(config-router)#network 10.1.0.0 0.0.0.255 area 0
R2(config-router)#network 10.0.0.0 0.0.0.255 area 1
```

R5 interface FastEthernet 2/0 should remain in Area 0. FastEthernet 3/0 needs to be reconfigured to be in Area 1.

```
R5#sh run | section ospf
 ip ospf cost 1500
 ip ospf cost 1500
router ospf 1
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R5(config)#router ospf 1
R5(config-router)#no network 10.0.0.0 0.255.255.255 area 0
R5(config-router)#network 10.1.3.0 0.0.0.255 area 0
R5(config-router)#network 10.0.3.0 0.0.0.255 area 1
```

18) Verify the router's interfaces are in the correct areas.

```
R2#sh ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Lo0          1     0               192.168.0.2/32     1     LOOP  0/0
Fa1/0        1     0               10.1.0.2/24        1000  BDR   1/1
Fa0/0        1     1               10.0.0.2/24        1000  BDR   1/1
```

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19) Verify the routers have formed adjacencies with each other.

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.5       1   FULL/BDR        00:00:33    10.0.3.2        FastEthernet3/0
192.168.0.2       1   FULL/BDR        00:00:31    10.0.0.2        FastEthernet0/0
```

20) What change do you expect to see on R1's routing table? Verify this (give the routing table a few seconds to converge).

The networks beyond R2 and R5 will appear as Inter Area routes (apart from the default route which will appear as an external route as it was redistributed into OSPF).

```
R1#sh 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 10.0.3.2 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 10.0.3.2, 00:05:54, FastEthernet3/0
                [110/1] via 10.0.0.2, 00:10:20, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
```

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```
O IA     10.1.0.0/24 [110/2000] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     10.1.1.0/24 [110/3000] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     10.1.2.0/24 [110/4000] via 10.0.3.2, 00:05:54, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     10.1.3.0/24 [110/3000] via 10.0.3.2, 00:05:54, FastEthernet3/0
      192.168.0.0/32 is subnetted, 5 subnets
C        192.168.0.1 is directly connected, Loopback0
O IA     192.168.0.2 [110/1001] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     192.168.0.3 [110/2001] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     192.168.0.4 [110/3001] via 10.0.3.2, 00:05:54, FastEthernet3/0
                     [110/3001] via 10.0.0.2, 00:10:20, FastEthernet0/0
O IA     192.168.0.5 [110/1501] via 10.0.3.2, 00:05:54, FastEthernet3/0
O IA  203.0.113.0/24 [110/4000] via 10.0.3.2, 00:05:54, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:10:20, FastEthernet0/0
```

21) Do you see less routes in R1's routing table? Why or why not?

R1 has the same amount of routes in its routing table because OSPF does not perform automatic summarisation. You must configure manual summarisation to reduce the size of the routing table.

22) Configure summary routes on the Area Border Routers for the 10.0.0.0/16 and 10.1.0.0/16 networks.

```
R2(config)#router ospf 1
R2(config-router)#area 0 range 10.1.0.0 255.255.0.0
R2(config-router)#area 1 range 10.0.0.0 255.255.0.0


R5(config-if)#router ospf 1
R5(config-router)#area 0 range 10.1.0.0 255.255.0.0
R5(config-router)#area 1 range 10.0.0.0 255.255.0.0
```

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23) Verify R1 now sees a single summary route for 10.1.0.0/16 rather than individual routes for the 10.1.x.x networks.

```
R1#sh 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 10.0.3.2 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 10.0.3.2, 00:27:35, FastEthernet3/0
                [110/1] via 10.0.0.2, 00:26:43, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 10 subnets, 3 masks
O IA     10.0.0.0/16 [110/6000] via 10.0.3.2, 00:03:47, FastEthernet3/0
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
C        10.0.2.0/24 is directly connected, FastEthernet2/0
L        10.0.2.1/32 is directly connected, FastEthernet2/0
C        10.0.3.0/24 is directly connected, FastEthernet3/0
L        10.0.3.1/32 is directly connected, FastEthernet3/0
O IA     10.1.0.0/16 [110/2000] via 10.0.0.2, 00:03:56, FastEthernet0/0
      192.168.0.0/32 is subnetted, 3 subnets
C        192.168.0.1 is directly connected, Loopback0
O IA     192.168.0.3 [110/2001] via 10.0.0.2, 00:28:43, FastEthernet0/0
O IA     192.168.0.4 [110/3001] via 10.0.3.2, 00:26:43, FastEthernet3/0
                     [110/3001] via 10.0.0.2, 00:26:43, FastEthernet0/0
O IA  203.0.113.0/24 [110/4000] via 10.0.3.2, 00:26:43, FastEthernet3/0
                     [110/4000] via 10.0.0.2, 00:26:43, FastEthernet0/0
```

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24) Verify R1 is receiving a summary route for the 10.1.0.0/16 network from both R2 and R5.

```
R1#sh ip ospf database

            OSPF Router with ID (192.168.0.1) (Process ID 1)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.0.1     192.168.0.1     18          0x80000005 0x00536E 5
192.168.0.2     192.168.0.2     27          0x80000003 0x0069ED 1
192.168.0.5     192.168.0.5     1890        0x80000003 0x00C490 1

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.1        192.168.0.1     18          0x80000002 0x00DF0E
10.0.3.1        192.168.0.1     18          0x80000002 0x00E8FE

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.0        192.168.0.5     509         0x80000001 0x0044DA
10.1.0.0        192.168.0.2     523         0x80000002 0x0015C4
10.1.0.0        192.168.0.5     475         0x80000003 0x009A45
192.168.0.3     192.168.0.2     27          0x80000002 0x00DD99
192.168.0.3     192.168.0.5     1889        0x80000002 0x0098F9
192.168.0.4     192.168.0.2     27          0x80000002 0x000783
192.168.0.4     192.168.0.5     1889        0x80000002 0x005B22
203.0.113.0     192.168.0.2     27          0x80000002 0x00D0FE
203.0.113.0     192.168.0.5     1889        0x80000002 0x00259D

                Summary ASB Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     192.168.0.2     27          0x80000002 0x00EE9B
```

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```
192.168.0.4     192.168.0.5     1889        0x80000002 0x00433A

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         192.168.0.4     207         0x80000002 0x00152F 1
```

25) R1 is routing traffic to 10.1.0.0/16 via R2 only. Why is it not load balancing the traffic through both R2 and R5?

We configured the link from R1 to R5 to have a higher cost than the link from R1 to R2 earlier.

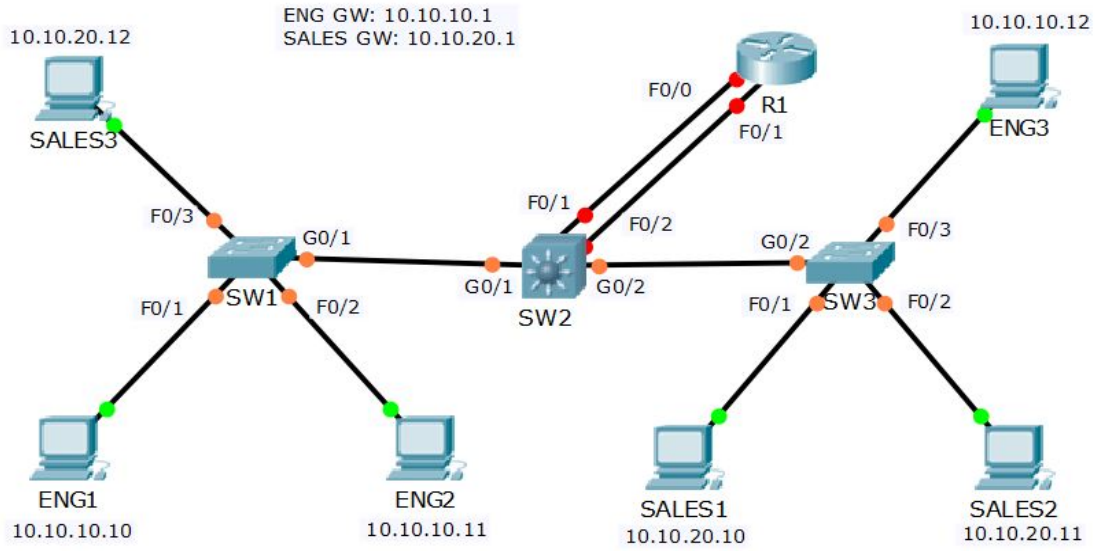
```
R1#sh run int f3/0
Building configuration...

Current configuration : 100 bytes
!
interface FastEthernet3/0
 ip address 10.0.3.1 255.255.255.0
 ip ospf cost 1500
 duplex full
end
```

23-1 VLAN and Inter-VLAN Routing Configuration – Lab Exercise

In this lab you will perform a VLAN configuration for a campus network, including Virtual Trunking Protocol, Access and Trunk ports, and inter-VLAN routing.

Lab Topology



Load the Startup Configurations

Download the '23-1 VLAN and Inter-VLAN Routing Configuration.pkt' file here. Open in Packet Tracer to load the lab.

VTP, Access and Trunk Ports

1) All routers and switches are in a factory default state. View the VLAN database on SW1 to verify no VLANs have been added.

2) View the default switchport status on the link from SW1 to SW2.

3) Configure the links between switches as trunks.

4) Configure SW1 as a VTP Server in the VTP domain Flackbox.

5) SW2 must not synchronise its VLAN database with SW1.

6) SW3 must learn VLAN information from SW1. VLANs should not be edited on SW3.

7) Add the Eng, Sales and Native VLANs on all switches.

8) Verify the VLANs are in the database on each switch.

9) Configure the trunk links to use VLAN 199 as the native VLAN for better security.

10) Configure the switchports connected to the PCs with the correct VLAN configuration.

11) Verify the Eng1 PC has connectivity to Eng3.

12) Verify Sales1 has connectivity to Sales3.

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Inter-VLAN Routing – Option 1

Separate Interfaces on Router

13) Configure interface FastEthernet0/0 on R1 as the default gateway for the Eng PCs.

14) Configure interface FastEthernet0/1 on R1 as the default gateway for the Sales PCs.

15) Configure SW2 to support inter-VLAN routing using R1 as the default gateway.

16) Verify the Eng1 PC has connectivity to Sales1.

17) Clean-up: Shut down interface FastEthernet0/1 on R1.

Inter-VLAN Routing – Option 2

Router on a Stick

18) Configure sub-interfaces on FastEthernet0/0 on R1 as the default gateway for the Eng and Sales PCs.

19) Configure SW2 to support inter-VLAN routing using R1 as the default gateway.

20) Verify the Eng1 PC has connectivity to Sales1.

21) Clean-up: Shut down interface FastEthernet0/0 on R1.

Inter-VLAN Routing – Option 3

Layer 3 Switch

22) Enable layer 3 routing on SW2.

23) Configure SVIs on SW2 to support inter-VLAN routing between the Eng and Sales VLANs.

24) Verify the Eng1 PC has connectivity to Sales1.

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23-1 VLAN and Inter-VLAN Routing Configuration - Answer Key

In this lab you will perform a VLAN configuration for a campus network, including Virtual Trunking Protocol, Access and Trunk ports, and inter-VLAN routing.

VTP, Access and Trunk Ports

1) All routers and switches are in a factory default state. View the VLAN database on SW1 to verify no VLANs have been added.

```
SW1#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, 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
                                                Gig0/1, Gig0/2
1002 fddi-default                     active
1003 token-ring-default               active
1004 fddinet-default                  active
1005 trnet-default                    active
```

2) View the default switchport status on the link from SW1 to SW2.

```
SW1#show interface gig0/1 switchport
Name: Gig0/1
Switchport: Enabled
Administrative Mode: dynamic auto
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Voice VLAN: none
Administrative private-vlan host-association: none
Administrative private-vlan mapping: none
Administrative private-vlan trunk native VLAN: none
Administrative private-vlan trunk encapsulation: dot1q
Administrative private-vlan trunk normal VLANs: none
Administrative private-vlan trunk private VLANs: none
Operational private-vlan: none
Trunking VLANs Enabled: ALL
Pruning VLANs Enabled: 2-1001
Capture Mode Disabled
Capture VLANs Allowed: ALL
Protected: false
Appliance trust: none
```

The trunking mode is set to dynamic auto and the interface is currently in the access port operational mode using the default VLAN 1.

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3) Configure the links between switches as trunks.

```
SW1(config)#int g0/1
SW1(config-if)#switch mode trunk


SW2(config)#int g0/1
SW2(config-if)#switch trunk encap dot1q
SW2(config-if)#switch mode trunk
SW2(config-if)#int g0/2
SW2(config-if)#switch trunk encap dot1q
SW2(config-if)#switch mode trunk


SW3(config)#int g0/2
SW3(config-if)#switch mode trunk
```

4) Configure SW1 as a VTP Server in the VTP domain Flackbox.

```
SW1(config)#vtp domain Flackbox
Changing VTP domain name from NULL to Flackbox
SW1(config)#vtp mode server
Device mode already VTP SERVER.
```

5) SW2 must not synchronise its VLAN database with SW1.

```
SW2(config)#vtp mode transparent
     Setting device to VTP TRANSPARENT mode.
```

6) SW3 must learn VLAN information from SW1. VLANs should not be edited on SW3.

```
SW3(config)#vtp mode client
Setting device to VTP CLIENT mode.
SW3(config)#vtp domain Flackbox
Changing VTP domain name from NULL to Flackbox
```

7) Add the Eng, Sales and Native VLANs on all switches.

VLANs must be configured on the VTP Server SW1 and on VTP Transparent SW2. VTP Client SW3 will learn the VLANs from SW1.

```
SW1(config)#vlan 10
SW1(config-vlan)#name Eng
SW1(config-vlan)#vlan 20
SW1(config-vlan)#name Sales
SW1(config-vlan)#vlan 199
SW1(config-vlan)#name Native
```

```
SW2(config)#vlan 10
SW2(config-vlan)#name Eng
SW2(config-vlan)#vlan 20
SW2(config-vlan)#name Sales
SW2(config-vlan)#vlan 199
SW2(config-vlan)#name Native
```

8) Verify the VLANs are in the database on each switch.

```
SW3#sh vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, 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
                                                Gig0/1
10   Eng                              active
20   Sales                            active
199  Native                           active
1002 fddi-default                     active
1003 token-ring-default               active
1004 fddinet-default                  active
1005 trnet-default                    active
```

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9) Configure the trunk links to use VLAN 199 as the native VLAN for better security.

```
SW1(config)#interface gig0/1
SW1(config-if)#switch trunk native vlan 199


SW2(config)#int gig0/1
SW2(config-if)#switch trunk native vlan 199
SW2(config-if)#int gig0/2
SW2(config-if)#switch trunk native vlan 199


SW3(config)#int gig0/2
SW3(config-if)#switch trunk native vlan 199
```

10) Configure the switchports connected to the PCs with the correct VLAN configuration.

Eng PCs should be in VLAN 10, Sales PCs in VLAN 20.

```
SW1(config)#int range f0/1 - 2
SW1(config-if-range)#switch mode access
SW1(config-if-range)#switch access vlan 10
SW1(config-if-range)#int f0/3
SW1(config-if)#switch mode access
SW1(config-if)#switch access vlan 20


SW3(config)#int range f0/1 - 2
SW3(config-if-range)#switch mode access
SW3(config-if-range)#switch access vlan 20
SW3(config-if-range)#int f0/3
SW3(config-if)#switch mode access
SW3(config-if)#switch access vlan 10
```

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11) Verify the Eng1 PC has connectivity to Eng3.

```
C:\>ping 10.10.10.12

Pinging 10.10.10.12 with 32 bytes of data:

Reply from 10.10.10.12: bytes=32 time<1ms TTL=128
Reply from 10.10.10.12: bytes=32 time<1ms TTL=128
Reply from 10.10.10.12: bytes=32 time<1ms TTL=128
Reply from 10.10.10.12: bytes=32 time=1ms TTL=128

Ping statistics for 10.10.10.12:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

12) Verify Sales1 has connectivity to Sales3.

```
C:\>ping 10.10.20.12

Pinging 10.10.20.12 with 32 bytes of data:

Reply from 10.10.20.12: bytes=32 time=1ms TTL=128
Reply from 10.10.20.12: bytes=32 time<1ms TTL=128
Reply from 10.10.20.12: bytes=32 time<1ms TTL=128
Reply from 10.10.20.12: bytes=32 time<1ms TTL=128

Ping statistics for 10.10.20.12:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

Inter-VLAN Routing – Option 1

Separate Interfaces on Router

13) Configure interface FastEthernet0/0 on R1 as the default gateway for the Eng PCs.

```
R1(config)#interface FastEthernet 0/0
R1(config-if)#ip address 10.10.10.1 255.255.255.0
R1(config-if)#no shutdown
```

14) Configure interface FastEthernet0/1 on R1 as the default gateway for the Sales PCs.

```
R1(config)#interface FastEthernet 0/1
R1(config-if)#ip address 10.10.20.1 255.255.255.0
R1(config-if)#no shutdown
```

15) Configure SW2 to support inter-VLAN routing using R1 as the default gateway.

```
SW2(config)#interface FastEthernet 0/1
SW2(config-if)#switchport mode access
SW2(config-if)#switchport access vlan 10
SW2(config-if)#interface FastEthernet 0/2
SW2(config-if)#switchport mode access
SW2(config-if)#switchport access vlan 20
```

16) Verify the Eng1 PC has connectivity to Sales1.

```
C:\>ping 10.10.20.10

Pinging 10.10.20.10 with 32 bytes of data:

Request timed out.
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127

Ping statistics for 10.10.20.10:
    Packets: Sent = 4, Received = 3, Lost = 1 (25%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

17) Clean-up: Shut down interface FastEthernet0/1 on R1.

```
R1(config)#int f0/1
R1(config-if)#shutdown
```

Inter-VLAN Routing – Option 2

Router on a Stick

18) Configure sub-interfaces on FastEthernet0/0 on R1 as the default gateway for the Eng and Sales PCs.

```
R1(config)#interface FastEthernet 0/0
R1(config-if)#no ip address
R1(config-if)#no shutdown
R1(config-if)#interface FastEthernet 0/0.10
R1(config-subif)#encapsulation dot1q 10
R1(config-subif)#ip address 10.10.10.1 255.255.255.0
R1(config-subif)#interface FastEthernet 0/0.20
R1(config-subif)#encapsulation dot1q 20
R1(config-subif)#ip address 10.10.20.1 255.255.255.0
```

19) Configure SW2 to support inter-VLAN routing using R1 as the default gateway.

```
SW2(config)#interface FastEthernet 0/1
SW2(config-if)#switch trunk encap dot1q
SW2(config-if)#switchport mode trunk
```

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20) Verify the Eng1 PC has connectivity to Sales1.

```
C:\>ping 10.10.20.10

Pinging 10.10.20.10 with 32 bytes of data:

Request timed out.
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127

Ping statistics for 10.10.20.10:
    Packets: Sent = 4, Received = 3, Lost = 1 (25%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

21) Clean-up: Shut down interface FastEthernet0/0 on R1.

```
R1(config)#int f0/0
R1(config-if)#shutdown
```

Inter-VLAN Routing – Option 3

Layer 3 Switch

22) Enable layer 3 routing on SW2.

```
SW2(config)#ip routing
```

23) Configure SVIs on SW2 to support inter-VLAN routing between the Eng and Sales VLANs.

```
SW2(config)#interface vlan 10
SW2(config-if)#ip address 10.10.10.1 255.255.255.0
SW2(config-if)#interface vlan 20
SW2(config-if)#ip address 10.10.20.1 255.255.255.0
```

24) Verify the Eng1 PC has connectivity to Sales1.

```
C:\>ping 10.10.20.10

Pinging 10.10.20.10 with 32 bytes of data:

Request timed out.
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127

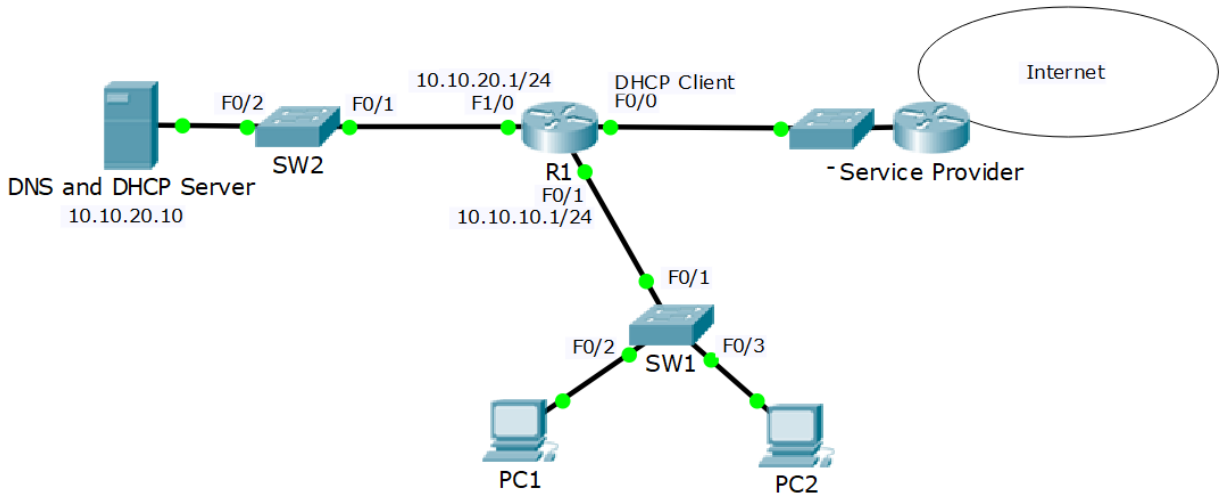
Ping statistics for 10.10.20.10:
    Packets: Sent = 4, Received = 3, Lost = 1 (25%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

24-1 DHCP Configuration – Lab Exercise

In this lab you will perform a DHCP configuration for a small campus network. You will configure a router's outside interface as a DHCP client. You will then set up DCHP services, using a Cisco router first and then an external DHCP server. The external DHCP server is inside the campus LAN but outside the router.

Note that the external DHCP server at 10.10.20.10 will not be used until the last part of the lab.

Lab Topology



Load the Startup Configurations

Download the '24-1 DHCP Configuration.pkt' file here. Open in Packet Tracer to load the lab.

Cisco DHCP Client

1) You have not acquired a static public IP address from the Internet service provider. Configure the outside interface FastEthernet 0/0 on R1 to receive its IP address using DHCP. The Service Provider is already configured and you have no access to it.

2) Verify that R1 received its public IP address via DHCP (you may need to wait a few minutes for the address to be assigned).

3) What is the IP address of R1's DHCP server?

Cisco DHCP Server

4) Enable the DHCP service on R1 so it gives out IP addresses to the PCs in the 10.10.10.0/24 subnet. Leave IP addresses 10.10.10.1 – 10 free to be assigned to servers and printers. 10.10.20.10 is the DNS server.

5) Verify the clients received their IP information via DHCP.

6) Verify the clients can ping the DNS server by its hostname 'DNSserver' (it might take some time for DNS to resolve the hostname).

7) On R1, verify both clients received an IP address via DHCP.

8) Cleanup – remove the DHCP server configuration on R1. You will use an external DHCP server instead in the next section.

9) Enter the command 'ipconfig /release' on the PCs to release their IP addresses.

10) Enter the command 'ipconfig /renew' on the PCs and verify they can no longer obtain an IP address via DHCP

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External DHCP Server

11) The server at 10.10.20.10 has been configured as a DHCP server with a scope of IP addresses for the 10.10.10.0/24 subnet, but the PCs there are not receiving IP addresses. Why is this?

12) Configure the network to allow the PCs to receive their IP addresses from the DHCP server.

13) Verify the clients received their IP information via DHCP.

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24-1 DHCP Configuration - Answer Key

In this lab you will perform a DHCP configuration for a small campus network. You will configure a router's outside interface as a DHCP client. You will then set up DCHP services, using a Cisco router first and then an external DHCP server. The external DHCP server is inside the campus LAN but outside the router.

Note that the external DHCP server at 10.10.20.10 will not be used until the last part of the lab.

Cisco DHCP Client

1) You have not acquired a static public IP address from the Internet service provider. Configure the outside interface FastEthernet 0/0 on R1 to receive its IP address using DHCP. The Service Provider is already configured and you have no access to it.

```
R1(config)#interface f0/0
R1(config-if)#ip address dhcp
R1(config-if)#no shutdown
```

2) Verify that R1 received its public IP address via DHCP (you may need to wait a few minutes for the address to be assigned).

```
%DHCP-6-ADDRESS_ASSIGN: Interface FastEthernet0/0 assigned
DHCP address 203.0.113.2, mask 255.255.255.0, hostname R1

R1#sh ip int brief
Interface IP-Address OK? Method Status Protocol
FastEthernet0/0 203.0.113.2 YES DHCP up up
FastEthernet0/1 unassigned YES unset administratively down down
FastEthernet1/0 unassigned YES unset administratively down down
FastEthernet1/1 unassigned YES unset administratively down down
Vlan1 unassigned YES unset administratively down down
```

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3) What is the IP address of R1's DHCP server?

The DHCP server is at 203.0.113.1. We can get this information by viewing the DHCP lease information.

```
R1#show dhcp lease
Temp IP addr: 203.0.113.2 for peer on Interface:
FastEthernet0/0
Temp sub net mask: 255.255.255.0
DHCP Lease server: 203.0.113.1 , state: Bound
DHCP Transaction id: 64B8EE07
Lease: 86400 secs, Renewal: 43200 secs, Rebind: 75600 secs
Temp default-gateway addr: 203.0.113.1
Next timer fires after: 11:53:13
Retry count: 0 Client-ID:cisco-0001.63C2.9701-Fa0/0
Client-ID hex dump: 636973636F2D303030312E363343322E
93730312D4661302F30
Hostname: R1
```

Cisco DHCP Server

4) Enable the DHCP service on R1 so it gives out IP addresses to the PCs in the 10.10.10.0/24 subnet. Leave IP addresses 10.10.10.1 – 10 free to be assigned to servers and printers. 10.10.20.10 is the DNS server.

```
R1(config)#ip dhcp excluded-address 10.10.10.1 10.10.10.10
R1(config)#ip dhcp pool Flackbox
R1(dhcp-config)#network 10.10.10.0 255.255.255.0
R1(dhcp-config)#default-router 10.10.10.1
R1(dhcp-config)#dns-server 10.10.20.10
```

5) Verify the clients received their IP information via DHCP.

```
C:\>ipconfig /all

FastEthernet0 Connection:(default port)

   Connection-specific DNS Suffix..:
   Physical Address................: 0000.0CA0.A359
   Link-local IPv6 Address.........:
FE80::200:CFF:FEA0:A359
   IP Address......................: 10.10.10.12
   Subnet Mask.....................: 255.255.255.0
   Default Gateway.................: 10.10.10.1
   DNS Servers.....................: 10.10.20.10
   DHCP Servers....................: 10.10.10.1
   DHCPv6 IAID.....................: 28262
   DHCPv6 Client DUID..............:
00-01-00-01-61-91-76-98-00-00-0C-A0-A3-59
```

6) Verify the clients can ping the DNS server by its hostname 'DNSserver' (it might take some time for DNS to resolve the hostname).

```
C:\>ping dnsserver

Pinging 10.10.20.10 with 32 bytes of data:

Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time=1ms TTL=127
Reply from 10.10.20.10: bytes=32 time<1ms TTL=127
Reply from 10.10.20.10: bytes=32 time=1ms TTL=127

Ping statistics for 10.10.20.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

7) On R1, verify both clients received an IP address via DHCP.

```
R1#show ip dhcp binding
IP address       Client-ID/              Lease expiration        Type
                 Hardware address
10.10.10.12      0000.0CA0.A359           --                     Automatic
10.10.10.11      0002.164E.D116           --                     Automatic
```

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8) Cleanup – remove the DHCP server configuration on R1. You will use an external DHCP server instead in the next section.

```
R1(config)#no ip dhcp excluded-address 10.10.10.1 10.10.10.10
R1(config)#no ip dhcp pool Flackbox
```

9) Enter the command 'ipconfig /release' on the PCs to release their IP addresses.

```
C:\>ipconfig /release

   IP Address.....................: 0.0.0.0
   Subnet Mask....................: 0.0.0.0
   Default Gateway................: 0.0.0.0
   DNS Server.....................: 0.0.0.0
```

10) Enter the command 'ipconfig /renew' on the PCs and verify they can no longer obtain an IP address via DHCP

```
C:\>ipconfig /renew
DHCP request failed.
```

External DHCP Server

11) The server at 10.10.20.10 has been configured as a DHCP server with a scope of IP addresses for the 10.10.10.0/24 subnet, but the PCs there are not receiving IP addresses. Why is this?

DHCP requests use broadcast traffic. R1 is not forwarding the requests on to the DHCP server as routers do not forward broadcast traffic by default.

12) Configure the network to allow the PCs to receive their IP addresses from the DHCP server.

On the interface where they are received, configure the router to forward DHCP requests to the server.

```
R1(config)#interface f0/1
R1(config-if)#ip helper-address 10.10.20.10
```

13) Verify the clients received their IP information via DHCP.

```
C:\>ipconfig /all

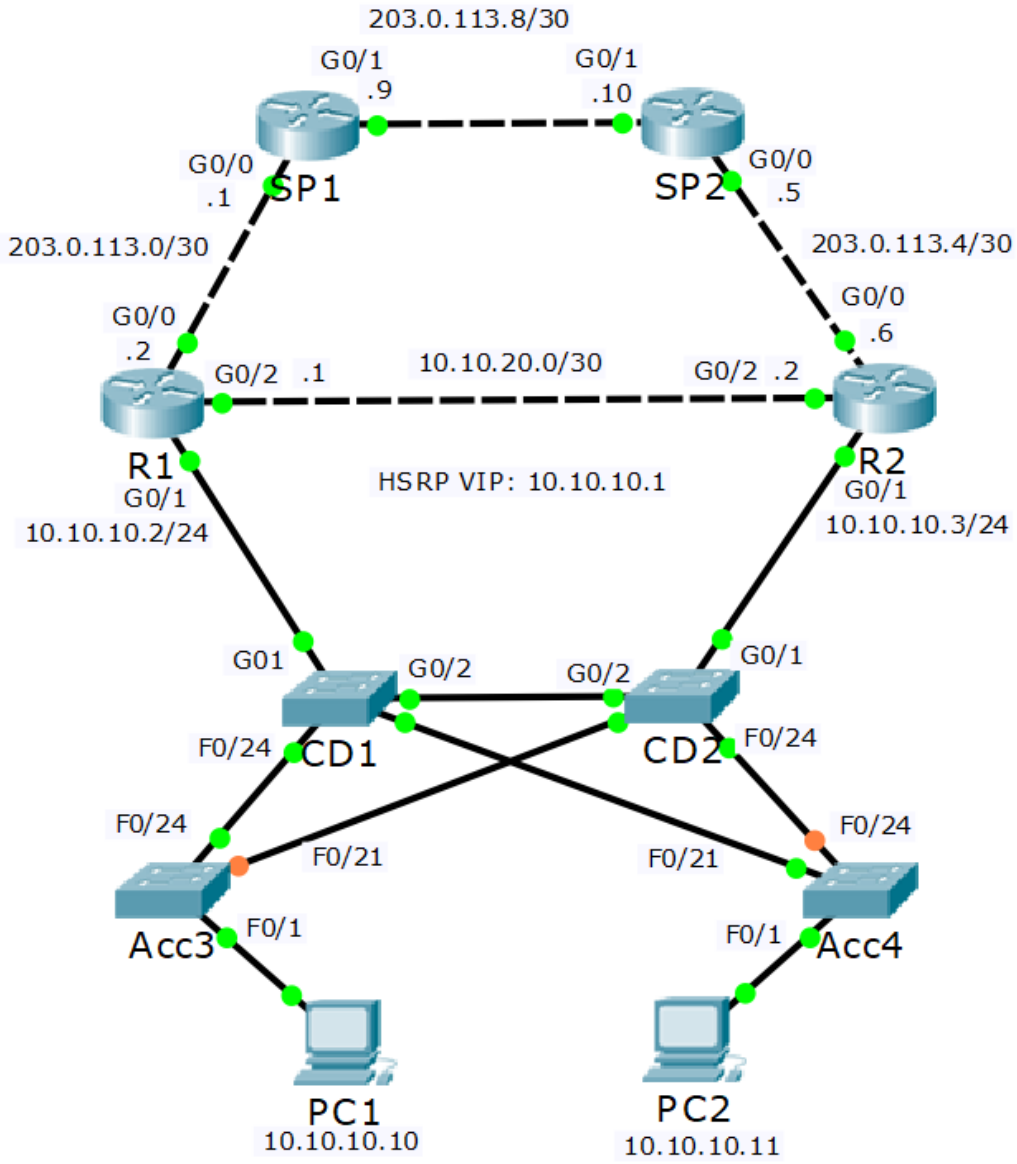
FastEthernet0 Connection:(default port)

   Connection-specific DNS Suffix..:
   Physical Address.................: 0000.0CA0.A359
   Link-local IPv6 Address.........:
FE80::200:CFF:FEA0:A359
   IP Address.......................: 10.10.10.101
   Subnet Mask......................: 255.255.255.0
   Default Gateway..................: 10.10.10.1
   DNS Servers......................: 10.10.20.10
   DHCP Servers.....................: 10.10.20.10
   DHCPv6 IAID......................: 28262
   DHCPv6 Client DUID...............:
00-01-00-01-61-91-76-98-00-00-0C-A0-A3-59
```

25-1 HSRP Configuration – Lab Exercise

In this lab you will configure and test HSRP for a small campus network.

Lab Topology



Load the Startup Configurations

Download the '25-1 HSRP Configuration.pkt' file here. Open in Packet Tracer to load the lab.

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Basic HSRP

1) Configure basic HSRP for the 10.10.10.0/24 network using the IP addresses shown in the topology diagram.

2) Wait for HSRP to come up on both routers and then check which is the active router.

3) Verify that the PCs can ping their default gateway using the HSRP address 10.10.10.1.

4) Verify that the PCs have upstream connectivity via their HSRP default gateway. Ping SP1 at 203.0.113.1

5) What is the MAC address on the physical interface of the active router?

6) What is the MAC address of the HSRP virtual interface?

7) Verify the PCs are using the virtual MAC address for their default gateway.

Priority and Pre-emption

8) Configure HSRP so that R1 will be the preferred router. Use a single command.

9) Which router do you expect will be active now? Verify this.

10) Ensure that R1 is the active router. Do not reboot.

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Test HSRP

11) Run a continuous ping to the HSRP IP address from PC1 with the 'ping 10.10.10.1 –n 1000' command.

12) Save the configuration on R1 then reboot.

13) View the ping output on PC1. You should see a few dropped pings as R2 transitions to active following the outage of R1.

14) Verify R2 has transitioned to HSRP active.

15) Wait for R1 to complete booting and HSRP to come up. Verify R1 transitions to HSRP active because pre-emption is enabled.

16) Hit 'Ctrl-C' to cancel the ping on PC1. If you scroll back you should see a dropped ping or two as R1 transitioned back to HSRP active.

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25-1 HSRP Configuration - Answer Key

In this lab you will configure and test HSRP for a small campus network.

Basic HSRP

1) Configure basic HSRP for the 10.10.10.0/24 network using the IP addresses shown in the topology diagram.

Check to see if the physical IP addresses for the HSRP interface GigabitEthernet0/1 have been configured on R1 and R2.

```
R1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0     203.0.113.2     YES manual up                    up
GigabitEthernet0/1     unassigned      YES unset  administratively down down
GigabitEthernet0/2     10.10.20.1      YES manual up                    up
Vlan1                  unassigned      YES unset  administratively down down
```

They haven't been configured yet so correct that. We'll do R1 first.

```
R1(config)#interface g0/1
R1(config-if)#ip address 10.10.10.2 255.255.255.0
R1(config-if)#no shutdown
```

Then add the virtual IP address.

```
R1(config-if)#standby 1 ip 10.10.10.1
```

Repeat on R2. Use a different physical address and the same virtual IP address.

```
R2(config)#interface g0/1
R2(config-if)#ip address 10.10.10.3 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#standby 1 ip 10.10.10.1
```

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2) Wait for HSRP to come up on both routers and then check which is the active router.

Both routers have the same default priority so the router with the highest IP address will be preferred. If you complete the configuration on both routers before HSRP comes up then R2 will be active.

```
R1#show standby
GigabitEthernet0/1 - Group 1
State is Standby
7 state changes, last state change 00:16:34
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 0.327 secs
Preemption disabled
Active router is 10.10.10.3
Standby router is local
Priority 100 (default 100)
Group name is hsrp-Gig0/1-1 (default)
```

3) Verify that the PCs can ping their default gateway using the HSRP address 10.10.10.1.

```
C:\>ping 10.10.10.1

Pinging 10.10.10.1 with 32 bytes of data:

Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=43ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255

Ping statistics for 10.10.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 43ms, Average = 11ms
```

4) Verify that the PCs have upstream connectivity via their HSRP default gateway. Ping SP1 at 203.0.113.1

```
C:\>ping 203.0.113.1

Pinging 203.0.113.1 with 32 bytes of data:

Request timed out.
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time=1ms TTL=254

Ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 3, Lost = 1 (25%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

5) What is the MAC address on the physical interface of the active router?

```
R2#show interface g0/1
GigabitEthernet0/1 is up, line protocol is up (connected)
Hardware is CN Gigabit Ethernet, address is 0001.6470.2502 truncated
```

MAC addresses may be different in your lab.

6) What is the MAC address of the HSRP virtual interface?

```
R2#show standby
GigabitEthernet0/1 - Group 1
State is Active
6 state changes, last state change 00:16:22
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 2.475 secs
Preemption disabled
Active router is local
Standby router is 10.10.10.2
Priority 100 (default 100)
Group name is hsrp-Gig0/1-1 (default)
```

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7) Verify the PCs are using the virtual MAC address for their default gateway.

```
C:\>arp -a
  Internet Address      Physical Address      Type
  10.10.10.1            0000.0c07.ac01        dynamic
  10.10.10.2            00d0.ffeb.2d02        dynamic
```

Priority and Pre-emption

8) Configure HSRP so that R1 will be the preferred router. Use a single command.

```
R1(config)#interface g0/1
R1(config-if)#standby 1 priority 110
```

9) Which router do you expect will be active now? Verify this.

R2 will remain active because we didn't configure pre-emption.

```
R1#show standby
GigabitEthernet0/1 - Group 1
State is Standby
7 state changes, last state change 00:06:06
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 0.782 secs
Preemption disabled
Active router is 10.10.10.3
Standby router is local
Priority 110 (configured 110)
Group name is hsrp-Gig0/1-1 (default)
```

10) Ensure that R1 is the active router. Do not reboot.

```
R1(config)#int g0/1
R1(config-if)#standby 1 preempt
```

```
R1#show standby
GigabitEthernet0/1 - Group 1
State is Active
9 state changes, last state change 00:27:09
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 1.275 secs
Preemption enabled
Active router is local
Standby router is 10.10.10.3, priority 100 (expires in 8 sec)
Priority 110 (configured 110)
Group name is hsrp-Gig0/1-1 (default)
```

Test HSRP

11) Run a continuous ping to the HSRP IP address from PC1 with the 'ping 10.10.10.1 –n 1000' command.

```
C:\>ping 10.10.10.1 -n 1000

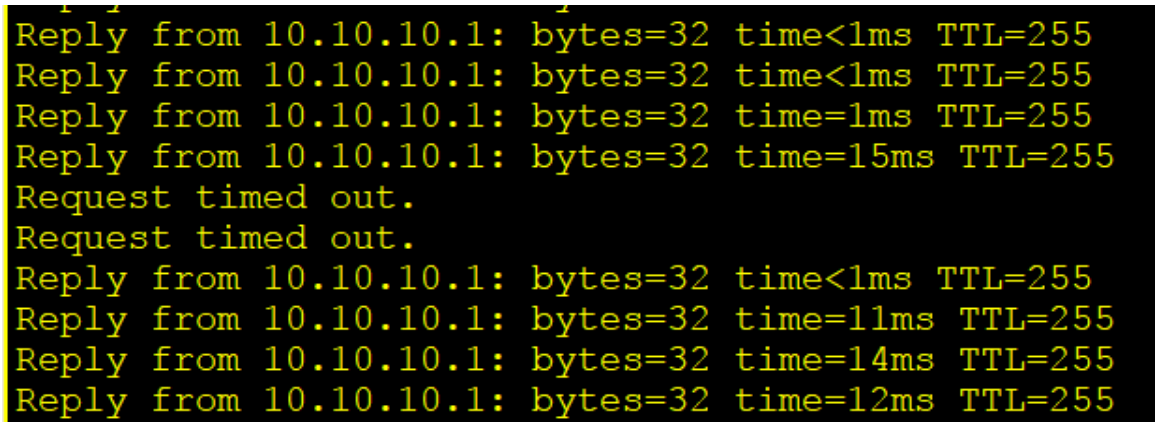
Pinging 10.10.10.1 with 32 bytes of data:

Reply from 10.10.10.1: bytes=32 time=13ms TTL=255
Reply from 10.10.10.1: bytes=32 time=32ms TTL=255
Reply from 10.10.10.1: bytes=32 time=2ms TTL=255
```

12) Save the configuration on R1 then reboot.

```
R1#copy run start
Destination filename [startup-config]?
Building configuration...
[OK]
R1#reload
Proceed with reload? [confirm]
```

13) View the ping output on PC1. You should see a few dropped pings as R2 transitions to active following the outage of R1.



14) Verify R2 has transitioned to HSRP active.

```
R2#show standby
GigabitEthernet0/1 - Group 1
State is Active
9 state changes, last state change 00:33:44
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 0.074 secs
Preemption disabled
Active router is local
Standby router is unknown, priority 110
Priority 100 (default 100)
Group name is hsrp-Gig0/1-1 (default)
```

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15) Wait for R1 to complete booting and HSRP to come up. Verify R1 transitions to HSRP active because pre-emption is enabled.

```
R1#show standby
GigabitEthernet0/1 - Group 1
State is Active
5 state changes, last state change 00:00:38
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 2.533 secs
Preemption enabled
Active router is local
Standby router is 10.10.10.3
Priority 110 (configured 110)
Group name is hsrp-Gig0/1-1 (default)
```

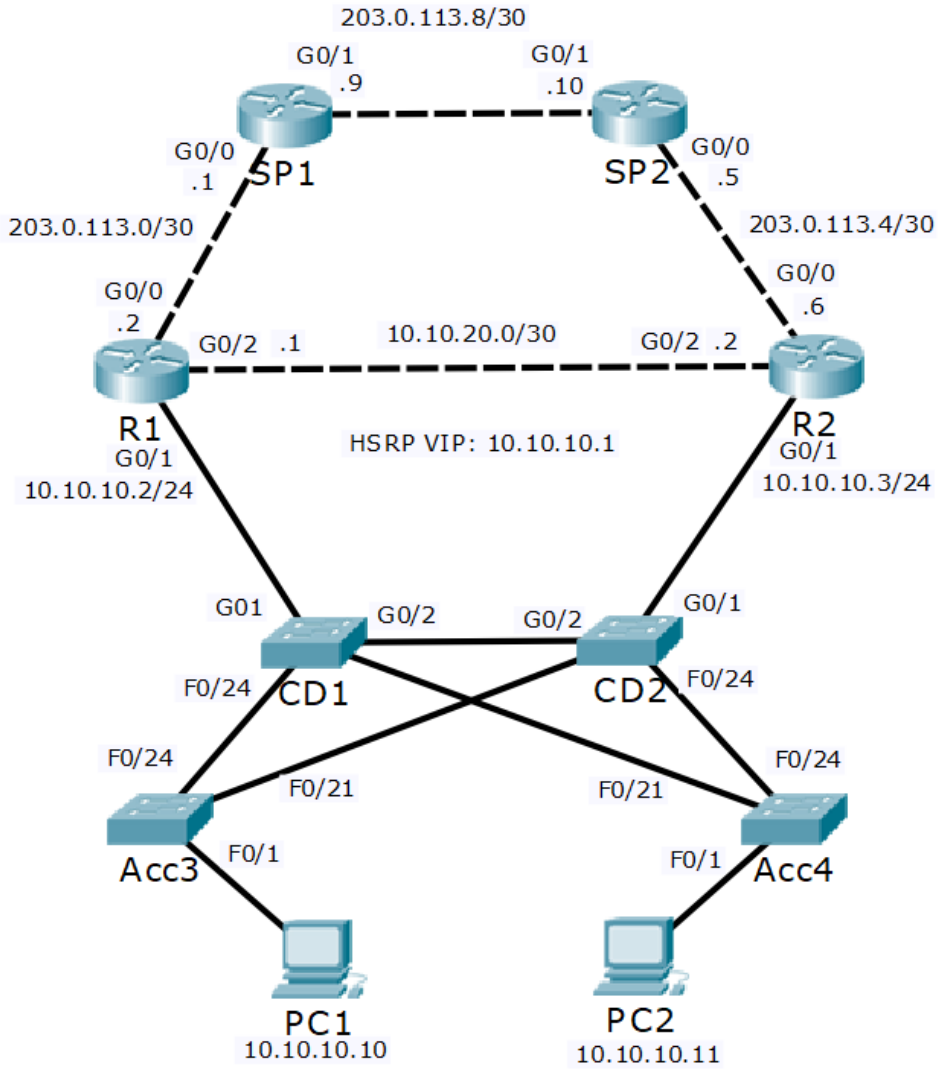
16) Hit 'Ctrl-C' to cancel the ping on PC1. If you scroll back you should see a dropped ping or two as R1 transitioned back to HSRP active.

```
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=10ms TTL=255
Reply from 10.10.10.1: bytes=32 time=19ms TTL=255
Request timed out.
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=13ms TTL=255
Reply from 10.10.10.1: bytes=32 time=13ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
```

26-1 Spanning Tree Troubleshooting – Lab Exercise

Spanning Tree is enabled by default. In this lab you will troubleshoot Spanning Tree for a small campus network.

Lab Topology

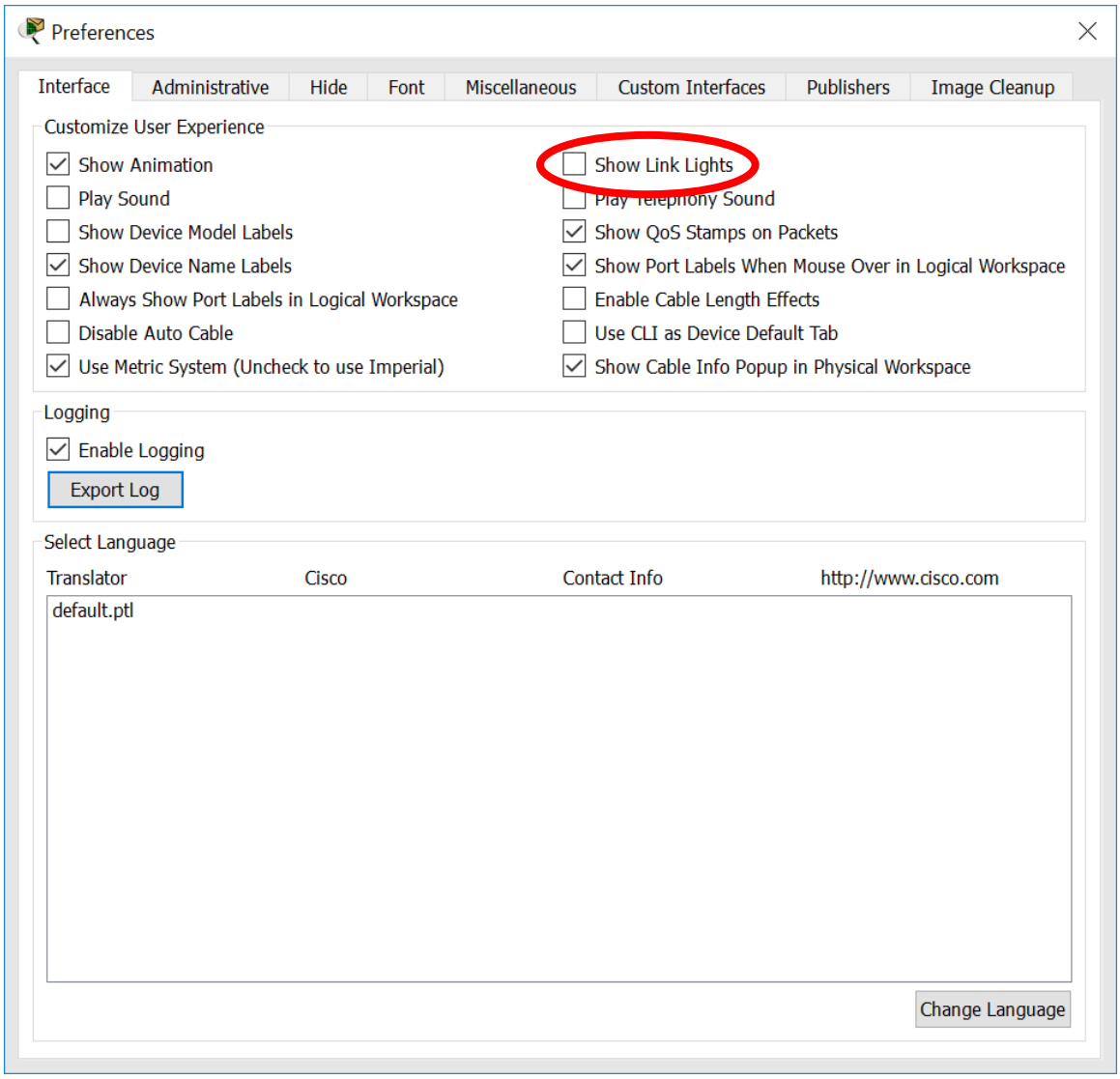


Load the Startup Configurations

IMPORTANT: Before loading the lab exercise, disable 'Show Link Lights' in Packet Tracer. (You can change it back at the end of the lab.)

In Packet Tracer, click 'Options > Preferences'

On the 'Interface' tab, uncheck 'Show Link Lights'



Download the '26-1 STP Troubleshooting.pkt' file here. Open in Packet Tracer to load the lab.

Troubleshooting the Spanning Tree Protocol

1) The Network Operations Centre has reported that traffic is not following the most direct path from the branch office PCs to the Internet. Your task at this stage is to verify this.

   Your task is to report which path traffic is currently taking from both PC1 and PC2 to 203.0.113.9. Do not change any configuration.

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26-1 Spanning Tree Troubleshooting - Answer Key

In this lab you will troubleshoot Spanning Tree for a small campus network.

Troubleshooting the Spanning Tree Protocol

1) The Network Operations Centre has reported that traffic is not following the most direct path from the branch office PCs to the Internet. Your task at this stage is to verify this.

   Your task is to report which path traffic is currently taking from both PC1 and PC2 to 203.0.113.9. Do not change any configuration.

There is not a set order of actions to troubleshoot this scenario. Troubleshooting in a logical fashion will however make it easier and quicker. This is how I would do it.

Check which router is the HSRP active gateway for the 10.10.10.0/24 network.

```
R1#show standby
GigabitEthernet0/1 - Group 1
State is Active
7 state changes, last state change 00:28:52
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
Local virtual MAC address is 0000.0C07.AC01 (v1 default)
Hello time 3 sec, hold time 10 sec
Next hello sent in 2.276 secs
Preemption enabled
Active router is local
Standby router is 10.10.10.3, priority 100 (expires in 7 sec)
Priority 110 (configured 110)
Group name is hsrp-Gig0/1-1 (default)
```

R1 has been preconfigured with a higher HSRP priority and pre-emption enabled.

Check the PCs have connectivity to 203.0.113.9. Ping from both PCs.

```
C:\>ping 203.0.113.9

Pinging 203.0.113.9 with 32 bytes of data:

Request timed out.
Reply from 203.0.113.9: bytes=32 time=15ms TTL=254
Reply from 203.0.113.9: bytes=32 time=10ms TTL=254
Reply from 203.0.113.9: bytes=32 time<1ms TTL=254

Ping statistics for 203.0.113.9:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 15ms, Average = 8ms
```

Check which Layer 3 path the PCs are using to get to 203.0.113.9. Run traceroute on both PCs.

```
C:\>tracert 203.0.113.9

Tracing route to 203.0.113.9 over a maximum of 30 hops:

  1    0 ms      0 ms      0 ms      10.10.10.2
  2    11 ms     0 ms      0 ms      203.0.113.9

Trace complete.
```

The PCs are taking the most direct path via their HSRP default gateway to get to 203.0.113.9. The Layer 3 configuration and operations all look good.

Check which VLAN the PCs are in on the Acc3 and Acc4 switches.

```
Acc3#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/2, Fa0/3, Fa0/4, Fa0/5
                                                Fa0/6, 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, Fa0/22
                                                Fa0/23, Gig0/1, Gig0/2
10   Eng                              active    Fa0/1
20   Sales                            active
199  Native                           active
1002 fddi-default                     active
1003 token-ring-default               active
1004 fddinet-default                  active
1005 trnet-default                    active
```

The PCs are in the Eng VLAN 10.

On CD1 and CD2, check the switch ports connecting to the routers have also been configured as access ports in VLAN 10.

```
CD1#sh run
! truncated
interface GigabitEthernet0/1
switchport access vlan 10
switchport mode access
```

On all switches, check the interfaces connecting switches have been configured as trunks with matching native VLANs.

```
CD1#sh run
! truncated
!
interface FastEthernet0/21
switchport trunk native vlan 199
switchport mode trunk
!
interface FastEthernet0/24
switchport trunk native vlan 199
switchport mode trunk
!
interface GigabitEthernet0/2
switchport trunk native vlan 199
switchport mode trunk
```

The existing HSRP and VLAN configuration looks good.

The next thing to verify is Spanning Tree. One of the central core/distribution switches should be used as the Root Bridge to ensure Layer 2 traffic uses the most direct path over the network.

Check the Spanning Tree topology for VLAN 10 on switch Acc3.

```
Acc3#show spanning-tree vlan 10
VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    32778
              Address     0001.C962.D43D
              This bridge is the root
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0001.C962.D43D
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/1            Desg FWD 19        128.1    P2p
Fa0/24           Desg FWD 19        128.24   P2p
Fa0/21           Desg FWD 19        128.21   P2p
```

Acc3 is the Root Bridge. That is not good. Check to see if this is because it has a configured Bridge Priority.

```
Acc3#sh run | include priority
Acc3#
```

Bridge Priority has not been configured on Acc3. Check the other switches.

```
CD1#sh run | include priority
CD1#
```

```
CD2#sh run | include priority
CD2#
```

```
Acc4#sh run | include priority
Acc4#
```

Bridge Priority has not been configured anywhere so the switch with the lowest MAC address should be selected as the Root Bridge.

We learned that Acc3's MAC address is 0001.C962.D43D from the output of the 'show spanning tree vlan 10' command we ran on it.

Verify that all switches have matching Spanning Tree Root Bridge information. They should all have the same default Bridge Priority value (as one was not manually set), and agree that Acc3 has the lowest MAC address and is the Root Bridge.

```
CD1#sh spanning-tree vlan 10
VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    32778
              Address     0001.C962.D43D
              Cost        19
              Port        24(FastEthernet0/24)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0090.0CA0.3902
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/21           Desg FWD 19        128.21   P2p
Fa0/24           Root FWD 19        128.24   P2p
Gi0/2            Altn BLK 4         128.26   P2p
Gi0/1            Desg FWD 4         128.25   P2p
```

CD1's MAC address is 0090.0CA0.3902. It agrees that Acc3 is the Root Bridge.

```
CD2#sh spanning-tree vlan 10
VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    32778
              Address     0001.C962.D43D
              Cost        19
              Port        21(FastEthernet0/21)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0090.0C16.7A9B
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/21           Root FWD 19        128.21   P2p
Fa0/24           Desg FWD 19        128.24   P2p
Gi0/2            Desg FWD 4         128.26   P2p
Gi0/1            Desg FWD 4         128.25   P2p
```

CD2's MAC address is 0090.0C16.7A9B. It agrees that Acc3 is the Root Bridge.

```
Acc4#show spanning-tree vlan 10
VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    32778
              Address     0001.C962.D43D
              Cost        38
              Port        24(FastEthernet0/24)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0060.708A.D564
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

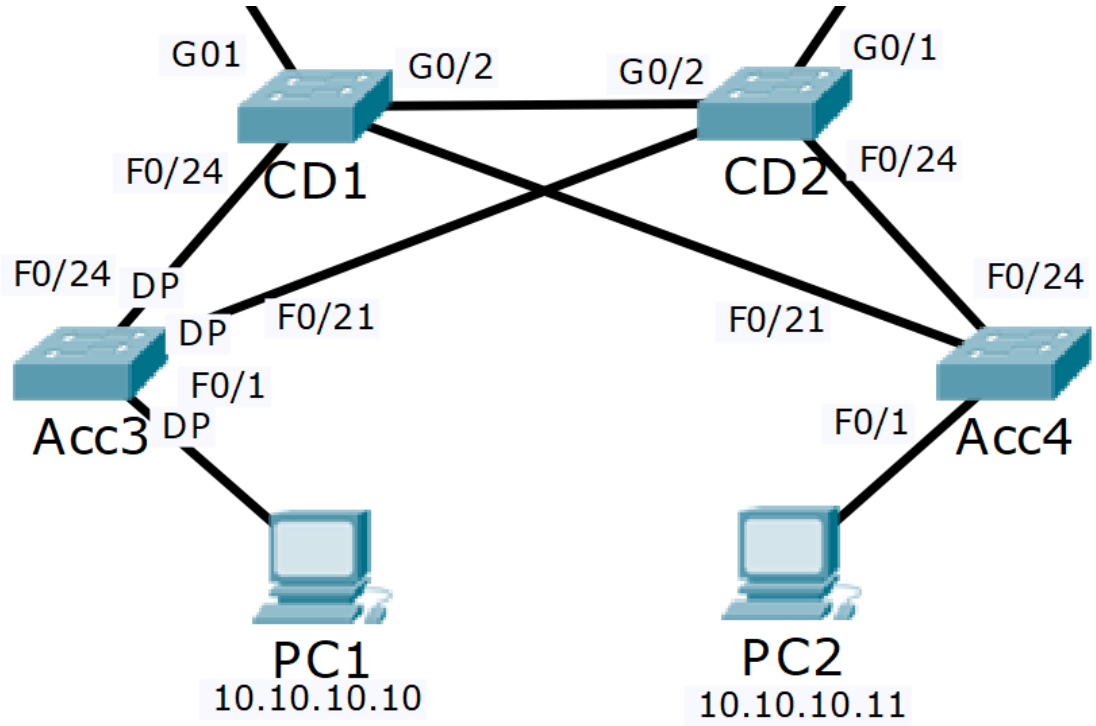
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/1            Desg FWD 19        128.1    P2p
Fa0/21           Altn BLK 19        128.21   P2p
Fa0/24           Root FWD 19        128.24   P2p
```

Acc4's MAC address is 0060.708A.D564. It agrees that Acc3 is the Root Bridge.

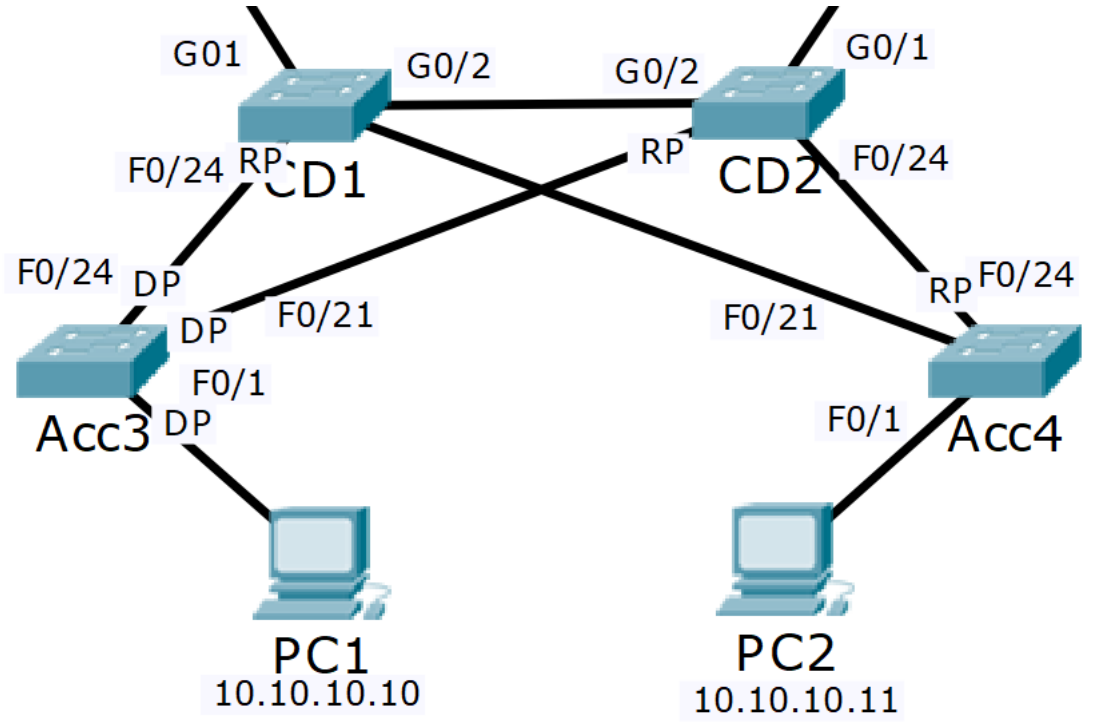
We were asked to report on the forwarding paths currently being used. Use the output of the 'show spanning-tree vlan 10' commands on each switch to diagram the Spanning Tree.

Acc3 is the Root Bridge so all its ports are Designated Ports.

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Add each switch's Root Port to the diagram. The 'Port' value in the 'Root ID' section of the 'show spanning-tree vlan 10' output shows this information.



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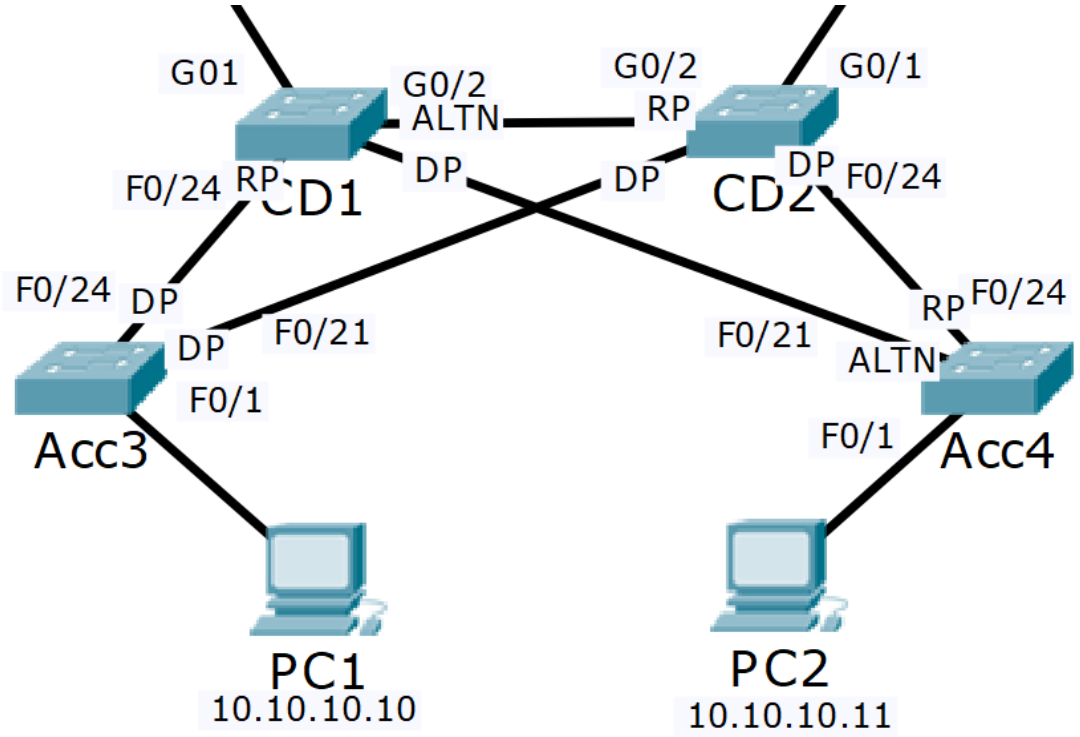
The port on the other side of Root Ports is always a Designated Port. Label F0/24 on CD2 as a Designated Port in the diagram.

The links which are left must be blocking. These are CD1 G0/2 to CD2 G0/2, and CD1 F0/21 to Acc4 F0/21. Check which side is blocking from the output of the 'show spanning-tree vlan 10' commands.

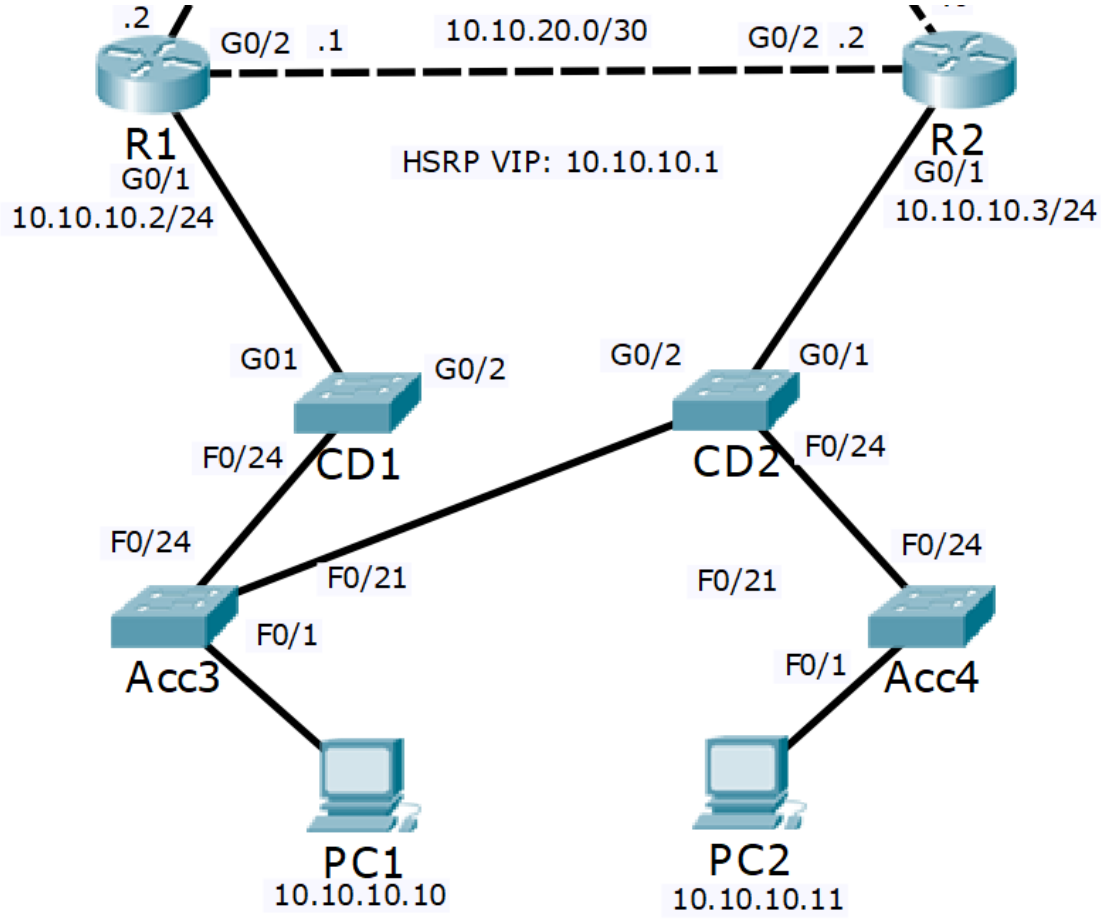
CD1 G0/2 is the blocking Alternate port, CD2 G0/2 is the forwarding Designated Port.

CD1 F0/21 is the forwarding Designated Port, Acc4 F0/21 is the blocking Alternate port.

Add this information to the diagram.



By removing the blocking links from the diagram we can see the Spanning Tree.



We can see that PC1 will take the path PC1 > Acc3 > CD1 > R1 to reach its HSRP default gateway. This is the most direct path and is good.

The end to end path from PC1 to 203.0.113.9 is PC1 > Acc3 > CD1 > R1 > SP1

PC2 however will use the path PC2 > Acc4 > CD2 > Acc3 > CD1 > R1. This is not the most direct path as traffic is transiting CD2 and Acc3 rather than going directly over the link from Acc4 to CD1.

The end to end path from PC2 to 203.0.113.9 is PC2 > Acc4 > CD2 > Acc3 > CD1 > R1 > SP1

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We can verify the path being used by checking the MAC address tables on the switches. First verify the HSRP virtual MAC address.

```
R1#sh standby
GigabitEthernet0/1 - Group 1
State is Active
5 state changes, last state change 00:00:30
Virtual IP address is 10.10.10.1
Active virtual MAC address is 0000.0C07.AC01
```

Then clear the ARP cache on PC2, and ping the virtual MAC address to generate traffic.

```
C:\>arp -d
C:\>ping 10.10.10.1

Pinging 10.10.10.1 with 32 bytes of data:

Reply from 10.10.10.1: bytes=32 time=22ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=11ms TTL=255
Reply from 10.10.10.1: bytes=32 time=11ms TTL=255

Ping statistics for 10.10.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 22ms, Average = 11ms
```

Then check the MAC address table on Acc4.

```
Acc4#show mac address-table
          Mac Address Table
-------------------------------------------

Vlan    Mac Address       Type        Ports
----    -----------       --------    -----

   1    0002.1690.e018    DYNAMIC     Fa0/24
  10    0000.0c07.ac01    DYNAMIC     Fa0/24
  10    0001.6310.5d05    DYNAMIC     Fa0/1
  10    0001.6470.2502    DYNAMIC     Fa0/24
  10    0002.1690.e018    DYNAMIC     Fa0/24
  10    00d0.ffeb.2d02    DYNAMIC     Fa0/24
  20    0002.1690.e018    DYNAMIC     Fa0/24
 199    0002.1690.e018    DYNAMIC     Fa0/24
```

We can see that the HSRP virtual MAC address 0000.0c07.ac01 is reached through interface F0/24 to CD2, rather than on the direct link to CD1 over interface F0/21.

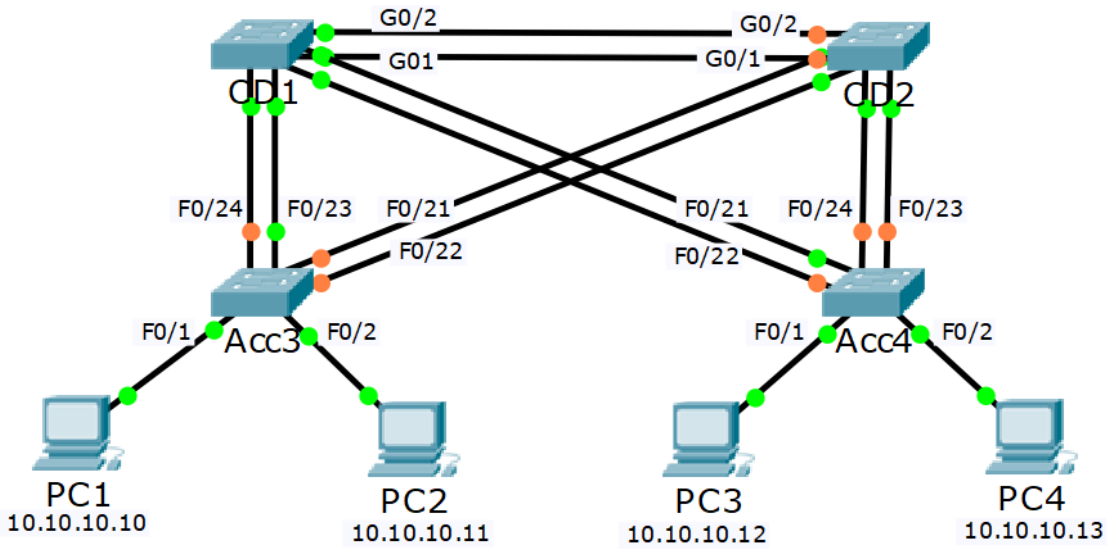
We can go hop by hop using the ‘show mac address-table’ command to verify the traffic path end to end across the switched network.

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27-1 EtherChannel Configuration – Lab Exercise

In this lab you will configure Etherchannel links in a campus LAN.

Lab Topology



Load the Startup Configurations

Download the '27-1 EtherChannel Configuration.pkt' file here. Open in Packet Tracer to load the lab.

LACP EtherChannel Configuration

1) The access layer switches Acc3 and Acc4 both have two FastEthernet uplinks. How much total bandwidth is available between the PCs attached to Acc3 and the PCs attached to Acc4?

2) Convert the existing uplinks from Acc3 to CD1 and CD2 to LACP EtherChannel. Configure descriptions on the port channel interfaces to help avoid confusion later.

3) Verify the EtherChannels come up.

PAgP EtherChannel Configuration

4) Convert the existing uplinks from Acc4 to CD1 and CD2 to PAgP EtherChannel. (Note that in a real world environment you should always use LACP if possible.)

5) Verify the EtherChannels come up.

Static EtherChannel Configuration

6) Convert the existing uplinks between CD1 and CD2 to static EtherChannel.

7) Verify the EtherChannel comes up.

8) How much total bandwidth is available between the PCs attached to Acc3 and the PCs attached to Acc4 now?

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27-1 EtherChannel Configuration - Answer Key

In this lab you will configure EtherChannel links in a campus LAN.

LACP EtherChannel Configuration

1) The access layer switches Acc3 and Acc4 both have two FastEthernet uplinks. How much total bandwidth is available between the PCs attached to Acc3 and the PCs attached to Acc4?

Spanning tree shuts down all but one uplink on both switches so the total bandwidth available between them is a single FastEthernet link – 100 Mbps.

2) Convert the existing uplinks from Acc3 to CD1 and CD2 to LACP EtherChannel. Configure descriptions on the port channel interfaces to help avoid confusion later.

The uplinks go to two separate redundant switches at the core/distribution layer so we need to configure two EtherChannels, one to CD1 and one to CD2.

We'll configure the Acc3 side of the EtherChannel to CD1 first. Don't forget to set the native VLAN on the new port channel interface.

```
Acc3(config)#interface range f0/23 - 24
Acc3(config-if-range)#channel-group 1 mode active
Acc3(config-if-range)#exit
Acc3(config)#interface port-channel 1
Acc3(config-if)#description Link to CD1
Acc3(config-if)#switchport mode trunk
Acc3(config-if)#switchport trunk native vlan 199
```

Then configure switch CD1 with matching settings.

```
CD1(config)#interface range f0/23 - 24
CD1(config-if-range)#channel-group 1 mode active
CD1(config-if-range)#exit
CD1(config)#interface port-channel 1
CD1(config-if)#description Link to Acc3
CD1(config-if)#switchport mode trunk
CD1(config-if)#switchport trunk native vlan 199
```

Next configure the Acc3 side of the EtherChannel to CD2. Remember to use a different port channel number.

```
Acc3(config)#interface range f0/21 - 22
Acc3(config-if-range)#channel-group 2 mode active
Acc3(config-if-range)#exit
Acc3(config)#interface port-channel 2
Acc3(config-if)#description Link to CD2
Acc3(config-if)#switchport mode trunk
Acc3(config-if)#switchport trunk native vlan 199
```

Then configure switch CD2 with matching settings.

```
CD2(config)#interface range f0/21 - 22
CD2(config-if-range)#channel-group 2 mode active
CD2(config-if-range)#exit
CD2(config)#interface port-channel 2
CD2(config-if)#description Link to Acc3
CD2(config-if)#switchport mode trunk
CD2(config-if)#switchport trunk native vlan 199
```

3) Verify the EtherChannels come up.

The port channels should show flags (SU) (Layer 2, in use) with member ports (P) (in port-channel). Verify on both sides of the port channel.

Acc3:

```
Acc3#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port

Number of channel-groups in use: 2
Number of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           LACP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           LACP   Fa0/21(P) Fa0/22(P)
```

CD1:

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```
CD1#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 1
Number of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           LACP    Fa0/23(P) Fa0/24(P)
```

CD2:

```
CD2#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 1
Number of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

2      Po2(SU)           LACP    Fa0/21(P) Fa0/22(P)
```

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PAgP EtherChannel Configuration

4) Convert the existing uplinks from Acc4 to CD1 and CD2 to PAgP EtherChannel. (Note that in a real world environment you should always use LACP if possible.)

It's good practice to use the same port channel number on both sides of the link. CD1 is already using port channel 1 to Acc3, and CD2 is using port channel 2 to Acc3. From Acc4 to CD1 we'll use port channel 2, and from Acc4 to CD2 we'll use port channel 1.

We'll configure the Acc4 side of the EtherChannel to CD2 first.

```
Acc4(config)#interface range f0/23 - 24
Acc4(config-if-range)#channel-group 1 mode desirable
Acc4(config-if-range)#exit
Acc4(config)#interface port-channel 1
Acc3(config-if)#description Link to CD2
Acc4(config-if)#switchport mode trunk
Acc4(config-if)#switchport trunk native vlan 199
```

Then configure switch CD2 with matching settings.

```
CD2(config)#interface range f0/23 - 24
CD2(config-if-range)#channel-group 1 mode desirable
CD2(config-if-range)#exit
CD2(config)#interface port-channel 1
Acc3(config-if)#description Link to Acc4
CD2(config-if)#switchport mode trunk
CD2(config-if)#switchport trunk native vlan 199
```

Next configure the Acc4 side of the EtherChannel to CD1. Remember to use a different port channel number.

```
Acc4(config)#interface range f0/21 - 22
Acc4(config-if-range)#channel-group 2 mode desirable
Acc4(config-if-range)#exit
Acc4(config)#interface port-channel 2
Acc3(config-if)#description Link to CD1
Acc4(config-if)#switchport mode trunk
Acc4(config-if)#switchport trunk native vlan 199
```

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Then configure switch CD1 with matching settings.

```
CD1(config)#interface range f0/21 - 22
CD1(config-if-range)#channel-group 2 mode desirable
CD1(config-if-range)#exit
CD1(config)#interface port-channel 2
Acc3(config-if)#description Link to Acc4
CD1(config-if)#switchport mode trunk
CD1(config-if)#switchport trunk native vlan 199
```

5) Verify the EtherChannels come up.

The port channels should show flags (SU) (Layer 2, in use) with member ports (P) (in port-channel). Verify on both sides of the port channel.

On the core/distribution layer switches you should see both the LACP and PAgP port channels up.

Acc4:

```
Acc4#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 2
Number of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           PAgP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           PAgP   Fa0/21(P) Fa0/22(P)
```

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CD1:

```
CD1#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 2
Number of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           LACP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           PAgP   Fa0/21(P) Fa0/22(P)
```

CD2:

```
CD2#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 2
Number of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           PAgP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           LACP   Fa0/21(P) Fa0/22(P)
```

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Static EtherChannel Configuration

6) Convert the existing uplinks between CD1 and CD2 to static EtherChannel.

Port channels 1 and 2 are already in use so we'll use port channel 3.

Configure the CD1 side first.

```
CD1(config)#interface range g0/1 - 2
CD1(config-if-range)#channel-group 3 mode on
CD1(config-if-range)#exit
CD1(config)#interface port-channel 3
Acc3(config-if)#description Link to CD2
CD1(config-if)#switchport mode trunk
CD1(config-if)#switchport trunk native vlan 199
```

Then configure switch CD2 with matching settings.

```
CD2(config)#interface range g0/1 - 2
CD2(config-if-range)#channel-group 3 mode on
CD2(config-if-range)#exit
CD2(config)#interface port-channel 3
Acc3(config-if)#description Link to CD1
CD2(config-if)#switchport mode trunk
CD2(config-if)#switchport trunk native vlan 199
```

7) Verify the EtherChannel comes up.

CD1:

```
CD1#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 3
Number of aggregators:           3

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           LACP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           PAgP   Fa0/21(P) Fa0/22(P)
3      Po3(SU)           -      Gig0/1(P) Gig0/2(P)
```

CD2:

```
CD2#show etherchannel summary
Flags:  D - down        P - in port-channel
        I - stand-alone s - suspended
        H - Hot-standby (LACP only)
        R - Layer3      S - Layer2
        U - in use      f - failed to allocate aggregator
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port


Number of channel-groups in use: 3
Number of aggregators:           3

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------

1      Po1(SU)           PAgP   Fa0/23(P) Fa0/24(P)
2      Po2(SU)           LACP   Fa0/21(P) Fa0/22(P)
3      Po3(SU)           -      Gig0/1(P) Gig0/2(P)
```

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8) How much total bandwidth is available between the PCs attached to Acc3 and the PCs attached to Acc4 now?

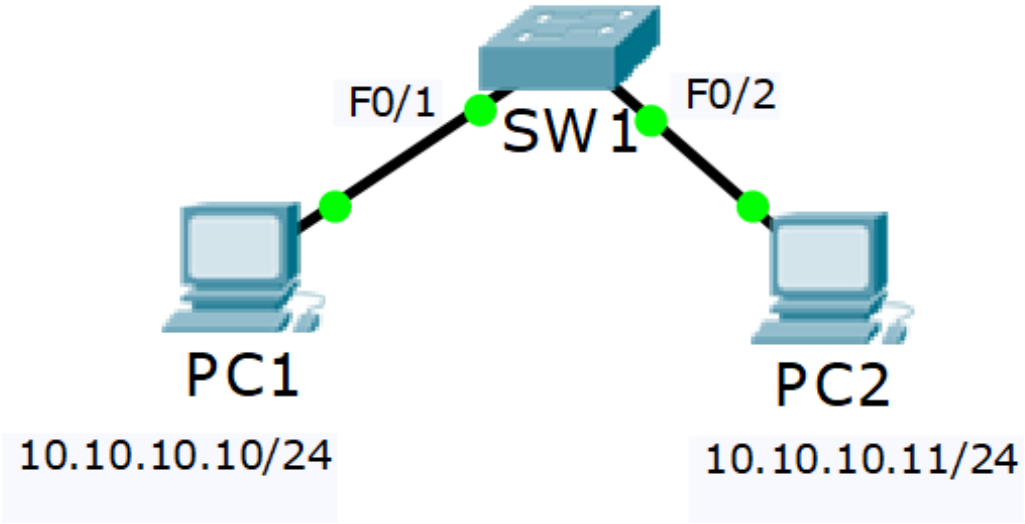
The port channels from the Acc3 and Acc4 switches towards the root bridge CD1 are up and forwarding. Spanning tree shuts down the port channels toward CD2 to prevent a loop.

The port channels from Acc3 and Acc4 facing the root bridge comprise two FastEthernet interfaces, so the total bandwidth available between the PCs attached to the different access layer switches is 200 Mbps.

28-1 Port Security Configuration Lab Exercise

In this lab you will configure Port Security on a small campus network.

Lab Topology



Load the Startup Configurations

Download the '28-1 Port Security Configuration.pkt' file here. Open in Packet Tracer to load the lab.

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Disable Unused Ports

1) Disable all unused ports on SW1. This prevents unauthorised hosts plugging in to them to gain access to the network.

Port Security Configuration

2) Configure port security on interface FastEthernet 0/1. Allow a maximum of two MAC addresses and manually add PC1's MAC address to the configuration.

3) Enable Port Security on interface FastEthernet 0/2 with the default settings.

4) Use a 'show port-security' command to verify the MAC address on PC2.

5) Verify the full Port Security configuration on both interfaces.

28-1 Port Security Configuration Answer Key

In this lab you will configure Port Security on a small campus network.

Disable Unused Ports

1) Disable all unused ports on SW1. This prevents unauthorised hosts plugging in to them to gain access to the network.

'show ip interface brief' shows ports FastEthernet 0/1 – 24 and GigabitEthernet0/1 – 2. Interfaces FastEthernet 0/1 and 0/2 are in use.

```
SW1#sh ip int brief
Interface IP-Address OK? Method Status Protocol
FastEthernet0/1 unassigned YES manual up up
! truncated
FastEthernet0/24 unassigned YES manual down down
GigabitEthernet0/1 unassigned YES manual down down
GigabitEthernet0/2 unassigned YES manual down down
Vlan1 unassigned YES manual administratively down down
```

Interfaces FastEthernet 0/1 and 0/2 are in use.

```
SW1(config)#interface range f0/3 - 24
SW1(config-if-range)#shutdown
```

```
SW1(config-if-range)#interface range g0/1 - 2
SW1(config-if-range)#shutdown
```

Port Security Configuration

2) Configure port security on interface FastEthernet 0/1. Allow a maximum of two MAC addresses and manually add PC1's MAC address to the configuration.

We need to discover PC1's MAC address. We can get this information from the PC itself or from the switch. Use 'ipconfig /all' to find it on the PC.

```
C:\>ipconfig /all

FastEthernet0 Connection:(default port)

   Connection-specific DNS Suffix..:
   Physical Address................: 0000.1111.1111
   Link-local IPv6 Address.........: FE80::200:CFF:FEA0:A359
   IP Address......................: 10.10.10.10
   Subnet Mask.....................: 255.255.255.0
   Default Gateway.................: 0.0.0.0
   DNS Servers.....................: 0.0.0.0
   DHCP Servers....................: 0.0.0.0
   DHCPv6 IAID.....................: 28262
   DHCPv6 Client DUID..............:
00-01-00-01-61-91-76-98-00-00-11-11-11-11
```

Use 'show mac address-table' to find it on the switch. Use ping to generate some traffic from the PC if it does not show up in the MAC address table.

```
C:\>ping 10.10.10.11

Pinging 10.10.10.11 with 32 bytes of data:

Reply from 10.10.10.11: bytes=32 time=14ms TTL=128
Reply from 10.10.10.11: bytes=32 time<1ms TTL=128
Reply from 10.10.10.11: bytes=32 time=19ms TTL=128
Reply from 10.10.10.11: bytes=32 time<1ms TTL=128

Ping statistics for 10.10.10.11:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 19ms, Average = 8ms
```

```
SW1#show mac address-table
          Mac Address Table
-------------------------------------------

Vlan    Mac Address       Type        Ports
----    -----------       --------    -----

   1    0000.1111.1111    DYNAMIC     Fa0/1
   1    0000.2222.2222    DYNAMIC     Fa0/2
```

You need to make the interface an access port before the switch will accept Port Security configuration. No VLANs are configured on the switch or specified in the lab task so leave it in the default VLAN 1.

```
SW1(config)#int f0/1
SW1(config-if)#switch mode access
```

Add the Port Security configuration.

```
SW1(config-if)#switchport port-security
SW1(config-if)#switchport port-security maximum 2
SW1(config-if)#switchport port-security mac-address 0000.1111.1111
```

3) Enable Port Security on interface FastEthernet 0/2 with the default settings.

```
SW1(config)#int f0/2
SW1(config-if)#switch mode access
SW1(config-if)#switchport port-security
```

4) Use a ‘show port-security’ command to verify the MAC address on PC2.

You may have to ping from PC2 first to generate some traffic.

```
C:\>ping 10.10.10.10

Pinging 10.10.10.10 with 32 bytes of data:

Reply from 10.10.10.10: bytes=32 time=1ms TTL=128
Reply from 10.10.10.10: bytes=32 time<1ms TTL=128
Reply from 10.10.10.10: bytes=32 time=13ms TTL=128
Reply from 10.10.10.10: bytes=32 time=17ms TTL=128

Ping statistics for 10.10.10.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 17ms, Average = 7ms
```

```
SW1#show port-security address
                  Secure Mac Address Table
------------------------------------------------------------------------
Vlan   Mac Address   Type                Ports         Remaining Age
                                                       (mins)
----   -----------   ----                -----         -------------
1      0000.1111.1111      SecureConfigured    FastEthernet0/1
1      0000.2222.2222      DynamicConfigured   FastEthernet0/2
------------------------------------------------------------------------
Total Addresses in System (excluding one mac per port)     : 0
Max Addresses limit in System (excluding one mac per port) : 1024
```

PC2’s MAC address is 0000.2222.2222

5) Verify the full Port Security configuration on both interfaces.

```
SW1#show port-security int f0/1
Port Security : Enabled
Port Status : Secure-up
Violation Mode : Shutdown
Aging Time : 0 mins
Aging Type : Absolute
SecureStatic Address Aging : Disabled
Maximum MAC Addresses : 2
Total MAC Addresses : 1
Configured MAC Addresses : 1
Sticky MAC Addresses : 0
Last Source Address:Vlan : 0000.1111.1111:1
Security Violation Count : 0

SW1#show port-security int f0/2
Port Security : Enabled
Port Status : Secure-up
Violation Mode : Shutdown
Aging Time : 0 mins
Aging Type : Absolute
SecureStatic Address Aging : Disabled
Maximum MAC Addresses : 1
Total MAC Addresses : 1
Configured MAC Addresses : 0
Sticky MAC Addresses : 0
Last Source Address:Vlan : 0000.2222.2222:1
Security Violation Count : 0
```

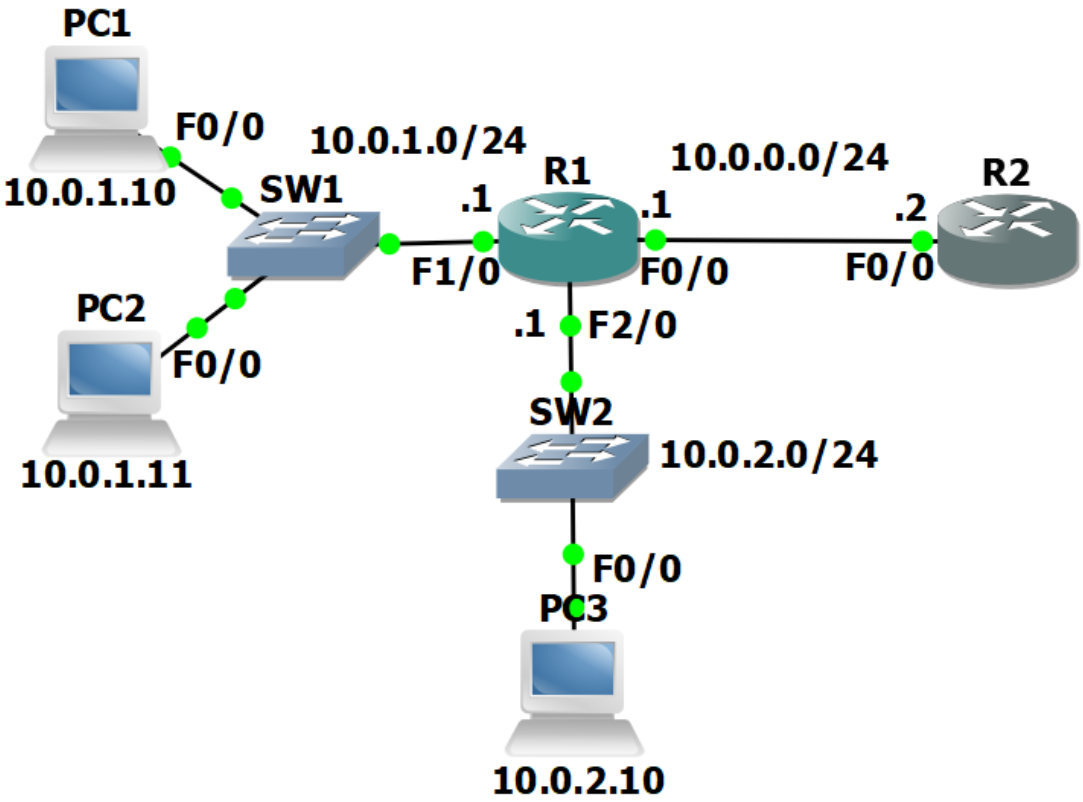
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29-1 ACL Configuration – Lab Exercise

In this lab you will configure standard and extended Access Control Lists.

PC1, PC2 and PC3 are Cisco IOS routers mimicking end hosts. They have been configured with IP addresses and a default static route to R1 as their default gateway.

Lab Topology



Load the Startup Configurations

Download the '29-1 ACL Configuration.gns3project' file here. Open in GNS3 to load the lab.

Numbered Standard ACL

1) Verify that all PCs have connectivity to each other, to R1 and to R2.

2) Configure and apply a numbered standard ACL on R1 which denies traffic from all hosts in the 10.0.2.0/24 subnet to R2.

   The PCs in the 10.0.1.0/24 and 10.0.2.0/24 subnets must maintain connectivity to each other.

   The PCs in the 10.0.1.0/24 subnet must maintain connectivity to R2.

3) Test that traffic is secured exactly as required.

   Verify PC1 and PC2 can ping R2.

   PC3 cannot ping R2.

   PC3 can ping PC1 and PC2.

Numbered Extended ACL

4) Configure and apply a numbered extended ACL on R1 which permits Telnet access from PC1 to R2. Telnet to R2 must be denied for all other PCs in the network.

   All other connectivity must be maintained.

   Do not change the existing ACL.

   Telnet access has already been enabled on R2. The password is 'Flackbox'

5) Test that traffic is secured exactly as required. Use the command 'telnet 10.0.0.2' from the PCs to test and the password 'Flackbox'. Type 'exit' to leave the Telnet session.

   Verify that PC1 can ping and Telnet to R2.

   PC2 can ping R2 but not Telnet to it.

   PC3 cannot ping or Telnet to R2.

   The PCs can all ping each other.

6) How many Telnet packets were permitted by the ACL?

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Named Extended ACL

7) Remove the numbered extended ACL you just configured from the interface. Do not delete the ACL.

8) Configure and apply a named extended ACL on R1 as follows:

   Permit Telnet from PC1 to R2. Telnet to R2 must be denied for all other PCs in the network.

   Permit ping from PC2 to R2. Ping to R2 must be denied for all other PCs in the network.

   All other connectivity must be maintained.

9) Test that traffic is secured exactly as required.

   Verify that PC1 cannot ping R2 but can Telnet to it.

   PC2 can ping R2 but cannot Telnet to it.

   PC3 cannot ping or Telnet to R2.

   The PCs can all ping each other.

29-1 ACL Configuration - Answer Key

In this lab you will configure standard and extended Access Control Lists.

PC1, PC2 and PC3 are Cisco IOS routers mimicking end hosts. They have been configured with IP addresses and a default static route to R1 as their default gateway.

Numbered Standard ACL

1) Verify that all PCs have connectivity to each other, to R1 and to R2.

From PC1, ping PC2, PC3, R1 and R2.

```
PC1#ping 10.0.1.11

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.1.11,
timeout is 2 seconds:

.!!!!

Success rate is 80 percent (4/5), round-trip
min/avg/max = 8/19/40 ms

PC1#ping 10.0.2.10

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.2.10,
timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip
min/avg/max = 20/34/48 ms

PC1#ping 10.0.1.1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.1.1, t
imeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip
min/avg/max = 16/20/24 ms
```

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```
PC1#ping 10.0.0.2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.0.2, t
imeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip
min/avg/max = 40/43/56 ms
```

We have already verified connectivity between the PCs in both subnets. Ping R1 and R2 from PC3.

```
PC3#ping 10.0.2.1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.2.1, t
imeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip
min/avg/max = 12/18/20 ms

PC3#ping 10.0.0.2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.0.2, t
imeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip
min/avg/max = 36/40/44 ms
```

2) Configure and apply a numbered standard ACL on R1 which denies traffic from all hosts in the 10.0.2.0/24 subnet to R2.

   The PCs in the 10.0.1.0/24 and 10.0.2.0/24 subnets must maintain connectivity to each other.

   The PCs in the 10.0.1.0/24 subnet must maintain connectivity to R2.

The task specifies that a numbered standard ACL be used on R1. This checks the source address only. This prevents us from configuring an ACL inbound on the F2/0 interface which denies traffic to R2 but permits it to the 10.0.1.0/24 network – that would require an extended ACL.

The only way the task can be completed is by applying the ACL outbound on the F0/0 interface facing R2.

Configure a numbered standard ACL that denies traffic from 10.0.2.0/24. Do not forget to permit from 10.0.1.0/24 as the implicit deny any at the end of the ACL would block the traffic otherwise.

```
R1(config)#access-list 1 deny 10.0.2.0 0.0.0.255
R1(config)#access-list 1 permit 10.0.1.0 0.0.0.255
```

Do not forget to apply the ACL to the interface.

```
R1(config)#interface f0/0
R1(config-if)#ip access-group 1 out
```

3) Test that traffic is secured exactly as required.

   Verify PC1 and PC2 can ping R2.

   PC3 cannot ping R2.

   PC3 can ping PC1 and PC2.

PC1 and PC2 should be able to ping R2.

```
PC1#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/44/60
ms
```

PC3 should not be able to ping R2.

```
PC3#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
UUUUU
Success rate is 0 percent (0/5)
```

PC3 should be able to ping PC1 and PC2.

```
PC3#ping 10.0.1.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.1.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms

PC3#ping 10.0.1.11
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.1.11, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms
```

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Numbered Extended ACL

4) Configure and apply a numbered extended ACL on R1 which permits Telnet access from PC1 to R2. Telnet to R2 must be denied for all other PCs in the network.

   All other connectivity must be maintained.

   Do not change the existing ACL.

   Telnet access has already been enabled on R2. The password is 'Flackbox'

All traffic from the 10.0.2.0/24 subnet to R2 is already denied by the numbered standard ACL we configured.

We need to create an ACL which will allow Telnet traffic to R2 at 10.0.0.2 from PC1 at 10.0.1.10 but deny it from all other hosts in the 10.0.1.0/24 subnet.

The implicit deny all at the end of the ACL would block Telnet traffic from the other hosts to R2, but it would also block all other traffic from the 10.0.1.0/24 subnet including other applications to R2 and traffic to the 10.0.2.0/24 subnet. We need to explicitly block the Telnet traffic but allow other traffic.

```
R1(config)#access-list 100 permit tcp host 10.0.1.10 host 10.0.0.2
eq telnet
R1(config)#access-list 100 deny tcp 10.0.1.0 0.0.0.255 host 10.0.0.2
eq telnet
R1(config)#access-list 100 permit ip any any
```

The access list should be applied as close to the source as possible, so apply it inbound on interface F1/0. We already have an outbound ACL on F0/0 so we could not apply it there anyway.

```
R1(config)#interface f1/0
R1(config-if)#ip access-group 100 in
```

5) Test that traffic is secured exactly as required. Use the command ‘telnet 10.0.0.2’ from the PCs to test and the password ‘Flackbox’. Type ‘exit’ to leave the Telnet session.

   Verify that PC1 can ping and Telnet to R2.

   PC2 can ping R2 but not Telnet to it.

   PC3 cannot ping or Telnet to R2.

   The PCs can all ping each other.

PC1 should be able to Telnet to R2.

```
PC1#telnet 10.0.0.2
Trying 10.0.0.2 ... Open

User Access Verification
Password:
R2>
```

PC2 should be able to ping but not Telnet to R2.

```
PC2#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/42/60
ms

PC2#telnet 10.0.0.2
Trying 10.0.0.2 ...
% Destination unreachable; gateway or host down
```

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PC3 should not be able to ping or Telnet to R2.

```
PC3#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
UUUUU
Success rate is 0 percent (0/5)

PC3#telnet 10.0.0.2
Trying 10.0.0.2 ...
% Destination unreachable; gateway or host down
```

PC3 should be able to ping PC1 and PC2.

```
PC3#ping 10.0.1.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.1.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms

PC3#ping 10.0.1.11
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.1.11, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms
```

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6) How many Telnet packets were permitted by the ACL?

'show access-list' to check the hit counts. Note that your values may be different.

```
R1#show access-list 100
Extended IP access list 100
    10 permit tcp host 10.0.1.10 host 10.0.0.2 eq telnet (21 matches)
    20 deny tcp 10.0.1.0 0.0.0.255 host 10.0.0.2 eq telnet (1 match)
    30 permit ip any any (15 matches)
```

Named Extended ACL

7) Remove the numbered extended ACL you just configured from the interface. Do not delete the ACL.

```
R1(config)#int f1/0
R1(config-if)#no ip access-group 100 in
```

8) Configure and apply a named extended ACL on R1 as follows:

   Permit Telnet from PC1 to R2. Telnet to R2 must be denied for all other PCs in the network.

   Permit ping from PC2 to R2. Ping to R2 must be denied for all other PCs in the network.

   All other connectivity must be maintained.

All traffic from the 10.0.2.0/24 subnet to R2 is already denied by the numbered standard ACL we configured.

We do need to configure an ACL to secure traffic from the 10.0.1.0/24 subnet.

```
R1(config)#ip access-list extended F1/0_in
R1(config-ext-nacl)#permit tcp host 10.0.1.10 host 10.0.0.2 eq
telnet
R1(config-ext-nacl)#deny tcp 10.0.1.0 0.0.0.255 host 10.0.0.2 eq
telnet
R1(config-ext-nacl)#permit icmp host 10.0.1.11 host 10.0.0.2 echo
R1(config-ext-nacl)#deny icmp 10.0.1.0 0.0.0.255 host 10.0.0.2 echo
R1(config-ext-nacl)#permit ip any any
```

Don't forget to apply the ACL to the interface.

```
R1(config)#int f1/0
R1(config-if)#ip access-group F1/0_in in
```

9) Test that traffic is secured exactly as required.

   Verify that PC1 cannot ping R2 but can Telnet to it.

   PC2 can ping R2 but cannot Telnet to it.

   PC3 cannot ping or Telnet to R2.

   The PCs can all ping each other.

PC1 cannot ping R2 but can Telnet to it.

```
PC1#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
UUUUU
Success rate is 0 percent (0/5)
```

```
PC1#telnet 10.0.0.2
Trying 10.0.0.2 ... Open

User Access Verification

Password:
R2>
```

PC2 can ping R2 but cannot Telnet to it.

```
PC2#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms

PC2#telnet 10.0.0.2
Trying 10.0.0.2 ...
% Destination unreachable; gateway or host down
```

PC3 cannot ping or Telnet to R2.

```
PC3#ping 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
UUUUU
Success rate is 0 percent (0/5)
PC3#telnet 10.0.0.2
Trying 10.0.0.2 ...
% Destination unreachable; gateway or host down
```

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PC3 should be able to ping PC1 and PC2.

```
PC3#ping 10.0.1.10

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.1.10, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms


PC3#ping 10.0.1.11

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 10.0.1.11, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 36/39/40
ms
```

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30-1 NAT Configuration – Lab Exercise

In this lab you will configure static and dynamic Network Address Translation, and Port Address Translation.

PC1, PC2, Int-S1 (internal server 1) and Ext-S1 (external server 1) are Cisco IOS routers mimicking end hosts. They have been configured with IP addresses and a default static route to their default gateways.

R1 is the WAN edge router at your company, it has a default route pointing to the Service Provider router SP1.

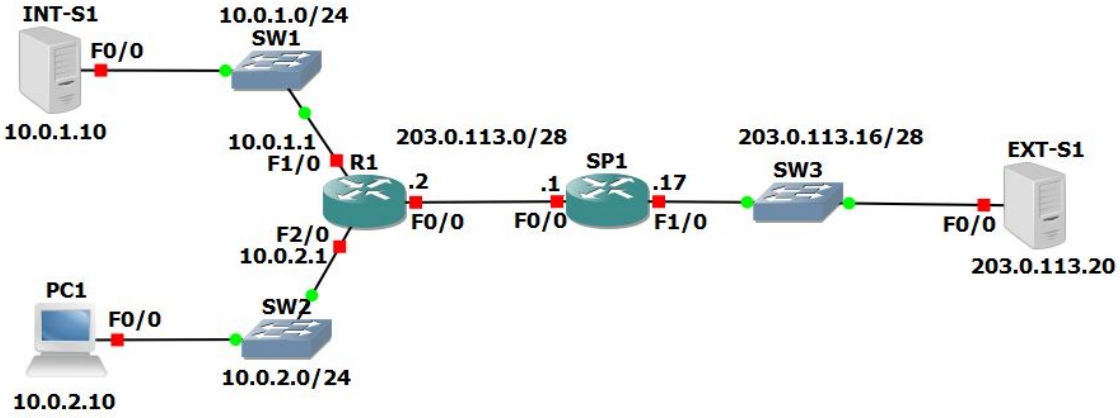
You have bought the range of public IP addresses 203.0.113.0/28.

203.0.113.1 is assigned to the Service Provider default gateway SP1, 203.0.113.2 is assigned to the Internet facing F0/0 interface on your router R1.

203.0.113.3 – 203.0.113.14 are your remaining available public IP addresses.

Note that entries in the NAT translation table age out quickly. Send the traffic again if you do not see the expected results in the table.

Lab Topology



Load the Startup Configurations

Download the '30-1 NAT Configuration.gns3project' file here. Open in GNS3 to load the lab.

Static NAT

1) Int-S1 is your company's web server. It must be reachable from external customers browsing the Internet. Configure NAT on R1 so that external customers can reach the server using the public IP address 203.0.113.3. Do not change any IP addressing or routing information.

2) Enable ICMP debugging on Ext-S1 with the command 'debug ip icmp'.

3) Ping Ext-S1 from Int-S1 to check the NAT rule is working and you have connectivity.

4) Check the debug output on Ext-S1 and verify the ping echo reply was sent to Int-S1's global address 203.0.113.3.

5) Telnet to 203.0.113.3 port 80 from Ext-S1 to verify that external customers on the Internet can reach your web server.
You will see the output shown below if your configuration is working:

```
EXT-S1#telnet 203.0.113.3 80
Trying 203.0.113.3, 80 ... Open
```

6) Verify the ping and Telnet connections appear in the NAT translation table. Note that entries age out quickly so generate the traffic again if you did not check the table quickly enough.

7) Type 'exit' to break the Telnet connection on Ext-S1. You should see the output shown below:

```
EXT-S1#telnet 203.0.113.3 80
Trying 203.0.113.3, 80 ... Open


exit
HTTP/1.1 400 Bad Request
Date: Mon, 21 Aug 2017 19:39:32 GMT
Server: cisco-IOS
Accept-Ranges: none


400 Bad Request
[Connection to 203.0.113.3 closed by foreign host]
```

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Dynamic NAT

8) Configure NAT on R1 so that PCs in the 10.0.2.0/24 subnet have connectivity to external networks on a first come first served basis. Assign global addresses from the range 203.0.113.4 to 203.0.113.12. Do not enable Port Address Translation.

9) Turn on NAT debugging on R1. Ping Ext-S1 from PC1. View the debug output on R1. You should see NAT entries for the 5 pings. Which global address was PC1 translated to?

10) Check the ICMP debug output on Ext-S1 and verify the ping echo reply was sent to PC1's global address.

11) Verify the ping connection appears in the NAT translation table.

12) When all the addresses in the pool 203.0.113.4 to 203.0.113.12 have been allocated, what will happen when the next PC tries to send traffic to an external host?

13) Enable Port Address Translation so that the last IP address in the range can be reused when all IP addresses have been allocated to clients.

14) Cleanup: Completely remove the access list and all NAT configuration from R1. Use the commands 'show run | section nat' and 'show access-list' to verify all configuration is removed.

Port Address Translation PAT

15) Your company no longer has a range of public IP addresses. Instead you will receive a single public IP address via DHCP from your service provider.

    Shutdown interface F0/0 on R1 and remove its IP address. Reconfigure it to receive its IP address via DHCP from the service provider router SP1.

16) Bring the interface back up and wait for DHCP. What IP address is it assigned?

17) Configure NAT on R1 so that PCs in the 10.0.2.0/24 subnet have connectivity to external networks on a first come first served basis. Allow multiple PCs to reuse the IP address on interface F0/0 on R1. Ensure that NAT continues to work if the DHCP address assigned by the provider changes.

18) Turn on NAT debugging on R1. Open a Telnet session from PC1 to Ext-S1, using the password 'Flackbox'.

19) View the debug output on R1. Which global IP address and source port was PC1 translated to?

20) Open a Telnet session from PC2 to Ext-S1. Which global IP address and source port is PC2 translated to?

21) Verify the connections in the NAT translation table.

22) Show the NAT statistics on R1.

30-1 NAT Configuration - Answer Key

In this lab you will configure static and dynamic Network Address Translation, and Port Address Translation.

PC1, PC2, Int-S1 (internal server 1) and Ext-S1 (external server 1) are Cisco IOS routers mimicking end hosts. They have been configured with IP addresses and a default static route to their default gateways.

R1 is the WAN edge router at your company, it has a default route pointing to the Service Provider router SP1.

You have bought the range of public IP addresses 203.0.113.0/28.

203.0.113.1 is assigned to the Service Provider default gateway SP1, 203.0.113.2 is assigned to the Internet facing F0/0 interface on your router R1.

203.0.113.3 – 203.0.113.14 are your remaining available public IP addresses.

Note that entries in the NAT translation table age out quickly. Send the traffic again if you do not see the expected results in the table.

Static NAT

1) Int-S1 is your company's web server. It must be reachable from external customers browsing the Internet. Configure NAT on R1 so that external customers can reach the server using the public IP address 203.0.113.3. Do not change any IP addressing or routing information.

Int-S1 needs a fixed public IP address so we must configure static NAT. Configure the F0/0 interface facing the Internet as the NAT outside interface.

```
R1(config)#int f0/0
R1(config-if)#ip nat outside
```

Configure the F1/0 interface facing Int-S1 as a NAT inside interface.

```
R1(config)#int f1/0
R1(config-if)#ip nat inside
```

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Configure a static NAT rule mapping the inside local address 10.0.1.10 to the global IP address 203.0.113.3.

```
R1(config)#ip nat inside source static 10.0.1.10 203.0.113.3
```

2) Enable ICMP debugging on Ext-S1 with the command ‘debug ip icmp’.

```
EXT-S1#debug ip icmp
```

3) Ping Ext-S1 from Int-S1 to check the NAT rule is working and you have connectivity.

```
INT-S1#ping 203.0.113.20

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 203.0.113.20, timeout is 2
seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 52/58/60
ms
```

4) Check the debug output on Ext-S1 and verify the ping echo reply was sent to Int-S1’s global address 203.0.113.3.

```
EXT-S1#

*Aug 21 20:38:50.691: ICMP: echo reply sent, src 203.0.113.20, dst
203.0.113.3, topology BASE, dscp 0 topoid 0

*Aug 21 20:38:50.743: ICMP: echo reply sent, src 203.0.113.20, dst
203.0.113.3, topology BASE, dscp 0 topoid 0

*Aug 21 20:38:50.803: ICMP: echo reply sent, src 203.0.113.20, dst
203.0.113.3, topology BASE, dscp 0 topoid 0

*Aug 21 20:38:50.863: ICMP: echo reply sent, src 203.0.113.20, dst
203.0.113.3, topology BASE, dscp 0 topoid 0

*Aug 21 20:38:50.923: ICMP: echo reply sent, src 203.0.113.20, dst
203.0.113.3, topology BASE, dscp 0 topoid 0

EXT-S1#
```

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5) Telnet to 203.0.113.3 port 80 from Ext-S1 to verify that external customers on the Internet can reach your web server.
You will see the output shown below if your configuration is working:

```
EXT-S1#telnet 203.0.113.3 80
Trying 203.0.113.3, 80 ... Open
```

6) Verify the ping and Telnet connections appear in the NAT translation table. Note that entries age out quickly so generate the traffic again if you did not check the table quickly enough.

Your output should look similar to below. The source port numbers may be different.

```
R1#sh ip nat translation
Pro Inside global      Inside local       Outside local      Outside global
icmp 203.0.113.3:1     10.0.1.10:1        203.0.113.20:1     203.0.113.20:1
tcp 203.0.113.3:80     10.0.1.10:80       203.0.113.20:45849 203.0.113.20:45849
--- 203.0.113.3        10.0.1.10          ---                ---
```

7) Type ‘exit’ to break the Telnet connection on Ext-S1. You should see the output shown below:

```
EXT-S1#telnet 203.0.113.3 80
Trying 203.0.113.3, 80 ... Open


exit
HTTP/1.1 400 Bad Request
Date: Mon, 21 Aug 2017 19:39:32 GMT
Server: cisco-IOS
Accept-Ranges: none


400 Bad Request
[Connection to 203.0.113.3 closed by foreign host]
EXT-S1#
```

Dynamic NAT

8) Configure NAT on R1 so that PCs in the 10.0.2.0/24 subnet have connectivity to external networks on a first come first served basis. Assign global addresses from the range 203.0.113.4 to 203.0.113.12. Do not enable Port Address Translation.

We already set the F0/0 interface facing the Internet as the NAT outside interface when we configured static NAT for Int-S1.

```
R1(config)#int f0/0
R1(config-if)#ip nat outside
```

Configure the F2/0 interface facing the PCs as a NAT inside interface.

```
R1(config)#int f2/0
R1(config-if)#ip nat inside
```

Configure the pool of global addresses.

```
R1(config)#ip nat pool Flackbox 203.0.113.4 203.0.113.12 netmask
255.255.255.240
```

Create an access list which references the internal IP addresses we want to translate.

```
R1(config)#access-list 1 permit 10.0.2.0 0.0.0.255
```

Associate the access list with the NAT pool to complete the configuration.

```
R1(config)#ip nat inside source list 1 pool Flackbox
```

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9) Turn on NAT debugging on R1. Ping Ext-S1 from PC1. View the debug output on R1. You should see NAT entries for the 5 pings. Which global address was PC1 translated to?

PC1 will be translated to the first available address in the pool, 203.0.113.4.

```
R1#debug ip nat
IP NAT debugging is on

PC1#ping 203.0.113.20
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.20, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/59/60
ms

R1#
*Aug 21 22:00:19.695: NAT: Entry assigned id 12
*Aug 21 22:00:19.699: NAT: Entry assigned id 13
*Aug 21 22:00:19.699: NAT*: s=10.0.2.10->203.0.113.4, d=203.0.113.20 [0]
*Aug 21 22:00:19.791: NAT*: s=203.0.113.20, d=203.0.113.4->10.0.2.10 [0]
*Aug 21 22:00:19.839: NAT*: s=10.0.2.10->203.0.113.4, d=203.0.113.20 [1]
*Aug 21 22:00:19.859: NAT*: s=203.0.113.20, d=203.0.113.4->10.0.2.10 [1]
*Aug 21 22:00:19.899: NAT*: s=10.0.2.10->203.0.113.4, d=203.0.113.20 [2]
*Aug 21 22:00:19.923: NAT*: s=203.0.113.20, d=203.0.113.4->10.0.2.10 [2]
*Aug 21 22:00:19.963: NAT*: s=10.0.2.10->203.0.113.4, d=203.0.113.20 [3]
*Aug 21 22:00:19.983: NAT*: s=203.0.113.20, d=203.0.113.4->10.0.2.10 [3]
*Aug 21 22:00:20.023: NAT*: s=10.0.2.10->203.0.113.4, d=203.0.113.20 [4]
*Aug 21 22:00:20.043: NAT*: s=203.0.113.20, d=203.0.113.4->10.0.2.10 [4]
```

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10) Check the ICMP debug output on Ext-S1 and verify the ping echo reply was sent to PC1's global address.

```
EXT-S1#

*Aug 21 22:00:19.411: ICMP: echo reply sent, src 203.0.113.20, dst 203.0.113.4,
topology BASE, dscp 0 topoid 0

*Aug 21 22:00:19.551: ICMP: echo reply sent, src 203.0.113.20, dst 203.0.113.4,
topology BASE, dscp 0 topoid 0

*Aug 21 22:00:19.599: ICMP: echo reply sent, src 203.0.113.20, dst 203.0.113.4,
topology BASE, dscp 0 topoid 0

*Aug 21 22:00:19.659: ICMP: echo reply sent, src 203.0.113.20, dst 203.0.113.4,
topology BASE, dscp 0 topoid 0

*Aug 21 22:00:19.719: ICMP: echo reply sent, src 203.0.113.20, dst 203.0.113.4,
topology BASE, dscp 0 topoid 0
```

11) Verify the ping connection appears in the NAT translation table.

```
R1#sh ip nat translation

Pro Inside global      Inside local       Outside local      Outside global

--- 203.0.113.3        10.0.1.10          ---                ---

icmp 203.0.113.4:1     10.0.2.10:1        203.0.113.20:1     203.0.113.20:1

--- 203.0.113.4        10.0.2.10          ---                ---
```

12) When all the addresses in the pool 203.0.113.4 to 203.0.113.12 have been allocated, what will happen when the next PC tries to send traffic to an external host?

It will not get a global IP address because they have all been given out. The traffic will fail. The user could try again after waiting for a translation to time out and its global address to be released back into the pool.

13) Enable Port Address Translation so that the last IP address in the range can be reused when all IP addresses have been allocated to clients.

```
R1#clear ip nat translation *

R1#config t

R1(config)#ip nat inside source list 1 pool Flackbox overload
```

14) Cleanup: Completely remove the access list and all NAT configuration from R1. Use the commands ‘show run | section nat’ and ‘show access-list’ to verify all configuration is removed.

```
R1(config)#int f0/0
R1(config-if)#no ip nat outside
R1(config-if)#int f1/0
R1(config-if)#no ip nat inside
R1(config-if)#int f2/0
R1(config-if)#no ip nat inside
R1(config-if)#no ip nat inside source static 10.0.1.10 203.0.113.3
R1(config)#end
R1#clear ip nat translation *
R1#config t
R1(config)#no ip nat inside source list 1 pool Flackbox overload
R1(config)#no ip nat pool Flackbox 203.0.113.4 203.0.113.12 netmask
255.255.255.240
R1(config)#no access-list 1


R1#show run | section nat
R1#


R1#show access-list
R1#
```

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Port Address Translation PAT

15) Your company no longer has a range of public IP addresses. Instead you will receive a single public IP address via DHCP from your service provider.

Shutdown interface F0/0 on R1 and remove its IP address. Reconfigure it to receive its IP address via DHCP from the service provider router SP1.

```
R1(config)#int f0/0
R1(config-if)#shutdown
R1(config-if)#no ip address
R1(config-if)#ip address dhcp
```

16) Bring the interface back up and wait for DHCP. What IP address is it assigned?

```
R1(config)#int f0/0
R1(config-if)#no shutdown
```

```
R1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        203.0.113.13    YES DHCP   up                    up
FastEthernet1/0        10.0.1.1        YES NVRAM  up                    up
FastEthernet2/0        10.0.2.1        YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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17) Configure NAT on R1 so that PCs in the 10.0.2.0/24 subnet have connectivity to external networks on a first come first served basis. Allow multiple PCs to reuse the IP address on interface F0/0 on R1. Ensure that NAT continues to work if the DHCP address assigned by the provider changes.

Configure the F0/0 interface facing the Internet as the NAT outside interface.

```
R1(config)#int f0/0
R1(config-if)#ip nat outside
```

Configure the F1/0 interface facing Int-S1 as a NAT inside interface.

```
R1(config)#int f2/0
R1(config-if)#ip nat inside
```

Create an access list which references the internal IP addresses we want to translate.

```
R1(config)#access-list 1 permit 10.0.2.0 0.0.0.255
```

Associate the access list with the outside interface and enable PAT to complete the configuration.

```
R1(config)#ip nat inside source list 1 interface f0/0 overload
```

18) Turn on NAT debugging on R1. Open a Telnet session from PC1 to Ext-S1, using the password 'Flackbox'.

```
PC1#telnet 203.0.113.20
Trying 203.0.113.20 ... Open

User Access Verification

Password:
EXT-S1>
```

19) View the debug output on R1. Which global IP address and source port was PC1 translated to?

PC1 is translated to the address on R1's F0/0 interface, 203.0.113.13. The source port may be a different number for you.

```
*Aug 21 23:49:07.851: NAT*: TCP s=54963->4096, d=23
*Aug 21 23:49:07.851: NAT*: s=10.0.2.10->203.0.113.13, d=203.0.113.20 [5401]
*Aug 21 23:49:07.915: NAT*: TCP s=23, d=4096->54963
*Aug 21 23:49:07.915: NAT*: s=203.0.113.20, d=203.0.113.13->10.0.2.10 [18315]
```

20) Open a Telnet session from PC2 to Ext-S1. Which global IP address and source port is PC2 translated to?

PC2 is also translated to 203.0.113.13, but a different source port number using PAT.

```
PC2#telnet 203.0.113.20
Trying 203.0.113.20 ... Open
User Access Verification
Password:
EXT-S1>
```

```
*Aug 21 23:52:55.739: NAT*: TCP s=52670->4097, d=23
*Aug 21 23:52:55.739: NAT*: s=10.0.2.11->203.0.113.13,
d=203.0.113.20 [34332]
*Aug 21 23:52:55.763: NAT*: TCP s=23, d=4097->52670
*Aug 21 23:52:55.763: NAT*: s=203.0.113.20, d=203.0.113.13-
>10.0.2.11 [45975]
```

21) Verify the connections in the NAT translation table.

```
R1#sh ip nat translation
Pro Inside global      Inside local       Outside local      Outside global
tcp 203.0.113.13:4096  10.0.2.10:54963    203.0.113.20:23    203.0.113.20:23
tcp 203.0.113.13:4097  10.0.2.11:52670    203.0.113.20:23    203.0.113.20:23
```

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22) Show the NAT statistics on R1.

The numbers in your output may be different.

```
R1#show ip nat statistics
Total active translations: 2 (0 static, 2 dynamic; 2 extended)
Outside interfaces:
  FastEthernet0/0
Inside interfaces:
  FastEthernet2/0
Hits: 148  Misses: 0
CEF Translated packets: 148, CEF Punted packets: 0
Expired translations: 7
Dynamic mappings:
-- Inside Source
[Id: 2] access-list 1 interface FastEthernet0/0 refcount 2
nat-limit statistics:
 max entry: max allowed 0, used 0, missed 0
```

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31 IPv6 Addressing Configuration - Lab Exercise

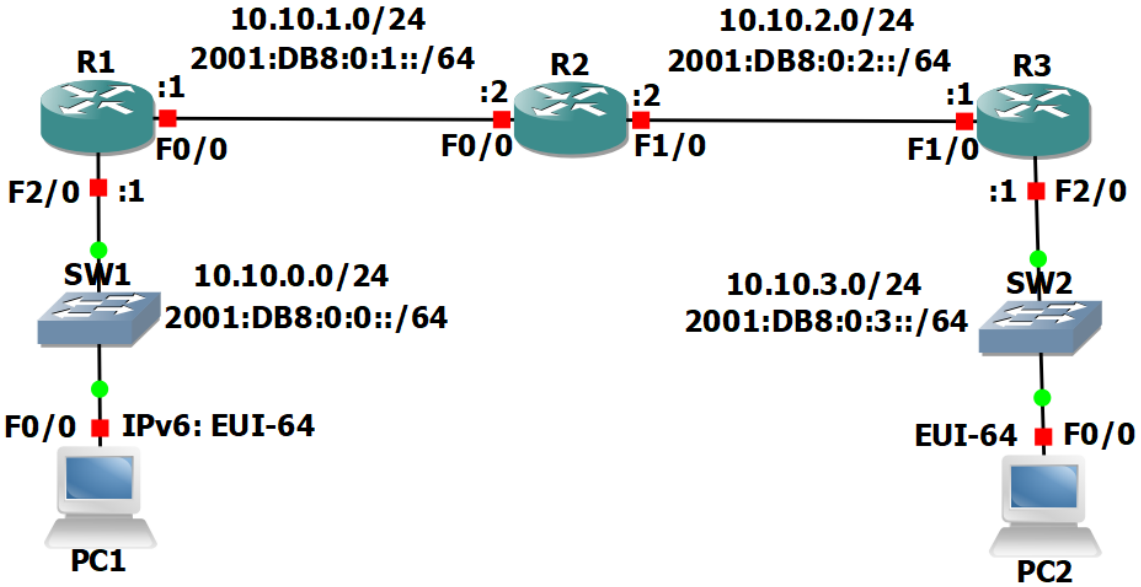
In this lab you will configure IPv6 addressing for a small campus network. The company already has IPv4 configured on their existing network but they will be introducing a new IPv6 application soon. Your task is to configure the network to be dual stack by adding support for IPv6 addresses. IPv6 routing will be configured in the next lab exercise.

Routers R1, R2 and R3 have been configured with IPv4 addresses and connectivity has been established with between all networks.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 addresses and an IPv4 default static route to their default gateways.

There is no IPv6 configuration on any of the devices.

Lab Topology



Load the Startup Configurations

Download the '31 IPv6 Addressing.gns3project' file here. Open in GNS3 to load the lab.

Verify IPv4 Connectivity

1) Verify R1, R2, R3, PC1 and PC2 have been configured with IPv4 addresses as shown in the topology diagram.

2) View the routing tables on R1, R2 and R3 to verify connectivity has been established between all networks. What routing protocol is being used?

3) Verify PC1 and PC2 have been configured with the correct default gateway.

4) Ping PC2 from PC1 to verify end to end reachability.

IPv6 Addressing

5) Configure global unicast IPv6 addresses on R1, R2, and R3, according to the network topology diagram. Do not enable ipv6 unicast-routing.

6) Configure global unicast EUI-64 IPv6 addresses on the FastEthernet 0/0 interfaces on PC1 and PC2.

7) Will the routers have IPv6 link local addresses on the interfaces where you just configured global unicast addresses? What about the other interfaces? Verify this.

8) Note down the EUI-64 global unicast addresses on PC1 and PC2.

9) Configure link local addresses on R1, R2 and R3. For each router, use the address shown below on each of its interfaces.

   R1: FE80::1/64

   R2: FE80::2/64

   R3: FE80::3/64

10) Verify the global unicast and link local addresses have been configured correctly on R1, R2 and R3.

11) Ping R1 and R3 on their link local addresses from R2.

12) View the IPv6 neighbors known by R2.

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31 IPv6 Addressing Configuration - Answer Key

In this lab you will configure IPv6 addressing for a small campus network. The company already has IPv4 configured on their existing network but they will be introducing a new IPv6 application soon. Your task is to configure the network to be dual stack by adding support for IPv6 addresses. IPv6 routing will be configured in the next lab exercise.

Routers R1, R2 and R3 have been configured with IPv4 addresses and connectivity has been established with between all networks.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 addresses and an IPv4 default static route to their default gateways.

There is no IPv6 configuration on any of the devices.

Verify IPv4 Connectivity

1) Verify R1, R2, R3, PC1 and PC2 have been configured with IPv4 addresses as shown in the topology diagram.

```
R1#sh ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.1.1       YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        10.10.0.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

R2#sh ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.1.2       YES NVRAM  up                    up
FastEthernet1/0        10.10.2.2       YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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```
R3#sh ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.10.2.1       YES NVRAM  up                    up
FastEthernet2/0        10.10.3.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

PC1#sh ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.0.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

PC2#sh ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.3.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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2) View the routing tables on R1, R2 and R3 to verify connectivity has been established between all networks. What routing protocol is being used?

EIGRP is the routing protocol.

```
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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet2/0
L        10.10.0.1/32 is directly connected, FastEthernet2/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.1/32 is directly connected, FastEthernet0/0
D        10.10.2.0/24 [90/30720] via 10.10.1.2, 00:48:15, FastEthernet0/0
D        10.10.3.0/24 [90/33280] via 10.10.1.2, 00:48:10, FastEthernet0/0
```

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```
R2#show ip route
! codes truncated
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/30720] via 10.10.1.1, 00:48:56, FastEthernet0/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.2/32 is directly connected, FastEthernet0/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.2/32 is directly connected, FastEthernet1/0
D        10.10.3.0/24 [90/30720] via 10.10.2.1, 00:48:55, FastEthernet1/0

R3#show ip route
! codes truncated
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/33280] via 10.10.2.2, 00:49:18, FastEthernet1/0
D        10.10.1.0/24 [90/30720] via 10.10.2.2, 00:49:18, FastEthernet1/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.1/32 is directly connected, FastEthernet1/0
C        10.10.3.0/24 is directly connected, FastEthernet2/0
L        10.10.3.1/32 is directly connected, FastEthernet2/0
```

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3) Verify PC1 and PC2 have been configured with the correct default gateway.

PC1 is using R1 as its default gateway.

```
PC1#show ip route
! codes truncated

Gateway of last resort is 10.10.0.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.0.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet0/0
L        10.10.0.10/32 is directly connected, FastEthernet0/0
```

PC2 is using R3 as its default gateway.

```
PC2#show ip route
! codes truncated

Gateway of last resort is 10.10.3.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.3.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.3.0/24 is directly connected, FastEthernet0/0
L        10.10.3.10/32 is directly connected, FastEthernet0/0
```

4) Ping PC2 from PC1 to verify end to end reachability.

```
PC1#ping 10.10.3.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.3.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/80/84
ms
```

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IPv6 Addressing

5) Configure global unicast IPv6 addresses on R1, R2, and R3, according to the network topology diagram. Do not enable ipv6 unicast-routing.

```
R1(config)#int f2/0
R1(config-if)#ipv6 address 2001:db8::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#int f0/0
R1(config-if)#ipv6 address 2001:db8:0:1::1/64
R1(config-if)#no shutdown

R2(config-if)#ipv6 address 2001:db8:0:1::2/64
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#int f1/0
R2(config-if)#ipv6 address 2001:db8:0:2::2/64
R2(config-if)#no shut

R3(config)#int f1/0
R3(config-if)#ipv6 address 2001:db8:0:2::1/64
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int f2/0
R3(config-if)#ipv6 address 2001:db8:0:3::1/64
R3(config-if)#no shut
```

6) Configure global unicast EUI-64 IPv6 addresses on the FastEthernet 0/0 interfaces on PC1 and PC2.

```
PC1(config)#int f0/0
PC1(config-if)#ipv6 address 2001:db8::/64 eui-64
PC1(config-if)#no shut
```

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```
PC2(config)#int f0/0
PC2(config-if)#ipv6 address 2001:db8:0:3::/64 eui-64
PC2(config-if)#no shut
```

7) Will the routers have IPv6 link local addresses on the interfaces where you just configured global unicast addresses? What about the other interfaces? Verify this.

EUI-64 link local addresses will be automatically configured when IPv6 is enabled on the interfaces (by applying the global unicast addresses). The other interfaces will not have link local addresses.

```
R1#show ipv6 interface brief
FastEthernet0/0        [up/up]
    FE80::C801:2FFF:FE24:0
    2001:DB8:0:1::1
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [up/up]
    FE80::C801:2FFF:FE24:38
    2001:DB8::1
FastEthernet3/0        [administratively down/down]
    unassigned
```

8) Note down the EUI-64 global unicast addresses on PC1 and PC2.

Note that these addresses are generated based on the interface MAC address and may be different in your lab.

```
PC1#show ipv6 interface brief
FastEthernet0/0        [up/up]
    FE80::C804:36FF:FE98:0
    2001:DB8::C804:36FF:FE98:0
```

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```
PC2#show ipv6 interface brief
FastEthernet0/0        [up/up]
    FE80::C805:CFF:FE28:0
    2001:DB8:0:3:C805:CFF:FE28:0
```

9) Configure link local addresses on R1, R2 and R3. For each router, use the address shown below on each of its interfaces.
R1: FE80::1/64

R2: FE80::2/64

R3: FE80::3/64

```
R1(config)#int f0/0
R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#exit
R1(config)#int f2/0
R1(config-if)#ipv6 address fe80::1 link-local

R2(config)#int f0/0
R2(config-if)#ipv6 address fe80::2 link-local
R2(config-if)#exit
R2(config)#int f1/0
R2(config-if)#ipv6 address fe80::2 link-local

R3(config)#int f1/0
R3(config-if)#ipv6 address fe80::3 link-local
R3(config-if)#exit
R3(config)#int f2/0
R3(config-if)#ipv6 address fe80::3 link-local
```

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10) Verify the global unicast and link local addresses have been configured correctly on R1, R2 and R3.

```
R1#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::1
    2001:DB8:0:1::1
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [up/up]
    FE80::1
    2001:DB8::1
FastEthernet3/0        [administratively down/down]
    unassigned


R2#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::2
    2001:DB8:0:1::2
FastEthernet1/0        [up/up]
    FE80::2
    2001:DB8:0:2::2
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    unassigned
```

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```
R3#sh ipv6 int brief
FastEthernet0/0        [administratively down/down]
    unassigned
FastEthernet1/0        [up/up]
    FE80::3
    2001:DB8:0:2::1
FastEthernet2/0        [up/up]
    FE80::3
    2001:DB8:0:3::1
FastEthernet3/0        [administratively down/down]
    Unassigned
```

11) Ping R1 and R3 on their link local addresses from R2.

```
R2#ping fe80::1
Output Interface: FastEthernet0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::1, timeout is 2 seconds:
Packet sent with a source address of FE80::2%FastEthernet0/0
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/22/40
ms

R2#ping fe80::3
Output Interface: FastEthernet1/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::3, timeout is 2 seconds:
Packet sent with a source address of FE80::2%FastEthernet1/0
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/26/52
ms
```

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12) View the IPv6 neighbors known by R2.

Note that your output may be different depending on what IPv6 traffic has been seen recently by R2.

```
R2#show ipv6 neighbors
IPv6 Address                              Age Link-layer Addr State Interface
FE80::C801:2FFF:FE24:0                    161 ca01.2f24.0000  STALE Fa0/0
FE80::1                                     0 ca01.2f24.0000  REACH Fa0/0
FE80::3                                     0 ca03.2db0.001c  REACH Fa1/0
```

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32-1 IPv6 Routing Configuration - Lab Exercise

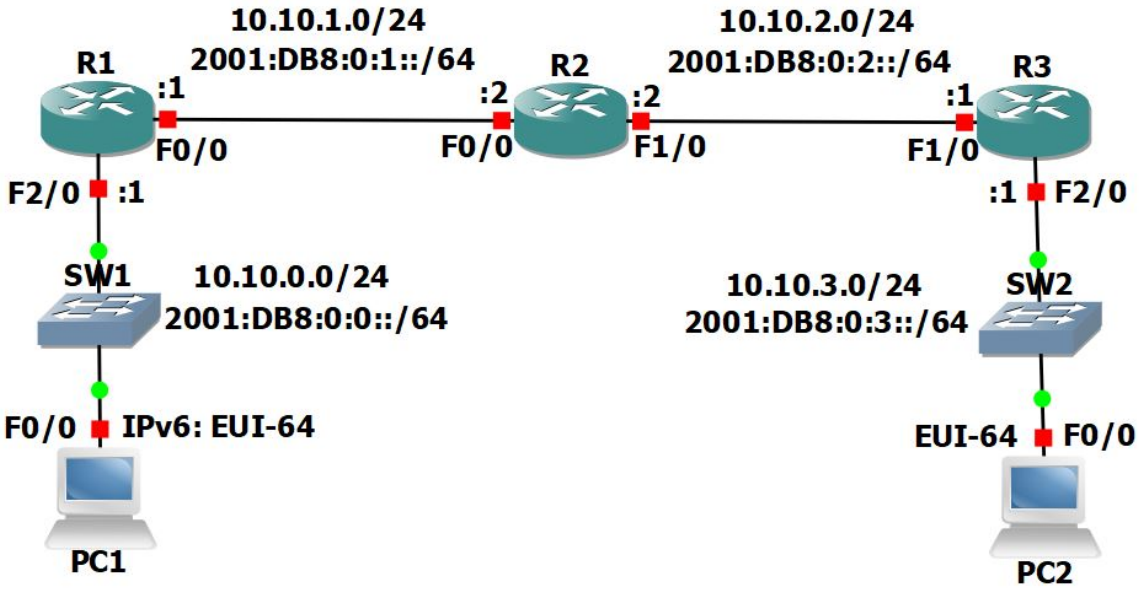
This lab continues where the last one left off. You have configured IPv6 addressing for a small campus network, now you need to configure routing between the different IPv6 subnets.

You will configure static routes, OSPF and EIGRP. Note that in a real world environment you would pick one of these options rather than configuring all of them.

Routers R1, R2 and R3 have been configured with IPv4 and IPv6 addresses. IPv4 routing has been configured on the existing network but IPv6 routing has not.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 and IPv6 addresses and default static routes to their default gateways have been added for both IPv4 and IPv6.

Lab Topology



Load the Startup Configurations

Download the '32-1 IPv6 Routing Configuration.gns3project' file here. Open in GNS3 to load the lab.

IPv4 and IPv6 Addressing Verification

1) Verify IPv4 and IPv6 addresses have been configured on R1, R2, R3, PC1 and PC2 according to the lab topology diagram. PC1 and PC2 use EUI-64 addresses for IPv6 and 10.10.x.10 for IPv4. Note that the EUI-64 addresses may be different in your lab.

2) Verify PC1 has been configured to use R1 as its default gateway for IPv4.

3) Verify PC2 has been configured to use R3 as its default gateway for IPv4.

4) Verify R1, R2 and R3 have routes to all IPv4 networks.

5) Verify PC1 can ping PC2 on its IPv4 address 10.10.3.10

6) Verify which IPv6 dynamic routing protocols are running on R1, R2 and R3. Do not use the 'show run' command.

7) Use the 'show run | include ipv6 route' command on R1, R2 and R3 to verify if they have been configured with IPv6 static routes.

8) Do you expect to see any routes in the IPv6 routing tables? Why or why not? Verify this.

9) Do you expect PC1 to be able to ping PC2 on its IPv6 address? Why or why not? Verify this.

Static Routing

10) Configure PC1 to use R1 as its IPv6 default gateway.

11) Configure PC2 to use R3 as its IPv6 default gateway.

12) Verify PC1 and PC2 can ping their default gateways.

13) Add a static route on R2 for the 2001:db8::/64 network.

14) PC1 has reachability to its default gateway R1, and R2 has a route to the 2001:db8::/64 network. Do you expect PC1 be able to ping R2 on 2001:db8:0:1::2? Why or why not? Verify this.

15) Fix the problem to allow PC1 to ping R2 on 2001:db8:0:1::2. Enter the command which will fix the problem on R1, R2 and R3.

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16) Verify PC1 can ping R2 on 2001:db8:0:1::2 now.

17) Will PC1 be able to ping PC2 by IPv6 address? Why or why not? Verify this.

18) Configure static routes to allow reachability between all IPv6 networks.

19) Verify the IPv6 routing tables on R1, R2 and R3.

20) Verify PC1 can now ping PC2 by its IPv6 address.

21) Cleanup: Remove the static IPv6 routes on R1, R2 and R3.

22) Verify there are only connected and local routes in R1, R2 and R3's IPv6 routing tables.

OSPFv2 Configuration

23) Enable a loopback interface on R1, R2 and R3. Use the IPv4 address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

24) Enable single area OSPFv2 on every router. Ensure all networks are advertised.

25) What do you expect the OSPF Router ID to be on R1? Verify this.

26) Verify the routers have formed adjacencies with each other.

27) Do you expect to see OSPF routes in R1, R2 and R3's IPv4 routing tables? Why or why not? Verify this.

OSPFv2 Basic Configuration

28) Configure IPv6 addresses on the existing loopback interfaces on R1, R2 and R3. Use the address 2001:db8:1:x::1/64, where 'x' is the router number. For example 2001:db8:1:3::1/64 on R3.

29) Enable single area OSPFv3 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

30) What do you expect the OSPF Router ID to be on R1? Verify this.

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31) Manually set the Router ID on R1 to be the highest loopback address.

32) Verify the routers have formed adjacencies with each other.

33) Do you expect to see OSPF routes in R1, R2 and R3's IPv6 routing tables? Why or why not? Verify this.

34) Verify end to end connectivity by pinging PC2 from PC1.

35) Verify the path traffic is taking from PC1 to PC2.

EIGRP for IPv6 Configuration

36) Enable EIGRP for IPv6 using AS 100 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

37) What do you expect the EIGRP Router ID to be on R1? Verify this.

38) Manually set the Router ID on R1 to be the highest loopback address.

39) Verify the routers have formed adjacencies with each other.

40) Do you expect EIGRP routes to be in the router's IPv6 routing tables? Why or why not? Verify this.

41) Verify end to end connectivity by pinging PC2 from PC1.

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32-1 IPv6 Routing Configuration - Answer Key

This lab continues where the last one left off. You have configured IPv6 addressing for a small campus network, now you need to configure routing between the different IPv6 subnets.

You will configure static routes, OSPF and EIGRP. Note that in a real world environment you would pick one of these options rather than configuring all of them.

Routers R1, R2 and R3 have been configured with IPv4 and IPv6 addresses. IPv4 routing has been configured on the existing network but IPv6 routing has not.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 and IPv6 addresses and default static routes to their default gateways have been added for both IPv4 and IPv6.

IPv4 and IPv6 Addressing Verification

1) Verify IPv4 and IPv6 addresses have been configured on R1, R2, R3, PC1 and PC2 according to the lab topology diagram. PC1 and PC2 use EUI-64 addresses for IPv6 and 10.10.x.10 for IPv4. Note that the EUI-64 addresses may be different in your lab.

```
R1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.1.1       YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        10.10.0.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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```
R1#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::1
    2001:DB8:0:1::1
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [up/up]
    FE80::1
    2001:DB8::1
FastEthernet3/0        [administratively down/down]
    Unassigned

R2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.1.2       YES NVRAM  up                    up
FastEthernet1/0        10.10.2.2       YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

R2#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::2
    2001:DB8:0:1::2
FastEthernet1/0        [up/up]
    FE80::2
    2001:DB8:0:2::2
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    unassigned

R3#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.10.2.1       YES NVRAM  up                    up
FastEthernet2/0        10.10.3.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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```
R3#sh ipv6 int brief
FastEthernet0/0        [administratively down/down]
    unassigned
FastEthernet1/0        [up/up]
    FE80::3
    2001:DB8:0:2::1
FastEthernet2/0        [up/up]
    FE80::3
    2001:DB8:0:3::1
FastEthernet3/0        [administratively down/down]
    Unassigned

PC1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.0.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

PC1#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::C804:36FF:FE98:0
    2001:DB8::C804:36FF:FE98:0
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    Unassigned

PC2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.3.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
```

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```
PC2#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::C805:CFF:FE28:0
    2001:DB8:0:3:C805:CFF:FE28:0
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    unassigned
```

2) Verify PC1 has been configured to use R1 as its default gateway for IPv4.

```
PC1#sh 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 10.10.0.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.0.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet0/0
L        10.10.0.10/32 is directly connected, FastEthernet0/0
```

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3) Verify PC2 has been configured to use R3 as its default gateway for IPv4.

```
PC2#sh 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 10.10.3.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.3.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.3.0/24 is directly connected, FastEthernet0/0
L        10.10.3.10/32 is directly connected, FastEthernet0/0
```

4) Verify R1, R2 and R3 have routes to all IPv4 networks.

```
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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet2/0
L        10.10.0.1/32 is directly connected, FastEthernet2/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.1/32 is directly connected, FastEthernet0/0
D        10.10.2.0/24 [90/30720] via 10.10.1.2, 00:48:15, FastEthernet0/0
D        10.10.3.0/24 [90/33280] via 10.10.1.2, 00:48:10, FastEthernet0/0
```

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```
R2#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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/30720] via 10.10.1.1, 00:48:56, FastEthernet0/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.2/32 is directly connected, FastEthernet0/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.2/32 is directly connected, FastEthernet1/0
D        10.10.3.0/24 [90/30720] via 10.10.2.1, 00:48:55, FastEthernet1/0

R3#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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/33280] via 10.10.2.2, 00:49:18, FastEthernet1/0
D        10.10.1.0/24 [90/30720] via 10.10.2.2, 00:49:18, FastEthernet1/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.1/32 is directly connected, FastEthernet1/0
C        10.10.3.0/24 is directly connected, FastEthernet2/0
L        10.10.3.1/32 is directly connected, FastEthernet2/0
```

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5) Verify PC1 can ping PC2 on its IPv4 address 10.10.3.10

```
PC1#ping 10.10.3.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.3.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/80/84
ms
```

6) Verify which IPv6 dynamic routing protocols are running on R1, R2 and R3. Do not use the 'show run' command.

The routers are not running any IPv6 dynamic routing protocol.

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"

R2#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"

R3#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
```

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7) Use the ‘show run | include ipv6 route’ command on R1, R2 and R3 to verify if they have been configured with IPv6 static routes.

The routers have not been configured with any IPv6 static routes.

```
R1#show run | include ipv6 route
R1#

R2#show run | include ipv6 route
R2#

R3#show run | include ipv6 route
R3#
```

8) Do you expect to see any routes in the IPv6 routing tables? Why or why not? Verify this.

The routers have been configured with IPv6 addresses so connected and local routes will appear in the routing table.

```
R1#show ipv6 route
IPv6 Routing Table - default - 5 entries

C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R2#sh ipv6 route
IPv6 Routing Table - default - 5 entries

C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive

R3#sh ipv6 route
IPv6 Routing Table - default - 5 entries

C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

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9) Do you expect PC1 to be able to ping PC2 on its IPv6 address? Why or why not? Verify this.

No IPv6 routing has been configured so there is no connectivity between different IPv6 subnets. (Note that PC2's EUI-64 IPv6 address may be different in your lab. Use 'show ipv6 interface brief to check its address.)

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

% No valid route for destination
Success rate is 0 percent (0/1)
```

Static Routing

10) Configure PC1 to use R1 as its IPv6 default gateway.

```
PC1(config)#ipv6 route ::/0 2001:db8::1
```

11) Configure PC2 to use R3 as its IPv6 default gateway.

```
PC2(config)#ipv6 route ::/0 2001:db8:0:3::1
```

12) Verify PC1 and PC2 can ping their default gateways.

```
PC1#ping 2001:db8::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/31/44
ms
```

```
PC2#ping 2001:DB8:0:3::1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3::1, timeout is 2
seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 16/26/56
ms
```

13) Add a static route on R2 for the 2001:db8::/64 network.

```
R2(config)#ipv6 route 2001:db8::/64 2001:db8:0:1::1
```

14) PC1 has reachability to its default gateway R1, and R2 has a route to the 2001:db8::/64 network. Do you expect PC1 be able to ping R2 on 2001:db8:0:1::2? Why or why not? Verify this.

PC1 cannot ping R2 on 2001:db8:0:1::2 because ipv6 unicast-routing has not been enabled on the routers.

```
PC1#ping 2001:db8:0:1::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:1::2, timeout is 2
seconds:

.....

Success rate is 0 percent (0/5)
```

15) Fix the problem to allow PC1 to ping R2 on 2001:db8:0:1::2. Enter the command which will fix the problem on R1, R2 and R3.

```
R1(config)#ipv6 unicast-routing


R2(config)#ipv6 unicast-routing


R3(config)#ipv6 unicast-routing
```

16) Verify PC1 can ping R2 on 2001:db8:0:1::2 now.

```
PC1#ping 2001:db8:0:1::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:1::2, timeout is 2
seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 60/60/64
ms
```

17) Will PC1 be able to ping PC2 by IPv6 address? Why or why not? Verify this.

PC1 cannot ping PC2 because routing has not been configured between the 2001:db8::/64 and 2001:db8:0:3::/64 networks.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

UUUUU

Success rate is 0 percent (0/5)
```

18) Configure static routes to allow reachability between all IPv6 networks.

```
R1(config)#ipv6 route 2001:db8:0:2::/64 2001:db8:0:1::2

R1(config)#ipv6 route 2001:db8:0:3::/64 2001:db8:0:1::2


R2(config)#ipv6 route 2001:db8::/64 2001:db8:0:1::1

R2(config)#ipv6 route 2001:db8:0:3::/64 2001:db8:0:2::1


R3(config)#ipv6 route 2001:db8::/64 2001:db8:0:2::2

R3(config)#ipv6 route 2001:db8:0:1::/64 2001:db8:0:2::2
```

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19) Verify the IPv6 routing tables on R1, R2 and R3.

```
R1#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
S   2001:DB8:0:2::/64 [1/0]
     via 2001:DB8:0:1::2
S   2001:DB8:0:3::/64 [1/0]
     via 2001:DB8:0:1::2
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R2#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
S   2001:DB8::/64 [1/0]
     via 2001:DB8:0:1::1
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
S   2001:DB8:0:3::/64 [1/0]
     via 2001:DB8:0:2::1
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R3#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
S   2001:DB8::/64 [1/0]
     via 2001:DB8:0:2::2
S   2001:DB8:0:1::/64 [1/0]
     via 2001:DB8:0:2::2
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

20) Verify PC1 can now ping PC2 by its IPv6 address.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/80/84
ms
```

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21) Cleanup: Remove the static IPv6 routes on R1, R2 and R3.

```
R1(config)#no ipv6 route 2001:db8:0:2::/64 2001:db8:0:1::2
R1(config)#no ipv6 route 2001:db8:0:3::/64 2001:db8:0:1::2

R2(config)#no ipv6 route 2001:db8::/64 2001:db8:0:1::1
R2(config)#no ipv6 route 2001:db8:0:3::/64 2001:db8:0:2::1

R3(config)#no ipv6 route 2001:db8::/64 2001:db8:0:2::2
R3(config)#no ipv6 route 2001:db8:0:1::/64 2001:db8:0:2::2
```

22) Verify there are only connected and local routes in R1, R2 and R3's IPv6 routing tables.

```
R1#show ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R2#sh ipv6 route
! codes truncated
IPv6 Routing Table - default - 5 entries

C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive

R3#sh ipv6 route
! codes truncated
IPv6 Routing Table - default - 5 entries

C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

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OSPFv2 Configuration

23) Enable a loopback interface on R1, R2 and R3. Use the IPv4 address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

```
R1(config)#int loop 0
R1(config-if)#ip add 192.168.0.1 255.255.255.255

R2(config)#int loop 0
R2(config-if)#ip add 192.168.0.2 255.255.255.255

R3(config)#int loop 0
R3(config-if)#ip add 192.168.0.3 255.255.255.255
```

24) Enable single area OSPFv2 on every router. Ensure all networks are advertised.

```
R1(config)#router ospf 1
R1(config-router)#network 10.10.0.0 0.0.255.255 area 0
R1(config-router)#network 192.168.0.0 0.0.0.255 area 0

R2(config)#router ospf 1
R2(config-router)#network 10.10.0.0 0.0.255.255 area 0
R2(config-router)#network 192.168.0.0 0.0.0.255 area 0

R3(config)#router ospf 1
R3(config-router)#network 10.10.0.0 0.0.255.255 area 0
R3(config-router)#network 192.168.0.0 0.0.0.255 area 0
```

You can use different network statements, as long as they cover the range of IP addresses configured on the router interfaces.

25) What do you expect the OSPF Router ID to be on R1? Verify this.

The loopback address is used for the Router ID, 192.168.0.1

```
R1#sh ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    NSF-aware route hold timer is 240
    Router-ID: 10.10.1.1
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1

  Automatic Summarization: disabled
  Maximum path: 4
  Routing for Networks:
    10.10.0.0/16
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.10.1.2             90      00:45:06
  Distance: internal 90 external 170
```

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```
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.255.255 area 0
    192.168.0.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.0.2          110      00:00:40
    192.168.0.3          110      00:00:30
  Distance: (default is 110)
```

26) Verify the routers have formed adjacencies with each other.

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.3.2          1   FULL/DR         00:00:34    10.0.3.2        FastEthernet3/0
10.1.0.2          1   FULL/DR         00:00:33    10.0.0.2        FastEthernet0/0
```

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27) Do you expect to see OSPF routes in R1, R2 and R3's IPv4 routing tables? Why or why not? Verify this.

OSPF routes will be in the routing table for the loopback interfaces only, as they are not being advertised by EIGRP. EIGRP and OSPF are both enabled for the 10.10.0.0/16 networks and EIGRP has a better administrative distance.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet2/0
L        10.10.0.1/32 is directly connected, FastEthernet2/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.1/32 is directly connected, FastEthernet0/0
D        10.10.2.0/24 [90/30720] via 10.10.1.2, 00:48:01, FastEthernet0/0
D        10.10.3.0/24 [90/33280] via 10.10.1.2, 00:48:01, FastEthernet0/0
      192.168.0.0/32 is subnetted, 3 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/2] via 10.10.1.2, 00:03:32, FastEthernet0/0
O        192.168.0.3 [110/3] via 10.10.1.2, 00:03:22, FastEthernet0/0
```

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OSPFv2 Basic Configuration

28) Configure IPv6 addresses on the existing loopback interfaces on R1, R2 and R3. Use the address 2001:db8:1:x::1/64, where 'x' is the router number. For example 2001:db8:1:3::1/64 on R3.

```
R1(config)#int loop 0
R1(config-if)#ipv6 add 2001:db8:1:1::1/64


R2(config)#int loop 0
R2(config-if)#ipv6 add 2001:db8:1:2::1/64


R3(config)#int loop 0
R3(config-if)#ipv6 add 2001:db8:1:3::1/64
```

29) Enable single area OSPFv3 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

```
R1(config)#ipv6 router ospf 1
R1(config-rtr)#passive-interface loopback 0
R1(config-rtr)#interface f0/0
R1(config-if)#ipv6 ospf 1 area 0
R1(config-if)#interface f2/0
R1(config-if)#ipv6 ospf 1 area 0
R1(config-if)#int loop 0
R1(config-if)#ipv6 ospf 1 area 0


R2(config)#ipv6 router ospf 1
R2(config-rtr)#passive-interface loopback 0
R2(config-rtr)#int f0/0
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#int f1/0
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#int loop 0
R2(config-if)#ipv6 ospf 1 area 0
```

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```
R3(config)#ipv6 router ospf 1
R3(config-rtr)#passive-interface loopback 0
R3(config-rtr)#int f1/0
R3(config-if)#ipv6 ospf 1 area 0
R3(config-if)#int f2/0
R3(config-if)#ipv6 ospf 1 area 0
R3(config-if)#int loop 0
R3(config-if)#ipv6 ospf 1 area 0
```

30) What do you expect the OSPF Router ID to be on R1? Verify this.

The Router ID is in the format of an IPv4 address (not an IPv6 address). The highest loopback address is used by default, 192.168.0.1

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Router ID 192.168.0.1
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Loopback0
    FastEthernet2/0
    FastEthernet0/0
  Redistribution:
    None
```

31) Manually set the Router ID on R1 to be the highest loopback address.

```
R1(config)#ipv6 router ospf 1
R1(config-rtr)#router-id 192.168.0.1
```

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32) Verify the routers have formed adjacencies with each other.

```
R2#sh ipv6 ospf neighbor

            OSPFv3 Router with ID (192.168.0.2) (Process ID 1)

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
192.168.0.3       1   FULL/BDR        00:00:33    3               FastEthernet1/0
192.168.0.1       1   FULL/DR         00:00:38    2               FastEthernet0/0
```

33) Do you expect to see OSPF routes in R1, R2 and R3's IPv6 routing tables? Why or why not? Verify this.

OSPF routes will be in the routing table for all IPv6 networks. EIGRP is configured for IPv4 but not for IPv6. (Note that OSPFv3 advertises loopback interfaces as /128 by default.)

```
R1#sh ipv6 route
IPv6 Routing Table - default - 11 entries

C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
O   2001:DB8:0:2::/64 [110/2]
     via FE80::2, FastEthernet0/0
O   2001:DB8:0:3::/64 [110/3]
     via FE80::2, FastEthernet0/0
C   2001:DB8:1:1::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:1::1/128 [0/0]
     via Loopback0, receive
O   2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet0/0
```

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```
O   2001:DB8:1:3::1/128 [110/2]
     via FE80::2, FastEthernet0/0
L   FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 11 entries

O   2001:DB8::/64 [110/2]
     via FE80::1, FastEthernet0/0
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
O   2001:DB8:0:3::/64 [110/2]
     via FE80::3, FastEthernet1/0
O   2001:DB8:1:1::1/128 [110/1]
     via FE80::1, FastEthernet0/0
C   2001:DB8:1:2::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:2::1/128 [0/0]
     via Loopback0, receive
O   2001:DB8:1:3::1/128 [110/1]
     via FE80::3, FastEthernet1/0
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R3#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
O   2001:DB8::/64 [110/3]
     via FE80::2, FastEthernet1/0
O   2001:DB8:0:1::/64 [110/2]
     via FE80::2, FastEthernet1/0
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
O   2001:DB8:1:1::1/128 [110/2]
     via FE80::2, FastEthernet1/0
O   2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet1/0
C   2001:DB8:1:3::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:3::1/128 [0/0]
     via Loopback0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

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34) Verify end to end connectivity by pinging PC2 from PC1.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 72/78/80
ms
```

35) Verify the path traffic is taking from PC1 to PC2.

```
PC1#traceroute 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Tracing the route to 2001:DB8:0:3:C805:CFF:FE28:0


  1 2001:DB8::1 28 msec 8 msec 8 msec

  2 2001:DB8:0:1::2 32 msec 28 msec 32 msec

  3 2001:DB8:0:2::1 48 msec 48 msec 48 msec

  4 2001:DB8:0:3:C805:CFF:FE28:0 60 msec 60 msec 56 msec

PC1#
```

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EIGRP for IPv6 Configuration

36) Enable EIGRP for IPv6 using AS 100 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

```
R1(config)#ipv6 router eigrp 100
R1(config-rtr)#passive-interface loopback 0
R1(config-rtr)#int f0/0
R1(config-if)#ipv6 eigrp 100
R1(config-if)#int f2/0
R1(config-if)#ipv6 eigrp 100
R1(config-if)#int loop 0
R1(config-if)#ipv6 eigrp 100

R2(config)#ipv6 router eigrp 100
R2(config-rtr)#passive-interface loopback 0
R2(config-rtr)#int f0/0
R2(config-if)#ipv6 eigrp 100
R2(config-if)#int f1/0
R2(config-if)#ipv6 eigrp 100
R2(config-if)#int loop 0
R2(config-if)#ipv6 eigrp 100

R3(config)#ipv6 router eigrp 100
R3(config-rtr)#passive-interface loopback 0
R3(config-rtr)#int f1/0
R3(config-if)#ipv6 eigrp 100
R3(config-if)#int f2/0
R3(config-if)#ipv6 eigrp 100
R3(config-if)#int loop 0
R3(config-if)#ipv6 eigrp 100
```

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37) What do you expect the EIGRP Router ID to be on R1? Verify this.

As with OSPFv3, the Router ID is in the format of an IPv4 address (not an IPv6 address). The highest loopback address is used by default, 192.168.0.1

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Router ID 192.168.0.1
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Loopback0
    FastEthernet2/0
    FastEthernet0/0
  Redistribution:
    None
IPv6 Routing Protocol is "eigrp 100"
EIGRP-IPv6 Protocol for AS(100)
  Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
  NSF-aware route hold timer is 240
  Router-ID: 192.168.0.1
  Topology : 0 (base)
    Active Timer: 3 min
    Distance: internal 90 external 170
    Maximum path: 16
    Maximum hopcount 100
    Maximum metric variance 1

  Interfaces:
    FastEthernet0/0
    FastEthernet2/0
    Loopback0 (passive)
```

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38) Manually set the Router ID on R1 to be the highest loopback address.

```
R1(config)# ipv6 router eigrp 100
R1(config-rtr)#eigrp router-id 192.168.0.1
```

39) Verify the routers have formed adjacencies with each other.

```
R2#show ipv6 eigrp neighbors
EIGRP-IPv6 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   Link-local address:     Fa1/0                    14 00:05:40   53   318  0  4
    FE80::3
0   Link-local address:     Fa0/0                    13 00:05:45   43   258  0  5
    FE80::1
```

40) Do you expect EIGRP routes to be in the router's IPv6 routing tables? Why or why not? Verify this.

The routes learned via EIGRP will replace the OSPF routes as they have a better Administrative Distance. (Note that OSPFv3 advertises loopback interfaces as /128 by default. These routes will main in the routing table as they have a longer prefix match than the /64 learned via EIGRP)

```
R1#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
```

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```
     via FastEthernet0/0, receive
D    2001:DB8:0:2::/64 [90/30720]
     via FE80::2, FastEthernet0/0
D    2001:DB8:0:3::/64 [90/33280]
     via FE80::2, FastEthernet0/0
C    2001:DB8:1:1::/64 [0/0]
     via Loopback0, directly connected
L    2001:DB8:1:1::1/128 [0/0]
     via Loopback0, receive
D    2001:DB8:1:2::/64 [90/156160]
     via FE80::2, FastEthernet0/0
O    2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet0/0
D    2001:DB8:1:3::/64 [90/158720]
     via FE80::2, FastEthernet0/0
O    2001:DB8:1:3::1/128 [110/2]
     via FE80::2, FastEthernet0/0
L    FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
D    2001:DB8::/64 [90/30720]
     via FE80::1, FastEthernet0/0
C    2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L    2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C    2001:DB8:0:2::/64 [0/0]
```

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```
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
D    2001:DB8:0:3::/64 [90/30720]
     via FE80::3, FastEthernet1/0
D    2001:DB8:1:1::/64 [90/156160]
     via FE80::1, FastEthernet0/0
O    2001:DB8:1:1::1/128 [110/1]
     via FE80::1, FastEthernet0/0
C    2001:DB8:1:2::/64 [0/0]
     via Loopback0, directly connected
L    2001:DB8:1:2::1/128 [0/0]
     via Loopback0, receive
D    2001:DB8:1:3::/64 [90/156160]
     via FE80::3, FastEthernet1/0
O    2001:DB8:1:3::1/128 [110/1]
     via FE80::3, FastEthernet1/0
L    FF00::/8 [0/0]
     via Null0, receive

R3#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
D    2001:DB8::/64 [90/33280]
     via FE80::2, FastEthernet1/0
D    2001:DB8:0:1::/64 [90/30720]
     via FE80::2, FastEthernet1/0
C    2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::1/128 [0/0]
```

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```
     via FastEthernet1/0, receive
C    2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L    2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
D    2001:DB8:1:1::/64 [90/158720]
     via FE80::2, FastEthernet1/0
O    2001:DB8:1:1::1/128 [110/2]
     via FE80::2, FastEthernet1/0
D    2001:DB8:1:2::/64 [90/156160]
     via FE80::2, FastEthernet1/0
O    2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet1/0
C    2001:DB8:1:3::/64 [0/0]
     via Loopback0, directly connected
L    2001:DB8:1:3::1/128 [0/0]
     via Loopback0, receive
L    FF00::/8 [0/0]
     via Null0, receive
```

41) Verify end to end connectivity by pinging PC2 from PC1.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 72/78/80
ms
```

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33-1 WAN Configuration – Lab Exercise

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

You will configure PPP with PAP authentication for a single leased line in New York site 1.

You will configure MultiLink PPP with CHAP authentication for New York site 2.

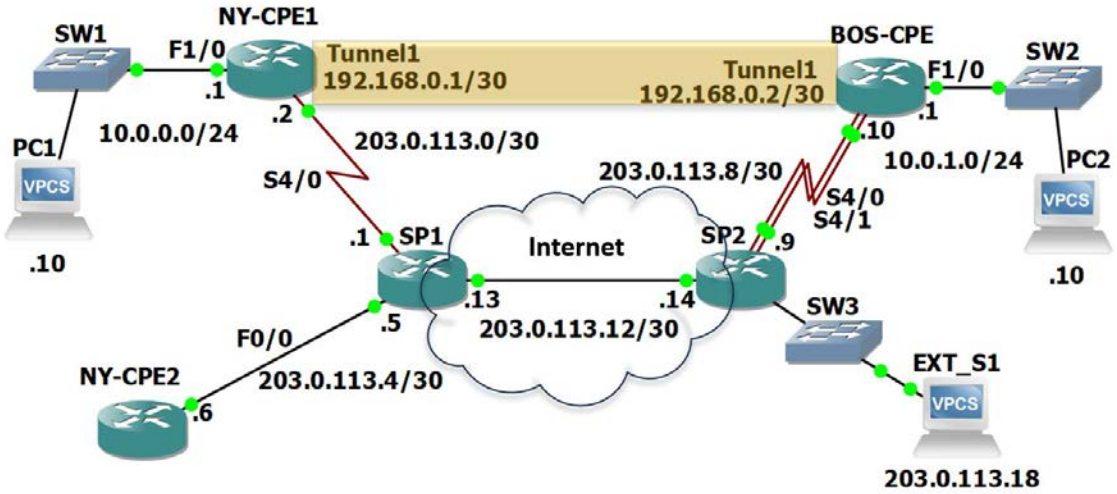
You will configure PPPoE for the DSL connection in the Boston office.

Finally you will configure a GRE tunnel between New York site 1 and Boston.

The SP1 and SP2 routers have already been configured at the service provider.

EXT_S1 is an external server at 203.0.113.18 which can be used to test Internet connectivity.

Lab Topology



Load the Startup Configurations

Download the '33-1 WAN Configuration.gns3project' file here. Open in GNS3 to load the lab.

Host Setup

1) Configure the IP address and default gateway on PC1, PC2 and Ext_S1 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1


PC2> ip 10.0.1.10/24 10.0.1.1


EXT_S1> ip 203.0.113.18/30 203.0.113.17
```

PPP with PAP Authentication

2) Configure the leased line from router NY-CPE1 to the service provider router SP1 according to the network topology diagram.
   Interface Serial 4/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with PAP authentication using the username **NY1** and password **Flackbox**.

   Configure one way authentication, do not authenticate the service provider.

   Configure a bandwidth of 128kbps.

3) Verify the interface is up.

4) Ping the service provider to verify connectivity.

5) Configure a default static route for Internet access over the leased line.

6) Ping the external server at 203.0.113.18 from NY-CPE1 to verify Internet access.

7) Do you expect PC1 to be able to ping the external server at 203.0.113.18? Why or why not? Verify this.

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MultiLink PPP with CHAP Authentication

8) Configure a MultiLink PPP leased line from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interfaces Serial 4/0 and 4/1 are used on both sides of the link.

   The service provider has instructed you to configure PPP with two way CHAP authentication using the password **Flackbox2**. The service provider router's hostname is **SP2**.

   Configure a bandwidth of 256kbps.

9) Verify the interface is up.

10) Ping the service provider to verify connectivity.

11) Configure a default static route for Internet access over the leased line.

12) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

PPPoE

13) Configure PPPoE from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interface FastEthernet 0/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with CHAP authentication using the password **Flackbox3**.

   Configure one way authentication, do not authenticate the service provider.

14) Verify the interface is up.

15) Ping the service provider to verify connectivity.

16) Configure a default static route for Internet access.

17) Ping the external server at 203.0.113.18 from BOS-CPE to verify Internet access.

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GRE

18) Configure a GRE tunnel between NY-CPE1 and BOS-CPE. Use IP addresses in the 192.168.0.0/30 subnet for the tunnel interfaces.

19) The tunnel interfaces will be up as long as the underlying physical interfaces are up. Verify the tunnel setup and connectivity by pinging the tunnel interface on BOS-CPE from NY-CPE1.

20) Do you expect PC1 in New York to be able to ping PC2 in Boston? Why or why not? Verify this.

21) Verify the tunnel interface appears in the routing tables on NY-CPE1 and BOS-CPE.

22) Enable single area OSPF on NY-CPE1 and BOS-CPE. Ensure that the PCs in New York site 1 and Boston have connectivity to each other. Do not enable OSPF on the Internet facing FastEthernet 0/0 interface.

23) Ping PC2 from PC1 to verify connectivity through the GRE tunnel.

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33-1 WAN Configuration - Answer Key

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

You will configure PPP with PAP authentication for a single leased line in New York site 1.

You will configure MultiLink PPP with CHAP authentication for New York site 2.

You will configure PPPoE for the DSL connection in the Boston office.

Finally you will configure a GRE tunnel between New York site 1 and Boston.

The SP1 and SP2 routers have already been configured at the service provider.

EXT_S1 is an external server at 203.0.113.18 which can be used to test Internet connectivity.

Host Setup

1) Configure the IP address and default gateway on PC1, PC2 and Ext_S1 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1
```

```
PC2> ip 10.0.1.10/24 10.0.1.1
```

```
EXT_S1> ip 203.0.113.18/30 203.0.113.17
```

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PPP with PAP Authentication

2) Configure the leased line from router NY-CPE1 to the service provider router SP1 according to the network topology diagram.
Interface Serial 4/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with PAP authentication using the username **NY1** and password **Flackbox**.

   Configure one way authentication, do not authenticate the service provider.

   Configure a bandwidth of 128kbps.

```
NY-CPE1(config)#int s4/0
NY-CPE1(config-if)#ip add 203.0.113.2 255.255.255.252
NY-CPE1(config-if)#encapsulation ppp
NY-CPE1(config-if)#ppp pap sent-username NY1 password Flackbox
NY-CPE1(config-if)#bandwidth 128
NY-CPE1(config-if)#no shutdown
```

3) Verify the interface is up.

```
NY-CPE1#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.0.0.1        YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
Serial4/0              203.0.113.2     YES manual up                    up
```

4) Ping the service provider to verify connectivity.

```
NY-CPE1#ping 203.0.113.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/52/56
ms
```

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5) Configure a default static route for Internet access over the leased line.

```
NY-CPE1(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.1
```

6) Ping the external server at 203.0.113.18 from NY-CPE1 to verify Internet access.

```
NY-CPE1#ping 203.0.113.18

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:

.!!!!

Success rate is 80 percent (4/5), round-trip min/avg/max =
72/157/404 ms
```

7) Do you expect PC1 to be able to ping the external server at 203.0.113.18? Why or why not? Verify this.

PC1 is using a private IP address and NAT has not been configured so it will not be able to ping the external server.

```
PC1> ping 203.0.113.18

203.0.113.18 icmp_seq=1 timeout

203.0.113.18 icmp_seq=2 timeout

203.0.113.18 icmp_seq=3 timeout

203.0.113.18 icmp_seq=4 timeout

203.0.113.18 icmp_seq=5 timeout
```

At this point we would normally configure NAT to allow Internet connectivity from the PCs in New York site 1 (and also configure security) but it is not required in this lab.

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MultiLink PPP with CHAP Authentication

8) Configure a MultiLink PPP leased line from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interfaces Serial 4/0 and 4/1 are used on both sides of the link.

   The service provider has instructed you to configure PPP with two way CHAP authentication using the password **Flackbox2**. The service provider router's hostname is **SP2**.

   Configure a bandwidth of 256kbps.

```
BOS-CPE(config)#username SP2 password Flackbox2


BOS-CPE(config)#interface multilink 1
BOS-CPE(config-if)#ip address 203.0.113.10 255.255.255.252
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#ppp authentication chap
BOS-CPE(config-if)#bandwidth 256
BOS-CPE(config-if)#exit

BOS-CPE(config)#interface serial 4/0
BOS-CPE(config-if)#no ip address
BOS-CPE(config-if)#encapsulation ppp
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#no shutdown
BOS-CPE(config-if)#exit

BOS-CPE(config)#interface serial 4/1
BOS-CPE(config)#no ip address
BOS-CPE(config-if)#encapsulation ppp
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#no shutdown
```

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9) Verify the interface is up.

```
BOS-CPE#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.0.1.1        YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
Serial4/0              unassigned      YES unset  up                    up
Serial4/1              unassigned      YES unset  up                    up
Serial4/2              unassigned      YES unset  administratively down down
Serial4/3              unassigned      YES unset  administratively down down
Multilink1             203.0.113.10    YES manual up                    up
```

10) Ping the service provider to verify connectivity.

```
BOS-CPE#ping 203.0.113.9
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.9, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/52/60
ms
```

11) Configure a default static route for Internet access over the leased line.

```
BOS-CPE(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.9
```

12) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

```
BOS-CPE#ping 203.0.113.18
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max =
52/139/388 ms
```

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PPPoE

13) Configure PPPoE from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interface FastEthernet 0/0 is used on both sides of the link.

The service provider has instructed you to configure PPP with CHAP authentication using the password **Flackbox3**.

Configure one way authentication, do not authenticate the service provider.

```
NY-CPE2(config)#interface dialer1
NY-CPE2(config-if)#dialer pool 1
NY-CPE2(config-if)#encapsulation ppp
NY-CPE2(config-if)#ip address negotiated
NY-CPE2(config-if)#ppp chap password Flackbox3

NY-CPE2(config)#interface f0/0
NY-CPE2(config-if)#no ip address
NY-CPE2(config-if)#pppoe-client dial-pool-number 1
NY-CPE2(config-if)#no shutdown
```

14) Verify the interface is up.

```
NY-CPE2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  up                    up
FastEthernet1/0        unassigned      YES unset  administratively down down
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down
Serial4/0              unassigned      YES unset  administratively down down
Serial4/1              unassigned      YES unset  administratively down down
Serial4/2              unassigned      YES unset  administratively down down
Serial4/3              unassigned      YES unset  administratively down down
Dialer1                203.0.113.6     YES IPCP   up                    up
Virtual-Access1        unassigned      YES unset  up                    up
```

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15) Ping the service provider to verify connectivity.

```
NY-CPE2#ping 203.0.113.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/54/68
ms
```

16) Configure a default static route for Internet access.

```
NY-CPE2(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.5
```

17) Ping the external server at 203.0.113.18 from BOS-CPE to verify Internet access.

```
NY-CPE2#ping 203.0.113.18
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max =
52/178/512 ms
```

GRE

18) Configure a GRE tunnel between NY-CPE1 and BOS-CPE. Use IP addresses in the 192.168.0.0/30 subnet for the tunnel interfaces.

```
NY-CPE1(config)#interface Tunnel1
NY-CPE1(config-if)#ip address 192.168.0.1 255.255.255.252
NY-CPE1(config-if)#tunnel source 203.0.113.2
NY-CPE1(config-if)#tunnel destination 203.0.113.10

BOS-CPE(config)#interface Tunnel1
BOS-CPE(config-if)#ip address 192.168.0.2 255.255.255.252
BOS-CPE(config-if)#tunnel source 203.0.113.10
BOS-CPE(config-if)#tunnel destination 203.0.113.2
```

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19) The tunnel interfaces will be up as long as the underlying physical interfaces are up. Verify the tunnel setup and connectivity by pinging the tunnel interface on BOS-CPE from NY-CPE1.

```
NY-CPE1#ping 192.168.0.2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max =
80/89/104 ms
```

20) Do you expect PC1 in New York to be able to ping PC2 in Boston? Why or why not? Verify this.

PC1 will not be able to ping PC2. The GRE tunnel is up but routing has not been configured to send any traffic over the tunnel.

```
PC1> ping 10.0.1.10

10.0.1.10 icmp_seq=1 timeout

10.0.1.10 icmp_seq=2 timeout

10.0.1.10 icmp_seq=3 timeout

10.0.1.10 icmp_seq=4 timeout

10.0.1.10 icmp_seq=5 timeout
```

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21) Verify the tunnel interface appears in the routing tables on NY-CPE1 and BOS-CPE.

```
NY-CPE1#sh ip route
! Codes truncated

Gateway of last resort is 203.0.113.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet1/0
L        10.0.0.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/30 is directly connected, Tunnel1
L        192.168.0.1/32 is directly connected, Tunnel1
      203.0.113.0/24 is variably subnetted, 3 subnets, 2 masks
C        203.0.113.0/30 is directly connected, Serial4/0
C        203.0.113.1/32 is directly connected, Serial4/0
L        203.0.113.2/32 is directly connected, Serial4/0

BOS-CPE#sh ip route
! Codes truncated

Gateway of last resort is 203.0.113.9 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.9
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/30 is directly connected, Tunnel1
L        192.168.0.2/32 is directly connected, Tunnel1
      203.0.113.0/24 is variably subnetted, 3 subnets, 2 masks
C        203.0.113.8/30 is directly connected, Multilink1
C        203.0.113.9/32 is directly connected, Multilink1
L        203.0.113.10/32 is directly connected, Multilink1
```

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22) Enable single area OSPF on NY-CPE1 and BOS-CPE. Ensure that the PCs in New York site 1 and Boston have connectivity to each other. Do not enable OSPF on the Internet facing FastEthernet 0/0 interface.

```
NY-CPE1(config)#router ospf 1
NY-CPE1(config-router)#network 10.0.0.0 0.0.255.255 area 0
NY-CPE1(config-router)#network 192.168.0.0 0.0.0.3 area 0


BOS-CPE(config)#router ospf 1
BOS-CPE(config-router)#network 10.0.0.0 0.0.255.255 area 0
BOS-CPE(config-router)#network 192.168.0.0 0.0.0.3 area 0
```

You can use different wildcard masks in the network statements as long as the FastEthernet1/0 and Tunnel1 interfaces are matched.

23) Ping PC2 from PC1 to verify connectivity through the GRE tunnel.

```
PC1> ping 10.0.1.10
84 bytes from 10.0.1.10 icmp_seq=1 ttl=62 time=150.103 ms
84 bytes from 10.0.1.10 icmp_seq=2 ttl=62 time=71.048 ms
84 bytes from 10.0.1.10 icmp_seq=3 ttl=62 time=80.053 ms
84 bytes from 10.0.1.10 icmp_seq=4 ttl=62 time=78.053 ms
84 bytes from 10.0.1.10 icmp_seq=5 ttl=62 time=80.056 ms
```

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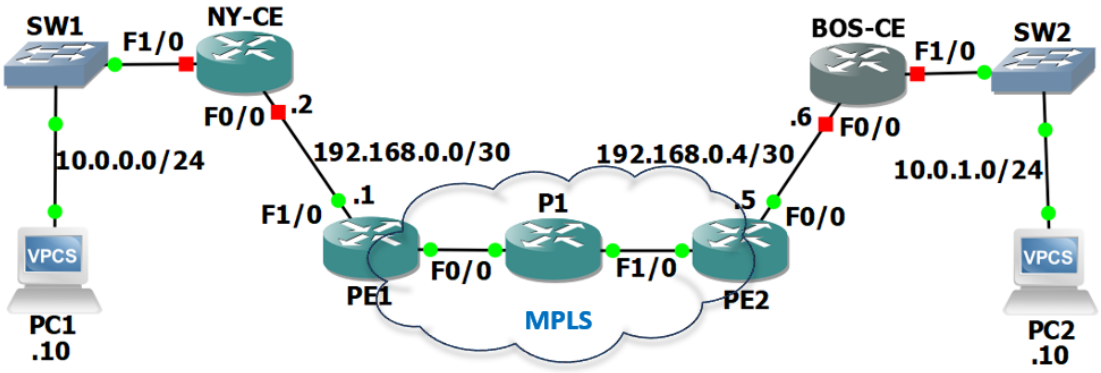
34-1 BGP Configuration – Lab Exercise

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

The WAN connectivity will be provided via a service provider's MPLS Layer 3 VPN service. eBGP will be used as the CE-PE routing protocol.

The MPLS Layer 3 VPN has already been provisioned on the service provider's routers. Your task is to configure the customer CE routers.

Lab Topology



Load the Startup Configurations

Download the '34-1 BGP Configuration.gns3project' file here. Open in GNS3 to load the lab.

You can learn the theory for this section and shortcut your path to CCNA certification by getting my CCNA Complete course. Get the course for only $10 USD (that's a massive 97% discount) with this link:

https://www.udemy.com/ccna-complete/?couponCode=DISCOUNTCEB

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Host Setup

1) Configure the IP address and default gateway on PC1 and PC2 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1


PC2> ip 10.0.1.10/24 10.0.1.1
```

eBGP Configuration

2) Verify IP addresses have already been configured on the CE's inside LAN interfaces.

3) Configure the IP addresses on the outside FastEthernet 0/0 interfaces on the customer CE routers according to the network topology diagram.

4) Verify the CE's have connectivity to their directly connected PE router.

5) Configure eBGP sessions on the CE routers. Use BGP AS 65001. The service provider AS is 65000. Advertise the internal 10.0.x.x networks in BGP.

6) Verify the BGP sessions with the PE routers are established successfully.

7) On NY-CE, verify the 10.0.1.0/24 network in Boston has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.4/30 network in Boston).

8) On BOS-CE, verify the 10.0.0.0/24 network in New York has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.0/30 network in New York).

9) Verify NY-CE has routes to the 10.0.1.0/24 and 192.168.0.4/30 networks in Boston in its routing table, with PE1 as the next hop.

10) Verify BOS-CE has routes to the 10.0.0.0/24 and 192.168.0.0/30 networks in New York in its routing table, with PE2 as the next hop.

11) Verify PC1 in New York has connectivity to PC2 in Boston.

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34-1 BGP Configuration - Answer Key

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

The WAN connectivity will be provided via a service provider's MPLS Layer 3 VPN service. eBGP will be used as the CE-PE routing protocol.

The MPLS Layer 3 VPN has already been provisioned on the service provider's routers. Your task is to configure the customer CE routers.

Host Setup

1) Configure the IP address and default gateway on PC1 and PC2 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1
```

```
PC2> ip 10.0.1.10/24 10.0.1.1
```

eBGP Configuration

2) Verify IP addresses have already been configured on the CE's inside LAN interfaces.

```
NY-CE#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet1/0        10.0.0.1        YES manual up                    up
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down

BOS-CE#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet1/0        10.0.1.1        YES manual up                    up
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down
```

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3) Configure the IP addresses on the outside FastEthernet 0/0 interfaces on the customer CE routers according to the network topology diagram.

```
NY-CE(config)#int f0/0
NY-CE(config-if)#ip address 192.168.0.2 255.255.255.252
NY-CE(config-if)#no shutdown


BOS-CE(config)#int f0/0
BOS-CE(config-if)#ip address 192.168.0.6 255.255.255.252
BOS-CE(config-if)#no shutdown
```

4) Verify the CE's have connectivity to their directly connected PE router.

```
NY-CE#ping 192.168.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/52/68
ms


BOS-CE#ping 192.168.0.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/48/56
ms
```

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5) Configure eBGP sessions on the CE routers. Use BGP AS 65001. The service provider AS is 65000. Advertise the internal 10.0.x.x networks in BGP.

Ensure you use the correct /24 subnet masks when entering the 'network' statements. BGP will not advertise a route unless an exact match is found in the routing table.

```
NY-CE(config)#router bgp 65001
NY-CE(config-router)#neighbor 192.168.0.1 remote-as 65000
NY-CE(config-router)#network 10.0.0.0 mask 255.255.255.0

BOS-CE(config)#router bgp 65001
BOS-CE(config-router)#neighbor 192.168.0.5 remote-as 65000
BOS-CE(config-router)#network 10.0.1.0 mask 255.255.255.0
```

6) Verify the BGP sessions with the PE routers are established successfully.

```
NY-CE#show ip bgp summary
BGP router identifier 10.0.0.1, local AS number 65001
BGP table version is 5, main routing table version 5
4 network entries using 576 bytes of memory
4 path entries using 320 bytes of memory
4/4 BGP path/bestpath attribute entries using 544 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1488 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.1     4        65000      12      12        5    0    0 00:06:30        3
```

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```
BOS-CE#show ip bgp summary
BGP router identifier 10.0.1.1, local AS number 65001
BGP table version is 5, main routing table version 5
4 network entries using 576 bytes of memory
4 path entries using 320 bytes of memory
4/4 BGP path/bestpath attribute entries using 544 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1488 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.5     4        65000      14      12        5    0    0 00:07:14        3
```

7) On NY-CE, verify the 10.0.1.0/24 network in Boston has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.4/30 network in Boston).

```
NY-CE#show bgp
BGP table version is 5, local router ID is 10.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.0.0.0/24      0.0.0.0                  0         32768 i
 *>  10.0.1.0/24      192.168.0.1                            0 65000 65000 i
 r>  192.168.0.0/30   192.168.0.1              0             0 65000 ?
 *>  192.168.0.4/30   192.168.0.1                            0 65000 ?
```

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8) On BOS-CE, verify the 10.0.0.0/24 network in New York has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.0/30 network in New York).

```
BOS-CE#show bgp
BGP table version is 5, local router ID is 10.0.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.0.0.0/24      192.168.0.5                            0 65000 65000 i
 *>  10.0.1.0/24      0.0.0.0                  0         32768 i
 *>  192.168.0.0/30   192.168.0.5                            0 65000 ?
 r>  192.168.0.4/30   192.168.0.5              0             0 65000 ?
```

9) Verify NY-CE has routes to the 10.0.1.0/24 and 192.168.0.4/30 networks in Boston in its routing table, with PE1 as the next hop.

```
NY-CE#show ip route
! Codes truncated

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet1/0
L        10.0.0.1/32 is directly connected, FastEthernet1/0
B        10.0.1.0/24 [20/0] via 192.168.0.1, 00:13:21
      192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.0.0/30 is directly connected, FastEthernet0/0
L        192.168.0.2/32 is directly connected, FastEthernet0/0
B        192.168.0.4/30 [20/0] via 192.168.0.1, 00:09:20
```

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10) Verify BOS-CE has routes to the 10.0.0.0/24 and 192.168.0.0/30 networks in New York in its routing table, with PE2 as the next hop.

```
BOS-CE#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

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
B        10.0.0.0/24 [20/0] via 192.168.0.5, 00:15:39
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
B        192.168.0.0/30 [20/0] via 192.168.0.5, 00:12:00
C        192.168.0.4/30 is directly connected, FastEthernet0/0
L        192.168.0.6/32 is directly connected, FastEthernet0/0
```

11) Verify PC1 in New York has connectivity to PC2 in Boston.

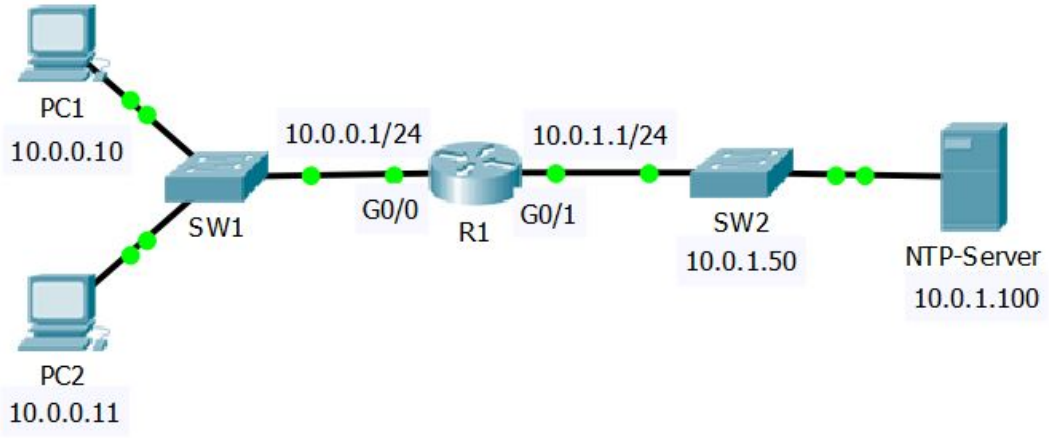
```
PC1> ping 10.0.1.10
10.0.1.10 icmp_seq=1 timeout
10.0.1.10 icmp_seq=2 timeout
84 bytes from 10.0.1.10 icmp_seq=3 ttl=59 time=97.082 ms
84 bytes from 10.0.1.10 icmp_seq=4 ttl=59 time=100.067 ms
84 bytes from 10.0.1.10 icmp_seq=5 ttl=59 time=93.059 ms0.056 ms
```

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35-1 Cisco Device Security Configuration – Lab Exercise

In this lab you will secure administrative access to the Cisco router in a small campus network.

Lab Topology



Load the Startup Configurations

Download the '35-1 Cisco Device Security Configuration.pkt' file here. Open in Packet Tracer to load the lab.

Secure Privileged Exec Mode

1) Set the enable password **Flackbox2** on R1 to secure access to Privileged Exec (Enable) mode.

2) Exit to User Exec mode.

3) Enter Privileged Exec mode.

4) Set the enable secret **Flackbox1**.

5) Exit to User Exec mode.

6) Do you expect to be able to enter Privileged Exec mode using the password **Flackbox2**? Why or why not? Verify this.

7) Show the running configuration on R1. Can you read the enable password and secret in plain text?

8) Ensure that passwords will not show in plain text in the output of 'show' commands.

9) Verify the enable password is now encrypted when you show the running configuration.

Secure Remote Telnet and SSH Access

10) Enable synchronous logging on R1 and ensure administrators are logged out after 15 minutes of activity on the console and virtual terminal lines 0-15.

11) Allow the administrator workstation at 10.0.0.10 to Telnet into R1 using the password **Flackbox3**. Ensure no other host has Telnet access to the router.

12) Ensure that users attempting to Telnet into the router see the message "Authorised users only"

13) Verify you can Telnet into R1 from PC1 and enter Privileged Exec mode. Close the Telnet session when done.

14) Verify Telnet access fails from PC2.

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15) Configure R1 so that administrators will be prompted to enter a username and password when they attempt to Telnet into the router. Use username **admin** and password **Flackbox4**.

16) Verify you are prompted for a username and password when you attempt to Telnet to the router.

17) Allow the administrator workstation at 10.0.0.10 to SSH into R1. Use the domain name **flackbox.com** and a 768 bit key.

18) Verify you can SSH into R1 from PC1. Close the session when done.

19) Do you expect to be able to SSH to R1 from PC2? Why or why not? Verify this.

20) You can currently access R1 using either Telnet or SSH. Telnet is an insecure protocol as all communication is sent in plain text. Configure R1 so that only SSHv2 remote access is allowed.

21) Verify you cannot Telnet into R1 from PC1 but can SSH. Exit when done.

22) What username and password do you need to use to login when you connect directly to R1 with a console cable?

23) Configure R1 to require no username but a password of **Flackbox5** to login over the console connection.

24) Verify you can access R1 over the console connection and enter Privileged Exec mode.

NTP Network Time Protocol

25) Configure R1 to synchronise its time with the NTP server at 10.0.1.100. Set the timezone as Pacific Standard Time which is 8 hours before UTC.

26) Check the current time on the router and verify it is synchronised with the NTP server.

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Switch Management

27) Configure SW2 with IP address 10.0.1.50 for management on VLAN 1. Ensure the switch has connectivity to other IP subnets.

(Note that it is best practice to NOT use VLAN 1 for any production traffic in a real world network and we would normally have a separate dedicated IP subnet for management traffic. We are using VLAN 1 in our lab environment to simplify the topology)

35-1 Cisco Device Security Configuration - Answer Key

In this lab you will secure administrative access to the Cisco router in a small campus network.

Secure Privileged Exec Mode

1) Set the enable password **Flackbox2** on R1 to secure access to Privileged Exec (Enable) mode.

```
R1(config)#enable password Flackbox2
```

2) Exit to User Exec mode.

```
R1#exit
```

3) Enter Privileged Exec mode.

```
R1>enable
Password:Flackbox2
R1#
```

4) Set the enable secret **Flackbox1**.

```
R1(config)#enable secret Flackbox1
```

5) Exit to User Exec mode.

```
R1#exit
```

6) Do you expect to be able to enter Privileged Exec mode using the password **Flackbox2**? Why or why not? Verify this.

You cannot enter Privileged Exec mode using the enable password because it has been superseded by the enable secret.

```
R1>enable
Password:Flackbox2
Password:Flackbox1
R1#
```

7) Show the running configuration on R1. Can you read the enable password and secret in plain text?

The enable password is shown in plain text but the enable secret is encrypted.

```
R1#show run
Building configuration...

Current configuration : 762 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname R1
!
enable secret 5 $1$mERr$J2XZHMOgpVVXdLjC9lYtE1
enable password Flackbox2
```

8) Ensure that passwords will not show in plain text in the output of ‘show’ commands.

```
R1(config)#service password-encryption
```

9) Verify the enable password is now encrypted when you show the running configuration.

```
R1#show running-config
Building configuration...

Current configuration : 772 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
service password-encryption
!
hostname R1
!
enable secret 5 $1$mERr$J2XZHMOgpVVXdLjC9lYtE1
enable password 7 0807404F0A1207180A59
```

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Secure Remote Telnet and SSH Access

10) Enable synchronous logging on R1 and ensure administrators are logged out after 15 minutes of activity on the console and virtual terminal lines 0-15.

```
R1(config)#line console 0
R1(config-line)#logging synchronous
R1(config-line)#exec-timeout 15


R1(config)#line vty 0 15
R1(config-line)#logging synchronous
R1(config-line)#exec-timeout 15
```

11) Allow the administrator workstation at 10.0.0.10 to Telnet into R1 using the password **Flackbox3**. Ensure no other host has Telnet access to the router.

```
R1(config)#access-list 1 permit host 10.0.0.10

R1(config)#line vty 0 15
R1(config-line)#login
R1(config-line)#password Flackbox3
R1(config-line)#access-class 1 in
```

12) Ensure that users attempting to Telnet into the router see the message “Authorised users only”

```
R1(config)#banner login "
Enter TEXT message. End with the character '"'.
Authorised users only"
```

13) Verify you can Telnet into R1 from PC1 and enter Privileged Exec mode. Close the Telnet session when done.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …Open

Authorised users only

User Access Verification

Password: Flackbox3
R1>enable
Password: Flackbox1
```

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```
R1#exit

[Connection to 10.0.0.1 closed by foreign host]
```

14) Verify Telnet access fails from PC2.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …
% Connection refused by remote host
```

15) Configure R1 so that administrators will be prompted to enter a username and password when they attempt to Telnet into the router. Use username **admin** and password **Flackbox4**.

```
R1(config)#username admin secret Flackbox4
R1(config)#line vty 0 15
R1(config-line)#login local
```

16) Verify you are prompted for a username and password when you attempt to Telnet to the router.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …Open

Authorised users only

User Access Verification

Username: admin

Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

17) Allow the administrator workstation at 10.0.0.10 to SSH into R1. Use the domain name **flackbox.com** and a 768 bit key.

```
R1(config)#ip domain-name flackbox.com
R1(config)#crypto key generate rsa
The name for the keys will be: R1.flackbox.com
Choose the size of the key modulus in the range of 360 to 2048
for your
General Purpose Keys. Choosing a key modulus greater than 512
may take
a few minutes.

How many bits in the modulus [512]: 768
% Generating 768 bit RSA keys, keys will be non-exportable...[OK]
```

18) Verify you can SSH into R1 from PC1. Close the session when done.

```
C:\> ssh –l admin 10.0.0.1
Open
Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

19) Do you expect to be able to SSH to R1 from PC2? Why or why not? Verify this.

You will not be able to SSH to R1 from PC2. Telnet and SSH access are both controlled by the ‘line vty’ configuration which has an access list applied only allowing access from PC1.

```
C:\> ssh –l admin 10.0.0.1
Trying 10.0.0.1 …
% Connection refused by remote host
```

20) You can currently access R1 using either Telnet or SSH. Telnet is an insecure protocol as all communication is sent in plain text. Configure R1 so that only SSHv2 remote access is allowed.

```
R1(config)#line vty 0 15
R1(config-line)#transport input ssh
R1(config-line)#exit
R1(config)#ip ssh version 2
```

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21) Verify you cannot Telnet into R1 from PC1 but can SSH. Exit when done.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …Open

[Connection to 10.0.0.1 closed by remote host]

C:\> ssh –l admin 10.0.0.1
Open
Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

22) What username and password do you need to use to login when you connect directly to R1 with a console cable?

No username and password are currently required to login to the console. The virtual terminal lines which control Telnet and SSH access have been secured but console access not.

23) Configure R1 to require no username but a password of **Flackbox5** to login over the console connection.

```
R1(config)#line console 0
R1(config-line)#login
% Login disabled on line 0, until 'password' is set
R1(config-line)#password Flackbox5
```

24) Verify you can access R1 over the console connection and enter Privileged Exec mode.

```
R1(config-line)#end
R1#logout

R1 con0 is now available
Press RETURN to get started.
Authorised users only
User Access Verification
Password: Flackbox5
R1>enable
Password: Flackbox1
R1#
```

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NTP Network Time Protocol

25) Configure R1 to synchronise its time with the NTP server at 10.0.1.100. Set the timezone as Pacific Standard Time which is 8 hours before UTC.

```
R1(config)#clock timezone PST -8
R1(config)#ntp server 10.0.1.100
```

26) Check the current time on the router and verify it is synchronised with the NTP server.

```
R1#show clock
16:19:36.51 PST Mon Oct 2 2017

R1#show ntp status
Clock is synchronized, stratum 2, reference is 10.0.1.100
nominal freq is 250.0000 Hz, actual freq is 249.9990 Hz,
precision is 2**19
reference time is DD53255C.0000039C (00:16:28.924 UTC Tue Oct
3 2017)
clock offset is 0.00 msec, root delay is 0.00 msec
root dispersion is 0.02 msec, peer dispersion is 0.02 msec.
```

Switch Management

27) Configure SW2 with IP address 10.0.1.50 for management on VLAN 1. Ensure the switch has connectivity to other IP subnets.

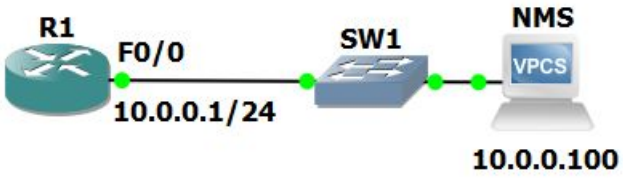
(Note that it is best practice to NOT use VLAN 1 for any production traffic in a real world network and we would normally have a separate dedicated IP subnet for management traffic. We are using VLAN 1 in our lab environment to simplify the topology).

```
SW2(config)#int vlan 1
SW2(config-if)#ip address 10.0.1.50 255.255.255.0
SW2(config-if)#no shutdown
SW2(config-if)#exit
SW2(config)#ip default-gateway 10.0.1.1
```

36 Network Device Management – Lab Exercise

You will configure Syslog and SNMP (Simple Network Management Protocol) logging in this lab exercise. The NMS server is acting as an external Syslog and SNMP destination (note the server has not actually been configured as a Syslog or SNMP server.)

Lab Topology



Load the Startup Configurations

Download the '36 Network Device Management.gns3project' file here. Open in GNS3 to load the lab.

Syslog

1) Configure R1 so it will show emergency, alerts and critical severity events when you are connected with a console cable.

2) Configure R1 so it will show emergency, alerts, critical and error severity level events when you are logged in with an SSH session.

3) Configure R1 so it will show events from all severity levels when you issue the 'show logging' command.

4) If you shut down interface FastEthernet 0/0 then bring it back up again do you expect to see logging messages in your console session? Why or why not? Verify this.

5) If you shut down interface FastEthernet 0/0 then bring it back up again do you expect to see messages in the logging buffer? Why or why not? Verify this.

6) Configure R1 so it will show events from all severity levels to the external Syslog server at 10.0.0.100.

7) Verify you have set the correct severity level for the different logging locations.

SNMP Simple Network Management Protocol

8) Configure R1 to use your email address as the SNMP contact. Use **Flackbox Lab** as the SNMP location.

9) Configure SNMP on R1. Use **Flackbox1** as the Read Only community string, and **Flackbox2** as the Read Write community string.

10) Configure R1 to send SNMP traps to the server at 10.0.0.100 when there is a configuration change on the router. Use the community string **Flackbox3**.

11) Shut down then bring back up the FastEthernet 0/0 interface. Verify an SNMP trap is sent to 10.0.0.100.

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36 Network Device Management – Answer Key

You will configure Syslog and SNMP (Simple Network Management Protocol) logging in this lab exercise. The NMS server is acting as an external Syslog and SNMP destination (note the server has not actually been configured as a Syslog or SNMP server.)

Syslog

1) Configure R1 so it will show emergency, alerts and critical severity events when you are connected with a console cable.

You can use the descriptive name or numerical level when configuring logging levels.

```
R1(config)#logging console critical or
R1(config)#logging console 2
```

2) Configure R1 so it will show emergency, alerts, critical and error severity level events when you are logged in with an SSH session.

```
R1(config)#logging monitor error or
R1(config)#logging monitor 3
```

3) Configure R1 so it will show events from all severity levels when you issue the ‘show logging’ command.

```
R1(config)#logging buffer debugging or
R1(config)#logging buffer 7
```

4) If you shut down interface FastEthernet 0/0 then bring it back up again do you expect to see logging messages in your console session? Why or why not? Verify this.

You will not see log messages because you are logging critical and more severe level messages to the console. Shutting down and bringing up an interface is informational severity.

```
R1(config)#int f0/0
R1(config-if)#shutdown
R1(config-if)#no shutdown
```

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5) If you shut down interface FastEthernet 0/0 then bring it back up again do you expect to see messages in the logging buffer? Why or why not? Verify this.

You will see messages because you have enabled debugging severity level to send all severity level messages to the logging buffer.

```
R1#show logging
Syslog logging: enabled (0 messages dropped, 0 messages rate-
limited, 0 flushes, 0 overruns, xml disabled, filtering disabled)


No Active Message Discriminator.

No Inactive Message Discriminator.


Console logging: level critical, 22 messages logged, xml disabled,
filtering disabled

Monitor logging: level errors, 0 messages logged, xml disabled,
filtering disabled

Buffer logging:  level debugging, 30 messages logged, xml disabled,
filtering disabled

Exception Logging: size (8192 bytes)

Count and timestamp logging messages: disabled

Persistent logging: disabled


No active filter modules.


Trap logging: level informational, 34 message lines logged

Logging Source-Interface:       VRF Name:


Log Buffer (8192 bytes):


*Oct  3 00:44:12.627: %LINK-5-CHANGED: Interface FastEthernet0/0,
changed state to administratively down

*Oct  3 00:44:13.627: %LINEPROTO-5-UPDOWN: Line protocol on
Interface FastEthernet0/0, changed state to down

*Oct  3 00:44:15.903: %SYS-5-CONFIG_I: Configured from console by
console

*Oct  3 00:44:16.471: %LINK-3-UPDOWN: Interface FastEthernet0/0,
changed state to up
```

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```
*Oct  3 00:44:17.591: %LINEPROTO-5-UPDOWN: Line protocol on
Interface FastEthernet0/0, changed state to up

*Oct  3 00:48:30.731: %LINK-5-CHANGED: Interface FastEthernet0/0,
changed state to administratively down

*Oct  3 00:48:32.779: %LINK-3-UPDOWN: Interface FastEthernet0/0,
changed state to up
```

6) Configure R1 so it will show events from all severity levels to the external Syslog server at 10.0.0.100.

```
R1(config)#logging 10.0.0.100

R1(config)#logging trap debugging
```

7) Verify you have set the correct severity level for the different logging locations.

```
R1#show logging

Syslog logging: enabled (0 messages dropped, 0 messages rate-
limited, 0 flushes, 0 overruns, xml disabled, filtering disabled)


No Active Message Discriminator.

No Inactive Message Discriminator.


Console logging: level critical, 22 messages logged, xml disabled,
filtering disabled

Monitor logging: level errors, 0 messages logged, xml disabled,
filtering disabled

Buffer logging:  level debugging, 33 messages logged, xml disabled,
filtering disabled

    Exception Logging: size (8192 bytes)
    Count and timestamp logging messages: disabled
    Persistent logging: disabled

No active filter modules.

Trap logging: level debugging, 37 message lines logged
Logging to 10.0.0.100 (udp port 514, audit disabled, link up),
! truncated
```

SNMP Simple Network Management Protocol

8) Configure R1 to use your email address as the SNMP contact. Use **Flackbox Lab** as the SNMP location.

```
R1(config)#snmp-server contact neil@flackbox.com
R1(config)#snmp-server location Flackbox Lab
```

9) Configure SNMP on R1. Use **Flackbox1** as the Read Only community string, and **Flackbox2** as the Read Write community string.

```
R1(config)#snmp-server community Flackbox1 ro
R1(config)#snmp-server community Flackbox2 rw
```

10) Configure R1 to send SNMP traps to the server at 10.0.0.100 when there is a configuration change on the router. Use the community string **Flackbox3**.

```
R1(config)#snmp-server host 10.0.0.100 Flackbox3
R1(config)#snmp-server enable traps config
```

11) Shut down then bring back up the FastEthernet 0/0 interface. Verify an SNMP trap is sent to 10.0.0.100.

```
R1(config)#int f0/0
R1(config-if)#shutdown
R1(config-if)#no shutdown

R1#show snmp
Chassis: 4279256517
Contact: neil@flackbox.com
Location: Flackbox Lab
0 SNMP packets input
    0 Bad SNMP version errors
    0 Unknown community name
    0 Illegal operation for community name supplied
    0 Encoding errors
    0 Number of requested variables
```

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```
    0 Number of altered variables
    0 Get-request PDUs
    0 Get-next PDUs
    0 Set-request PDUs
    0 Input queue packet drops (Maximum queue size 1000)
4 SNMP packets output
    0 Too big errors (Maximum packet size 1500)
    0 No such name errors
    0 Bad values errors
    0 General errors
    0 Response PDUs
    4 Trap PDUs

SNMP logging: enabled
    Logging to 10.0.0.100.162, 3/10, 1 sent, 0 dropped.
```

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32-1 IPv6 Routing Configuration

- Lab Exercise

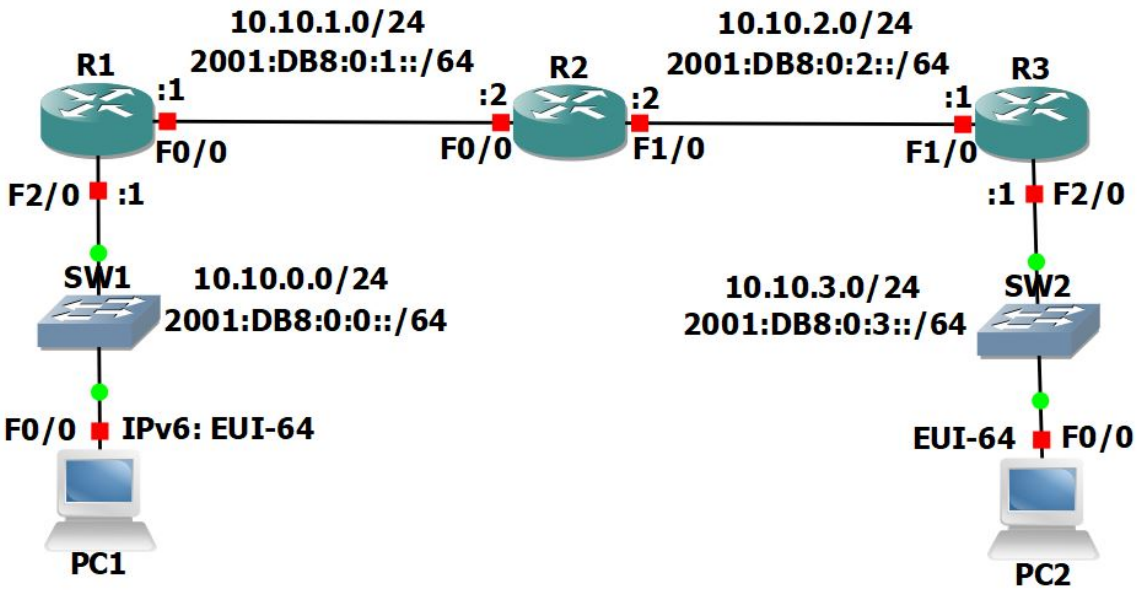
This lab continues where the last one left off. You have configured IPv6 addressing for a small campus network, now you need to configure routing between the different IPv6 subnets.

You will configure static routes, OSPF and EIGRP. Note that in a real world environment you would pick one of these options rather than configuring all of them.

Routers R1, R2 and R3 have been configured with IPv4 and IPv6 addresses. IPv4 routing has been configured on the existing network but IPv6 routing has not.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 and IPv6 addresses and default static routes to their default gateways have been added for both IPv4 and IPv6.

Lab Topology



Load the Startup Configurations

Open the ’32-1 IPv6 Routing Configuration.gns3project’ GNS3 file to load the lab.

IPv4 and IPv6 Addressing Verification

1) Verify IPv4 and IPv6 addresses have been configured on R1, R2, R3, PC1 and PC2 according to the lab topology diagram. PC1 and PC2 use EUI-64 addresses for IPv6 and 10.10.x.10 for IPv4. Note that the EUI-64 addresses may be different in your lab.

2) Verify PC1 has been configured to use R1 as its default gateway for IPv4.

3) Verify PC2 has been configured to use R3 as its default gateway for IPv4.

4) Verify R1, R2 and R3 have routes to all IPv4 networks.

5) Verify PC1 can ping PC2 on its IPv4 address 10.10.3.10

6) Verify which IPv6 dynamic routing protocols are running on R1, R2 and R3. Do not use the ‘show run’ command.

7) Use the ‘show run | include ipv6 route’ command on R1, R2 and R3 to verify if they have been configured with IPv6 static routes.

8) Do you expect to see any routes in the IPv6 routing tables? Why or why not? Verify this.

9) Do you expect PC1 to be able to ping PC2 on its IPv6 address? Why or why not? Verify this.

Static Routing

10) Configure PC1 to use R1 as its IPv6 default gateway.

11) Configure PC2 to use R3 as its IPv6 default gateway.

12) Verify PC1 and PC2 can ping their default gateways.

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13) Add a static route on R2 for the 2001:db8::/64 network.

14) PC1 has reachability to its default gateway R1, and R2 has a route to the 2001:db8::/64 network. Do you expect PC1 be able to ping R2 on 2001:db8:0:1::2? Why or why not? Verify this.

15) Fix the problem to allow PC1 to ping R2 on 2001:db8:0:1::2. Enter the command which will fix the problem on R1, R2 and R3.

16) Verify PC1 can ping R2 on 2001:db8:0:1::2 now.

17) Will PC1 be able to ping PC2 by IPv6 address? Why or why not? Verify this.

18) Configure static routes to allow reachability between all IPv6 networks.

19) Verify the IPv6 routing tables on R1, R2 and R3.

20) Verify PC1 can now ping PC2 by its IPv6 address.

21) Cleanup: Remove the static IPv6 routes on R1, R2 and R3.

22) Verify there are only connected and local routes in R1, R2 and R3's IPv6 routing tables.

OSPFv2 Configuration

23) Enable a loopback interface on R1, R2 and R3. Use the IPv4 address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

24) Enable single area OSPFv2 on every router. Ensure all networks are advertised.

25) What do you expect the OSPF Router ID to be on R1? Verify this.

26) Verify the routers have formed adjacencies with each other.

27) Do you expect to see OSPF routes in R1, R2 and R3's IPv4 routing tables? Why or why not? Verify this.

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OSPFv2 Basic Configuration

28) Configure IPv6 addresses on the existing loopback interfaces on R1, R2 and R3. Use the address 2001:db8:1:x::1/64, where 'x' is the router number. For example 2001:db8:1:3::1/64 on R3.

29) Enable single area OSPFv3 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

30) What do you expect the OSPF Router ID to be on R1? Verify this.

31) Manually set the Router ID on R1 to be the highest loopback address.

32) Verify the routers have formed adjacencies with each other.

33) Do you expect to see OSPF routes in R1, R2 and R3's IPv6 routing tables? Why or why not? Verify this.

34) Verify end to end connectivity by pinging PC2 from PC1.

35) Verify the path traffic is taking from PC1 to PC2.

EIGRP for IPv6 Configuration

36) Enable EIGRP for IPv6 using AS 100 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

37) What do you expect the EIGRP Router ID to be on R1? Verify this.

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38) Manually set the Router ID on R1 to be the highest loopback address.

39) Verify the routers have formed adjacencies with each other.

40) Do you expect EIGRP routes to be in the router's IPv6 routing tables? Why or why not? Verify this.

41) Verify end to end connectivity by pinging PC2 from PC1.

32-1 IPv6 Routing Configuration - Answer Key

This lab continues where the last one left off. You have configured IPv6 addressing for a small campus network, now you need to configure routing between the different IPv6 subnets.

You will configure static routes, OSPF and EIGRP. Note that in a real world environment you would pick one of these options rather than configuring all of them.

Routers R1, R2 and R3 have been configured with IPv4 and IPv6 addresses. IPv4 routing has been configured on the existing network but IPv6 routing has not.

PC1 and PC2 are Cisco IOS routers mimicking end hosts. They have been configured with IPv4 and IPv6 addresses and default static routes to their default gateways have been added for both IPv4 and IPv6.

IPv4 and IPv6 Addressing Verification

1) Verify IPv4 and IPv6 addresses have been configured on R1, R2, R3, PC1 and PC2 according to the lab topology diagram. PC1 and PC2 use EUI-64 addresses for IPv6 and 10.10.x.10 for IPv4. Note that the EUI-64 addresses may be different in your lab.

```
R1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
```

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```
FastEthernet0/0        10.10.1.1       YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        10.10.0.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

R1#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::1
    2001:DB8:0:1::1
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [up/up]
    FE80::1
    2001:DB8::1
FastEthernet3/0        [administratively down/down]
    Unassigned


R2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.1.2       YES NVRAM  up                    up
FastEthernet1/0        10.10.2.2       YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

R2#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::2
    2001:DB8:0:1::2
FastEthernet1/0        [up/up]
    FE80::2
    2001:DB8:0:2::2
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    unassigned

R3#sh ip int brief
```

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```
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.10.2.1       YES NVRAM  up                    up
FastEthernet2/0        10.10.3.1       YES NVRAM  up                    up
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

R3#sh ipv6 int brief
FastEthernet0/0        [administratively down/down]
    unassigned
FastEthernet1/0        [up/up]
    FE80::3
    2001:DB8:0:2::1
FastEthernet2/0        [up/up]
    FE80::3
    2001:DB8:0:3::1
FastEthernet3/0        [administratively down/down]
    Unassigned

PC1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.0.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

PC1#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::C804:36FF:FE98:0
    2001:DB8::C804:36FF:FE98:0
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    Unassigned
```

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```
PC2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        10.10.3.10      YES NVRAM  up                    up
FastEthernet1/0        unassigned      YES NVRAM  administratively down down
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down

PC2#sh ipv6 int brief
FastEthernet0/0        [up/up]
    FE80::C805:CFF:FE28:0
    2001:DB8:0:3:C805:CFF:FE28:0
FastEthernet1/0        [administratively down/down]
    unassigned
FastEthernet2/0        [administratively down/down]
    unassigned
FastEthernet3/0        [administratively down/down]
    unassigned
```

2) Verify PC1 has been configured to use R1 as its default gateway for IPv4.

```
PC1#sh 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 10.10.0.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.0.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet0/0
```

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```
L        10.10.0.10/32 is directly connected, FastEthernet0/0
```

3) Verify PC2 has been configured to use R3 as its default gateway for IPv4.

```
PC2#sh 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 10.10.3.1 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 10.10.3.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.10.3.0/24 is directly connected, FastEthernet0/0
L        10.10.3.10/32 is directly connected, FastEthernet0/0
```

4) Verify R1, R2 and R3 have routes to all IPv4 networks.

```
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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet2/0
```

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```
L        10.10.0.1/32 is directly connected, FastEthernet2/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.1/32 is directly connected, FastEthernet0/0
D        10.10.2.0/24 [90/30720] via 10.10.1.2, 00:48:15, FastEthernet0/0
D        10.10.3.0/24 [90/33280] via 10.10.1.2, 00:48:10, FastEthernet0/0

R2#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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/30720] via 10.10.1.1, 00:48:56, FastEthernet0/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.2/32 is directly connected, FastEthernet0/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.2/32 is directly connected, FastEthernet1/0
D        10.10.3.0/24 [90/30720] via 10.10.2.1, 00:48:55, FastEthernet1/0

R3#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
```

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```
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
D        10.10.0.0/24 [90/33280] via 10.10.2.2, 00:49:18, FastEthernet1/0
D        10.10.1.0/24 [90/30720] via 10.10.2.2, 00:49:18, FastEthernet1/0
C        10.10.2.0/24 is directly connected, FastEthernet1/0
L        10.10.2.1/32 is directly connected, FastEthernet1/0
C        10.10.3.0/24 is directly connected, FastEthernet2/0
L        10.10.3.1/32 is directly connected, FastEthernet2/0
```

5) Verify PC1 can ping PC2 on its IPv4 address 10.10.3.10

```
PC1#ping 10.10.3.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.3.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/80/84
ms
```

6) Verify which IPv6 dynamic routing protocols are running on R1, R2 and R3. Do not use the ‘show run’ command.

The routers are not running any IPv6 dynamic routing protocol.

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"

R2#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"

R3#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
```

7) Use the ‘show run | include ipv6 route’ command on R1, R2 and R3 to verify if they have been configured with IPv6 static routes.

The routers have not been configured with any IPv6 static routes.

```
R1#show run | include ipv6 route
R1#

R2#show run | include ipv6 route
R2#

R3#show run | include ipv6 route
R3#
```

8) Do you expect to see any routes in the IPv6 routing tables? Why or why not? Verify this.

The routers have been configured with IPv6 addresses so connected and local routes will appear in the routing table.

```
R1#show ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
```

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```
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive

R3#sh ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
```

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```
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

9) Do you expect PC1 to be able to ping PC2 on its IPv6 address? Why or why not? Verify this.

No IPv6 routing has been configured so there is no connectivity between different IPv6 subnets. (Note that PC2's EUI-64 IPv6 address may be different in your lab. Use 'show ipv6 interface brief to check its address.)

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

% No valid route for destination
Success rate is 0 percent (0/1)
```

Static Routing

10) Configure PC1 to use R1 as its IPv6 default gateway.

```
PC1(config)#ipv6 route ::/0 2001:db8::1
```

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11) Configure PC2 to use R3 as its IPv6 default gateway.

```
PC2(config)#ipv6 route ::/0 2001:db8:0:3::1
```

12) Verify PC1 and PC2 can ping their default gateways.

```
PC1#ping 2001:db8::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/31/44
ms


PC2#ping 2001:DB8:0:3::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3::1, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/26/56
ms
```

13) Add a static route on R2 for the 2001:db8::/64 network.

```
R2(config)#ipv6 route 2001:db8::/64 2001:db8:0:1::1
```

14) PC1 has reachability to its default gateway R1, and R2 has a route to the 2001:db8::/64 network. Do you expect PC1 be able to ping R2 on 2001:db8:0:1::2? Why or why not? Verify this.

PC1 cannot ping R2 on 2001:db8:0:1::2 because ipv6 unicast-routing has not been enabled on the routers.

```
PC1#ping 2001:db8:0:1::2
Type escape sequence to abort.
```

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```
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:1::2, timeout is 2
seconds:

.....

Success rate is 0 percent (0/5)
```

15) Fix the problem to allow PC1 to ping R2 on 2001:db8:0:1::2. Enter the command which will fix the problem on R1, R2 and R3.

```
R1(config)#ipv6 unicast-routing


R2(config)#ipv6 unicast-routing


R3(config)#ipv6 unicast-routing
```

16) Verify PC1 can ping R2 on 2001:db8:0:1::2 now.

```
PC1#ping 2001:db8:0:1::2

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:1::2, timeout is 2
seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 60/60/64
ms
```

17) Will PC1 be able to ping PC2 by IPv6 address? Why or why not? Verify this.

PC1 cannot ping PC2 because routing has not been configured between the 2001:db8::/64 and 2001:db8:0:3::/64 networks.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

UUUUU

Success rate is 0 percent (0/5)
```

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18) Configure static routes to allow reachability between all IPv6 networks.

```
R1(config)#ipv6 route 2001:db8:0:2::/64 2001:db8:0:1::2
R1(config)#ipv6 route 2001:db8:0:3::/64 2001:db8:0:1::2

R2(config)#ipv6 route 2001:db8::/64 2001:db8:0:1::1
R2(config)#ipv6 route 2001:db8:0:3::/64 2001:db8:0:2::1

R3(config)#ipv6 route 2001:db8::/64 2001:db8:0:2::2
R3(config)#ipv6 route 2001:db8:0:1::/64 2001:db8:0:2::2
```

19) Verify the IPv6 routing tables on R1, R2 and R3.

```
R1#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
```

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```
     via FastEthernet2/0, directly connected
L    2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C    2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L    2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
S    2001:DB8:0:2::/64 [1/0]
     via 2001:DB8:0:1::2
S    2001:DB8:0:3::/64 [1/0]
     via 2001:DB8:0:1::2
L    FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
S    2001:DB8::/64 [1/0]
     via 2001:DB8:0:1::1
C    2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L    2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C    2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
S    2001:DB8:0:3::/64 [1/0]
     via 2001:DB8:0:2::1
L    FF00::/8 [0/0]
```

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```
      via Null0, receive
```

```
R3#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
S   2001:DB8::/64 [1/0]
     via 2001:DB8:0:2::2
S   2001:DB8:0:1::/64 [1/0]
     via 2001:DB8:0:2::2
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

20) Verify PC1 can now ping PC2 by its IPv6 address.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/80/84
ms
```

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21) Cleanup: Remove the static IPv6 routes on R1, R2 and R3.

```
R1(config)#no ipv6 route 2001:db8:0:2::/64 2001:db8:0:1::2
R1(config)#no ipv6 route 2001:db8:0:3::/64 2001:db8:0:1::2

R2(config)#no ipv6 route 2001:db8::/64 2001:db8:0:1::1
R2(config)#no ipv6 route 2001:db8:0:3::/64 2001:db8:0:2::1

R3(config)#no ipv6 route 2001:db8::/64 2001:db8:0:2::2
R3(config)#no ipv6 route 2001:db8:0:1::/64 2001:db8:0:2::2
```

22) Verify there are only connected and local routes in R1, R2 and R3's IPv6 routing tables.

```
R1#show ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
```

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```
L   FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive

R3#sh ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
```

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```
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

OSPFv2 Configuration

23) Enable a loopback interface on R1, R2 and R3. Use the IPv4 address 192.168.0.x/32, where ‘x’ is the router number. For example 192.168.0.3/32 on R3.

```
R1(config)#int loop 0
R1(config-if)#ip add 192.168.0.1 255.255.255.255

R2(config)#int loop 0
R2(config-if)#ip add 192.168.0.2 255.255.255.255

R3(config)#int loop 0
R3(config-if)#ip add 192.168.0.3 255.255.255.255
```

24) Enable single area OSPFv2 on every router. Ensure all networks are advertised.

```
R1(config)#router ospf 1
R1(config-router)#network 10.10.0.0 0.0.255.255 area 0
R1(config-router)#network 192.168.0.0 0.0.0.255 area 0

R2(config)#router ospf 1
R2(config-router)#network 10.10.0.0 0.0.255.255 area 0
R2(config-router)#network 192.168.0.0 0.0.0.255 area 0

R3(config)#router ospf 1
R3(config-router)#network 10.10.0.0 0.0.255.255 area 0
R3(config-router)#network 192.168.0.0 0.0.0.255 area 0
```

You can use different network statements, as long as they cover the range of IP addresses configured on the router interfaces.

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25) What do you expect the OSPF Router ID to be on R1? Verify this.

The loopback address is used for the Router ID, 192.168.0.1

```
R1#sh ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    NSF-aware route hold timer is 240
    Router-ID: 10.10.1.1
```

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```
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1

  Automatic Summarization: disabled
  Maximum path: 4
  Routing for Networks:
    10.10.0.0/16
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.10.1.2             90      00:45:06
  Distance: internal 90 external 170

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.255.255 area 0
    192.168.0.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.0.2          110      00:00:40
    192.168.0.3          110      00:00:30
  Distance: (default is 110)
```

26) Verify the routers have formed adjacencies with each other.

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
```

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```
10.1.3.2          1   FULL/DR         00:00:34    10.0.3.2        FastEthernet3/0
10.1.0.2          1   FULL/DR         00:00:33    10.0.0.2        FastEthernet0/0
```

27) Do you expect to see OSPF routes in R1, R2 and R3's IPv4 routing tables? Why or why not? Verify this.

OSPF routes will be in the routing table for the loopback interfaces only, as they are not being advertised by EIGRP. EIGRP and OSPF are both enabled for the 10.10.0.0/16 networks and EIGRP has a better administrative distance.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.10.0.0/24 is directly connected, FastEthernet2/0
L        10.10.0.1/32 is directly connected, FastEthernet2/0
C        10.10.1.0/24 is directly connected, FastEthernet0/0
L        10.10.1.1/32 is directly connected, FastEthernet0/0
D        10.10.2.0/24 [90/30720] via 10.10.1.2, 00:48:01, FastEthernet0/0
D        10.10.3.0/24 [90/33280] via 10.10.1.2, 00:48:01, FastEthernet0/0
      192.168.0.0/32 is subnetted, 3 subnets
C        192.168.0.1 is directly connected, Loopback0
O        192.168.0.2 [110/2] via 10.10.1.2, 00:03:32, FastEthernet0/0
O        192.168.0.3 [110/3] via 10.10.1.2, 00:03:22, FastEthernet0/0
```

OSPFv2 Basic Configuration

28) Configure IPv6 addresses on the existing loopback interfaces on R1, R2 and R3. Use the address 2001:db8:1:x::1/64, where 'x' is the router number. For example 2001:db8:1:3::1/64 on R3.

```
R1(config)#int loop 0
R1(config-if)#ipv6 add 2001:db8:1:1::1/64


R2(config)#int loop 0
R2(config-if)#ipv6 add 2001:db8:1:2::1/64


R3(config)#int loop 0
R3(config-if)#ipv6 add 2001:db8:1:3::1/64
```

29) Enable single area OSPFv3 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

```
R1(config)#ipv6 router ospf 1
R1(config-rtr)#passive-interface loopback 0
R1(config-rtr)#interface f0/0
R1(config-if)#ipv6 ospf 1 area 0
R1(config-if)#interface f2/0
R1(config-if)#ipv6 ospf 1 area 0
```

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```
R1(config-if)#int loop 0
R1(config-if)#ipv6 ospf 1 area 0

R2(config)#ipv6 router ospf 1
R2(config-rtr)#passive-interface loopback 0
R2(config-rtr)#int f0/0
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#int f1/0
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#int loop 0
R2(config-if)#ipv6 ospf 1 area 0

R3(config)#ipv6 router ospf 1
R3(config-rtr)#passive-interface loopback 0
R3(config-rtr)#int f1/0
R3(config-if)#ipv6 ospf 1 area 0
R3(config-if)#int f2/0
R3(config-if)#ipv6 ospf 1 area 0
R3(config-if)#int loop 0
R3(config-if)#ipv6 ospf 1 area 0
```

30) What do you expect the OSPF Router ID to be on R1? Verify this.

The Router ID is in the format of an IPv4 address (not an IPv6 address). The highest loopback address is used by default, 192.168.0.1

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Router ID 192.168.0.1
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Loopback0
```

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```
    FastEthernet2/0
    FastEthernet0/0
  Redistribution:
    None
```

31) Manually set the Router ID on R1 to be the highest loopback address.

```
R1(config)#ipv6 router ospf 1
R1(config-rtr)#router-id 192.168.0.1
```

32) Verify the routers have formed adjacencies with each other.

```
R2#sh ipv6 ospf neighbor

            OSPFv3 Router with ID (192.168.0.2) (Process ID 1)

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
192.168.0.3       1   FULL/BDR        00:00:33    3               FastEthernet1/0
192.168.0.1       1   FULL/DR         00:00:38    2               FastEthernet0/0
```

33) Do you expect to see OSPF routes in R1, R2 and R3's IPv6 routing tables? Why or why not? Verify this.

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OSPF routes will be in the routing table for all IPv6 networks. EIGRP is configured for IPv4 but not for IPv6. (Note that OSPFv3 advertises loopback interfaces as /128 by default.)

```
R1#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
O   2001:DB8:0:2::/64 [110/2]
     via FE80::2, FastEthernet0/0
O   2001:DB8:0:3::/64 [110/3]
     via FE80::2, FastEthernet0/0
C   2001:DB8:1:1::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:1::1/128 [0/0]
     via Loopback0, receive
O   2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet0/0
O   2001:DB8:1:3::1/128 [110/2]
     via FE80::2, FastEthernet0/0
L   FF00::/8 [0/0]
     via Null0, receive
```

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```
R2#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
O   2001:DB8::/64 [110/2]
     via FE80::1, FastEthernet0/0
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C   2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
O   2001:DB8:0:3::/64 [110/2]
     via FE80::3, FastEthernet1/0
O   2001:DB8:1:1::1/128 [110/1]
     via FE80::1, FastEthernet0/0
C   2001:DB8:1:2::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:2::1/128 [0/0]
```

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```
     via Loopback0, receive
O    2001:DB8:1:3::1/128 [110/1]
     via FE80::3, FastEthernet1/0
L    FF00::/8 [0/0]
     via Null0, receive
```

```
R3#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
O    2001:DB8::/64 [110/3]
     via FE80::2, FastEthernet1/0
O    2001:DB8:0:1::/64 [110/2]
```

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```
     via FE80::2, FastEthernet1/0
C    2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
C    2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L    2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
O    2001:DB8:1:1::1/128 [110/2]
     via FE80::2, FastEthernet1/0
O    2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet1/0
C    2001:DB8:1:3::/64 [0/0]
     via Loopback0, directly connected
L    2001:DB8:1:3::1/128 [0/0]
     via Loopback0, receive
L    FF00::/8 [0/0]
     via Null0, receive
```

34) Verify end to end connectivity by pinging PC2 from PC1.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 72/78/80
ms
```

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35) Verify the path traffic is taking from PC1 to PC2.

```
PC1#traceroute 2001:DB8:0:3:C805:CFF:FE28:0
Type escape sequence to abort.
Tracing the route to 2001:DB8:0:3:C805:CFF:FE28:0

  1 2001:DB8::1 28 msec 8 msec 8 msec
  2 2001:DB8:0:1::2 32 msec 28 msec 32 msec
  3 2001:DB8:0:2::1 48 msec 48 msec 48 msec
  4 2001:DB8:0:3:C805:CFF:FE28:0 60 msec 60 msec 56 msec
PC1#
```

EIGRP for IPv6 Configuration

36) Enable EIGRP for IPv6 using AS 100 on every router. Ensure all networks are advertised. Configure the loopbacks as passive interfaces.

```
R1(config)#ipv6 router eigrp 100
R1(config-rtr)#passive-interface loopback 0
R1(config-rtr)#int f0/0
R1(config-if)#ipv6 eigrp 100
R1(config-if)#int f2/0
R1(config-if)#ipv6 eigrp 100
R1(config-if)#int loop 0
R1(config-if)#ipv6 eigrp 100

R2(config)#ipv6 router eigrp 100
R2(config-rtr)#passive-interface loopback 0
R2(config-rtr)#int f0/0
```

```
R2(config-if)#ipv6 eigrp 100
R2(config-if)#int f1/0
R2(config-if)#ipv6 eigrp 100
R2(config-if)#int loop 0
R2(config-if)#ipv6 eigrp 100

R3(config)#ipv6 router eigrp 100
R3(config-rtr)#passive-interface loopback 0
R3(config-rtr)#int f1/0
R3(config-if)#ipv6 eigrp 100
R3(config-if)#int f2/0
R3(config-if)#ipv6 eigrp 100
R3(config-if)#int loop 0
R3(config-if)#ipv6 eigrp 100
```

37) What do you expect the EIGRP Router ID to be on R1? Verify this.

As with OSPFv3, the Router ID is in the format of an IPv4 address (not an IPv6 address). The highest loopback address is used by default, 192.168.0.1

```
R1#sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Router ID 192.168.0.1
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Loopback0
    FastEthernet2/0
    FastEthernet0/0
  Redistribution:
    None
IPv6 Routing Protocol is "eigrp 100"
EIGRP-IPv6 Protocol for AS(100)
```

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```
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    NSF-aware route hold timer is 240
    Router-ID: 192.168.0.1
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 16
      Maximum hopcount 100
      Maximum metric variance 1

    Interfaces:
      FastEthernet0/0
      FastEthernet2/0
      Loopback0 (passive)
    Redistribution:
      None
```

38) Manually set the Router ID on R1 to be the highest loopback address.

```
R1(config)# ipv6 router eigrp 100
R1(config-rtr)#eigrp router-id 192.168.0.1
```

39) Verify the routers have formed adjacencies with each other.

```
R2#show ipv6 eigrp neighbors
EIGRP-IPv6 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   Link-local address:     Fa1/0                    14 00:05:40   53   318  0  4
    FE80::3
0   Link-local address:     Fa0/0                    13 00:05:45   43   258  0  5
```

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```
    FE80::1
```

40) Do you expect EIGRP routes to be in the router's IPv6 routing tables? Why or why not? Verify this.

The routes learned via EIGRP will replace the OSPF routes as they have a better Administrative Distance. (Note that OSPFv3 advertises loopback interfaces as /128 by default. These routes will main in the routing table as they have a longer prefix match than the /64 learned via EIGRP)

```
R1#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8::1/128 [0/0]
     via FastEthernet2/0, receive
C   2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:0:1::1/128 [0/0]
     via FastEthernet0/0, receive
D   2001:DB8:0:2::/64 [90/30720]
     via FE80::2, FastEthernet0/0
D   2001:DB8:0:3::/64 [90/33280]
     via FE80::2, FastEthernet0/0
C   2001:DB8:1:1::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:1::1/128 [0/0]
     via Loopback0, receive
D   2001:DB8:1:2::/64 [90/156160]
     via FE80::2, FastEthernet0/0
O   2001:DB8:1:2::1/128 [110/1]
```

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```
     via FE80::2, FastEthernet0/0
D    2001:DB8:1:3::/64 [90/158720]
     via FE80::2, FastEthernet0/0
O    2001:DB8:1:3::1/128 [110/2]
     via FE80::2, FastEthernet0/0
L    FF00::/8 [0/0]
     via Null0, receive

R2#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
D    2001:DB8::/64 [90/30720]
     via FE80::1, FastEthernet0/0
C    2001:DB8:0:1::/64 [0/0]
     via FastEthernet0/0, directly connected
L    2001:DB8:0:1::2/128 [0/0]
     via FastEthernet0/0, receive
C    2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::2/128 [0/0]
     via FastEthernet1/0, receive
D    2001:DB8:0:3::/64 [90/30720]
     via FE80::3, FastEthernet1/0
D    2001:DB8:1:1::/64 [90/156160]
     via FE80::1, FastEthernet0/0
O    2001:DB8:1:1::1/128 [110/1]
     via FE80::1, FastEthernet0/0
C    2001:DB8:1:2::/64 [0/0]
     via Loopback0, directly connected
L    2001:DB8:1:2::1/128 [0/0]
```

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```
     via Loopback0, receive
D    2001:DB8:1:3::/64 [90/156160]
     via FE80::3, FastEthernet1/0
O    2001:DB8:1:3::1/128 [110/1]
     via FE80::3, FastEthernet1/0
L    FF00::/8 [0/0]
     via Null0, receive
```

```
R3#sh ipv6 route
IPv6 Routing Table - default - 13 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
D    2001:DB8::/64 [90/33280]
     via FE80::2, FastEthernet1/0
D    2001:DB8:0:1::/64 [90/30720]
     via FE80::2, FastEthernet1/0
C    2001:DB8:0:2::/64 [0/0]
     via FastEthernet1/0, directly connected
L    2001:DB8:0:2::1/128 [0/0]
     via FastEthernet1/0, receive
```

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```
C   2001:DB8:0:3::/64 [0/0]
     via FastEthernet2/0, directly connected
L   2001:DB8:0:3::1/128 [0/0]
     via FastEthernet2/0, receive
D   2001:DB8:1:1::/64 [90/158720]
     via FE80::2, FastEthernet1/0
O   2001:DB8:1:1::1/128 [110/2]
     via FE80::2, FastEthernet1/0
D   2001:DB8:1:2::/64 [90/156160]
     via FE80::2, FastEthernet1/0
O   2001:DB8:1:2::1/128 [110/1]
     via FE80::2, FastEthernet1/0
C   2001:DB8:1:3::/64 [0/0]
     via Loopback0, directly connected
L   2001:DB8:1:3::1/128 [0/0]
     via Loopback0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

41) Verify end to end connectivity by pinging PC2 from PC1.

```
PC1#ping 2001:DB8:0:3:C805:CFF:FE28:0

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 2001:DB8:0:3:C805:CFF:FE28:0,
timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 72/78/80
ms
```

33-1 WAN Configuration – Lab Exercise

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

You will configure PPP with PAP authentication for a single leased line in New York site 1.

You will configure MultiLink PPP with CHAP authentication for New York site 2.

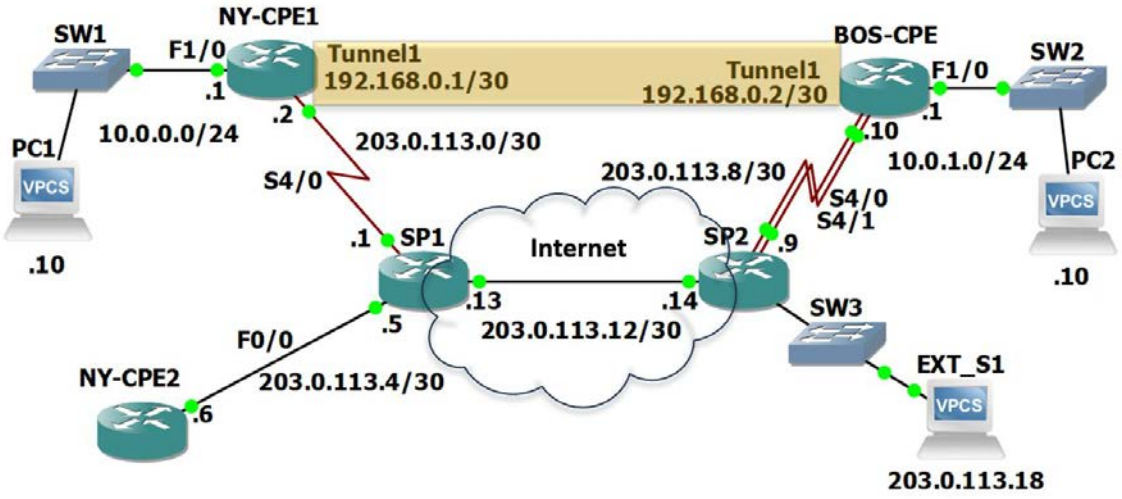
You will configure PPPoE for the DSL connection in the Boston office.

Finally you will configure a GRE tunnel between New York site 1 and Boston.

The SP1 and SP2 routers have already been configured at the service provider.

EXT_S1 is an external server at 203.0.113.18 which can be used to test Internet connectivity.

Lab Topology



Load the Startup Configurations

Open the ’33-1 WAN Configuration.gns3project’ file in GNS3 to load the lab.

Host Setup

1) Configure the IP address and default gateway on PC1, PC2 and Ext_S1 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1

PC2> ip 10.0.1.10/24 10.0.1.1

EXT_S1> ip 203.0.113.18/30 203.0.113.17
```

PPP with PAP Authentication

2) Configure the leased line from router NY-CPE1 to the service provider router SP1 according to the network topology diagram.
   Interface Serial 4/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with PAP authentication using the username **NY1** and password **Flackbox**.

   Configure one way authentication, do not authenticate the service provider.

   Configure a bandwidth of 128kbps.

3) Verify the interface is up.

4) Ping the service provider to verify connectivity.

5) Configure a default static route for Internet access over the leased line.

6) Ping the external server at 203.0.113.18 from NY-CPE1 to verify Internet access.

7) Do you expect PC1 to be able to ping the external server at 203.0.113.18? Why or why not? Verify this.

MultiLink PPP with CHAP Authentication

8) Configure a MultiLink PPP leased line from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interfaces Serial 4/0 and 4/1 are used on both sides of the link.

   The service provider has instructed you to configure PPP with two way CHAP authentication using the password **Flackbox2**. The service provider router's hostname is **SP2**.

   Configure a bandwidth of 256kbps.

9) Verify the interface is up.

10) Ping the service provider to verify connectivity.

11) Configure a default static route for Internet access over the leased line.

12) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

PPPoE

13) Configure PPPoE from router NY-CPE2 to the service provider router SP1 according to the network topology diagram.
Interface FastEthernet 0/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with CHAP authentication using the password **Flackbox3**.

   Configure one way authentication, do not authenticate the service provider.

14) Verify the interface is up.

15) Ping the service provider to verify connectivity.

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16) Configure a default static route for Internet access.

17) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

GRE

18) Configure a GRE tunnel between NY-CPE1 and BOS-CPE. Use IP addresses in the 192.168.0.0/30 subnet for the tunnel interfaces.

19) The tunnel interfaces will be up as long as the underlying physical interfaces are up. Verify the tunnel setup and connectivity by pinging the tunnel interface on BOS-CPE from NY-CPE1.

20) Do you expect PC1 in New York to be able to ping PC2 in Boston? Why or why not? Verify this.

21) Verify the tunnel interface appears in the routing tables on NY-CPE1 and BOS-CPE.

22) Enable single area OSPF on NY-CPE1 and BOS-CPE. Ensure that the PCs in New York site 1 and Boston have connectivity to each other. Do not enable OSPF on the Internet facing FastEthernet 0/0 interface.

Ping PC2 from PC1 to verify connectivity through the GRE tunnel.

33-1 WAN Configuration - Answer Key

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

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You will configure PPP with PAP authentication for a single leased line in New York site 1.

You will configure MultiLink PPP with CHAP authentication for New York site 2.

You will configure PPPoE for the DSL connection in the Boston office.

Finally you will configure a GRE tunnel between New York site 1 and Boston.

The SP1 and SP2 routers have already been configured at the service provider.

EXT_S1 is an external server at 203.0.113.18 which can be used to test Internet connectivity.

Host Setup

1) Configure the IP address and default gateway on PC1, PC2 and Ext_S1 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1

PC2> ip 10.0.1.10/24 10.0.1.1

EXT_S1> ip 203.0.113.18/30 203.0.113.17
```

PPP with PAP Authentication

2) Configure the leased line from router NY-CPE1 to the service provider router SP1 according to the network topology diagram.
Interface Serial 4/0 is used on both sides of the link.

   The service provider has instructed you to configure PPP with PAP authentication using the username **NY1** and password **Flackbox**.

   Configure one way authentication, do not authenticate the service provider.

   Configure a bandwidth of 128kbps.

```
NY-CPE1(config)#int s4/0
NY-CPE1(config-if)#ip add 203.0.113.2 255.255.255.252
NY-CPE1(config-if)#encapsulation ppp
NY-CPE1(config-if)#ppp pap sent-username NY1 password Flackbox
NY-CPE1(config-if)#bandwidth 128
NY-CPE1(config-if)#no shutdown
```

3) Verify the interface is up.

```
NY-CPE1#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.0.0.1        YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
Serial4/0              203.0.113.2     YES manual up                    up
```

4) Ping the service provider to verify connectivity.

```
NY-CPE1#ping 203.0.113.1
```

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/52/56
ms
```

5) Configure a default static route for Internet access over the leased line.

```
NY-CPE1(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.1
```

6) Ping the external server at 203.0.113.18 from NY-CPE1 to verify Internet access.

```
NY-CPE1#ping 203.0.113.18
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max =
72/157/404 ms
```

7) Do you expect PC1 to be able to ping the external server at 203.0.113.18? Why or why not? Verify this.

PC1 is using a private IP address and NAT has not been configured so it will not be able to ping the external server.

```
PC1> ping 203.0.113.18
203.0.113.18 icmp_seq=1 timeout
203.0.113.18 icmp_seq=2 timeout
203.0.113.18 icmp_seq=3 timeout
203.0.113.18 icmp_seq=4 timeout
203.0.113.18 icmp_seq=5 timeout
```

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At this point we would normally configure NAT to allow Internet connectivity from the PCs in New York site 1 (and also configure security) but it is not required in this lab.

MultiLink PPP with CHAP Authentication

8) Configure a MultiLink PPP leased line from router BOS-CPE to the service provider router SP2 according to the network topology diagram.
Interfaces Serial 4/0 and 4/1 are used on both sides of the link.

   The service provider has instructed you to configure PPP with two way CHAP authentication using the password **Flackbox2**. The service provider router's hostname is **SP2**.

   Configure a bandwidth of 256kbps.

```
BOS-CPE(config)#username SP2 password Flackbox2


BOS-CPE(config)#interface multilink 1
BOS-CPE(config-if)#ip address 203.0.113.10 255.255.255.252
```

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```
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#ppp authentication chap
BOS-CPE(config-if)#bandwidth 256
BOS-CPE(config-if)#exit

BOS-CPE(config)#interface serial 4/0
BOS-CPE(config-if)#no ip address
BOS-CPE(config-if)#encapsulation ppp
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#no shutdown
BOS-CPE(config-if)#exit

BOS-CPE(config)#interface serial 4/1
BOS-CPE(config)#no ip address
BOS-CPE(config-if)#encapsulation ppp
BOS-CPE(config-if)#ppp multilink
BOS-CPE(config-if)#ppp multilink group 1
BOS-CPE(config-if)#no shutdown
```

9) Verify the interface is up.

```
BOS-CPE#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
FastEthernet1/0        10.0.1.1        YES NVRAM  up                    up
FastEthernet2/0        unassigned      YES NVRAM  administratively down down
FastEthernet3/0        unassigned      YES NVRAM  administratively down down
Serial4/0              unassigned      YES unset  up                    up
Serial4/1              unassigned      YES unset  up                    up
Serial4/2              unassigned      YES unset  administratively down down
Serial4/3              unassigned      YES unset  administratively down down
Multilink1             203.0.113.10    YES manual up                    up
```

10) Ping the service provider to verify connectivity.

```
BOS-CPE#ping 203.0.113.9

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 203.0.113.9, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 48/52/60
ms
```

11) Configure a default static route for Internet access over the leased line.

```
BOS-CPE(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.9
```

12) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

```
BOS-CPE#ping 203.0.113.18

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:

.!!!!

Success rate is 80 percent (4/5), round-trip min/avg/max =
52/139/388 ms
```

PPPoE

13) Configure PPPoE from router NY-CPE2 to the service provider router SP1 according to the network topology diagram.
Interface FastEthernet 0/0 is used on both sides of the link.

The service provider has instructed you to configure PPP with CHAP authentication using the password **Flackbox3**.

Configure one way authentication, do not authenticate the service provider.

```
NY-CPE2(config)#interface dialer1

NY-CPE2(config-if)#dialer pool 1

NY-CPE2(config-if)#encapsulation ppp

NY-CPE2(config-if)#ip address negotiated

NY-CPE2(config-if)#ppp chap password Flackbox3
```

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```
NY-CPE2(config)#interface f0/0
NY-CPE2(config-if)#no ip address
NY-CPE2(config-if)#pppoe-client dial-pool-number 1
NY-CPE2(config-if)#no shutdown
```

14) Verify the interface is up.

```
NY-CPE2#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  up                    up
FastEthernet1/0        unassigned      YES unset  administratively down down
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down
Serial4/0              unassigned      YES unset  administratively down down
Serial4/1              unassigned      YES unset  administratively down down
Serial4/2              unassigned      YES unset  administratively down down
Serial4/3              unassigned      YES unset  administratively down down
Dialer1                203.0.113.6     YES IPCP   up                    up
Virtual-Access1        unassigned      YES unset  up                    up
```

15) Ping the service provider to verify connectivity.

```
NY-CPE2#ping 203.0.113.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 203.0.113.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/54/68
ms
```

16) Configure a default static route for Internet access.

```
NY-CPE2(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.5
```

17) Ping the external server at 203.0.113.18 from NY-CPE2 to verify Internet access.

```
NY-CPE2#ping 203.0.113.18
```

```
Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 203.0.113.18, timeout is 2
seconds:

.!!!!

Success rate is 80 percent (4/5), round-trip min/avg/max =
52/178/512 ms
```

GRE

18) Configure a GRE tunnel between NY-CPE1 and BOS-CPE. Use IP addresses in the 192.168.0.0/30 subnet for the tunnel interfaces.

```
NY-CPE1(config)#interface Tunnel1

NY-CPE1(config-if)#ip address 192.168.0.1 255.255.255.252

NY-CPE1(config-if)#tunnel source 203.0.113.2

NY-CPE1(config-if)#tunnel destination 203.0.113.10


BOS-CPE(config)#interface Tunnel1

BOS-CPE(config-if)#ip address 192.168.0.2 255.255.255.252

BOS-CPE(config-if)#tunnel source 203.0.113.10

BOS-CPE(config-if)#tunnel destination 203.0.113.2
```

19) The tunnel interfaces will be up as long as the underlying physical interfaces are up. Verify the tunnel setup and connectivity by pinging the tunnel interface on BOS-CPE from NY-CPE1.

```
NY-CPE1#ping 192.168.0.2

Type escape sequence to abort.
```

```
Sending 5, 100-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max =
80/89/104 ms
```

20) Do you expect PC1 in New York to be able to ping PC2 in Boston? Why or why not? Verify this.

PC1 will not be able to ping PC2. The GRE tunnel is up but routing has not been configured to send any traffic over the tunnel.

```
PC1> ping 10.0.1.10
10.0.1.10 icmp_seq=1 timeout
10.0.1.10 icmp_seq=2 timeout
10.0.1.10 icmp_seq=3 timeout
10.0.1.10 icmp_seq=4 timeout
10.0.1.10 icmp_seq=5 timeout
```

21) Verify the tunnel interface appears in the routing tables on NY-CPE1 and BOS-CPE.

```
NY-CPE1#sh 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 203.0.113.1 to network 0.0.0.0
```

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```
S*    0.0.0.0/0 [1/0] via 203.0.113.1
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet1/0
L        10.0.0.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/30 is directly connected, Tunnel1
L        192.168.0.1/32 is directly connected, Tunnel1
      203.0.113.0/24 is variably subnetted, 3 subnets, 2 masks
C        203.0.113.0/30 is directly connected, Serial4/0
C        203.0.113.1/32 is directly connected, Serial4/0
L        203.0.113.2/32 is directly connected, Serial4/0

BOS-CPE#sh 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 203.0.113.9 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.9
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/30 is directly connected, Tunnel1
L        192.168.0.2/32 is directly connected, Tunnel1
      203.0.113.0/24 is variably subnetted, 3 subnets, 2 masks
C        203.0.113.8/30 is directly connected, Multilink1
C        203.0.113.9/32 is directly connected, Multilink1
L        203.0.113.10/32 is directly connected, Multilink1
```

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22) Enable single area OSPF on NY-CPE1 and BOS-CPE. Ensure that the PCs in New York site 1 and Boston have connectivity to each other. Do not enable OSPF on the Internet facing FastEthernet 0/0 interface.

```
NY-CPE1(config)#router ospf 1
NY-CPE1(config-router)#network 10.0.0.0 0.0.255.255 area 0
NY-CPE1(config-router)#network 192.168.0.0 0.0.0.3 area 0

BOS-CPE(config)#router ospf 1
BOS-CPE(config-router)#network 10.0.0.0 0.0.255.255 area 0
BOS-CPE(config-router)#network 192.168.0.0 0.0.0.3 area 0
```

You can use different wildcard masks in the network statements as long as the FastEthernet1/0 and Tunnel1 interfaces are matched.

23) Ping PC2 from PC1 to verify connectivity through the GRE tunnel.

```
PC1> ping 10.0.1.10
84 bytes from 10.0.1.10 icmp_seq=1 ttl=62 time=150.103 ms
84 bytes from 10.0.1.10 icmp_seq=2 ttl=62 time=71.048 ms
84 bytes from 10.0.1.10 icmp_seq=3 ttl=62 time=80.053 ms
84 bytes from 10.0.1.10 icmp_seq=4 ttl=62 time=78.053 ms
84 bytes from 10.0.1.10 icmp_seq=5 ttl=62 time=80.056 ms
```

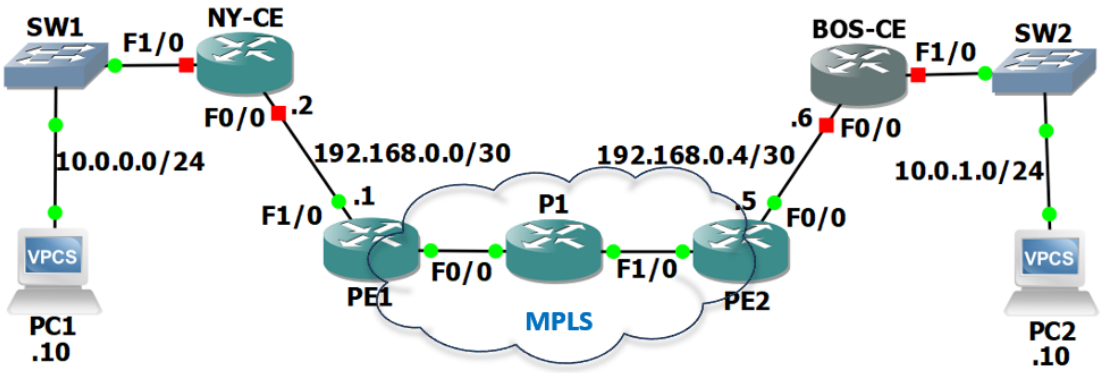
34-1 BGP Configuration – Lab Exercise

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

The WAN connectivity will be provided via a service provider's MPLS Layer 3 VPN service. eBGP will be used as the CE-PE routing protocol.

The MPLS Layer 3 VPN has already been provisioned on the service provider's routers. Your task is to configure the customer CE routers.

Lab Topology



Load the Startup Configurations

Open the '34-1 BGP Configuration.gns3project' file in GNS3 to load the lab.

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Host Setup

14) Configure the IP address and default gateway on PC1 and PC2 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1

PC2> ip 10.0.1.10/24 10.0.1.1
```

eBGP Configuration

1) Verify IP addresses have already been configured on the CE's inside LAN interfaces.

2) Configure the IP addresses on the outside FastEthernet 0/0 interfaces on the customer CE routers according to the network topology diagram.

3) Verify the CE's have connectivity to their directly connected PE router.

4) Configure eBGP sessions on the CE routers. Use BGP AS 65001. The service provider AS is 65000. Advertise the internal 10.0.x.x networks in BGP.

5) Verify the BGP sessions with the PE routers are established successfully.

6) On NY-CE, verify the 10.0.1.0/24 network in Boston has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.4/30 network in Boston).

7) On BOS-CE, verify the 10.0.0.0/24 network in New York has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.0/30 network in New York).

8) Verify NY-CE has routes to the 10.0.1.0/24 and 192.168.0.4/30 networks in Boston in its routing table, with PE1 as the next hop.

9) Verify BOS-CE has routes to the 10.0.0.0/24 and 192.168.0.0/30 networks in New York in its routing table, with PE2 as the next hop.

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10) Verify PC1 in New York has connectivity to PC2 in Boston.

34-1 BGP Configuration - Answer Key

In this lab you will configure Wide Area Network connectivity for a company with offices in New York and Boston.

The WAN connectivity will be provided via a service provider's MPLS Layer 3 VPN service. eBGP will be used as the CE-PE routing protocol.

The MPLS Layer 3 VPN has already been provisioned on the service provider's routers. Your task is to configure the customer CE routers.

Host Setup

15) Configure the IP address and default gateway on PC1 and PC2 as shown:

```
PC1> ip 10.0.0.10/24 10.0.0.1
```

```
PC2> ip 10.0.1.10/24 10.0.1.1
```

eBGP Configuration

11) Verify IP addresses have already been configured on the CE's inside LAN interfaces.

```
NY-CE#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet1/0        10.0.0.1        YES manual up                    up
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down

BOS-CE#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
FastEthernet1/0        10.0.1.1        YES manual up                    up
FastEthernet2/0        unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down
```

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12) Configure the IP addresses on the outside FastEthernet 0/0 interfaces on the customer CE routers according to the network topology diagram.

```
NY-CE(config)#int f0/0
NY-CE(config-if)#ip address 192.168.0.2 255.255.255.252
NY-CE(config-if)#no shutdown


BOS-CE(config)#int f0/0
BOS-CE(config-if)#ip address 192.168.0.6 255.255.255.252
BOS-CE(config-if)#no shutdown
```

13) Verify the CE's have connectivity to their directly connected PE router.

```
NY-CE#ping 192.168.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/52/68
ms


BOS-CE#ping 192.168.0.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/48/56
ms
```

14) Configure eBGP sessions on the CE routers. Use BGP AS 65001. The service provider AS is 65000. Advertise the internal 10.0.x.x networks in BGP.

Ensure you use the correct /24 subnet masks when entering the 'network' statements. BGP will not advertise a route unless an exact match is found in the routing table.

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```
NY-CE(config)#router bgp 65001
NY-CE(config-router)#neighbor 192.168.0.1 remote-as 65000
NY-CE(config-router)#network 10.0.0.0 mask 255.255.255.0

BOS-CE(config)#router bgp 65001
BOS-CE(config-router)#neighbor 192.168.0.5 remote-as 65000
BOS-CE(config-router)#network 10.0.1.0 mask 255.255.255.0
```

15) Verify the BGP sessions with the PE routers are established successfully.

```
NY-CE#show ip bgp summary
BGP router identifier 10.0.0.1, local AS number 65001
BGP table version is 5, main routing table version 5
4 network entries using 576 bytes of memory
4 path entries using 320 bytes of memory
4/4 BGP path/bestpath attribute entries using 544 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1488 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.1     4        65000      12      12        5    0    0 00:06:30        3

BOS-CE#show ip bgp summary
BGP router identifier 10.0.1.1, local AS number 65001
BGP table version is 5, main routing table version 5
4 network entries using 576 bytes of memory
4 path entries using 320 bytes of memory
4/4 BGP path/bestpath attribute entries using 544 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1488 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs
```

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```
Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.5     4        65000      14      12        5    0    0 00:07:14        3
```

16) On NY-CE, verify the 10.0.1.0/24 network in Boston has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.4/30 network in Boston).

```
NY-CE#show bgp
BGP table version is 5, local router ID is 10.0.0.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.0.0.0/24      0.0.0.0                  0         32768 i
 *>  10.0.1.0/24      192.168.0.1                            0 65000 65000 i
 r>  192.168.0.0/30   192.168.0.1              0             0 65000 ?
 *>  192.168.0.4/30   192.168.0.1                            0 65000 ?
```

17) On BOS-CE, verify the 10.0.0.0/24 network in New York has been learned via BGP and is in the BGP table. (Note the service provider router has been configured to also advertise the 192.168.0.0/30 network in New York).

```
BOS-CE#show bgp
BGP table version is 5, local router ID is 10.0.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
```

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```
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.0.0.0/24      192.168.0.5                            0 65000 65000 i
 *>  10.0.1.0/24      0.0.0.0                  0         32768 i
 *>  192.168.0.0/30   192.168.0.5                            0 65000 ?
 r>  192.168.0.4/30   192.168.0.5              0             0 65000 ?
```

18) Verify NY-CE has routes to the 10.0.1.0/24 and 192.168.0.4/30 networks in Boston in its routing table, with PE1 as the next hop.

```
NY-CE#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

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet1/0
L        10.0.0.1/32 is directly connected, FastEthernet1/0
B        10.0.1.0/24 [20/0] via 192.168.0.1, 00:13:21
      192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.0.0/30 is directly connected, FastEthernet0/0
L        192.168.0.2/32 is directly connected, FastEthernet0/0
B        192.168.0.4/30 [20/0] via 192.168.0.1, 00:09:20
```

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19) Verify BOS-CE has routes to the 10.0.0.0/24 and 192.168.0.0/30 networks in New York in its routing table, with PE2 as the next hop.

```
BOS-CE#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

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
B        10.0.0.0/24 [20/0] via 192.168.0.5, 00:15:39
C        10.0.1.0/24 is directly connected, FastEthernet1/0
L        10.0.1.1/32 is directly connected, FastEthernet1/0
      192.168.0.0/24 is variably subnetted, 3 subnets, 2 masks
B        192.168.0.0/30 [20/0] via 192.168.0.5, 00:12:00
C        192.168.0.4/30 is directly connected, FastEthernet0/0
L        192.168.0.6/32 is directly connected, FastEthernet0/0
```

20) Verify PC1 in New York has connectivity to PC2 in Boston.

```
PC1> ping 10.0.1.10
10.0.1.10 icmp_seq=1 timeout
10.0.1.10 icmp_seq=2 timeout
84 bytes from 10.0.1.10 icmp_seq=3 ttl=59 time=97.082 ms
```

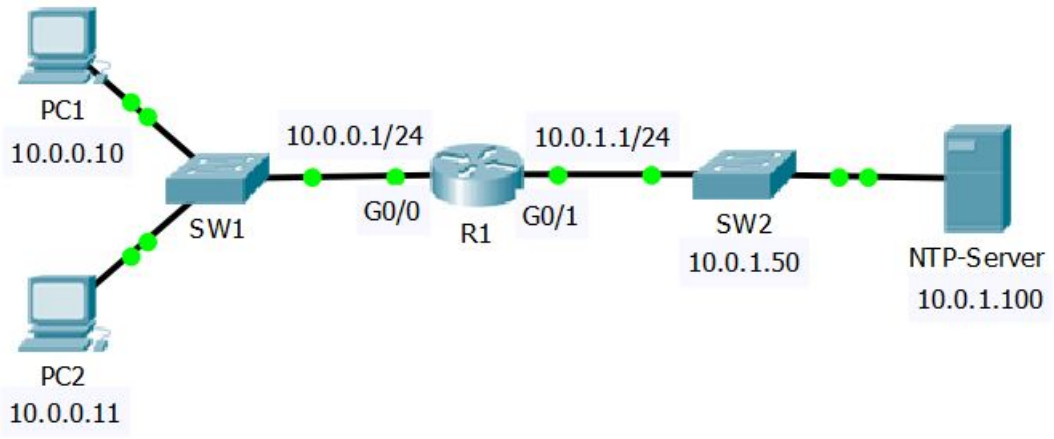
```
84 bytes from 10.0.1.10 icmp_seq=4 ttl=59 time=100.067 ms
84 bytes from 10.0.1.10 icmp_seq=5 ttl=59 time=93.059 ms0.056 ms
```

35-1 Cisco Device Security Configuration – Lab Exercise

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In this lab you will secure administrative access to the Cisco router in a small campus network.

Lab Topology



Load the Startup Configurations

Open the ' 35-1 Cisco Device Security Configuration.pkt' file in Packet Tracer to load the lab.

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Secure Privileged Exec Mode

1) Set the enable password **Flackbox2** on R1 to secure access to Privileged Exec (Enable) mode.

2) Exit to User Exec mode.

3) Enter Privileged Exec mode.

4) Set the enable secret **Flackbox1**.

5) Exit to User Exec mode.

6) Do you expect to be able to enter Privileged Exec mode using the password **Flackbox2**? Why or why not? Verify this.

7) Show the running configuration on R1. Can you read the enable password and secret in plain text?

8) Ensure that passwords will not show in plain text in the output of 'show' commands.

9) Verify the enable password is now encrypted when you show the running configuration.

Secure Remote Telnet and SSH Access

10) Enable synchronous logging on R1 and ensure administrators are logged out after 15 minutes of activity on the console and virtual terminal lines 0-15.

11) Allow the administrator workstation at 10.0.0.10 to Telnet into R1 using the password **Flackbox3**. Ensure no other host has Telnet access to the router.

12) Ensure that users attempting to Telnet into the router see the message "Authorised users only"

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13) Verify you can Telnet into R1 from PC1 and enter Privileged Exec mode. Close the Telnet session when done.

14) Verify Telnet access fails from PC2.

15) Configure R1 so that administrators will be prompted to enter a username and password when they attempt to Telnet into the router. Use username **admin** and password **Flackbox4**.

16) Verify you are prompted for a username and password when you attempt to Telnet to the router.

17) Allow the administrator workstation at 10.0.0.10 to SSH into R1. Use the domain name **flackbox.com** and a 768 bit key.

18) Verify you can SSH into R1 from PC1. Close the session when done.

19) Do you expect to be able to SSH to R1 from PC2? Why or why not? Verify this.

20) You can currently access R1 using either Telnet or SSH. Telnet is an insecure protocol as all communication is sent in plain text. Configure R1 so that only SSHv2 remote access is allowed.

21) Verify you cannot Telnet into R1 from PC1 but can SSH. Exit when done.

22) What username and password do you need to use to login when you connect directly to R1 with a console cable?

23) Configure R1 to require no username but a password of **Flackbox5** to login over the console connection.

24) Verify you can access R1 over the console connection and enter Privileged Exec mode.

NTP Network Time Protocol

25) Configure R1 to synchronise its time with the NTP server at 10.0.1.100. Set the timezone as Pacific Standard Time which is 8 hours before UTC.

26) Check the current time on the router and verify it is synchronised with the NTP server.

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Switch Management

27) Configure SW2 with IP address 10.0.1.50 for management on VLAN 1. Ensure the switch has connectivity to other IP subnets.

(Note that it is best practice to NOT use VLAN 1 for any production traffic in a real world network and we would normally have a separate dedicated IP subnet for management traffic. We are using VLAN 1 in our lab environment to simplify the topology)

35-1 Cisco Device Security Configuration - Answer Key

In this lab you will secure administrative access to the Cisco router in a small campus network.

Secure Privileged Exec Mode

1) Set the enable password **Flackbox2** on R1 to secure access to Privileged Exec (Enable) mode.

```
R1(config)#enable password Flackbox2
```

2) Exit to User Exec mode.

```
R1#exit
```

3) Enter Privileged Exec mode.

```
R1>enable
Password:Flackbox2
R1#
```

4) Set the enable secret **Flackbox1**.

```
R1(config)#enable secret Flackbox1
```

5) Exit to User Exec mode.

```
R1#exit
```

6) Do you expect to be able to enter Privileged Exec mode using the password **Flackbox2**? Why or why not? Verify this.

You cannot enter Privileged Exec mode using the enable password because it has been superseded by the enable secret.

```
R1>enable
Password:Flackbox2
```

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```
Password:Flackbox1
R1#
```

7) Show the running configuration on R1. Can you read the enable password and secret in plain text?

The enable password is shown in plain text but the enable secret is encrypted.

```
R1#show run
Building configuration...

Current configuration : 762 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname R1
!
enable secret 5 $1$mERr$J2XZHMOgpVVXdLjC9lYtE1
enable password Flackbox2
```

8) Ensure that passwords will not show in plain text in the output of ‘show’ commands.

```
R1(config)#service password-encryption
```

9) Verify the enable password is now encrypted when you show the running configuration.

```
R1#show running-config
Building configuration...

Current configuration : 772 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
service password-encryption
!
hostname R1
!
enable secret 5 $1$mERr$J2XZHMOgpVVXdLjC9lYtE1
enable password 7 0807404F0A1207180A59
```

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Secure Remote Telnet and SSH Access

10) Enable synchronous logging on R1 and ensure administrators are logged out after 15 minutes of activity on the console and virtual terminal lines 0-15.

```
R1(config)#line console 0
R1(config-line)#logging synchronous
R1(config-line)#exec-timeout 15


R1(config)#line vty 0 15
R1(config-line)#logging synchronous
R1(config-line)#exec-timeout 15
```

11) Allow the administrator workstation at 10.0.0.10 to Telnet into R1 using the password **Flackbox3**. Ensure no other host has Telnet access to the router.

```
R1(config)#access-list 1 permit host 10.0.0.10

R1(config)#line vty 0 15
R1(config-line)#login
R1(config-line)#password Flackbox3
R1(config-line)#access-class 1 in
```

12) Ensure that users attempting to Telnet into the router see the message “Authorised users only”

```
R1(config)#banner login "
Enter TEXT message. End with the character '"'.
Authorised users only"
```

13) Verify you can Telnet into R1 from PC1 and enter Privileged Exec mode. Close the Telnet session when done.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …Open

Authorised users only

User Access Verification

Password: Flackbox3
R1>enable
Password: Flackbox1
R1#exit

[Connection to 10.0.0.1 closed by foreign host]
```

14) Verify Telnet access fails from PC2.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …
% Connection refused by remote host
```

15) Configure R1 so that administrators will be prompted to enter a username and password when they attempt to Telnet into the router. Use username **admin** and password **Flackbox4**.

```
R1(config)#username admin secret Flackbox4
R1(config)#line vty 0 15
R1(config-line)#login local
```

16) Verify you are prompted for a username and password when you attempt to Telnet to the router.

```
C:\> telnet 10.0.0.1
```

```
Trying 10.0.0.1 …Open

Authorised users only

User Access Verification

Username: admin

Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

17) Allow the administrator workstation at 10.0.0.10 to SSH into R1. Use the domain name **flackbox.com** and a 768 bit key.

```
R1(config)#ip domain-name flackbox.com
R1(config)#crypto key generate rsa
The name for the keys will be: R1.flackbox.com
Choose the size of the key modulus in the range of 360 to 2048
for your
General Purpose Keys. Choosing a key modulus greater than 512
may take
a few minutes.

How many bits in the modulus [512]: 768
% Generating 768 bit RSA keys, keys will be non-exportable...[OK]
```

18) Verify you can SSH into R1 from PC1. Close the session when done.

```
C:\> ssh –l admin 10.0.0.1
Open
Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

19) Do you expect to be able to SSH to R1 from PC2? Why or why not? Verify this.

You will not be able to SSH to R1 from PC2. Telnet and SSH access are both controlled by the ‘line vty’ configuration which has an access list applied only allowing access from PC1.

```
C:\> ssh –l admin 10.0.0.1
Trying 10.0.0.1 …
% Connection refused by remote host
```

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20) You can currently access R1 using either Telnet or SSH. Telnet is an insecure protocol as all communication is sent in plain text. Configure R1 so that only SSHv2 remote access is allowed.

```
R1(config)#line vty 0 15
R1(config-line)#transport input ssh
R1(config-line)#exit
R1(config)#ip ssh version 2
```

21) Verify you cannot Telnet into R1 from PC1 but can SSH. Exit when done.

```
C:\> telnet 10.0.0.1
Trying 10.0.0.1 …Open

[Connection to 10.0.0.1 closed by remote host]

C:\> ssh –l admin 10.0.0.1
Open
Password: Flackbox4
R1>exit

[Connection to 10.0.0.1 closed by foreign host]
```

22) What username and password do you need to use to login when you connect directly to R1 with a console cable?

No username and password are currently required to login to the console. The virtual terminal lines which control Telnet and SSH access have been secured but console access not.

23) Configure R1 to require no username but a password of **Flackbox5** to login over the console connection.

```
R1(config)#line console 0
R1(config-line)#login
% Login disabled on line 0, until 'password' is set
R1(config-line)#password Flackbox5
```

24) Verify you can access R1 over the console connection and enter Privileged Exec mode.

```
R1(config-line)#end
```

```
R1#logout

R1 con0 is now available
Press RETURN to get started.
Authorised users only
User Access Verification
Password: Flackbox5
R1>enable
Password: Flackbox1
R1#
```

NTP Network Time Protocol

25) Configure R1 to synchronise its time with the NTP server at 10.0.1.100. Set the timezone as Pacific Standard Time which is 8 hours before UTC.

```
R1(config)#clock timezone PST -8
R1(config)#ntp server 10.0.1.100
```

26) Check the current time on the router and verify it is synchronised with the NTP server.

```
R1#show clock
16:19:36.51 PST Mon Oct 2 2017

R1#show ntp status
Clock is synchronized, stratum 2, reference is 10.0.1.100
nominal freq is 250.0000 Hz, actual freq is 249.9990 Hz,
precision is 2**19
reference time is DD53255C.0000039C (00:16:28.924 UTC Tue Oct
3 2017)
clock offset is 0.00 msec, root delay is 0.00 msec
root dispersion is 0.02 msec, peer dispersion is 0.02 msec.
```

Switch Management

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27) Configure SW2 with IP address 10.0.1.50 for management on VLAN 1. Ensure the switch has connectivity to other IP subnets.

(Note that it is best practice to NOT use VLAN 1 for any production traffic in a real world network and we would normally have a separate dedicated IP subnet for management traffic. We are using VLAN 1 in our lab environment to simplify the topology).

```
SW2(config)#int vlan 1
SW2(config-if)#ip address 10.0.1.50 255.255.255.0
SW2(config-if)#no shutdown
SW2(config-if)#exit
SW2(config)#ip default-gateway 10.0.1.1
```

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- Engaging delivery
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- Accurate course description
- Knowledgeable instructor

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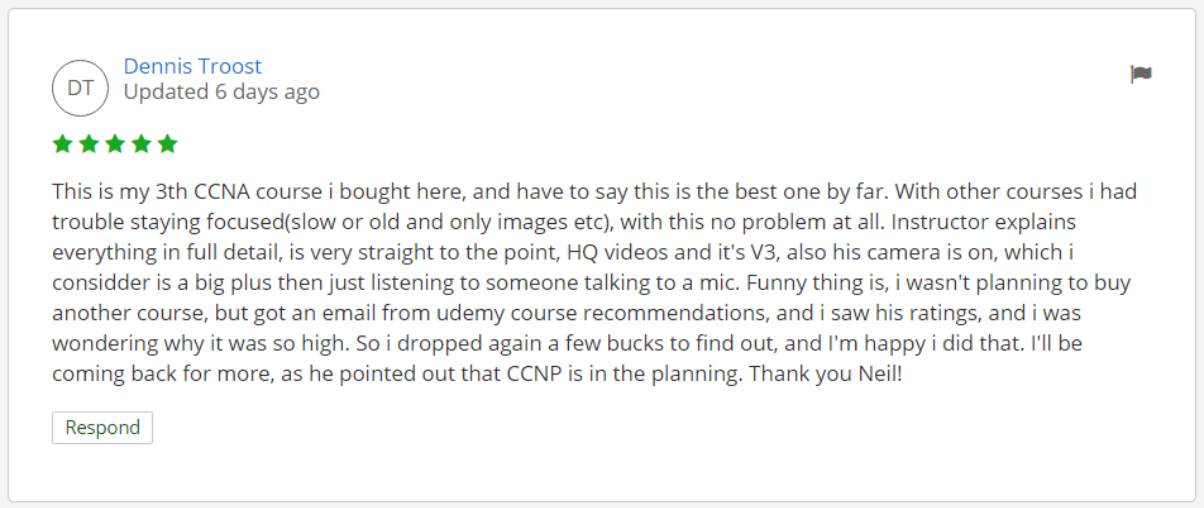
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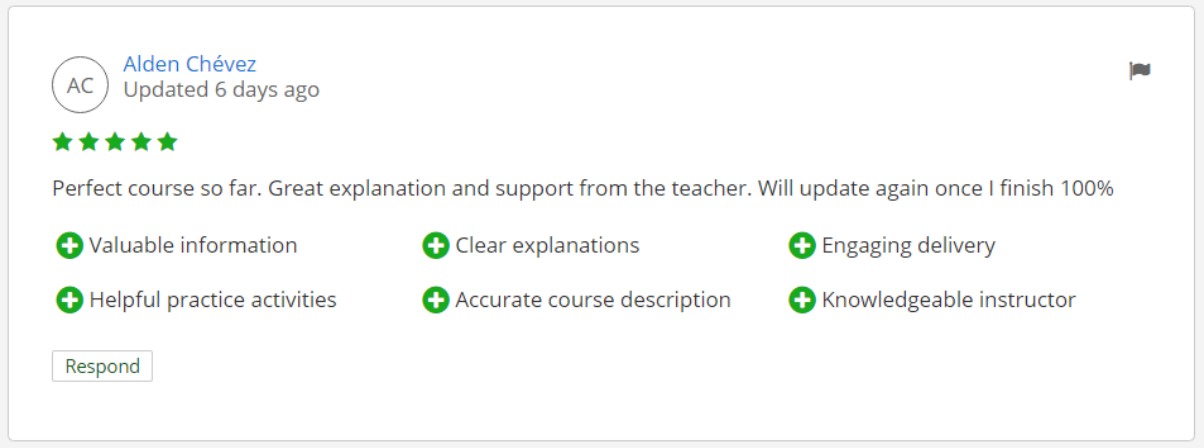
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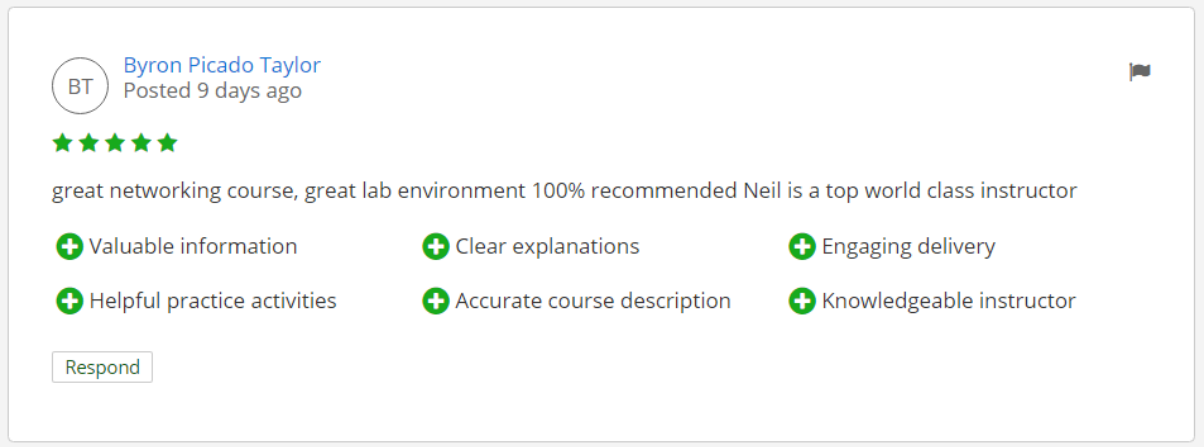
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