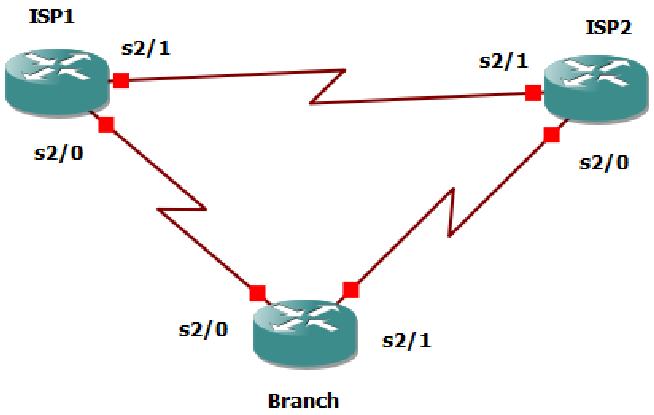
Index

Practical 1

Aim: Configure IP SLA Tracking and Path Control Topology



Objectives

- Configure and verify the IP SLA feature.
- Test the IP SLA tracking feature.
- Verify the configuration and operation using **show** and **debug** commands.

Background

You want to experiment with the Cisco IP Service Level Agreement (SLA) feature to study how it could be of value to your organization.At times, a link to an ISP could be operational, yet users cannot connect to any other outside Internet resources. The problem might be with the ISP or downstream from them. Although policy-based routing (PBR) can be implemented to alter path control, you will implement the Cisco IOS SLA feature to monitor this behaviour and intervene by injecting another default route to a backup ISP.

To test this, you have set up a three-router topology in a lab environment. Router R1 represents a branch office connected to two different ISPs. ISP1 is the preferred connection to the Internet, while ISP2 provides a backup link. ISP1 and ISP2 can also interconnect, and both can reach the web server. To monitor ISP1 for failure, you will configure IP SLA probes to track the reachability to the ISP1 DNS server. If connectivity to the ISP1 server fails, the SLA probes detect the failure and alter the default static route to point to the ISP2 server.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources:

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Prepare the routers and configure the router hostname and interface addresses and Cable the network as shown in the topology diagram.

a. Using the addressing scheme in the diagram, create the loopback interfaces and apply IP addresses to them as well as the serial interfaces on R1, ISP1, and ISP2.

Note: Depending on the router model, interfaces might be numbered differently than those listed. You might need to alter them accordingly.

Router R1

```
Branch(config)#interface Loopback 0
Branch(config-if)#de
*Mar  1 00:03:37.019: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
Branch(config-if)#description Branch LAN
Branch(config-if)#ip address 192.168.1.1 255.255.255.0
Branch(config-if)#interface Seral2/0
                            ^
% Invalid input detected at '^' marker.

Branch(config)#interface Serial2/0
Branch(config-if)#ip address 209.165.201.2 255.255.255.252
Branch(config-if)#clock rate 128000
Branch(config-if)#bandwith 128
                        ^
% Invalid input detected at '^' marker.

Branch(config-if)#bandwidth 128
Branch(config-if)#no shutdown
Branch(config-if)#
```

```
Branch(config)#interface Serial2/1
Branch(config-if)#ip address 209.165.202.130 255.255.255.252
Branch(config-if)#bandwidth 128
Branch(config-if)#no shutdown
Branch(config-if)#
*Mar  1 00:07:16.507: %LINK-3-UPDOWN: Interface Serial2/1, changed state to up
*Mar  1 00:07:17.507: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/1, changed state to up
Branch(config-if)#
```

Router ISP1 (R2)

```
ISP1(config-if)#exit
ISP1(config)#interface loopback0
ISP1(config-if)#ip address 209.165.200.254 255.255.255.255
ISP1(config-if)#exit
ISP1(config)#interface loopback1
ISP1(config-if)#ip address 209.165.200.30 255.255.255.255
ISP1(config-if)#interface serial2/0
ISP1(config-if)#ip address 209.165.201.1 255.255.255.252
ISP1(config-if)#bandwidth 128
ISP1(config-if)#no shutdown
ISP1(config-if)#
*Mar  1 00:16:44.467: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
ISP1(config-if)#
*Mar  1 00:16:45.471: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/0, changed state to up
ISP1(config-if)#exit
ISP1(config)#interface serial2/1
ISP1(config-if)#ip address 209.165.200.255 255.255.255.252
Bad mask /30 for address 209.165.200.255
ISP1(config-if)#clock rate 128000
ISP1(config-if)#bandwidth 128
ISP1(config-if)#no shutdown
ISP1(config-if)#
*Mar  1 00:18:22.811: %LINK-3-UPDOWN: Interface Serial2/1, changed state to up
ISP1(config-if)#
*Mar  1 00:18:23.815: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/1, changed state to up
ISP1(config-if)#
```

Router ISP2 (R3)

```
ISP2(config)#interface loopback0
ISP2(config-if)#ip address 209.165.200.254 255.255.255.255
% 209.165.200.254 overlaps with Loopback1
ISP2(config-if)#
*Mar  1 00:20:46.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, chang
ISP2(config-if)#exit
ISP2(config)#interface loopback1
ISP2(config-if)#ip address 209.165.202.158 255.255.255.255
ISP2(config-if)#exit
ISP2(config)#interface serial2/0
ISP2(config-if)#ip address 209.165.202.129 255.255.255.252
ISP2(config-if)#clock rate 128000
ISP2(config-if)#bandwidth 128
ISP2(config-if)#no shutdown
ISP2(config-if)#
*Mar  1 00:22:24.867: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
*Mar  1 00:22:25.867: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/0, chang
ISP2(config-if)#exit
ISP2(config)#interface serial2/1
ISP2(config-if)#ip address 209.165.200.226 255.255.255.252
ISP2(config-if)#bandwidth 128
ISP2(config-if)#no shutdown
ISP2(config-if)#
*Mar  1 00:23:16.375: %LINK-3-UPDOWN: Interface Serial2/1, changed state to up
ISP2(config-if)#
```

b. Verify the configuration by using the **show interfaces description** command. The output from router R1 is shown here as an example.

```
Branch#show interfaces description
Interface                      Status         Protocol Description
Fa0/0                          admin down     down
Se0/0                          admin down     down
Fa0/1                          admin down     down
Fa1/0                          up             down
Fa1/1                          up             down
Fa1/2                          up             down
Fa1/3                          up             down
Fa1/4                          up             down
Fa1/5                          up             down
Fa1/6                          up             down
Fa1/7                          up             down
Fa1/8                          up             down
Fa1/9                          up             down
Fa1/10                         up             down
Fa1/11                         up             down
Fa1/12                         up             down
Fa1/13                         up             down
Fa1/14                         up             down
Fa1/15                         up             down
Se2/0                          up             up
Se2/1                          up             up
Se2/2                          admin down     down
 --More--
```

All three interfaces should be active. Troubleshoot if necessary.

c. The current routing policy in the topology is as follows:

• Router R1 establishes connectivity to the Internet through ISP1 using a default static route.

• ISP1 and ISP2 have dynamic routing enabled between them, advertising their respective public addresspools.

• ISP1 and ISP2 both have static routes back to the ISPLAN.

Note: For the purpose of this lab, the ISPs have a static route to an RFC 1918 private network address on the branch router R1. In an actual branch implementation, Network Address Translation (NAT) would be configured for all traffic exiting the branch LAN. Therefore, the static routes on the ISP routers would be pointing to the provided public pool of the branch office. Implement the routing policies on the respective routers.

Branch (R1)

```
Branch#config t
Enter configuration commands, one per line.  End with CNTL/Z.
Branch(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1
Branch(config)#
```

ISP1 (R2)

```
ISP1(config-if)#router eigrp 1
ISP1(config-router)#network 209.165.200.224 0.0.0.3
ISP1(config-router)#network 209.165.201.0 0.0.0.31
ISP1(config-router)#no auto-summary
ISP1(config-router)#ip route 192.168.1.0 255.255.255.0 209.165.201.2
ISP1(config)#
ISP1(config)#
```

ISP2 (R3)

```
ISP2(config)#router eigrp 1
ISP2(config-router)#network 209.165.200.224 0.0.0.3
ISP2(config-router)#network 209.165.202.128 0.0.0.31
ISP2(config-router)#no auto-summary
ISP2(config-router)#ip route 192.168.1.0 255.255.255.0 209.165.202.130
ISP2(config)#
```

Step 2- Verify server reachability.

a. Before implementing the Cisco ISO SLA feature, you must verify reachability to the Internet servers. From router R1, ping the web server, ISP1 DNS server, and ISP2 DNS server to verify connectivity. Write the following TCL script into R1.

```
Branch#tclsh
Branch(tcl)#
Branch(tcl)#foreach address {
+>209.165.200.254
+>209.165.201.30
+>209.165.202.158
+>} {
+>ping $address source 192.168.1.1
+>}
```

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.254, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.201.30, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
UUUUU
Success rate is 0 percent (0/5)
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.202.158, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
UUUUU
Success rate is 0 percent (0/5)
Branch(tcl)#
```

b. Trace the path taken to the web server, ISP1 DNS server, and ISP2 DNS server. Write the following Tcl script into R1.

```
Branch#tclsh
Branch(tcl)#foreach address {
+>209.165.200.254
+>209.165.201.30
+>209.165.202.158
+>} {
+>trace $address source 192.168.1.1
+>}

Type escape sequence to abort.
Tracing the route to 209.165.200.254

  1 209.165.201.1 20 msec 32 msec 32 msec
Type escape sequence to abort.
Tracing the route to 209.165.201.30

  1 209.165.201.1 20 msec 28 msec 28 msec
  2 209.165.201.1 !H  !H  !H
Type escape sequence to abort.
Tracing the route to 209.165.202.158

  1 209.165.201.1 16 msec 32 msec 28 msec
  2 209.165.201.1 !H  !H  !H
Branch(tcl)#
```

Step 3- Configure IP SLA probes.

When the reachability tests are successful, you can configure the Cisco IOS IP SLAs probes. Different types of probes can be created, including FTP, HTTP, and jitter probes. In this scenario, you will configure ICMP echo probes.

a. Create an ICMP echo probe on R1 to the primary DNS server on ISP1 using the **ip sla monitor** command.

Note With Cisco IOS Release 12.4(4)T, 12.2(33)SB, and 12.2(33)SXI, the ip sla command has replaced the previous **ip sla monitor** command. In addition, the icmp-echo command has replaced the **type echo protocol ipIcmpEcho** command.

```
Branch(config)#ip sla monitor 11
Branch(config-rtr)#ip sla monitor 11
Branch(config-rtr)#exit
Branch(config)#ip sla monitor 11
Branch(config-rtr)#exit
Branch(config)#ip sla 11
Branch(config-ip-sla)#icmp-echo 209.165.201.30
Branch(config-ip-sla-echo)#frequency 10
Branch(config-ip-sla-echo)#exit
Branch(config)#ip sla schedule 11 life forever start-time now
Branch(config)#
```

The operation number of 11 is only locally significant to the router. The **frequency 10** command schedules the connectivity test to repeat every 10 seconds. The probe is scheduled to start now and to run forever.

b. Verify the IP SLAs configuration of operation 11 using the **show ip sla configuration 11** command.

Note: With Cisco IOS Release 12.4(4)T, 12.2(33)SB, and 12.2(33)SXI, the **show ip sla configuration** command has replaced the **show ip sla monitor configuration** command

```
Branch#show ip sla configuration 11
IP SLAs, Infrastructure Engine-II.
Entry number: 11
Owner:
Tag:
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.201.30/0.0.0.0
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Vrf Name:
Request size (ARR data portion): 28
Verify data: No
Schedule:
   Operation frequency (seconds): 10  (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
 --More--
```

The output lists the details of the configuration of operation 11. The operation is an ICMP echo to 209.165.201.30, with a frequency of 10 seconds, and it has already started (the start time has already passed).

c. Issue the **show ip sla statistics** command to display the number of successes, failures, and results of the latest operations.

Note: With Cisco IOS Release 12.4(4)T, 12.2(33)SB, and 12.2(33)SXI, the **show ip sla statistics** command has replaced the **show ip sla monitor statistics** command.

```
Branch#show ip sla statistics

Round Trip Time (RTT) for       Index 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:53:32.439 UTC Fri Mar 1 2002
Latest operation return code: No connection
Number of successes: 0
Number of failures: 31
Operation time to live: Forever
```

You can see that operation 11 has already succeeded five times, has had no failures, and the last operation returned an OK result.

d. Although not actually required because IP SLA session 11 alone could provide the desired fault tolerance, create a second probe, 22, to test connectivity to the second DNS server located on router ISP2

```
Branch(config)#ip sla 22
Branch(config-ip-sla)#icmp-echo 209.165.202.158
Branch(config-ip-sla-echo)#frequency 10
Branch(config-ip-sla-echo)#exit
Branch(config)#ip sla schedule 22 lite forever start-time now
                                    ^
% Invalid input detected at '^' marker.

Branch(config)#ip sla schedule 22 life forever start-time now
Branch(config)#
```

e. Verify the new probe using the show **ip sla configuration** and **show ip sla statistics** commands

```
Branch#show ip sla configuration 22
IP SLAs, Infrastructure Engine-II.
Entry number: 22
Owner:
Tag:
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.202.158/0.0.0.0
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Vrf Name:
Request size (ARR data portion): 28
Verify data: No
Schedule:
   Operation frequency (seconds): 10  (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): 4294967295
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
Enhanced History:
```

```
Branch#show ip sla statistics 22

Round Trip Time (RTT) for       Index 22
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:59:31.083 UTC Fri Mar 1 2002
Latest operation return code: No connection
Number of successes: 0
Number of failures: 21
Operation time to live: Forever
```

Step 4: Configure tracking options.

Although PBR could be used, you will configure a floating static route that appears or disappears depending on the success or failure of the IP SLA.

a. Remove the current default route on R1, and replace it with a floating static route having an administrative distance of 5

```
Branch(config)#no ip route 0.0.0.0 0.0.0.0 209.165.201.1
Branch(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1 5
Branch(config)#exit
Branch#
*Mar  1 01:03:49.607: %SYS-5-CONFIG_I: Configured from console by console
Branch#
```

b. Verify the routing table

```
Branch#show 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 209.165.201.1 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial2/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial2/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [5/0] via 209.165.201.1
Branch#
```

Notice that the default static route is now using the route with the administrative distance of 5.

The first tracking object is tied to IP SLA object 11

c. Use the **track 1 ip sla 11 reachability** command to enter the config-track subconfiguration mode.

Note: With Cisco IOS Release 12.4(20)T, 12.2(33)SXI1, and 12.2(33)SRE and Cisco IOS XE Release 2.4, the **track ip sla command** has replaced the **track rtr** command.

d. Specify the level of sensitivity to changes of tracked objects to 10 seconds of down delay and 1 second of up delay using the **delay down 10 up 1** command. The delay helps to alleviate the effect of flapping objects—objects that are going down and up rapidly. In this situation, if the DNS server fails momentarily and comes back up within 10 seconds, there is no impact.

```
Branch(config)#track 1 rtr 11 reachability
Branch(config-track)#delay down 10 up 1
Branch(config-track)#exit
Branch(config)#
```

e . Configure the floating static route that will be implemented when tracking object 1 is active. To view routing table changes as they happen, first enable the **debug ip routing** command. Next, use the **ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1** command to create a floating static default route via 209.165.201.1 (ISP1). Notice that this command references the tracking object number 1, which in turn references IP SLA operation number11.

```
Branch#debug ip routing
IP routing debugging is on
Branch#config t
Enter configuration commands, one per line.  End with CNTL/Z.
Branch(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1
Branch(config)#
*Mar  1 01:15:02.835: RT: NET-RED 0.0.0.0/0
Branch(config)#
Branch(config)#
```

Notice that the default route with an administrative distance of 5 has been immediately flushed because of a route with a better admin distance. It then adds the new default route with the admin distance of 2.

f. Repeat the steps for operation 22, track number 2, and assign the static route an admin distance higher than track 1 and lower than 5. On R1 sets an admin distance of 3 and view routing table again

```
Branch(config)#track 2 rtr 22 reachability
Branch(config-track)#delay down 10 up 1
Branch(config-track)#exit
Branch(config)#ip route 0.0.0.0 0.0.0.0 209.165.202.129 3 track 2
*Mar  1 01:17:02.835: RT: NET-RED 0.0.0.0/0
Branch(config)#ip route 0.0.0.0 0.0.0.0 209.165.202.129 3 track 2
Branch(config)#exit show ip route
                    ^
% Invalid input detected at '^' marker.

Branch(config)#exit
Branch#debug ip routing
*Mar  1 01:17:18.199: %SYS-5-CONFIG_I: Configured from console by console
Branch#show 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 209.165.201.1 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial2/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial2/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [5/0] via 209.165.201.1
Branch#
```

Although a new default route was entered, its administrative distance is not better than 2. Therefore, it does not replace the previously entered default route.

Step 5: Verify IP SLA operation.

In this step you observe and verify the dynamic operations and routing changes when tracked objects fail. The following summarizes the process:

- Disable the DNS loopback interface on ISP1(R2).
- Observe the output of the **debug** command on R1.
- Verify the static route entries in the routing table and the IP SLA statistics of R1.
- Re-enable the loopback interface on ISP1 (R2) and again observe the operation of the IP SLA tracking feature.

```
ISP1(config)#
ISP1(config)#interface loopback 1
ISP1(config-if)#shutdown
ISP1(config-if)#
*Mar  1 01:18:59.571: %LINK-5-CHANGED: Interface Loopback1, changed state to administratively down
*Mar  1 01:19:00.571: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to down
ISP1(config-if)#
```

A Shortly after the loopback interface is administratively down, observe the debug output being generated on R1.

```
Branch#
*Mar  1 01:18:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:19:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:20:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:21:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:22:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:23:02.839: RT: NET-RED 0.0.0.0/0
Branch#
*Mar  1 01:24:02.839: RT: NET-RED 0.0.0.0/0
Branch#
```

The tracking state of track 1 changes from up to down. This is the object that tracked reachability for IP SLA object 11, with an ICMP echo to the ISP1 DNS server at 209.165.201.30.

R1 then proceeds to delete the default route with the administrative distance of 2 and installs the next highest default route to ISP2 with the administrative distance of 3.

b. Verify the routing table

```
Branch#show 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 209.165.202.129 to network 0.0.0.0

     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial2/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [3/0] via 209.165.202.129
Branch#
```

The new static route has an administrative distance of 3 and is being forwarded to ISP2 as it should.

c. Verify the IP SLA statistics

```
Branch#show ip sla statistics

Round Trip Time (RTT) for       Index 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:06:03.695 UTC Fri Mar 1 2002
Latest operation return code: No connection
Number of successes: 0
Number of failures: 37
Operation time to live: Forever



Round Trip Time (RTT) for       Index 22
        Latest RTT: 44 milliseconds
Latest operation start time: *00:06:03.699 UTC Fri Mar 1 2002
Latest operation return code: OK
Number of successes: 34
Number of failures: 3
Operation time to live: Forever
```

d. Initiate a trace to the web server from the internal LAN IP address

```
Branch#trace 209.165.200.254 source 192.168.1.1

Type escape sequence to abort.
Tracing the route to 209.165.200.254

  1 209.165.202.129 20 msec 32 msec 32 msec
  2 209.165.202.129 !H  !H  !H
Branch#
```

This confirms that traffic is leaving router R1 and being forwarded to the ISP2 router.

e. To examine the routing behavior when connectivity to the ISP1 DNS is restored, re-enable the DNS address on ISP1 (R2) by issuing the no shutdown command on the loopback 1 interface on ISP2.

Notice the output of the **debug ip routing** command on R1

```
*Mar  1 00:11:02.767: RT: NET-RED 0.0.0.0/0
Branch#debug ip routing
IP routing debugging is on
Branch#
```

Now the IP SLA 11 operation transitions back to an up state and re-establishes the default static route to ISP1 with an administrative distance of 2.

f. Again examine the IP SLA statistics.

```
Branch#show ip sla statistics

Round Trip Time (RTT) for       Index 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:01:03.707 UTC Fri Mar 1 2002
Latest operation return code: OK
Number of successes: 0
Number of failures: 7
Operation time to live: Forever
```

```
Round Trip Time (RTT) for       Index 22
        Latest RTT: 40 milliseconds
Latest operation start time: *00:01:03.711 UTC Fri Mar 1 2002
Latest operation return code: OK
Number of successes: 4
Number of failures: 3
Operation time to live: Forever
```

The IP SLA 11 operation is active again, as indicated by the OK return code, and the number of successes is incrementing.

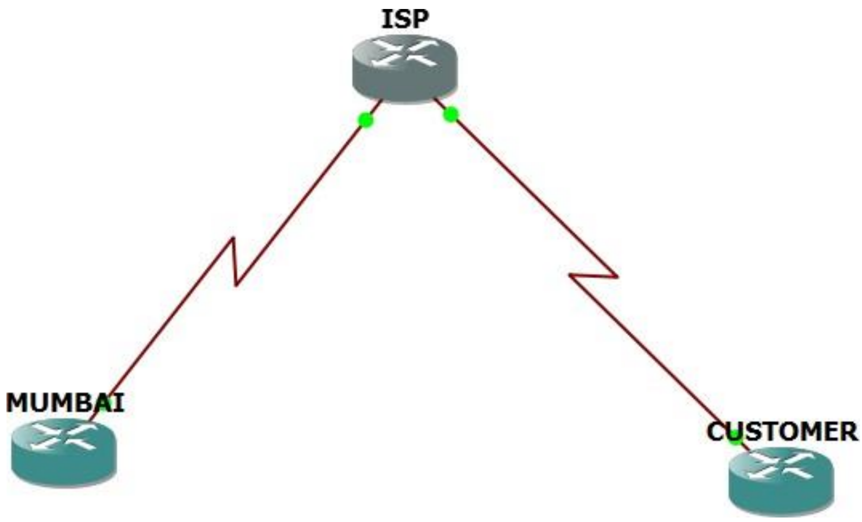
g. Verify the routing table

```
Branch#show 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 209.165.202.129 to network 0.0.0.0

     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial2/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [3/0] via 209.165.202.129
Branch#
```

The default static through ISP1 with an administrative distance of 2 is re-established.
There are many possibilities available with object tracking and Cisco IOS IP SLAs. As shown in this lab, a probe can be based on reachability, changing routing operations, and path control based on the ability to reach an object. However, Cisco IOS IP SLAs also allow paths to be changed based on network conditions such as delay, load, and other factors.
Before deploying a Cisco IOS IP SLA solution, the impact of the additional probe traffic being generated should be considered, including how that traffic affects bandwidth utilization, and congestion levels. Tuning the configuration (for example, with the delay and frequency commands) is critical to mitigate possible issues related to excessive transitions and route changes in the presence of flapping tracked objects.
The benefits of running IP SLAs should be carefully evaluated. The IP SLA is an additional task that must be performed by the router's CPU. A large number of intensive SLAs could be a significant burden on the CPU, possibly interfering with other router functions and having detrimental impact on the overall router performance. The CPU load should be monitored after the SLAs are deployed to verify that they do not cause excessive utilization of the router CPU.

Practical 2

Aim: Using the AS_PATH Attribute



Objectives

- Use BGP commands to prevent private AS numbers from being advertised to the outside world.
- Use the AS_PATH attribute to filter BGP routes based on their source AS numbers.

Background

The International Travel Agency's ISP has been assigned an AS number of 300. This provider uses BGP to exchange routing information with several customer networks. Each customer network is assigned an AS number from the private range, such as AS 65000. Configure the ISP router to remove the private AS numbers from the AS Path information of Customer. In addition, the ISP would like to prevent its customer networks from receiving route information from International Travel Agency's AS 100. Use the AS_PATH attribute to implement this policy.

Note: This lab uses Cisco 1841 routers with Cisco 10S Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as 2801 or 2811) and Cisco IOS Software versions, if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco I0S Release 12.4(24)T1 Advanced IP Sexvices or comparable)
- Serial and console cables

Step 1: Prepare the routers for the lab. Cable the network as shown in the topology diagram.

Step 2: Configure the hostname and interface addresses and use ping command to test connectivity.

Router R1 (hostname Mumbai)

```
et1/6, changed state to down
MUMBAI#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
MUMBAI(config)#int Loopback0
MUMBAI(config-if)#ip ad
*Mar  1 00:00:55.859: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
MUMBAI(config-if)#ip address 10.1.1.1 255.255.255.0
MUMBAI(config-if)#int s0/0
MUMBAI(config-if)#ip address 192.168.1.5 255.255.255.252
MUMBAI(config-if)#clock rate 128000
MUMBAI(config-if)#no shut
MUMBAI(config-if)#do wri
*Mar  1 00:02:03.043: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar  1 00:02:04.043: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0,
 changed state to up
MUMBAI(config-if)#do write
Building configuration...
[OK]
```

Router R2 (hostname ISP)

```
ISP#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
ISP(config)#int Loopback0
ISP(config-if)#
*Mar  1 00:02:25.435: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
ISP(config-if)#ip address 10.2.2.1 255.255.255.0
ISP(config-if)#int s0/0
ISP(config-if)#ip address 192.168.1.6 255.255.255.252
ISP(config-if)#no shut
ISP(config-if)#in
*Mar  1 00:03:23.263: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
ISP(config-if)#int
*Mar  1 00:03:24.267: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0,
 changed state to up
ISP(config-if)#int s0/1
ISP(config-if)#ip address 172.24.1.17 255.255.255.252
ISP(config-if)#clock rate 128000
ISP(config-if)#no shut
ISP(config-if)#do write
```

Router R3 (hostname Customer)

```
CUSTOMER#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
CUSTOMER(config)#int Loopback0
CUSTOMER(config-if)#ip ad
*Mar  1 00:02:28.331: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
CUSTOMER(config-if)#ip address 10.3.3.1 255.255.255.0
CUSTOMER(config-if)#int s0/1
CUSTOMER(config-if)#ip address 172.24.1.18 255.255.255.252
CUSTOMER(config-if)#no shut
CUSTOMER(config-if)#n
*Mar  1 00:03:17.763: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
CUSTOMER(config-if)#no
*Mar  1 00:03:18.767: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1,
 changed state to up
CUSTOMER(config-if)#no shut
CUSTOMER(config-if)#do write
Building configuration...
[OK]
```

Note: Mumbai will not be able to reach either ISP's loopback (10.2.2.1)-or* Customer's loopback(10.3.3.1), nor will it be able to reach either end of the link joining ISP to Customer (172.24.1.17 and 172.24.1.18).

Step 3: Configure BGP

a. Configure BGP for normal operation. Enter the appropriate BGP commands on each router so that they identify their BGP neighbors and advertise their loopback networks.

```
MUMBAI(config)#router bgp 100
MUMBAI(config-router)#neighbor 192.168.1.6 remote-as 300
MUMBAI(config-router)#network 10.1.1.0 mask 255.255.255.0
MUMBAI(config-router)#do write
Building configuration...
[OK]
MUMBAI(config-router)#
*Mar  1 00:08:17.207: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Up
MUMBAI(config-router)#exit
MUMBAI(config)#exit
MUMBAI#
```

```
ISP(config)#router bgp 300
ISP(config-router)#neighbor 192.168.1.5 remote-as 100
ISP(config-router)#neighbor 1 remote-as 65000
*Mar  1 00:08:05.151: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
ISP(config-router)#neighbor 172.24.1.18 remote-as 65000
ISP(config-router)#network 10.2.2.0 mask 255.255.255.0
ISP(config-router)#do write
Building configuration...
[OK]
```

```
CUSTOMER(config-if)#exit
CUSTOMER(config)#router bgp 65000
CUSTOMER(config-router)#neighbor 172.24.1.17 remote-as 300
CUSTOMER(config-router)#network 10.3.3.0 mask 255.255.255.0
CUSTOMER(config-router)#do write
Building configuration...
[OK]
```

b. Verify that these routers have established the appropriate neighbor relationships by issuing the show ip bgp neighbors command on each router.

```
ISP#show ip bgp neighbors
BGP neighbor is 172.24.1.18,  remote AS 65000, external link
  BGP version 4, remote router ID 10.3.3.1
  BGP state = Established, up for 00:00:32
  Last read 00:00:31, last write 00:00:01, hold time is 180, keepalive interval
is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                3          1
    Keepalives:             3          3
    Route Refresh:          0          0
    Total:                  7          5
  Default minimum time between advertisement runs is 30 seconds
```

```
For address family: IPv4 Unicast
 BGP table version 4, neighbor version 4/0
 Output queue size: 0
 Index 1, Offset 0, Mask 0x2
 1 update-group member
                               Sent       Rcvd
 Prefix activity:              ----       ----
   Prefixes Current:              3          1 (Consumes 52 bytes)
   Prefixes Total:                3          1
   Implicit Withdraw:             2          0
   Explicit Withdraw:             0          0
   Used as bestpath:            n/a          1
   Used as multipath:           n/a          0
```

Step 4: Remove the private AS.

a. Display the Mumbai routing table using the show ip route command. Mumbai should have a route to both 10.2.2.0 and 10.3.3.0. Troubleshoot if necessary.

```
MUMBAI#show 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

     10.0.0.0/24 is subnetted, 3 subnets
B       10.3.3.0 [20/0] via 192.168.1.6, 00:01:02
B       10.2.2.0 [20/0] via 192.168.1.6, 00:02:29
C       10.1.1.0 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0
```

b. Ping the 10.3.3. address from Mumbai. Why does this fail?

c. Ping again, this time as an extended ping, sourcing from the Loopback0 interface address.

```
MUMBAI#ping
Protocol [ip]:
Target IP address: 10.3.3.1
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 10.1.1.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
Packet sent with a source address of 10.1.1.1
!!!!!
```

```
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/4/16 ms
MUMBAI#ping 10.3.3.1 source 10.1.1.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
Packet sent with a source address of 10.1.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

Note: You can bypass extended ping mode and specify a source address using one of these commands:

d. Check the BGP table from Mumbai by using the show ip bgp command. Note the AS path for the 10.3.3.0 network. The AS 65000 should be listed in the path to 10.3.3.0

e. Configure ISP to strip the private AS numbers from BGP routes exchanged with Mumbai using the following commands.

```
ISP(config)#router bgp 300
ISP(config-router)#neighbor 192.168.1.5 remove-private-as
ISP(config-router)#do write
Building configuration...
[OK]
```

f. After issuing these commands, use the dleat i ip, bgp * Command on ISP to re-establish the BGP relationship between the three routers. Wait several seconds and then return to Mumbai to check its routing table.

Note: The clear ip bgp * soft command can also be used to force each router to resend its BGP table.

Does Mumbai still have a route to 10.3.3.0?

Mumbai should be able to ping 10.3.3.1 using its loopback 0 interface as the source of the ping.

```
MUMBAI#ping 10.3.3.1 source lo0

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
Packet sent with a source address of 10.1.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/4/16 ms
MUMBAI#show ip bgp
BGP table version is 9, local router ID is 10.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 10.1.1.0/24      0.0.0.0                  0         32768 i
*> 10.2.2.0/24      192.168.1.6              0             0 300 i
*> 10.3.3.0/24      192.168.1.6                            0 300 i
```

g. Now check the BGP table on Mumbai. The AS_ PATH to the 10.3.3.0 network should be AS 300. It no longer has the private AS in the path.

Step 5: Use the AS_PATH attribute to filter routes.

As a final configuration, use the AS_PATH attribute to filter routes based on their origin. In a complex environment, you can use this attribute to enforce routing policy. In this case, the provider router, ISP, must be configured so that it does not propagate routes that originate from AS 100 to the customer router Customer.

AS-path access lists are read like regular access lists.-The statements are read sequentially, and there is an implicit deny at the end. Rather than matching an address in each statement like a conventional access list, AS path access ists match on something called a regular expression. Regular expressions are a way of matching text patterns and have many uses. In this case, you will be using them in the AS path access list to match text patterns in AS paths.

a. Configure a special kind of access list to match BGP routes with an AS_PATH attribute that both begins and ends with the number 100. Enter the following commands on ISP.

```
ISP(config)#ip as-path access-list 1 deny ^100$
ISP(config)#ip as-path access-list 1 permit .*
```

The first command uses the # character to indicate (hat the AS path must begin with the given number 100. The $ character indicates that the AS_PATH attribute must also end with 100. Essentially, this statement matches only paths that are sourced from AS 100. Other paths, which might include AS 100 along the way, will not match this list.

In the second statement, the (period) is a wildcard, and the * (asterisk) stands for a repetition of the wildcard. Together, matches any value of the AS _PATH attribute, which in effect permits any update that has not been denied by the previous access- list statemen

b. Apply the configured access list using the neighbor command with the filter-list option.

```
ISP(config)#router bgp 300
ISP(config-router)#neighbor 172.24.1. 18 filter-list 1 out
```

```
ISP(config-router)#neighbor 172.24.1.18 filter-list 1 out
ISP(config-router)#exit
ISP(config)#exit
ISP#
*Mar  1 00:21:25.919: %SYS-5-CONFIG_I: Configured from console by console
ISP#clear ip bgp *
ISP#
*Mar  1 00:21:36.035: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Down User reset
*Mar  1 00:21:36.035: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar  1 00:21:36.539: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
*Mar  1 00:21:36.743: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Up
ISP#clear ip bgp * out
```

The out keyword specifies that the fist is applied to routing information sent to this neighbor.

c. Use the clear ip bgp *command to reset the routing information. Wait several seconds and then check the routing table for ISP. The route t0°10.1.1.0 should be in the routing table.

Note: To force the local router to resend its BGP table, a less disruptive option is to use the clear ip gp * out or clear ip bgp * soft command (the second command performs both outgoing and incoming route resync)

```
ISP#clear ip bgp * out
ISP#show 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

     172.24.0.0/30 is subnetted, 1 subnets
C       172.24.1.16 is directly connected, Serial0/1
     10.0.0.0/24 is subnetted, 3 subnets
B       10.3.3.0 [20/0] via 172.24.1.18, 00:00:39
C       10.2.2.0 is directly connected, Loopback0
B       10.1.1.0 [20/0] via 192.168.1.5, 00:00:39
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0
```

d. Check the routing table for Customer. It should not have a route to 10.1.1.0 in its routing table.

```
CUSTOMER#show 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

     172.24.0.0/30 is subnetted, 1 subnets
C       172.24.1.16 is directly connected, Serial0/1
     10.0.0.0/24 is subnetted, 2 subnets
C       10.3.3.0 is directly connected, Loopback0
B       10.2.2.0 [20/0] via 172.24.1.17, 00:00:26
```

e. Return to ISP and verify that the filter is working as intended. Issue the show ip bgp regexp" 100$ command

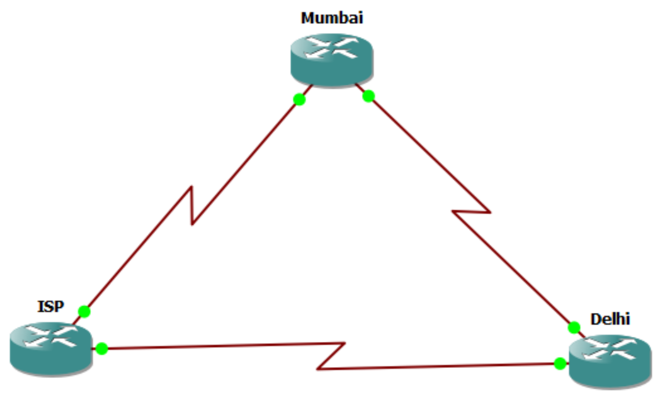
```
ISP#show ip bgp regexp ^100$
BGP table version is 4, local router ID is 10.2.2.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 10.1.1.0/24      192.168.1.5              0             0 100 i
```

The output of this command shows all matches for the regular expressions that were used in the access list. The path to 10.1.1.0 matches the access List and is filtered from updates to Customer.

f. Run the following Tcl script on all routers to verify whether there is connectivity. All pings from ISP should be successful. Mumbai should not be able to ping the Customer loopback 10.3.3.1 or the WAN link 172.24.1.16/30. Customer should not be able to ping the Mumbai loopback 10.1.1.1 or the WAN link 192.168.1.4/3

Practical 3

Aim: Configuring IBGP and EBGP Sessions, Local Preference, and MED (Multi Exit Discriminator)



Objectives

- For IBGP peers to correctly exchange routing information, use the next-hop-self command with the Local-Preference and MED attributes.
- Ensure that the flat-rate, unlimited-use T1 link is used for sending and receiving data to and from the AS 200 on ISP and that the metered T1 only be used in the event that the primary T1 link has failed.

Background

The International Travel Agency runs BGP on its Mumbai and Delhi routers externally with the ISP router in AS 200. IBGP is run internally between Mumbai and Delhi. Your job is to configure both EBGP and IBGP for this internetwork to allow for redundancy. The metered T1 should only be used in the event that the primary T1 link has failed. Traffic sent across the metered T1 link offers the same bandwidth of the primary link but at a huge expense. Ensure that this link is not used unnecessarily.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

• 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)

• Serial and console cables

Step 1: Prepare the routers for the lab. Cable the network as shown in the topology diagram.

Step 2: Configure the hostname and interface addresses and use ping to test the connectivity between the directly connected routers. Both Mumbai and Delhi routers should be able to ping each other and their local ISP serial link IP address. The ISP router cannot reach the segment between Mumbai and Delhi.

Router R1 (hostname ISP)

```
ISP(config)#interface Loopback0
ISP(config-if)#ip address 192.168.100.1 255.255.255.0
ISP(config-if)#interface Serial2/0
ISP(config-if)#ip addrss 192.168.1.5 255.255.255.252
                      ^
% Invalid input detected at '^' marker.

ISP(config-if)#ip address 192.168.1.5 255.255.255.252
ISP(config-if)#clock rate 128000
ISP(config-if)#no shutdown
ISP(config-if)#interface Serial2/1
ISP(config-if)#ip address 192.168.1.1 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#
*Mar  1 00:09:42.331: %LINK-3-UPDOWN: Interface Serial2/1, changed state to up
ISP(config-if)#
*Mar  1 00:09:43.335: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/1, changed state to up
ISP(config-if)#
```

Router R2 (hostname Mumbai)

```
Mumbai(config)#interface Loopback0
Mumbai(config-if)#
*Mar  1 00:12:00.431: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
Mumbai(config-if)#ip address 172.16.64.1 255.255.255.0
Mumbai(config-if)#interface Serial2/0
Mumbai(config-if)#ip address 192.168.1.6 255.255.255.252
Mumbai(config-if)#no shutdown
Mumbai(config-if)#
*Mar  1 00:12:59.627: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
Mumbai(config-if)#
*Mar  1 00:13:00.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/0, changed state to up
Mumbai(config-if)#interface Serial2/1
Mumbai(config-if)#ip address 172.16.1.1 255.255.255.0
Mumbai(config-if)#clocl rate 128000
                      ^
% Invalid input detected at '^' marker.

Mumbai(config-if)#clock rate 128000
Mumbai(config-if)#no shutdown
```

Router R3 (hostname Delhi)

```
Delhi(config)#interface Loopback0
Delhi(config-if)#ip
*Mar  1 00:15:31.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
Delhi(config-if)#ip address 172.16.32.1 255.255.255.0
Delhi(config-if)#interface Serial2/0
Delhi(config-if)#ip address 192.168.1.2 255.255.255.252
Delhi(config-if)#clock rate 128000
Delhi(config-if)#no shutdown
Delhi(config-if)#interface
*Mar  1 00:16:36.947: %LINK-3-UPDOWN: Interface Serial2/0, changed state to up
*Mar  1 00:16:37.947: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial2/0, changed state to up
Delhi(config-if)#interface Serial2/1
Delhi(config-if)#ip address 172.16.1.2 255.255.255.0
Delhi(config-if)#no shutdown
```

Step 3: Configure EIGRP between the Mumbai and Delhi routers

```
Mumbai(config)#
*Mar  1 00:17:12.715: %LINEPROTO-5-UPDOWN: Line protocol on I
Mumbai(config)#router eigrp 64512
Mumbai(config-router)#no auto-summary
Mumbai(config-router)#network 172.16.0.0
Mumbai(config-router)#
```

```
Delhi(config)#router eigrp 64512
Delhi(config-router)#no auto-summary
Delhi(config-router)#network 172.16.0.0
Delhi(config-router)#
```

Step 4: Configure IBGP and verify BGP neighbors.

a. Configure IBGP between the Mumbai and Delhi routers. On the Mumbai router, enter the following configuration.

```
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighbor 172.16.32.1 remote-as 64512
Mumbai(config-router)#neighbor 172.16.32.1 update-source lo0
Mumbai(config-router)#
```

If multiple pathways to the BGP neighbor exist, the router can use multiple IP interfaces to communicate with the neighbor. The source IP address therefore depends on the outgoing interface. The update- source lo0 command instructs the router to use the IP address of the interface Loopback0 as the source IP address for all BGP messages sent to that neighbor.

b. Complete the IBGP configuration on Delhi using the following commands.

```
Delhi(config)#router bgp 64512
Delhi(config-router)#neighbor 172.16.64.1 remote-as 64512
Delhi(config-router)#neighbor 172.16.64.1 update-source lo0
```

c. Verify that Mumbai and Delhi become BGP neighbors by issuing the show ip bgp neighbors command on Mumbai. View the following partial output. If the BGP state is not established, troubleshoot the connection

```
Delhi#show ip bgp neighbor
BGP neighbor is 172.16.64.1,  remote AS 64512, internal link
  BGP version 4, remote router ID 172.16.64.1
  BGP state = Established, up for 00:01:44
  Last read 00:00:43, last write 00:00:43, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
```

The link between Mumbai and Delhi should be identified as an internal link, as shown in the output.

Step 5: Configure EBGP and verify BGP neighbors.

a. Configure ISP to run EBGP with Mumbai and Delhi. Enter the following commands on ISP.

```
ISP(config)#router bgp 200
ISP(config-router)#neighbor 192.168.1.6 remote-as 64512
ISP(config-router)#neighbor 192.168.1.2 remote-as 64512
ISP(config-router)#network 192.168.100.0
ISP(config-router)#
```

Because EBGP sessions are almost always established over point-to-point links, there is no reason to use the update-source keyword in this configuration. Only one path exists between the peers. If this path goes down, alternative paths are not available.

b. Configure Mumbai as an EBGP peer to ISP

```
Mumbai(config)#ip route 172.16.0.0 255.255.0.0 null0
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighbor 192.168.1.5 remote-as 200
Mumbai(config-router)#network 172.16.0.0
Mumbai(config-router)#
```

c. Use the show ip bgp neighbors command to verify that Mumbai and ISP have reached the established state. Troubleshoot if necessary.

```
Mumbai#show ip bgp neighbors
BGP neighbor is 172.16.32.1,  remote AS 64512, internal link
  BGP version 4, remote router ID 172.16.32.1
  BGP state = Established, up for 00:08:08
  Last read 00:00:07, last write 00:00:07, hold time is 180, keepalive interval is 60 seconds
```

d. Configure Delhi as an EBGP peer to ISP.

```
Delhi(config)#ip route 172.16.0.0 255.255.0.0 null0
Delhi(config)#router bgp 64512
Delhi(config-router)#neighbor 192.168.1.1 remote-as 200
Delhi(config-router)#network 172.16.0.0
Delhi(config-router)#
```

Step 6: View BGP summary output.

In Step 5, the **show ip bgp neighbors** command was used to verify that Mumbai and ISP had reached the established state. A useful alternative command is **show ip bgp summary**. The output should be similar to the following

```
Delhi#show ip bgp summary
BGP router identifier 172.16.32.1, local AS number 64512
BGP table version is 5, main routing table version 5
2 network entries using 240 bytes of memory
4 path entries using 208 bytes of memory
5/2 BGP path/bestpath attribute entries using 620 bytes of memory
1 BGP AS-PATH entries using 24 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
Bitfield cache entries: current 2 (at peak 2) using 64 bytes of memory
BGP using 1156 total bytes of memory
BGP activity 2/0 prefixes, 4/0 paths, scan interval 60 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
172.16.64.1     4 64512      24      24        5    0    0 00:19:42        2
192.168.1.1     4   200       7       6        5    0    0 00:01:06        1
Delhi#
```

Step 7: Verify which path the traffic takes.

a. Clear the IP BGP conversation with the **clear ip bgp *** command on ISP. Wait for the conversations to re-establish with both Mumbai and Delhi router.

b. Test whether ISP can ping the loopback 0 address of 172.16.64.1 on Mumbai and the serial link between Mumbai and Delhi,172.16.1.1.

c. Now ping from ISP to the loopback 0 address of 172.16.32.1 on Delhi and the serial link between Mumbai and Delhi, 172.16.1.2. You should see successful pings to each IP address on Delhi router. Ping attempts to 172.16.64.1 and 172.16.1.1 should fail. Why does this happen?

d. Issue the show ip bgp command on ISP to verify BGP routes and metrics.

```
ISP#show ip bgp
BGP table version is 3, local router ID is 192.168.100.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*  172.16.0.0       192.168.1.6              0             0 64512 i
*>                  192.168.1.2              0             0 64512 i
*> 192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

Notice that ISP has two valid routes to the 172.16.0.0 network, as indicated by the *. However, the link to Delhi has been selected as the best path. Why did the ISP prefer the link to Delhi over Mumbai? Would changing the bandwidth metric on each link help to correct this issue? Explain.

BGP operates differently than all other protocols. Unlike other routing protocols that use complex algorithms involving factors such as bandwidth, delay, reliability, and load to formulate a metric, BGP is policy-based. BGP determines the best path based on variables, such as AS path, weight, local preference, MED, and so on. If all things are equal, BGP prefers the route leading to the BGP speaker with the lowest BGP router ID. The Delhi router with BGP router ID 172.16.32.1 was preferred to the higher BGP router ID of the Mumbai router (172.16.64.1).

e. At this point, the ISP router should be able to get to each network connected to Mumbai and Delhi from the loopback address 192.168.100.1. Use the extended ping command and specify the source address of ISP Lo0 to test

```
ISP#ping 172.16.1.1 source 192.168.100.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.100.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/45/60 ms
ISP#ping 172.16.32.1 source 192.168.100.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.32.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.100.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/31/36 ms
ISP#ping 172.16.64.1 source 192.168.100.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.64.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.100.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/45/56 ms
```

```
ISP#ping
Protocol [ip]:
Target IP address: 172.16.64.1
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 192.168.100.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.64.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.100.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/48/60 ms
ISP#
```

Complete reachability has been demonstrated between the ISP router and both Mumbai and Delhi.

Step 8: Configure the BGP next-hop-self feature.

Mumbai is unaware of the link between ISP and Delhi, and Delhi is unaware of the link between ISP and Mumbai. Before ISP can successfully ping all the internal serial interfaces of AS 64512, these serial links should be advertised via BGP on the ISP router. This can also be resolved via EIGRP on both Mumbai and Delhi router. The preferred method is for ISP to advertise these links.

a. Issue the following commands on the ISP router.

```
ISP(config)#router bgp 200
ISP(config-router)#network 192.168.1.0 mask 255.255.255.252
ISP(config-router)#network 192.168.1.4 mask 255.255.255.252
ISP(config-router)#
```

b. Issue the **show ip bgp** command to verify that the ISP is correctly injecting its own WAN links into BGP.

```
ISP#show ip bgp
BGP table version is 5, local router ID is 192.168.100.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*  172.16.0.0       192.168.1.6              0             0 64512 i
*>                  192.168.1.2              0             0 64512 i
*> 192.168.1.0/30   0.0.0.0                  0         32768 i
*> 192.168.1.4/30   0.0.0.0                  0         32768 i
*> 192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

c. Verify on Mumbai and Delhi that the opposite WAN link is included in the routing table. The output from Delhi is as follows

```
Delhi#show 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

     172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
C       172.16.32.0/24 is directly connected, Loopback0
S       172.16.0.0/16 is directly connected, Null0
C       172.16.1.0/24 is directly connected, Serial2/1
D       172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:44:44, Serial2/1
     192.168.1.0/30 is subnetted, 2 subnets
C       192.168.1.0 is directly connected, Serial2/0
B       192.168.1.4 [20/0] via 192.168.1.1, 00:01:19
B    192.168.100.0/24 [20/0] via 192.168.1.1, 00:43:46
Delhi#
```

The next issue to consider is BGP policy routing between autonomous systems. The next-hop attribute of a route in a different AS is set to the IP address of the border router in the next AS toward the destination, and this attribute is not modified by default when advertising this route through IBGP. Therefore, for all IBGP peers, it is either necessary to know the route to that border router (in a different neighboring AS), or our own border router needs to advertise the foreign routes using the next-hop
self feature, overriding the next-hop address with its own IP address. The Delhi router is passing a policy to Mumbai and vice versa. The policy for routing from AS 64512 to AS 200 is to forward packets to the 192.168.1.1 interface. Mumbai has a similar yet opposite policy: it forwards requests to the 192.168.1.5 interface. If either WAN link fails, it is critical that the opposite router become a valid gateway. This is achieved if the next-hop-self command is configured on Mumbai and Delhi.

d. View the output before the next-hop-self command is issued.

```
Delhi#show ip bgp
BGP table version is 6, local router ID is 172.16.32.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.64.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
r i192.168.1.0/30   192.168.1.5              0    100      0 200 i
r>                  192.168.1.1              0             0 200 i
* i192.168.1.4/30   192.168.1.5              0    100      0 200 i
*>                  192.168.1.1              0             0 200 i
* i192.168.100.0    192.168.1.5              0    100      0 200 i
*>                  192.168.1.1              0             0 200 i
Delhi#
```

Issue the next-hop-self command on Mumbai and Delhi.

```
Mumbai(config-router)#exit
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighbor 172.16.32.1 next-hop-self
Mumbai(config-router)#
```

```
Delhi(config)#router bgp 64512
Delhi(config-router)#neighbor 172.16.64.1 next-hop-self
Delhi(config-router)#
```

f. Reset BGP operation on either router with the **clear ip bgp * soft** command.

g. After the routers have returned to established BGP speakers, issue the show ip bgp command to
validate that the next hop has also been corrected.

```
Delhi#show ip bgp
BGP table version is 6, local router ID is 172.16.32.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.64.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
r i192.168.1.0/30   172.16.64.1              0    100      0 200 i
r>                  192.168.1.1              0             0 200 i
* i192.168.1.4/30   172.16.64.1              0    100      0 200 i
*>                  192.168.1.1              0             0 200 i
* i192.168.100.0    172.16.64.1              0    100      0 200 i
*>                  192.168.1.1              0             0 200 i
Delhi#
```

Step 9: Set BGP local preference.

At this point, everything looks good, with the exception of default routes, the outbound flow of data, and inbound packet flow.

a. Because the local preference value is shared between IBGP neighbors, configure a simple route
map that references the local preference value on Mumbai and Delhi. This policy adjusts outbound
traffic to prefer the link off the Mumbai router instead of the metered T1 off Delhi.

```
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighbor 172.16.32.1 next-hop-self
Mumbai(config-router)#exit
Mumbai(config)#route-map PRIMARY_T1_IN permit 10
Mumbai(config-route-map)#set local-preference 150
Mumbai(config-route-map)#exit
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighbor 192.168.1.5 router-map PRIMARY_T1_IN in
                                                ^
% Invalid input detected at '^' marker.

Mumbai(config-router)#neighbor 192.168.1.5 route-map PRIMARY_T1_IN in
Mumbai(config-router)#exit
Mumbai(config)#
```

```
Delhi#config t
Enter configuration commands, one per line.  End with CNTL/Z.
Delhi(config)#route-map SECONDARY_T1_IN permit 10
Delhi(config-route-map)#set local-preference 125
Delhi(config-route-map)#exit
Delhi(config)#router bgp 64512
Delhi(config-router)#neighbour 192.168.1.1 route-map SECONDARY_T1_IN in
                            ^
% Invalid input detected at '^' marker.

Delhi(config-router)#neighbor 192.168.1.1 route-map SECONDARY_T1_IN in
Delhi(config-router)#
```

b. Use the **clear ip bgp * soft** command after configuring this new policy. When the conversations
have been re-established, issue the show ip bgp command on Mumbai and Delhi

```
Mumbai#clear ip bgp * soft
Mumbai#show ip bgp
BGP table version is 9, local router ID is 172.16.64.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.32.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
*>i192.168.1.0/30   172.16.32.1              0    125      0 200 i
*                   192.168.1.5              0             0 200 i
r>i192.168.1.4/30   172.16.32.1              0    125      0 200 i
r                   192.168.1.5              0             0 200 i
*>i192.168.100.0    172.16.32.1              0    125      0 200 i
*                   192.168.1.5              0             0 200 i
Mumbai#
```

```
Delhi#clear ip bgp * soft
Delhi#show ip bgp
BGP table version is 9, local router ID is 172.16.32.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.64.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
r> 192.168.1.0/30   192.168.1.1              0    125      0 200 i
*> 192.168.1.4/30   192.168.1.1              0    125      0 200 i
*> 192.168.100.0    192.168.1.1              0    125      0 200 i
Delhi#
```

This now indicates that routing to the loopback segment for ISP 192.168.100.0 /24 can be reached only through the link common to Mumbai and ISP.

Step 10: Set BGP MED (Multi Exit Discriminator)

How will traffic return from network 192.168.100.0 /24? Will it be routed through Mumbai or Delhi?

The simplest solution is to issue the **show ip bgp** command on the ISP router. What if access was not given to the ISP router? Traffic returning from the Internet should not be passed across the metered T1. Is there a simple way to verify before receiving the monthly bill? How can it be checked instantly?

a. Use an extended **ping** command in this situation. Specify the record option and compare your output to the following

```
Delhi#ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]: 2
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 172.16.32.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]: record
Number of hops [ 9 ]:
Loose, Strict, Record, Timestamp, Verbose[RV]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 2, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
Packet sent with a source address of 172.16.32.1
Packet has IP options:  Total option bytes= 39, padded length=40
 Record route: <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)

Reply to request 0 (40 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.100.1)
   (192.168.1.1)
   (172.16.32.1) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 1 (48 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.100.1)
   (192.168.1.1)
   (172.16.32.1) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Success rate is 100 percent (2/2), round-trip min/avg/max = 40/44/48 ms
Delhi#
```

If you are unfamiliar with the record option, the important thing to note is that each IP address in brackets is an outgoing interface. The output can be interpreted as follows:
1. A ping that is sourced from 172.16.32.1 exits Delhi through s0/0/1, 172.16.1.2. It then arrives at the s0/0/1 interface for Mumbai.
2. Mumbai S0/0/0, 192.168.1.6, routes the packet out to arrive at the S0/0/0 interface of ISP.
3. The target of 192.168.100.1 is reached:192.168.100.1.
4. The packet is next forwarded out the S0/0/1, 192.168.1.1 interface for ISP and arrives at the S0/0/0 interface for Delhi.
5. Delhi then forwards the packet out the last interface, loopback 0,172.16.32.1.
Although the unlimited use of the T1 from Mumbai is preferred here, ISP currently takes the link from Delhi for all return traffic.
b. Create a new policy to force the ISP router to return all traffic via Mumbai. Create a second route map utilizing the MED (metric) that is shared between EBGP neighbors.

```
Enter configuration commands, one per line.  End with CNTL/Z.
Mumbai(config)#route-map PRIMARY_T1_MED_OUT permit 10
Mumbai(config-route-map)#set Metric 50
Mumbai(config-route-map)#exit
Mumbai(config)#router bgp 64512
Mumbai(config-router)#neighor 192.168.1.5 route-map PRIMARY_T1_MED_OUT out
                           ^
% Invalid input detected at '^' marker.

Mumbai(config-router)#neighbor 192.168.1.5 route-map PRIMARY_T1_MED_OUT out
Mumbai(config-router)#
```

```
Delhi(config)#route-map SECONDARY_T1_MED_OUT permit 10
Delhi(config-route-map)#set Metric 75
Delhi(config-route-map)#exit
Delhi(config)#router bgp 64512
Delhi(config-router)#neighbour 192.168.1.1 route-map
                            ^
% Invalid input detected at '^' marker.

Delhi(config-router)#neighbor 192.168.1.1 route-map SECONDARY_T1_MED_OUT out
Delhi(config-router)#
```

c. Use the clear ip bgp * soft command after issuing this new policy. Issuing the show ip bgp command as follows on Mumbai or Delhi does not indicate anything about this newly defined policy

```
Mumbai#clear ip bgp * soft
Mumbai#show ip bgp
BGP table version is 12, local router ID is 172.16.64.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.32.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
*> 192.168.1.0/30   192.168.1.5              0    150      0 200 i
r> 192.168.1.4/30   192.168.1.5              0    150      0 200 i
*> 192.168.100.0    192.168.1.5              0    150      0 200 i
Mumbai#
```

```
Delhi#clear ip bgp * soft
Delhi#show ip bgp
BGP table version is 12, local router ID is 172.16.32.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i172.16.0.0       172.16.64.1              0    100      0 i
*>                  0.0.0.0                  0         32768 i
r>i192.168.1.0/30   172.16.64.1              0    150      0 200 i
r                   192.168.1.1              0    125      0 200 i
*>i192.168.1.4/30   172.16.64.1              0    150      0 200 i
*                   192.168.1.1              0    125      0 200 i
*>i192.168.100.0    172.16.64.1              0    150      0 200 i
*                   192.168.1.1              0    125      0 200 i
Delhi#
```

d. Reissue an extended ping command with the record command.

```
Delhi#ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]: 2
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 172.16.32.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]: record
Number of hops [ 9 ]:
Loose, Strict, Record, Timestamp, Verbose[RV]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 2, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
Packet sent with a source address of 172.16.32.1
Packet has IP options:  Total option bytes= 39, padded length=40
 Record route: <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)

Reply to request 0 (64 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.100.1)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.32.1) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 1 (64 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.100.1)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.32.1) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Success rate is 100 percent (2/2), round-trip min/avg/max = 64/64/64 m
Delhi#
```

Does the output look correct? Does the 192.168.1.5 above mean that the ISP now prefers Mumbai for return traffic? There might not be a chance to use Telnet to the ISP router and to issue the **show ip bgp** command. However, the command on the opposite side of the newly configured policy MED is clear, showing that the lower value is considered best. The ISP now prefers the route with the lower MED value to AS 64512. This is just opposite from the local-preference command configured earlier.

```
ISP#show ip bgp
BGP table version is 6, local router ID is 192.168.100.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 172.16.0.0       192.168.1.6             50             0 64512 i
*                   192.168.1.2             75             0 64512 i
*> 192.168.1.0/30   0.0.0.0                  0         32768 i
*> 192.168.1.4/30   0.0.0.0                  0         32768 i
*> 192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

Step 11: Establish a default network.

The final step is to establish a default route that uses a policy statement that adjusts to changes in the network. Configure both Mumbai and Delhi to use the 192.168.100.0 /24 network as the default network. The following steps configure the Mumbai router. Do the same on the Delhi router.

a. View the routing table prior to issuing the ip default-network statement.

```
Mumbai#show 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

     172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
D       172.16.32.0/24 [90/2297856] via 172.16.1.2, 01:10:49, Serial2/1
S       172.16.0.0/16 is directly connected, Null0
C       172.16.1.0/24 is directly connected, Serial2/1
C       172.16.64.0/24 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 2 subnets
B       192.168.1.0 [20/0] via 192.168.1.5, 00:13:04
C       192.168.1.4 is directly connected, Serial2/0
B    192.168.100.0/24 [20/0] via 192.168.1.5, 00:13:04
Mumbai#
```

Note: The above command works well only with remotely-learned classful networks. It should not be used with classless networks. An alternative to using the ip default-network command on Mumbai is issuing the neighbor X.X.X.X default-originate configuration on the ISP router.

b. View the routing table after issuing the ip default-network statement.

```
Mumbai(config)#ip default-network 192.168.100.0
Mumbai(config)#exit
Mumbai#config t
*Mar  1 01:14:32.011: %SYS-5-CONFIG_I: Configured from console by console
Mumbai#show 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 192.168.1.5 to network 192.168.100.0

     172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
D       172.16.32.0/24 [90/2297856] via 172.16.1.2, 01:14:31, Serial2/1
S       172.16.0.0/16 is directly connected, Null0
C       172.16.1.0/24 is directly connected, Serial2/1
C       172.16.64.0/24 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 2 subnets
B       192.168.1.0 [20/0] via 192.168.1.5, 00:16:45
C       192.168.1.4 is directly connected, Serial2/0
B*   192.168.100.0/24 [20/0] via 192.168.1.5, 00:16:47
Mumbai#
```

What would be required to add a future T3 link on Delhi and for it to have preference for incoming and outgoing traffic?

A newly added route is as easy as adding another route map for local preference with a value of 175 and a route map referencing a MED (metric) value of 35.

NOTE: By default, the MED is compared only when the route is being received from the same neighboring AS, although advertised by different border routers. The nondefault behavior of comparing the MED regardless of the AS advertising the route can be activated using the bgp always-comparemed command, however, the results of this command have to be carefully considered .

Note: Because the MED is an optional attribute, it might not be present in BGP updates. RFC 4271 requires that a missing MED is equivalent to having the MED set to 0. However, a missing MED can also be considered to be the worst possible MED, which is activated using the bgp best path med missing- as-worst command.

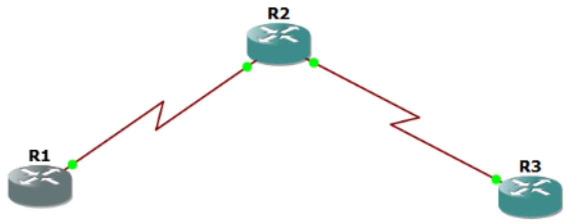
c. Run the following Tcl script on all routers to verify full connectivity

```
IPC(tcl)#
IPC(tcl)#foreach address {
+>192.168.100.1
+>172.16.64.1
+>172.16.32.1
+>192.168.1.1
+>192.168.1.2
+>192.168.1.5
+>192.168.1.6
+>172.16.1.1
+>172.16.1.2
+>} {
+>ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.64.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/86/104 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.32.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 88/113/132 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 168/178/196 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/93/128 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 136/156/204 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/66/72 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/47/68 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/41/64 ms
IPC(tcl)#
```

PRACTICAL 4

Aim- Secure the Management Plane

Topology



Procedure:

Step 1: Configure loopbacks and assign addresses

Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear previous configurations. Using the addressing scheme in the diagram, apply the IP addresses to the interfaces on the R1, R2, and R3 routers.

R1 Router

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int Loopback0
R1(config-if)#
*Mar  1 00:00:44.655: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
R1(config-if)#Description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#exit
R1(config)#int s0/0
R1(config-if)#description R1-->r2
R1(config-if)#description R1-->R2
R1(config-if)#ip address 10.1.1.1 255.255.255.252
R1(config-if)#clock rate 128000
R1(config-if)#no shutdown
```

R2 Router

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R1
R1(config)#int s0/0
R1(config-if)#description R2-->R1
R1(config-if)#ip address 10.1.1.2 255.255.255.252
R1(config-if)#no shutdown
R1(config-if)#exi
*Mar  1 00:04:58.743: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R1(config-if)#exit
*Mar  1 00:04:59.747: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R1(config-if)#exit
R1(config)#int s0/1
R1(config-if)#description R2-->R3
R1(config-if)#ip address 10.2.2.1 255.255.255.252
R1(config-if)#clock rate 128000
R1(config-if)#no shutdown
```

R3 Router

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int Loopback 0
R3(config-if)#
*Mar  1 00:07:03.527: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopb
R3(config-if)#description R3 LAN
R3(config-if)#ip address 192.168.3.1 255.255.255.0
R3(config-if)#exit
R3(config)#int s0/1
R3(config-if)#description R3-->R2
R3(config-if)#ip address 10.2.2.2 255.255.255.252
R3(config-if)#no shutdown
```

Step 2: Configure static routes

a. On R1, configure a default static route to ISP

```
R1(config)#
*Mar  1 00:03:42.339: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to down
R1(config)#
*Mar  1 00:05:12.339: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R1(config)#ip route 0.0.0.0 0.0.0.0 10.1.1.2
R1(config)#exit
```

b. On R3, configure a default static route to ISP.

```
R3(config)#ip route 0.0.0.0 0.0.0.0 10.2.2.1
```

c. On R2, configure two static routes.

```
*Mar  1 00:08:32.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface Se
R1(config)#ip route 192.168.1.0 255.255.255.0 10.1.1.1
R1(config)#ip route 192.168.3.0 255.255.255.0 10.2.2.2
R1(config)#
```

d. From the R1 router, run the following Tcl script to verify connectivity.

```
R1#tclsh
R1(tcl)#$1 10.1.1.2 10.2.2.1 10.2.2.2 192.168.3.1 } { ping $address }
can't read "192.168.1.1 10.1.1.1 10.1.1.2 10.2.2.1 10.2.2.2 192.168.3.1 ": no such variable
R1(tcl)#$0.1.1.1 10.1.1.2 10.2.2.1 10.2.2.2 192.168.3.1 } { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/6/28 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/7/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.2.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/4/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.2.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/4/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1(tcl)#exit
```

Step 3: Secure management access

a. On R1, use the security passwords command to set a minimum password length of 10 characters.

R1(config)# security passwords min-length 10

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#security passwords min-length 10
```

b. Configure the enable secret encrypted password on both routers.

R1(config)# enable secret class12345

```
R1(config)#security passwords min-length 10
R1(config)#enable secret class12345
```

c. Configure a console password and enable login for routers.

For additional security, the exec-timeout command causes the line to log out after 5 minutes of inactivity.The logging synchronous command prevents console messages from interrupting command entry

```
R1(config)#line console 0
R1(config-line)#password ciscoconpass
R1(config-line)#exec-timeout 5 0
R1(config-line)#login
R1(config-line)#logging synchronous
R1(config-line)#exit
```

d. Configure the password on the vty lines for router R1.

```
R1(config)#line vty 0 4
R1(config-line)#password ciscovtypass
R1(config-line)#exec-timeout 5 0
R1(config-line)#login
R1(config-line)#exit
```

e. The aux port is a legacy port used to manage a router remotely using a modem and is hardly ever used. Therefore, disable the aux port

```
R1(config)#line aux 0
R1(config-line)#no exec
R1(config-line)#end
R1#
```

f. Use the service password-encryption command to encrypt the line console and vty passwords.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#service password-encryption
R1(config)#exit
```

g. Issue the show run command. Can you read the console, aux, and vty passwords? Why or why not?

```
R1#show run
Building configuration...

Current configuration : 2070 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
security passwords min-length 10
enable secret 5 $1$M3bB$0gfOteZXwHpkrxXpHEdjc/
!
no aaa new-model
```

h. Configure a warning to unauthorized users with a message-of-the-day (MOTD) banner using the banner motd command. When a user connects to one of the routers, the MOTD banner appears before the login prompt. In this example, the dollar sign ($) is used to start and end the message.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#banner motd $unathorized access strictly prohibited!$
R1(config)#exit
R1#
```

Step 4: Configure enhanced username password security.

To increase the encryption level of console and VTY lines, it is recommended to enable authentication using the local database. The local database consists of usernames and password combinations that are created locally on each device. The local and VTY lines are configured to refer to the local database when authenticating a user

a. To create local database entry encrypted to level 4 (SHA256), use the username name secret password global configuration command. In global configuration mode, enter the following

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#username JR-ADMIN secret class12345
R1(config)#username ADMIN secret54321
                                   ^
% Invalid input detected at '^' marker.

R1(config)#username ADMIN secret class54321
```

b. Set the console line to use the locally defined login accounts

```
R1(config)#line console 0
R1(config-line)#login local
R1(config-line)#exit
```

c. Set the vty lines to use the locally defined login accounts

```
R1(config)#line vty 0 4
R1(config-line)#login local
R1(config-line)#end
```

d. To verify the configuration, telnet to R3 from R1 and login using the ADMIN local database account.

```
R3(config)#security passwords min-length 10
R3(config)#enable secret class12345
R3(config)#line console 0
R3(config-line)#password ciscoconpass
R3(config-line)#exec-timeout 5 0
R3(config-line)#login
R3(config-line)#logging synchronous
R3(config-line)#exit
R3(config)#line vty 0 4
R3(config-line)#password ciscovtypass1
R3(config-line)#exec-timeout 5 0
R3(config-line)#login
R3(config-line)#exit
R3(config)#line aux 0
R3(config-line)#no exec
R3(config-line)#end
```

```
*Mar  1 00:30:17.883: %SYS-5-CONFIG_I: Configured from console by console
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#service password-encryption
R3(config)#banner motd $unauthorized access strictly prohibited!$
R3(config)#username JR-ADMIN secret class12345
R3(config)#username ADMIN secret class54321
R3(config)#line console 0
R3(config-line)#login local
R3(config-line)#exit
R3(config)#line vty 0 4
R3(config-line)#login local
R3(config-line)#end
R3#
```

```
*Mar  1 00:32:54.479: %SYS-5-CONFIG_I: Configured from console by console
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#username ADMIN secret class56789
R3(config)#username JR-ADMIN secret class98765
R3(config)#line console 0
R3(config-line)#login local
R3(config-line)#exit
R3(config)#line vty 0 4
R3(config-line)#login local
R3(config-line)#end
```

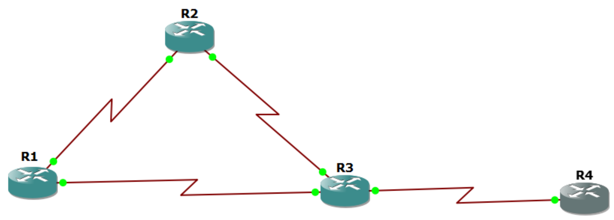
e. To verify the configuration, telnet to R3 from R1 and login using the ADMIN local database account

```
R1#telnet 10.2.2.2
Trying 10.2.2.2 ... Open
unauthorized access strictly prohibited!

User Access Verification

Username: ADMIN
Password:
% Password:  timeout expired!
Username: ADMIN
Password:
% Login invalid

Username: ADMIN
Password:
R3>
```

```
*Mar  1 00:34:48.455: %SYS-5-CONFIG_I: Configured from con
R3#telnet 10.1.1.1
Trying 10.1.1.1 ... Open
unathorized access strictly prohibited!

User Access Verification

Username: ADMIN
Password:
R1>
```

Practical 5

Aim: Configure and Verify Path Control Using PBR



Objectives

• Configure and verify policy-based routing.

• Select the required tools and commands to configure policy-based routing operations.

• Verify the configuration and operation by using the proper show and debug commands.

Background

You want to experiment with policy-based routing (PBR) to see how it is implemented and to study how it could be of value to your organization. To this end, you have interconnected and configured a test network with four routers. All routers are exchanging routing information using EIGRP. Note: This lab uses Cisco 1941 routers with Cisco IOS Release 15.2 with IP Base. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

• 4 routers (Cisco IOS Release 15.2 or comparable)

• Serial and Ethernet cables

Step 1: Configure loopbacks and assign addresses.

a. Cable the network as shown in the topology diagram. Erase the startup configuration, and reload each router to clear previous configurations.

b. Using the addressing scheme in the diagram, create the loopback interfaces and apply IP addresses to these and the serial interfaces on R1, R2, R3, and R4. On the serial interfaces connecting R1 to R3 and R3 to R4, specify the bandwidth as 64 Kb/s and set a clock rate on the DCE using the clock rate 64000 command. On the serial interfaces connecting R1 to R2 and R2 to R3, specify the bandwidth as 128 Kb/s and set a clock rate on the DCE using the clock rate 128000 command. You can copy and paste the following configurations into your routers to begin. Note: Depending on the router model, interfaces might be numbered differently than those listed. You might need to alter them accordingly.

Router R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface Lo1
R1(config-if)#
*Mar  1 00:01:18.347: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface serial0/0
R1(config-if)#description R1 -->R2
R1(config-if)#ip address 172.16.12.1 255.255.255.248
R1(config-if)#clock rate 128000
R1(config-if)#bandwidth 128
R1(config-if)#no shut
```

Router R2:

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#interface Lo2
R2(config-if)#d
*Mar  1 00:00:44.663: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
R2(config-if)#description R2 LAN
R2(config-if)#ip address 192.168.2.1 255.255.255.0
R2(config-if)#interface s0/0
R2(config-if)#description R2-->R1
R2(config-if)#ip address 172.16.12.2 255.255.255.248
R2(config-if)#bandwidth 128
R2(config-if)#no shut
R2(config-if)#inter
*Mar  1 00:02:38.043: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R2(config-if)#interface
*Mar  1 00:02:39.047: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R2(config-if)#interface s0/1
R2(config-if)#ip address 172.16.23.2 255.255.255.248
R2(config-if)#clock rate 128000
R2(config-if)#bandwidth 128
R2(config-if)#no shut
```

Router R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface Lo3
R3(config-if)#desc
*Mar  1 00:01:12.527: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed state to up
R3(config-if)#description R3 LAN
R3(config-if)#ip address 192.168.3.1 255.255.255.0
R3(config-if)#interface s0/0
R3(config-if)#description R3-->R1
R3(config-if)#ip address 172.16.13.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
R3(config-if)#no shut
R3(config-if)#interfa
*Mar  1 00:03:23.231: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R3(config-if)#interface
*Mar  1 00:03:24.235: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R3(config-if)#interface s0/1
R3(config-if)#description R3-->R2
R3(config-if)#ip address 172.16.23.3 255.255.255.248
R3(config-if)#bandwidth 128
R3(config-if)#no shut
R3(config-if)#
*Mar  1 00:04:27.235: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
*Mar  1 00:04:28.235: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R3(config-if)#interface s0/2
R3(config-if)#description R3--R4
R3(config-if)#description R3-->R4
R3(config-if)#ip address 172.16.34.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
```

Router R4:

```
R4#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#interface Lo4
R4(config-if)#des
*Mar  1 00:00:42.963: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback4, changed state to up
R4(config-if)#description R4 LAN A
R4(config-if)#ip address 192.168.4.1 255.255.255.128
R4(config-if)#interface lo5
R4(config-if)#desc
*Mar  1 00:01:45.895: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback5, changed state to up
R4(config-if)#description R4 LAN B
R4(config-if)#ip address 192.168.4.1 255.255.255.128
% 192.168.4.0 overlaps with Loopback4
R4(config-if)#interface Lo5
R4(config-if)#description R4 LAN B
R4(config-if)#ip address 192.168.4.1 255.255.255.128
% 192.168.4.0 overlaps with Loopback4
R4(config-if)#interface Lo5
R4(config-if)#description R4 LAN B
R4(config-if)#ip address 192.168.4.129 255.255.255.128
R4(config-if)#interface s0/0
R4(config-if)#interface s0/2
R4(config-if)#description R4-->R3
R4(config-if)#ip address 172.16.34.4 255.255.255.248
R4(config-if)#bandwidth 64
R4(config-if)#no shut
R4(config-if)#
```

c. Verify the configuration with the show ip interface brief, show protocols, and show interfaces

description commands. The output from router R3 is shown here as an example

```
R3#show ip interface brief | include up
Serial0/0              172.16.13.3    YES manual up                    up
Serial0/1              172.16.23.3    YES manual up                    up
Serial0/2              172.16.34.3    YES manual up                    up
FastEthernet1/0        unassigned     YES unset  up                    down
FastEthernet1/1        unassigned     YES unset  up                    down
FastEthernet1/2        unassigned     YES unset  up                    down
FastEthernet1/3        unassigned     YES unset  up                    down
FastEthernet1/4        unassigned     YES unset  up                    down
FastEthernet1/5        unassigned     YES unset  up                    down
FastEthernet1/6        unassigned     YES unset  up                    down
FastEthernet1/7        unassigned     YES unset  up                    down
FastEthernet1/8        unassigned     YES unset  up                    down
```

```
FastEthernet1/8        unassigned     YES unset  up                    down
FastEthernet1/9        unassigned     YES unset  up                    down
FastEthernet1/10       unassigned     YES unset  up                    down
FastEthernet1/11       unassigned     YES unset  up                    down
FastEthernet1/12       unassigned     YES unset  up                    down
FastEthernet1/13       unassigned     YES unset  up                    down
FastEthernet1/14       unassigned     YES unset  up                    down
FastEthernet1/15       unassigned     YES unset  up                    down
Vlan1                  unassigned     YES unset  up                    down
Loopback3              192.168.3.1    YES manual up                    up
R3#
```

```
R3#show protocols
Global values:
  Internet Protocol routing is enabled
FastEthernet0/0 is administratively down, line protocol is down
Serial0/0 is up, line protocol is up
  Internet address is 172.16.13.3/29
FastEthernet0/1 is administratively down, line protocol is down
Serial0/1 is up, line protocol is up
  Internet address is 172.16.23.3/29
Serial0/2 is up, line protocol is up
  Internet address is 172.16.34.3/29
Serial0/3 is administratively down, line protocol is down
FastEthernet1/0 is up, line protocol is down
FastEthernet1/1 is up, line protocol is down
FastEthernet1/2 is up, line protocol is down
FastEthernet1/3 is up, line protocol is down
FastEthernet1/4 is up, line protocol is down
FastEthernet1/5 is up, line protocol is down
FastEthernet1/6 is up, line protocol is down
FastEthernet1/7 is up, line protocol is down
FastEthernet1/8 is up, line protocol is down
FastEthernet1/9 is up, line protocol is down
FastEthernet1/10 is up, line protocol is down
FastEthernet1/11 is up, line protocol is down
FastEthernet1/12 is up, line protocol is down
FastEthernet1/13 is up, line protocol is down
FastEthernet1/14 is up, line protocol is down
FastEthernet1/15 is up, line protocol is down
FastEthernet2/0 is administratively down, line protocol is down
Vlan1 is up, line protocol is down
Loopback3 is up, line protocol is up
  Internet address is 192.168.3.1/24
R3#
```

```
R3#
R3#show interfaces description | include up
Se0/0                          up             up        R3-->R1
Se0/1                          up             up        R3-->R2
Se0/2                          up             up        R3-->R4
Fa1/0                          up             down
Fa1/1                          up             down
Fa1/2                          up             down
Fa1/3                          up             down
Fa1/4                          up             down
Fa1/5                          up             down
Fa1/6                          up             down
Fa1/7                          up             down
Fa1/8                          up             down
Fa1/9                          up             down
Fa1/10                         up             down
Fa1/11                         up             down
```

Step 3: Configure basic EIGRP.

a. Implement EIGRP AS 1 over the serial and loopback interfaces as you have configured it for the other EIGRP labs.

b. Advertise networks 172.16.12.0/29, 172.16.13.0/29, 172.16.23.0/29, 172.16.34.0/29, 192.168.1.0/24, 192.168.2.0/24, 192.168.3.0/24, and 192.168.4.0/24 from their respective routers. You can copy and paste the following configurations into your routers.

```
Enter configuration commands, one per lin
R1(config)#router eigrp 1
```

```
R1(config-router)#network 192.168.1.0
R1(config-router)#network 172.16.12.1 0.0.0.7
R1(config-router)#network 172.16.13.1 0.0.0.7
R1(config-router)#n
*Mar  1 00:43:17.379: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1
R1(config-router)#no auto-summary
```

```
R2(config)#router eigrp 1
R2(config-router)#network 192.168.2.0
R2(config-router)#network 172.16.12.0 0.0.0.7
R2(config-router)#172
*Mar  1 00:28:17.203: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighb
R2(config-router)#network 172.16.23.0 0.0.0.7
R2(config-router)#no auto-summary
```

```
R3(config)#router eigrp 1
```

```
R3(config-router)#network 192.168.3.1
R3(config-router)#network 172.16.13.3 0.0.0.7
R3(config-router)#network 172.16.23.3 0.0.0.7
R3(config-router)#network 172.16.34.3 0.0.0.7
R3(config-router)#no auto-summary
```

```
R4(config)#router eigrp 1
```

```
R4(config-router)#network 192.168.4.1
R4(config-router)#network 172.16.34.4 0.0.0.7
R4(config-router)#no auto-summary
```

You should see EIGRP neighbor relationship messages being generated.

Step 4: Verify EIGRP connectivity.

a. Verify the configuration by using the show ip eigrp neighbors command to check which routers have EIGRP adjacencies.

```
R1#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
1   172.16.13.3             Se0/1             13 00:00:29   30   2280  0  22
0   172.16.12.2             Se0/0             12 00:09:22   34   1140  0  25
```

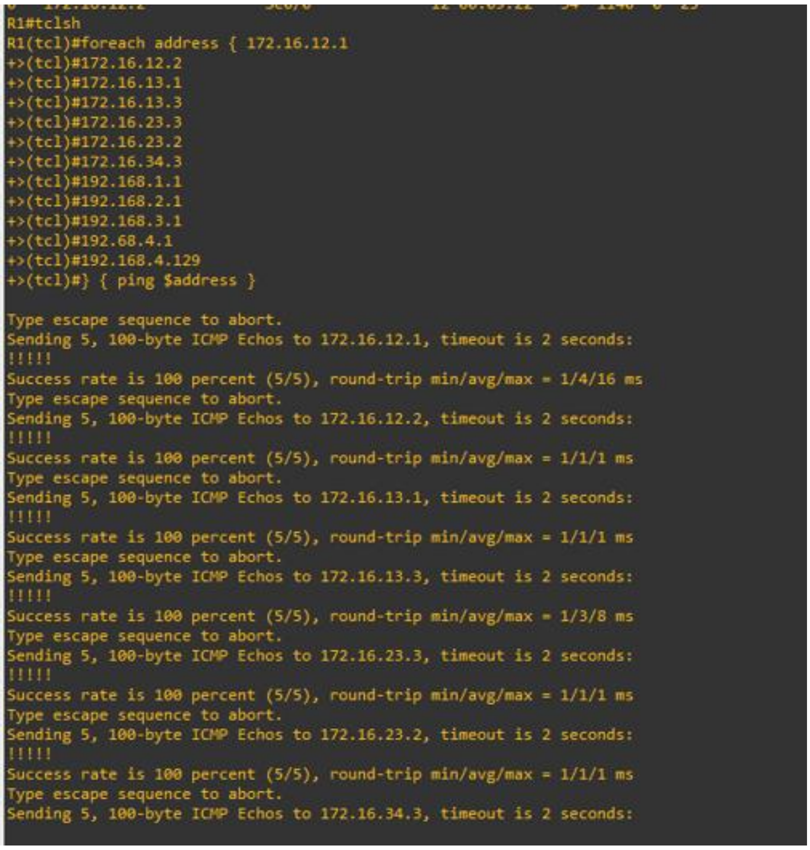
```
R2#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
1   172.16.23.3             Se0/1             13 00:10:04   25   1140  0  15
0   172.16.12.1             Se0/0             12 00:12:18   35   1140  0  18
R2#
```

```
R3#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
2   172.16.13.1             Se0/0             14 00:07:08   18   2280  0  19
1   172.16.34.4             Se0/2             13 00:11:46   29   2280  0  7
0   172.16.23.2             Se0/1             11 00:13:48   18   1140  0  26
```

```
R4#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
0   172.16.34.3             Se0/2             14 00:14:02   30   2280  0  19
```

R4 Did you receive the output you expected? The output should be similar to that shown above.

b. Run the following Tcl script on all routers to verify full connectivity.



```
R1#tclsh
R1(tcl)#foreach address { 172.16.12.1
+>(tcl)#172.16.12.2
+>(tcl)#172.16.13.1
+>(tcl)#172.16.13.3
+>(tcl)#172.16.23.3
+>(tcl)#172.16.23.2
+>(tcl)#172.16.34.3
+>(tcl)#192.168.1.1
+>(tcl)#192.168.2.1
+>(tcl)#192.168.3.1
+>(tcl)#192.68.4.1
+>(tcl)#192.168.4.129
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/4/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/8 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.23.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.23.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.34.3, timeout is 2 seconds:
```

You should get ICMP echo replies for every address pinged. Make sure to run the Tcl script on each router.

Step 5: Verify the current path.

Before you configure PBR, verify the routing table on R1.

a. On R1, use the show ip route command. Notice the next-hop IP address for all networks discovered by EIGRP.

```
R1(tcl)#exit
R1#show ip route | begin Gateway
Gateway of last resort is not set

     172.16.0.0/29 is subnetted, 4 subnets
D       172.16.34.0 [90/41024000] via 172.16.13.3, 00:15:56, Serial0/1
D       172.16.23.0 [90/21024000] via 172.16.12.2, 00:15:56, Serial0/0
C       172.16.12.0 is directly connected, Serial0/0
C       172.16.13.0 is directly connected, Serial0/1
     192.168.4.0/25 is subnetted, 2 subnets
D       192.168.4.0 [90/41152000] via 172.16.13.3, 00:15:56, Serial0/1
D       192.168.4.128 [90/41152000] via 172.16.13.3, 00:15:56, Serial0/1
C    192.168.1.0/24 is directly connected, Loopback1
D    192.168.2.0/24 [90/20640000] via 172.16.12.2, 00:15:56, Serial0/0
D    192.168.3.0/24 [90/21152000] via 172.16.12.2, 00:15:56, Serial0/0
R1#
```

b. On R4, use the traceroute command to the R1 LAN address and source the ICMP packet from R4 LAN A and LAN B.

Note: You can specify the source as the interface address (for example 192.168.4.1) or the interface designator (for example, Fa0/0).

```
R4#traceroute 192.168.1.1 source 192.168.4.1

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 0 msec 0 msec 8 msec
  2 172.16.23.2 8 msec 0 msec 0 msec
  3 172.16.12.1 0 msec 0 msec 0 msec
R4#traceroute 192.168.1.1 source 192.168.4.129

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 40 msec 24 msec 20 msec
  2 172.16.23.2 36 msec 0 msec 0 msec
  3 172.16.12.1 0 msec 0 msec 0 msec
R4#traceroute 192.168.1.1 source 192.168.4.1

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 36 msec 0 msec 0 msec
  2 172.16.23.2 0 msec 0 msec 0 msec
  3 172.16.12.1 16 msec 0 msec 0 msec
R4#traceroute 192.168.1.1 source 192.168.4.129

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 24 msec 0 msec 12 msec
  2 172.16.13.1 0 msec 0 msec 0 msec
R4#
```

Notice that the path taken for the packets sourced from the R4 LANs are going through R3 --> R2 -->R1.

Why are the R4 interfaces not using the R3 --> R1 path?

Because the serial interfaces between routers R1 and R3 have been configured with a lower bandwidth of 64 Kb/s, giving it a higher metric. All other serial interfaces are using the bandwidth setting of 128 Kb/s. R3 chooses to send all packets to R2 because of its lower metric.

c. On R3, use the show ip route command and note that the preferred route from R3 to R1 LAN192.168.1.0/24 is via R2 using the R3 exit interface S0/0/1.

```
R3#show ip route | begin Gateway
Gateway of last resort is not set

     172.16.0.0/29 is subnetted, 4 subnets
C       172.16.34.0 is directly connected, Serial0/2
C       172.16.23.0 is directly connected, Serial0/1
D       172.16.12.0 [90/21024000] via 172.16.23.2, 00:18:22, Serial0/1
C       172.16.13.0 is directly connected, Serial0/0
```

```
C       172.16.13.0 is directly connected, Serial0/0
     192.168.4.0/25 is subnetted, 2 subnets
D       192.168.4.0 [90/40640000] via 172.16.34.4, 00:22:51, Serial0/2
D       192.168.4.128 [90/40640000] via 172.16.34.4, 00:22:51, Serial0/2
D    192.168.1.0/24 [90/21152000] via 172.16.23.2, 00:18:22, Serial0/1
D    192.168.2.0/24 [90/20640000] via 172.16.23.2, 00:18:22, Serial0/1
C    192.168.3.0/24 is directly connected, Loopback3
```

d. On R3, use the show interfaces serial 0/0/0 and show interfaces s0/0/1 commands.

```
R3#show interfaces serial 0/0
Serial0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Description: R3-->R1
  Internet address is 172.16.13.3/29
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input 00:00:01, output 00:00:00, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: weighted fair
  Output queue: 0/1000/64/0 (size/max total/threshold/drops)
     Conversations  0/1/256 (active/max active/max total)
     Reserved Conversations 0/0 (allocated/max allocated)
     Available Bandwidth 48 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     649 packets input, 43432 bytes, 0 no buffer
     Received 356 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     711 packets output, 48771 bytes, 0 underruns
     0 output errors, 0 collisions, 6 interface resets
     0 output buffer failures, 0 output buffers swapped out
     0 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up

R3#show interface serial 0/0 | include BW
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
R3#show interface serial 0/1 | include BW
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
```

Notice that the bandwidth of the serial link between R3 and R1 (S0/0/0) is set to 64 Kb/s, while the bandwidth of the serial link between R3 and R2 (S0/0/1) is set to 128 Kb/s.

e. Confirm that R3 has a valid route to reach R1 from its serial 0/0/0 interface using the show ipeigrp topology 192.168.1.0 command.

```
R3#show ip eigrp topology 192.168.1.0
IP-EIGRP (AS 1): Topology entry for 192.168.1.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 21152000
  Routing Descriptor Blocks:
  172.16.23.2 (Serial0/1), from 172.16.23.2, Send flag is 0x0
      Composite metric is (21152000/20640000), Route is Internal
      Vector metric:
        Minimum bandwidth is 128 Kbit
        Total delay is 45000 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
  172.16.13.1 (Serial0/0), from 172.16.13.1, Send flag is 0x0
      Composite metric is (40640000/128256), Route is Internal
      Vector metric:
        Minimum bandwidth is 64 Kbit
        Total delay is 25000 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 1
```

As indicated, R4 has two routes to reach 192.168.1.0. However, the metric for the route to R1 (172.16.13.1) is much higher (40640000) than the metric of the route to R2 (21152000), making the route through R2 the successor route.

Step 6: Configure PBR to provide path control.

Now you will deploy source-based IP routing by using PBR. You will change a default IP routing decision based on the EIGRP-acquired routing information for selected IP source-to-destination flows and apply a different next-hop router.

Recall that routers normally forward packets to destination addresses based on information in their routing table. By using PBR, you can implement policies that selectively cause packets to take different paths based on source address, protocol type, or application type. Therefore, PBR overrides the router's normal routing behavior. Configuring PBR involves configuring a route map with match and set commands and then applying the route map to the interface.

The steps required to implement path control include the following:

- Choose the path control tool to use. Path control tools manipulate or bypass the IP routing
- table. For PBR, route-map commands are used.
- Implement the traffic-matching configuration, specifying which traffic will be manipulated.
- The match commands are used within route maps.
- Define the action for the matched traffic using set commands within route maps.
- Apply the route map to incoming traffic.

As a test, you will configure the following policy on router R3:

- All traffic sourced from R4 LAN A must take the R3 --> R2 --> R1 path.
- All traffic sourced from R4 LAN B must take the R3 --> R1 path.

a. On router R3, create a standard access list called PBR-ACL to identify the R4 LAN B network.

```
R3(config)#ip access-list standard PBR-ACL
R3(config-std-nacl)#remark ACL matches R4 LAN B traffic
R3(config-std-nacl)#permit 192.168.4.128 0.0.0.127
R3(config-std-nacl)#exit
```

b. Create a route map called R3-to-R1 that matches PBR-ACL and sets the next-hop interface to the R1 serial 0/0/1 interface.

c. Apply the R3-to-R1 route map to the serial interface on R3 that receives the traffic from R4. Use the ip policy route-map command on interface S0/1/0.

```
R3(config)#route-map R3-to-R1 permit
R3(config-route-map)#description RM to forward LAN B traffic to R1
R3(config-route-map)#match ip address PBR-ACL
R3(config-route-map)#set ip next-hop 172.16.13.1
R3(config-route-map)#exit
R3(config)#interface s0/2
R3(config-if)#ip policy route-map R3-to-R1
R3(config-if)#end
```

d. On R3, display the policy and matches using the show route-map command.

```
R3#show route-map
route-map R3-to-R1, permit, sequence 10
  Match clauses:
    ip address (access-lists): PBR-ACL
  Set clauses:
    ip next-hop 172.16.13.1
  Policy routing matches: 0 packets, 0 bytes
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
```

Note: There are currently no matches because no packets matching the ACL have passed through R3

S0/1/0.

Step 7: Test the policy.

Now you are ready to test the policy configured on R3. Enable the debug ip policy command on R3 so that you can observe the policy decision-making in action. To help filter the traffic, first create a standard ACL that identifies all traffic from the R4 LANs.

a. On R3, create a standard ACL which identifies all of the R4 LANs.

```
  Policy routing matches: 0 packets, 0 bytes
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#access-list 1 permit 192.168.4.0 0.0.0.255
R3(config)#exit
R3#
*Mar  1 00:58:15.151: %SYS-5-CONFIG_I: Configured from console by console
R3#debug ip policy ?
  dynamic  dynamic PBR

R3#debug ip policy ?
  dynamic  dynamic PBR

R3#debug ip policy 1
Policy routing debugging is on for access list 1
```

c. Test the policy from R4 with the traceroute command, using R4 LAN A as the source network.

```
R4#traceroute 192.168.1.1 source 192.168.4.1

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 0 msec 0 msec 8 msec
  2 172.16.23.2 8 msec 0 msec 0 msec
  3 172.16.12.1 0 msec 0 msec 0 msec
```

Notice the path taken for the packet sourced from R4 LAN A is still going through R3 --> R2 --> R1.

As the traceroute was being executed, router R3 should be generating the following debug output.

```
R3#
*Mar  1 00:59:47.055: IP: s=192.168.4.1 (Serial0/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Mar  1 00:59:47.055: IP: s=192.168.4.1 (Serial0/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Mar  1 00:59:47.055: IP: s=192.168.4.1 (Serial0/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Mar  1 00:59:47.055: IP: s=192.168.4.1 (Serial0/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Mar  1 00:59:47.067: IP: s=192.168.4.1 (Serial0/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
R3#
```

Why is the traceroute traffic not using the R3 --> R1 path as specified in the R3-to-R1 policy? It does not take the PBR-specified path because LAN A does not meet the criteria specified in the PBR-ACL access list.

d. Test the policy from R4 with the traceroute command, using R4 LAN B as the source network.

```
R4#traceroute 192.168.1.1 source 192.168.4.129

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 40 msec 24 msec 20 msec
  2 172.16.23.2 36 msec 0 msec 0 msec
  3 172.16.12.1 0 msec 0 msec 0 msec
```

Now the path taken for the packet sourced from R4 LAN B is R3 --> R1, as expected.

The debug output on R3 also confirms that the traffic meets the criteria of the R3-to-R1 policy.

```
R3#
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, len 28, FIB policy match
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, len 28, FIB policy match
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, len 28, FIB policy match
*Mar  1 01:01:17.715: IP: s=192.168.4.129 (Serial0/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
```

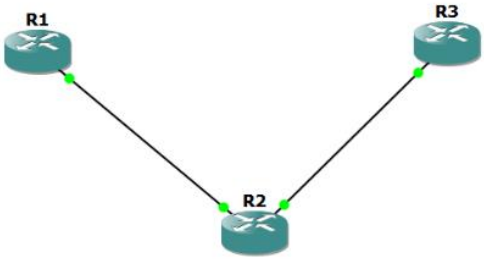
e. On R3, display the policy and matches using the show route-map command.

```
R3#show route-map
route-map R3-to-R1, permit, sequence 10
  Match clauses:
    ip address (access-lists): PBR-ACL
  Set clauses:
    ip next-hop 172.16.13.1
  Policy routing matches: 3 packets, 96 bytes
R3#
```

Note: There are now matches to the policy because packets matching the ACL have passed through R3 S0/1/0.

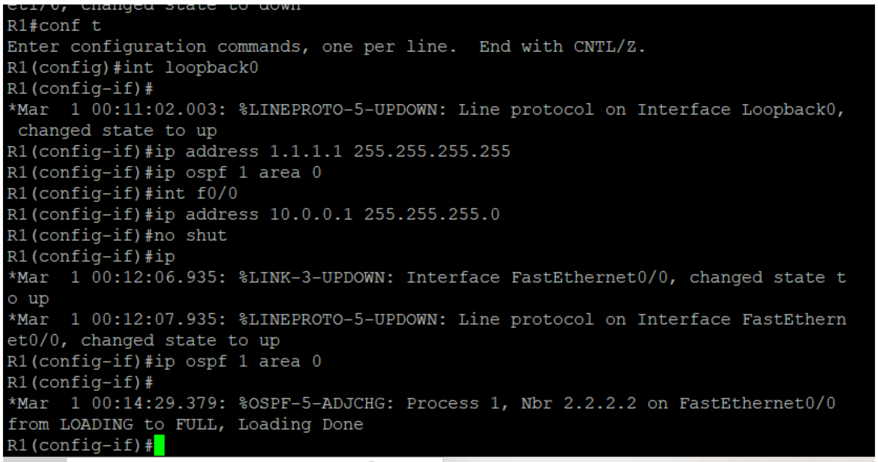
PRACTICAL 6

Aim:- Simulating MPLS Environment



Steps 1-IP addressing of MPLS Core and OSPF. First bring 3 routers into your topology R1, R2, R4 position them as below. We are going to address the routers and configure ospf to ensure loopback to loopback connectivity between R1 and R3.

R1 Router



```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int loopback0
R1(config-if)#
*Mar  1 00:11:02.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
R1(config-if)#ip address 1.1.1.1 255.255.255.255
R1(config-if)#ip ospf 1 area 0
R1(config-if)#int f0/0
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#ip
*Mar  1 00:12:06.935: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
*Mar  1 00:12:07.935: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to up
R1(config-if)#ip ospf 1 area 0
R1(config-if)#
*Mar  1 00:14:29.379: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0
from LOADING to FULL, Loading Done
R1(config-if)#
```

R2 Router

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int loopback0
R2(config-if)#
*Mar  1 00:12:38.071: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
R2(config-if)#ip address 2.2.2.2 255.255.255.255
R2(config-if)#ip ospf 1 area 0
R2(config-if)#exit
R2(config)#int f0/0
R2(config-if)#ip address 10.0.0.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#i
*Mar  1 00:14:15.599: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
*Mar  1 00:14:16.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
*Mar  1 00:14:27.251: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0
from LOADING to FULL, Loading Done
R2(config-if)#exit
R2(config)#int f0/1
R2(config-if)#ip address 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#
*Mar  1 00:15:02.967: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state t
o up
*Mar  1 00:15:03.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
*Mar  1 00:17:33.543: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on FastEthernet0/1
from LOADING to FULL, Loading Done
R2(config-if)#
```

R3 Router

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int loopback0
R3(config-if)#
*Mar  1 00:15:40.627: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
R3(config-if)#ip address 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 area 0
R3(config-if)#exit
R3(config)#int f0/0
R3(config-if)#ip address 10.0.1.3 255.255.255.0
R3(config-if)#no shut
R3(config-if)#ip os
*Mar  1 00:16:38.547: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state t
o up
*Mar  1 00:16:39.547: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to up
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
*Mar  1 00:17:35.739: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0
from LOADING to FULL, Loading Done
```

You should now have full ip connectivity between R1, R2, R4 to verify this we need to see if we can ping between the loopbacks of R1 and R4.

```
R1#ping 3.3.3.3 source loopback 0

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 3.3.3.3, timeout is 2 seconds:
Packet sent with a source address of 1.1.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/65/80 ms
```

You could show the routing table here, but the fact that you can ping between the loopbacks is verification enough and it is safe to move on.

Step 2 – Configure LDP on all the interfaces in the MPLS Core In order to run MPLS you need to enable it, there are two ways to do this. At each interface enter the mpls ip command. Under the ospf process use the mpls ldp autoconfig command For this tutorial we will be using the second option, so go int the ospf process and enter mpls ldp autoconfig – this will enable mpls label distribution protocol on every interface running ospf under that specific process.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#mpls ldp autoconfig
                          ^
% Invalid input detected at '^' marker.

R1(config-router)#mpls ldp autoconfig
```

```
R2(config)#router ospf 1
R2(config-router)#mpls ldp autoconfig
R2(config-router)#
*Mar  1 00:23:44.319: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
R2(config-router)#
```

```
R3(config)#router ospf 1
R3(config-router)#mpls ldp autoconfig
R3(config-router)#
*Mar  1 00:24:50.587: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
R3(config-router)#
```

You should see log messages coming up showing the LDP neighbors are up. To verify the mpls interfaces the command is very simple – sh mpls interface. This is done on R2 and you can see that both interfaces are running mpls and using LDP.

```
*Mar  1 00:25:32.899: %SYS-5-CONFIG_I: Configured from console by c
R2#sh mpls interface
Interface              IP            Tunnel   Operational
FastEthernet0/0        Yes (ldp)     No       Yes
FastEthernet0/1        Yes (ldp)     No       Yes
R2#
```

You can also verify the LDP neighbors with the sh mpls ldp neighbors command.

```
R2#sh mpls ldp neigh
    Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 1.1.1.1.646 - 2.2.2.2.30501
        State: Oper; Msgs sent/rcvd: 11/11; Downstream
        Up time: 00:03:08
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 10.0.0.1
        Addresses bound to peer LDP Ident:
          10.0.0.1        1.1.1.1
    Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 3.3.3.3.33929 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 10/10; Downstream
        Up time: 00:02:04
        LDP discovery sources:
          FastEthernet0/1, Src IP addr: 10.0.1.3
        Addresses bound to peer LDP Ident:
          10.0.1.3        3.3.3.3
```

One more verification to confirm LDP is running ok is to do a trace between R1 and R3 and verify if you get MPLS Labels show up in the trace

```
*Mar  1 00:27:39.891: %SYS-5-CONFIG_I: Configured from console
R1#trace 3.3.3.3

Type escape sequence to abort.
Tracing the route to 3.3.3.3

  1 10.0.0.2 [MPLS: Label 17 Exp 0] 52 msec 96 msec 60 msec
  2 10.0.1.3 60 msec 56 msec 64 msec
```

As you can see the trace to R2 used an MPLS Label in the path, as this is a very small MPLS core only one label was used as R3 was the final hop. So, to review we have now configured IP addresses on the MPLS core, enabled OSPF and full IP connectivity between all routers and finally enabled mpls on all the interfaces in the core and have established ldp neighbors between all routers. The next step is to configure MP-BGP between R1 and R3. This is when you start to see the layer 3 vpn configuration come to life. Step 3 – MPLS BGP Configuration between R1 and R4. We need to establish a Multi-Protocol BGP session between R1 and R4 this is done by configuring the vpnv4 address family as below.

```
  2 10.0.1.3 60 msec 56 msec 64 msec
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router bgp 1
R1(config-router)#neighbor 3.3.3.3 remote-as 1
R1(config-router)#neighbor 3.3.3.3 update-source loopback0
R1(config-router)#no auto-summary
R1(config-router)#address-family vpnv4
R1(config-router-af)#neighbor 3.3.3.3 active
                                          ^
% Invalid input detected at '^' marker.

R1(config-router-af)#neighbor 3.3.3.3 activate
```

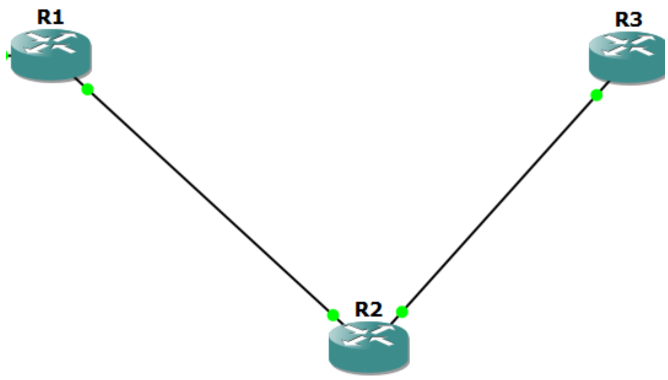
```
R3(config)#router bgp 1
R3(config-router)#neighbor 1.1.1.1 remote-as 1
R3(config-router)#neighbor 1.1.1.1 up
*Mar  1 00:31:45.023: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
R3(config-router)#neighbor 1.1.1.1 update-source
% Incomplete command.

R3(config-router)#neighbor 1.1.1.1 update-source
% Incomplete command.

R3(config-router)#neighbor 1.1.1.1 update-source loopback0
R3(config-router)#no auto-summary
R3(config-router)#address-family vpnv4
R3(config-router-af)#neighbor 1.1.1.1 activate
R3(config-router-af)#
*Mar  1 00:33:17.651: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Down Address family activated
R3(config-router-af)#
*Mar  1 00:33:19.807: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
R3(config-router-af)#
```

You should see log messages showing the BGP sessions coming up. To verify the BGP session between R1 and R4 issue the command sh bgp vpnv4 unicast all summary.

```
R1#sh bgp vpnv4 unicast all summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
3.3.3.3         4     1       9       9        1    0    0 00:01:17        0
R1#
```

Practical-7

Aim-Simulating VRF.



Step 1 – IP addressing of MPLS Core and OSPF.

First bring 3 routers into your topology R1, R2, R3 position them as below. We are going to address the routers and configure ospf to ensure loopback to loopback connectivity between R1 and R3.

R1 Router-

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface loopback 0
R1(config-if)#
*Mar  1 00:00:43.631: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 1.1.1.1 255.255.255.255
R1(config-if)#ip ospf 1 area 0
R1(config-if)#exit
R1(config)#interface f0/0
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#
*Mar  1 00:02:03.127: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:02:04.127: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config-if)#ip ospf 1 area 0
R1(config-if)#do write
Building configuration...
[OK]
R1(config-if)#
R1(config-if)#
*Mar  1 00:05:23.847: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading Done
R1(config-if)#
```

R2 Router-

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#interface loopback0
R2(config-if)#
*Mar  1 00:01:59.531: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip address 2.2.2.2 255.255.255.255
R2(config-if)#ip ospf 1 area 0
R2(config-if)#exit
R2(config)#interface f0/0
R2(config-if)#ip address 10.0.0.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#
*Mar  1 00:03:24.531: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:25.531: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#exit
R2(config)#
*Mar  1 00:04:01.183: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
R2(config)#interface f0/1
R2(config-if)#ip address 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#
*Mar  1 00:04:49.203: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:04:50.203: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
*Mar  1 00:07:53.007: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on FastEthernet0/1 from LOADING to FULL, Loading Done
R2(config-if)#
```

```
R2(config-if)#no shutdown
R2(config-if)#
*Mar  1 00:05:56.595: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state
to up
*Mar  1 00:05:57.595: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEther
net0/1, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
```

Router R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#interface loopback0
R3(config-if)#ip
*Mar  1 00:02:45.223: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip address 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 area 0
R3(config-if)#exit
R3(config)#interface f0/0
R3(config-if)#ip address 10.0.1.3 255.255.255.0
R3(config-if)#no shut
R3(config-if)#ip os
*Mar  1 00:03:59.819: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:04:00.819: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
*Mar  1 00:04:14.847: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading Done
R3(config-if)#do write
Building configuration...
[OK]
R3(config-if)#
```

You should now have full ip connectivity between R1, R2, R3 to verify this we need to see if we can ping between the loopbacks of R1 and R3.

```
R1#
*Mar  1 00:11:55.771: %SYS-5-CONFIG_I: Configured from console by console
R1#ping 3.3.3.3 source loopback0

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 3.3.3.3, timeout is 2 seconds:
Packet sent with a source address of 1.1.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/56/64 ms
R1#
```

You could show the routing table here, but the fact that you can ping between the loopbacks isverification enough and it is safe to move on.

Step 2 – Configure LDP on all the interfaces in the MPLS Core. In order to run MPLS you need toenable it, there are two ways to do this.

- At each interface enter the mpls ip command
- Under the ospf process use the mpls ldp autoconfig command.

For this tutorial we will be using the second option, so go int the ospf process and enter mpls ldpautoconfig – this will enable mpls label distribution protocol on every interface running ospf under that specific process.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#mpls 1dp autoconfig
                                 ^
% Invalid input detected at '^' marker.

R1(config-router)#mpls ldp autoconfig
R1(config-router)#
```

```
R2(config-if)#exit
R2(config)#router ospf 1
R2(config-router)#mpls ldp autoconfig
R2(config-router)#
*Mar  1 00:14:18.731: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
R2(config-router)#
```

```
R3(config-if)#exit
R3(config)#router ospf 1
R3(config-router)#mpls ldp autoconfig
R3(config-router)#
*Mar  1 00:12:09.751: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
R3(config-router)#
```

You should see log messages coming up showing the LDP neighbors are up. To verify the mpls interfaces the command is very simple – sh mpls interface. This is done on R2 and you can see that both interfaces are running mpls and using LDP.

```
R2#sh mpls interface
Interface              IP            Tunnel   Operational
FastEthernet0/0        Yes (ldp)     No       Yes
FastEthernet0/1        Yes (ldp)     No       Yes
R2#
```

You can also verify the LDP neighbors with the **sh mpls ldp** neighbors command.

```
R2#sh mpls ldp neigh
    Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 1.1.1.1.646 - 2.2.2.2.20216
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:03:34
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 10.0.0.1
        Addresses bound to peer LDP Ident:
          10.0.0.1        1.1.1.1
    Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 3.3.3.3.22413 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 10/10; Downstream
        Up time: 00:02:05
        LDP discovery sources:
          FastEthernet0/1, Src IP addr: 10.0.1.3
        Addresses bound to peer LDP Ident:
          10.0.1.3        3.3.3.3
R2#
```

One more verification to confirm LDP is running ok is to do a trace between R1 and R3 and verify if you get MPLS Labels show up in the trace.

```
R1#trace 3.3.3.3

Type escape sequence to abort.
Tracing the route to 3.3.3.3

  1 10.0.0.2 [MPLS: Label 17 Exp 0] 96 msec 220 msec 184 msec
  2 10.0.1.3 156 msec 268 msec 232 msec
R1#
```

As you can see the trace to R2 used an MPLS Label in the path, as this is a very small MPLS core only one label was used as R3 was the final hop. So, to review we have now configured IP addresses on the MPLS core, enabled OSPF and full IP connectivity between all routers and finally enabled mpls on all the interfaces in the core and have established ldp neighbors between all routers. The next step is to configure MP-BGP between R1 and R3. This is when you start to see the layer 3 vpn configuration come to life.

Step 3 – MPLS BGP Configuration between R1 and R3.

We need to establish a Multi-Protocol BGP session between R1 and R3 this is done by configuring thevpnv4 address family as below.

```
R1(config)#router bgp 1
R1(config-router)#neighbor 3.3.3.3 remote-as 1
R1(config-router)#neighbor 3.3.3.3 update-source loopback
% Incomplete command.

R1(config-router)#neighbor 3.3.3.3 update-source loopback0
R1(config-router)#no auto-summary
R1(config-router)#address-family vpnv4
R1(config-router-af)#neighbor 3.3.3.3 activate
R1(config-router-af)#
```

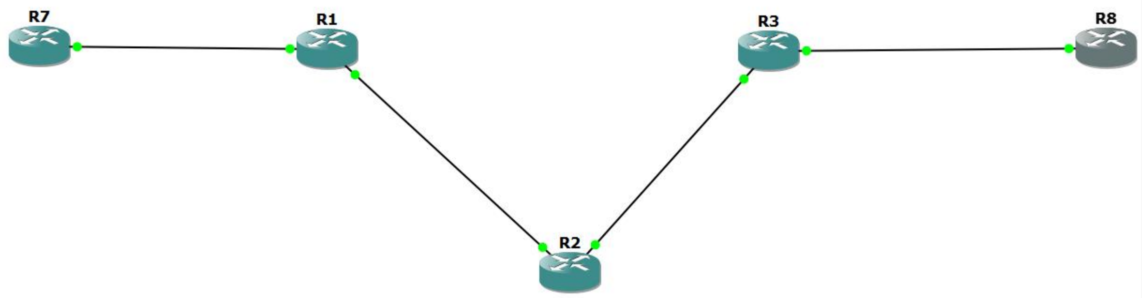
```
R3(config)#router bgp 1
R3(config-router)#neighbor 1.1.1.1 remote-as 1
R3(config-router)#neighbor 1.1.1.1 update-source
*Mar  1 00:19:32.263: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
R3(config-router)#neighbor 1.1.1.1 update-source loopback0
R3(config-router)#no auto-summary
R3(config-router)#address-family vpnv4
R3(config-router-af)#neighbor 1.1.1.1 activate
R3(config-router-af)#
*Mar  1 00:20:29.623: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Down Address family activated
R3(config-router-af)#
*Mar  1 00:20:31.775: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
R3(config-router-af)#
```

You should see log messages showing the BGP sessions coming up. To verify the BGP session betweenR1 and R3 issue the command sh bgp vpnv4 unicast all summary.

```
R1#sh bgp vpnv4 unicast all summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRc
d
3.3.3.3         4     1       8       8        1    0    0 00:01:26        0
R1#
```

You can see here that we do have a bgp vpnv4 peering to R3 – looking at the PfxRcd you can see it says0 this is because we have not got any routes in BGP. We are now going to add two more routers to the topology. These will be the customer sites connected to R1 and R3. We will then create a VRF on each router and put the interfaces connected to each site router into that VRF.

Step 4 – Add two more routers, create VRFs. We will add two more routers into the topology so it now looks like the final topology.



Note-In Place of R4 router I am assume R7 And Instead of R5 is R8.

```
R7#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R7(config)#interface loopback0
R7(config-if)#
*Mar  1 00:08:12.243: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to upi
R7(config-if)#ip address 4.4.4.4 255.255.255.255
R7(config-if)#ip ospf 2 area 2
R7(config-if)#exit
R7(config)#interface f0/0
R7(config-if)#ip address 192.168.1.4 255.255.255.0
R7(config-if)#ip ospf 2 area 2
R7(config-if)#no shut
R7(config-if)#
*Mar  1 00:10:01.179: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:10:02.179: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R7(config-if)#
```

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface f0/1
R1(config-if)#no shut
R1(config-if)#ip ad
*Mar  1 00:49:36.499: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:49:37.499: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#
```

Now at this point we have R4 peering to R1 but in the global routing table of R1 which is not what we

want. We are now going to start using VRF's. What is a VRF in networking? Virtual routing and forwarding (VRF) is a technology included in IP (Internet Protocol) that allows multiple instances of a routing table to co-exist in a router and work together but not interfere with each other. This increases functionality by allowing network paths to be segmented without using multiple devices. As an example, if R1 was a PE Provider Edge router of an ISP and it had two customers that were both addressed locally with the 192.168.1.0/24 address space it could accommodate both their routing tables in different VRFs – it distinguishes between the two of them using a Route Distinguisher So back to the topology – we now need to create a VRF on R1.

```
R1(config)#interface f0/1
R1(config-if)#no shut
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#
```

The RD and route-target do not need to be the same.

So now we have configured the VRF on R1 we need to move the interface F0/1 into that VRF.

```
R1(config)#interface f0/1
R1(config-if)#no shutdown
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#exit
R1(config)#interface f0/1
R1(config-if)#no shutdown
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#exit
R1(config)#interface f0/1
R1(config-if)#ip vrf forwarding RED
% Interface FastEthernet0/1 IP address 192.168.1.1 removed due to enabling VRF
RED
R1(config-if)#
```

Now notice what happens when you do that – the IP address is removed You just need to re-apply it.

```
R1(config)#interface f0/1
R1(config-if)#no shutdown
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#exit
R1(config)#interface f0/1
R1(config-if)#ip vrf forwarding RED
R1(config-if)#exit
R1(config)#interface f0/1
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#
```

Now if we view the config on R1 int f0/1 you can see the VRF configured.

```
R1#sh run int f0/1
Building configuration...

Current configuration : 96 bytes
!
interface FastEthernet0/1
 ip vrf forwarding RED
 no ip address
 duplex auto
 speed auto
end

R1#
```

Now we can start to look int VRF's and how they operate – you need to understand now that there are 2routing tables within R1.

```
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

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 10.0.0.2, 00:55:37, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/21] via 10.0.0.2, 00:51:45, FastEthernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
O       10.0.1.0 [110/20] via 10.0.0.2, 00:54:25, FastEthernet0/0
R1#
```

If you now issue the command sh ip route vrf red – this will show the routes in the routing table for VRF RED.

```
R1#sh ip route vrf red
% IP routing table red does not exist
R1#
```

Note The VRF name is case sensitive!

```
R1#sh ip route vrf red
% IP routing table red does not exist
R1#
R1#sh ip route vrf RED

Routing Table: RED
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

C    192.168.1.0/24 is directly connected, FastEthernet0/1
R1#
```

We just need to enable OSPF on this interface and get the loopback address for R4 in the VRF RED routing table before proceeding. You should see a log message showing the OSPF neighbor come up.

```
R1#config t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface f0/1
R1(config-if)#ip ospf 2 area 2
R1(config-if)#
*Mar  1 00:20:25.951: %OSPF-5-ADJCHG: Process 2, Nbr 4.4.4.4 on FastEthernet0/
 from LOADING to FULL, Loading Done
R1(config-if)#
```

If we now check the routes in the VRF RED routing table you should see 4.4.4.4 in there as well.

```
R1#sh ip route vrf RED

Routing Table: RED
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

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.1.4, 00:00:35, FastEthernet0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/1
R1#
```

We now need to repeat this process for R3 & R5. Router 5 will peer OSPF using process number 2 to a VRF configured on R3. It will use the local site addressing of 192.168.2.0/24.

```
R8#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R8(config)#interface loopback0
R8(config-if)#
*Mar  1 00:15:33.403: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R8(config-if)#ip address 6.6.6.6 255.255.255.255
R8(config-if)#ip ospf 2 area 2
R8(config-if)#exit
R8(config)#interface f0/0
R8(config-if)#ip address 192.168.2.6 255.255.255.0
R8(config-if)#ip ospf 2 area 2
R8(config-if)#no shut
R8(config-if)#
*Mar  1 00:17:10.895: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:17:11.895: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R8(config-if)#
```

```
R3(config)#interface f0/1
R3(config-if)#no shut
R3(config-if)#ip addre
*Mar  1 01:04:28.411: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 01:04:29.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R3(config-if)#ip address 192.168.2.3 255.255.255.0
R3(config-if)#
```

We also need to configure a VRF onto R3 as well.

```
R3(config)#interface f0/1
R3(config-if)#no shut
R3(config-if)#ip address 192.168.2.3 255.255.255.0
R3(config-if)#exit
R3(config)#interface f0/1
R3(config-if)#no shut
R3(config-if)#ip address 192.168.2.3 255.255.255.0
R3(config-if)#ip vrf RED
R3(config-vrf)#rd 4:4
R3(config-vrf)#route-taregt both 4:4
                         ^
% Invalid input detected at '^' marker.

R3(config-vrf)#route-target both 4:4
R3(config-vrf)#
```

So now we have configured the VRF on R3 we need to move the interface F0/1 into that VRF.

```
R3(config)#interface f0/1
R3(config-if)#ip address 192.168.2.3 255.255.255.0
R3(config-if)#ip vrf RED
R3(config-vrf)#rd 4:4
R3(config-vrf)#route-target both 4:4
R3(config-vrf)#interface f0/1
R3(config-if)#ip vrf forwarding RED
% Interface FastEthernet0/1 IP address 192.168.2.3 removed due to enabling VRF RED
R3(config-if)#exit
R3(config)#interface f0/1
R3(config-if)#ip vrf forwarding RED
R3(config-if)#ip address 192.168.2.1 255.255.255.0
R3(config-if)#exit
R3(config)#
```

Now if we view the config on R3 int f0/1 you can see the VRF configured.

```
R3(config)#interface f0/1
R3(config-if)#ip address 192.168.2.1 255.255.255.0
R3(config-if)#exit
R3(config)#exit
R3#
*Mar  1 01:16:42.563: %SYS-5-CONFIG_I: Configured from console by console
R3#sh run int f0/1
Building configuration...

Current configuration : 119 bytes
!
interface FastEthernet0/1
 ip vrf forwarding RED
 ip address 192.168.2.1 255.255.255.0
 duplex auto
 speed auto
end

R3#
```

Finally, we just need to enable OSPF on that interface and verify the routes are in the RED routing table.

```
R3(config)#interface f0/1
R3(config-if)#ip ospf 2 area 2
R3(config-if)#
*Mar  1 01:18:38.011: %OSPF-5-ADJCHG: Process 2, Nbr 6.6.6.6 on FastEthernet0/1 from LOADING to FULL, Loading Done
R3(config-if)#
```

Check the routes in vrf RED.

```
R3#sh ip route vrf RED

Routing Table: RED
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

     6.0.0.0/32 is subnetted, 1 subnets
O       6.6.6.6 [110/11] via 192.168.2.6, 00:00:58, FastEthernet0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/1
R3#
```

R1, R2, R3 form the MPLS Core and are running OSPF with all loopbacks running a /32 address and all have full connectivity. R1 and R3 are peering with MP-BGP.

LDP is enabled on all the internal interfaces. The external interfaces of the MPLS core have been placed into a VRF called RED and then a site router has been joined to that VRF on each side of the MPLS core – (These represent a small office) The final step to get full connectivity across the MPLS core is to redistribute the routes in OSPF on R1 and R3 into MP-BGP and MP-BGP into OSPF, this is what we are going to do now. We need to redistribute the OSPF routes from R4 into BGP in the VRF on R1, the OSPF routes from R6 into MP-BGP in the VRF on R3 and then the routes in MP-BGP in R1 and R3 back out to OSPF .

Before we start let's do some verifications. Check the routes on R4.

```
R7#
*Mar  1 00:50:16.931: %SYS-5-CONFIG_I: Configured from console by console
R7#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

     4.0.0.0/32 is subnetted, 1 subnets
C       4.4.4.4 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
R7#
```

As expected, we have the local interface and the loopback address. When we are done, we want to see 6.6.6.6 in there so we can ping across the MPLS Check the routes on R1.

```
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

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 10.0.0.2, 01:23:38, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/21] via 10.0.0.2, 01:19:46, FastEthernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
O       10.0.1.0 [110/20] via 10.0.0.2, 01:22:26, FastEthernet0/0
R1#
```

Remember we have a VRF configured on this router so this command will show routes in the global routing table (the MPLS Core) and it will not show the 192.168.1.0/24 route as that is in VRF RED – to see that we run the following command.

```
R1#sh ip route vrf RED

Routing Table: RED
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

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.1.4, 00:38:16, FastEthernet0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/1
R1#
```

Here you can see Routing Table: RED is shown and the routes to R4 are now visible with 4.4.4.4 being in OSPF. So, we need to do the following;

- Redistribute OSPF into MP-BGP on R1.
- Redistribute MP-BGP into OSPF on R3.
- Redistribute OSPF into MP-BGP on R3.
- Redistribute MP-BGP into OSPF on R3.

- Redistribute OSPF into MP-BGP on R1.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router bgp 1
R1(config-router)#address-family ipv4 vrf RED
R1(config-router-af)#redistribute ospf 2
R1(config-router-af)#
```

Redistribute OSPF into MP-BGP on R3.

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router bgp 1
R3(config-router)#address-family ipv4 vrf RED
R3(config-router-af)#redistribute ospf 2
R3(config-router-af)#
```

This has enabled redistribution of the OSPF routes into BGP. We can check the routes from R4 and R6 are now showing in the BGP table for their VRF with this command **sh ip bgp vpnv4 vrf RED.**

```
R1#sh ip bgp vpnv4 vrf RED
BGP table version is 9, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
*> 4.4.4.4/32       192.168.1.4             11         32768 ?
*>i6.6.6.6/32       3.3.3.3                 11    100      0 ?
*> 192.168.1.0      0.0.0.0                  0         32768 ?
*>i192.168.2.0      3.3.3.3                  0    100      0 ?
R1#
```

Here we can see that 4.4.4.4 is now in the BGP table in VRF RED on R1 with a next hop of 192.168.1.4(R4) and also 6.6.6.6 is in there as well with a next hop of 3.3.3.3 (which is the loopback of R3 –showing that it is going over the MPLS and R1 is not in the picture). The same should be true on R3.

```
R3#sh ip bgp vpnv4 vrf RED
BGP table version is 9, local router ID is 3.3.3.3
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
*>i4.4.4.4/32       1.1.1.1                 11    100      0 ?
*> 6.6.6.6/32       192.168.2.6             11         32768 ?
*>i192.168.1.0      1.1.1.1                  0    100      0 ?
*> 192.168.2.0      0.0.0.0                  0         32768 ?
R3#
```

Which it is! 6.6.6.6 is now in the BGP table in VRF RED on R3 with a next hop of 192.168.2.6 (R6) and also 4.4.4 is in there as well with a next hop of 1.1.1.1 (which is the loopback of R1 – showing that it is going over the MPLS and R2 is not in the picture) The final step is to get the routes that have comeacross the MPLS back into OSPF and then we can get end to end connectivity.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 2
R1(config-router)#redistribute bgp 1 subnets
R1(config-router)#
```

```
R3(config)#
R3(config)#router ospf 2
R3(config-router)#redistribute bgp 1 subnets
R3(config-router)#
```

If all has worked, we should be now able to ping 6.6.6.6 from R4. Before we do let's see what the routing table looks like on R4.

```
R7#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

     4.0.0.0/32 is subnetted, 1 subnets
C       4.4.4.4 is directly connected, Loopback0
     6.0.0.0/32 is subnetted, 1 subnets
O IA    6.6.6.6 [110/21] via 192.168.1.1, 00:02:48, FastEthernet0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
O IA 192.168.2.0/24 [110/11] via 192.168.1.1, 00:02:48, FastEthernet0/0
R7#
```

Great we have 6.6.6.6 in there Also **check the routing table on R5.**

```
R8#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

     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/21] via 192.168.2.1, 00:01:42, FastEthernet0/0
     6.0.0.0/32 is subnetted, 1 subnets
C       6.6.6.6 is directly connected, Loopback0
O IA 192.168.1.0/24 [110/11] via 192.168.2.1, 00:01:42, FastEthernet0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
R8#
```

Brilliant we have 4.4.4.4 in there so we should be able to ping across the MPLS.

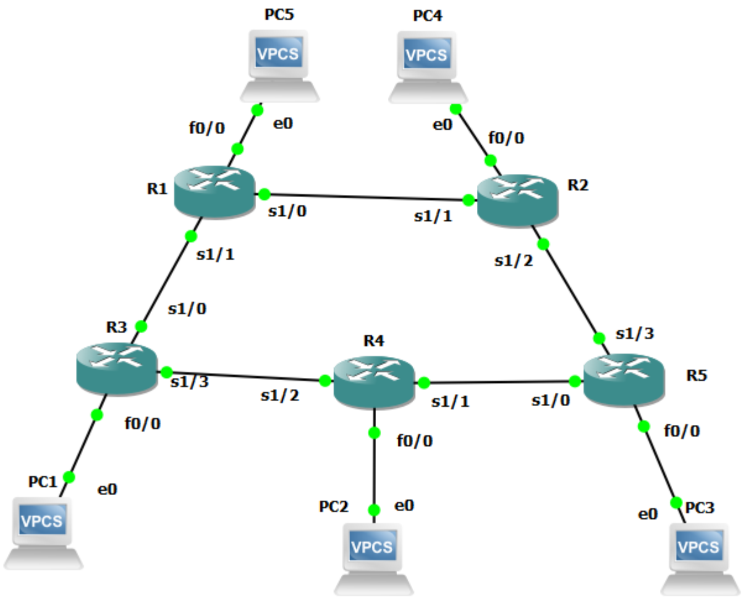
```
R7#
R7#ping 6.6.6.6

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 6.6.6.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 876/1000/1124 ms
R7#
```

Which we can – to prove this is going over the MPLS and be label switched and not routed, let's do a trace.

```
R7#trace 6.6.6.6

Type escape sequence to abort.
Tracing the route to 6.6.6.6

  1 192.168.1.1 172 msec 228 msec 300 msec
  2 10.0.0.2 [MPLS: Labels 17/19 Exp 0] 1076 msec 1080 msec 1316 msec
  3 192.168.2.1 [MPLS: Label 19 Exp 0] 664 msec 888 msec 716 msec
  4 192.168.2.6 808 msec 988 msec 876 msec
R7#
```

Practical 8

Aim – Configure Static Routing



Step 1 : Configuring interface and Assigning Ip Address

R1

```
R1(config)#interface s1/0
R1(config-if)#ip address 20.0.0.1 255.0.0.0
R1(config-if)#no shutdown
R1(config-if)#exit
```

```
R1(config)#interface s1/1
R1(config-if)#ip address 10.0.0.2 255.0.0.0
R1(config-if)#no shutdown
R1(config-if)#
```

```
R1(config)#interface f0/0
*Mar  1 00:36:22.579: %LINEPROTO-5-UPDOWN: Line
R1(config)#interface f0/0
R1(config-if)#ip address 60.0.0.1 255.0.0.0
R1(config-if)#no shutdown
```

```
R1#show ip interface brief | ex un
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        60.0.0.1        YES NVRAM  up                    up
Serial1/0              20.0.0.1        YES NVRAM  up                    down
Serial1/1              10.0.0.2        YES NVRAM  up                    down
R1#
```

R2

```
R2(config-if)#interface s1/1
R2(config-if)#ip address 20.0.0.2 255.0.0.0
R2(config-if)#no shutdown
R2(config-if)#exit
```

```
R2(config)#interface s1/2
R2(config-if)#ip address 30.0.0.1 255.0.0.0
R2(config-if)#no shutdown
R2(config-if)#exit
```

```
R2(config)#interface f0/0
R2(config-if)#ip address 70.0.0.1 255.0.0.0
R2(config-if)#no shutdown
R2(config-if)#exit
```

```
R2#show ip interface brief | ex un
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            70.0.0.1        YES manual up                    up
Serial1/1                  20.0.0.2        YES manual up                    up
Serial1/2                  30.0.0.1        YES manual up                    down
R2#
```

R3

```
R3(config)#interface s1/0
R3(config-if)#ip address 10.0.0.1 255.0.0.0
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#
```

```
R3(config)#interface s1/3
R3(config-if)#ip address 50.0.0.2 255.0.0.0
R3(config-if)#no shutdown
R3(config-if)#exit
```

```
R3(config)#interface f0/0
R3(config-if)#ip address 80.0.0.1 255.0.0.0
R3(config-if)#no shutdown
R3(config-if)#
```

```
R3#show ip interface brief | ex un
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            80.0.0.1        YES manual up                    up
Serial1/0                  10.0.0.1        YES manual up                    up
Serial1/3                  50.0.0.2        YES manual up                    down
R3#
```

R4

```
R4(config)#interface s1/1
R4(config-if)#ip address 40.0.0.2 255.0.0.0
R4(config-if)#no shutdown
R4(config-if)#exit
R4(config)#
```

```
R4(config)#interface s1/2
R4(config-if)#ip address 50.0.0.1 255.0.0.0
R4(config-if)#no shut down
*Mar  1 00:14:56.643: %LINEPROTO-5-UPDOWN: Li
R4(config-if)#no shutdown
R4(config-if)#exit
```

```
R4(config)#interface f0/0
R4(config-if)#ip address 90.0.0.1 255.0.0.0
R4(config-if)#no shutdown
R4(config-if)#exi
```

```
R4#show ip interface brief | ex un
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            90.0.0.1        YES manual up                    up
Serial1/1                  40.0.0.2        YES manual up                    down
Serial1/2                  50.0.0.1        YES manual up                    up
R4#
```

R5

```
R5(config)#interface s1/3
R5(config-if)#ip address 30.0.0.2 255.0.0.0
R5(config-if)#no shutdown
R5(config-if)#exit
R5(config)#
```

```
R5(config)#interface s1/0
R5(config-if)#ip address 40.0.0.1 255.0.0.0
R5(config-if)#no shutdown
R5(config-if)#exit
R5(config)#
```

```
R5(config)#interface f0/0
R5(config-if)#ip address 100.0.0.1 255.0.0.0
R5(config-if)#no shutdown
R5(config-if)#exit
```

```
*Mar  1 00:20:21.059: %SYS-5-CONFIG_I: Configured from console by console
R5#show ip interface brief | ex un
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            100.0.0.1       YES manual up                    up
Serial1/0                  40.0.0.1        YES manual up                    up
Serial1/3                  30.0.0.2        YES manual up                    up
R5#
```

Configuring gateway for pc1,2,3,4,5

```
PC1> ip 80.0.0.2 255.0.0.0 gateway 80.0.0.1
Checking for duplicate address...
PC1 : 80.0.0.2 255.0.0.0 gateway 80.0.0.1
```

```
PC2> ip 90.0.0.2 255.0.0.0 gateway 90.0.0.1
Checking for duplicate address...
PC1 : 90.0.0.2 255.0.0.0 gateway 90.0.0.1
```

```
PC3> ip 100.0.0.2 255.0.0.0 gateway 100.0.0.1
Checking for duplicate address...
PC1 : 100.0.0.2 255.0.0.0 gateway 100.0.0.1
```

```
PC4> ip 60.0.0.2 255.0.0.0 gateway 60.0.0.1
Checking for duplicate address...
PC1 : 60.0.0.2 255.0.0.0 gateway 60.0.0.1
```

```
PC5> ip 70.0.0.2 255.0.0.0 gateway 70.0.0.1
Checking for duplicate address...
PC1 : 70.0.0.2 255.0.0.0 gateway 70.0.0.1
```

Step 2: Configure Static routing in Router 1

```
R1(config)#ip forward-protocol nd
R1(config)#ip route 30.0.0.0 255.0.0.0 20.0.0.2
R1(config)#ip route 50.0.0.0 255.0.0.0 10.0.0.1
R1(config)#ip route 80.0.0.0 255.0.0.0 10.0.0.1
R1(config)#ip route 90.0.0.0 255.0.0.0 50.0.0.1
R1(config)#ip route 100.0.0.0 255.0.0.0 30.0.0.2
R1(config)#do show 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

S    50.0.0.0/8 [1/0] via 10.0.0.1
S    100.0.0.0/8 [1/0] via 30.0.0.2
S    80.0.0.0/8 [1/0] via 10.0.0.1
C    20.0.0.0/8 is directly connected, Serial1/0
C    10.0.0.0/8 is directly connected, Serial1/1
S    90.0.0.0/8 [1/0] via 50.0.0.1
C    60.0.0.0/8 is directly connected, FastEthernet0/0
S    30.0.0.0/8 [1/0] via 20.0.0.2
R1(config)#
```

Configure Static routing in Router 2

```
R2(config)#ip forward-protocol nd
R2(config)#ip route 10.0.0.0 255.0.0.0 20.0.0.1
R2(config)#ip route 80.0.0.0 255.0.0.0 10.0.0.1
R2(config)#ip route 50.0.0.0 255.0.0.0 10.0.0.1
R2(config)#ip route 90.0.0.0 255.0.0.0 50.0.0.1
R2(config)#ip route 100.0.0.0 255.0.0.0 30.0.0.2
R2(config)#ip route 40.0.0.0 255.0.0.0 30.0.0.2
R2(config)#do show 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

S    50.0.0.0/8 [1/0] via 10.0.0.1
S    100.0.0.0/8 [1/0] via 30.0.0.2
C    70.0.0.0/8 is directly connected, FastEthernet0/0
S    80.0.0.0/8 [1/0] via 10.0.0.1
C    20.0.0.0/8 is directly connected, Serial1/1
S    40.0.0.0/8 [1/0] via 30.0.0.2
S    10.0.0.0/8 [1/0] via 20.0.0.1
S    90.0.0.0/8 [1/0] via 50.0.0.1
C    30.0.0.0/8 is directly connected, Serial1/2
R2(config)#
```

Configure Static routing in Router 3

```
R3(config)#ip forward-protocol nd
R3(config)#ip route 60.0.0.0 255.0.0.0 10.0.0.2
R3(config)#ip route 20.0.0.0 255.0.0.0 10.0.0.2
R3(config)#ip route 70.0.0.0 255.0.0.0 20.0.0.2
R3(config)#ip route 30.0.0.0 255.0.0.0 20.0.0.2
R3(config)#ip route 90.0.0.0 255.0.0.0 50.0.0.1
R3(config)#ip route 40.0.0.0 255.0.0.0 50.0.0.1
R3(config)#ip route 100.0.0.0 255.0.0.0 40.0.0.1
R3(config)#do show 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

C    50.0.0.0/8 is directly connected, Serial1/3
S    100.0.0.0/8 [1/0] via 40.0.0.1
                 [1/0] via 30.0.0.2
S    70.0.0.0/8 [1/0] via 20.0.0.2
C    80.0.0.0/8 is directly connected, FastEthernet0/0
S    20.0.0.0/8 [1/0] via 10.0.0.2
S    40.0.0.0/8 [1/0] via 50.0.0.1
C    10.0.0.0/8 is directly connected, Serial1/0
S    90.0.0.0/8 [1/0] via 50.0.0.1
S    60.0.0.0/8 [1/0] via 10.0.0.2
S    30.0.0.0/8 [1/0] via 20.0.0.2
R3(config)#
```

Configure Static routing in Router 4

```
R4(config)#ip forward-protocol nd
R4(config)#ip route 80.0.0.0 255.0.0.0 50.0.0.2
R4(config)#ip route 10.0.0.0 255.0.0.0 50.0.0.2
R4(config)#ip route 60.0.0.0 255.0.0.0 10.0.0.2
R4(config)#ip route 20.0.0.0 255.0.0.0 10.0.0.2
R4(config)#ip route 100.0.0.0 255.0.0.0 40.0.0.1
R4(config)#ip route 30.0.0.0 255.0.0.0 40.0.0.1
R4(config)#ip route 70.0.0.0 255.0.0.0 30.0.0.1
R4(config)#do show 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

C    50.0.0.0/8 is directly connected, Serial1/2
S    100.0.0.0/8 [1/0] via 40.0.0.1
S    70.0.0.0/8 [1/0] via 30.0.0.1
S    80.0.0.0/8 [1/0] via 50.0.0.2
S    20.0.0.0/8 [1/0] via 10.0.0.2
C    40.0.0.0/8 is directly connected, Serial1/1
S    10.0.0.0/8 [1/0] via 50.0.0.2
C    90.0.0.0/8 is directly connected, FastEthernet0/0
S    60.0.0.0/8 [1/0] via 10.0.0.2
S    30.0.0.0/8 [1/0] via 40.0.0.1
R4(config)#
```

Configure Static routing in Router 5

```
R5(config)#ip forward-protocol nd
R5(config)#ip route 90.0.0.0 255.0.0.0 40.0.0.2
R5(config)#ip route 50.0.0.0 255.0.0.0 40.0.0.2
R5(config)#ip route 80.0.0.0 255.0.0.0 50.0.0.2
R5(config)#ip route 10.0.0.0 255.0.0.0 50.0.0.2
R5(config)#ip route 70.0.0.0 255.0.0.0 30.0.0.1
R5(config)#ip route 20.0.0.0 255.0.0.0 30.0.0.1
R5(config)#ip route 60.0.0.0 255.0.0.0 20.0.0.1
R5(config)#do show 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

S    50.0.0.0/8 [1/0] via 40.0.0.2
C    100.0.0.0/8 is directly connected, FastEthernet0/0
S    70.0.0.0/8 [1/0] via 30.0.0.1
S    80.0.0.0/8 [1/0] via 50.0.0.2
S    20.0.0.0/8 [1/0] via 30.0.0.1
C    40.0.0.0/8 is directly connected, Serial1/0
S    10.0.0.0/8 [1/0] via 50.0.0.2
S    90.0.0.0/8 [1/0] via 40.0.0.2
S    60.0.0.0/8 [1/0] via 20.0.0.1
C    30.0.0.0/8 is directly connected, Serial1/3
R5(config)#
```

Step 4 : Here we are checking the packet transfer only between PC5 and PC4

```
PC5> ping 70.0.0.2
70.0.0.2 icmp_seq=1 ttl=64 time=0.001 ms
70.0.0.2 icmp_seq=2 ttl=64 time=0.001 ms
70.0.0.2 icmp_seq=3 ttl=64 time=0.001 ms
70.0.0.2 icmp_seq=4 ttl=64 time=0.001 ms
70.0.0.2 icmp_seq=5 ttl=64 time=0.001 ms
```

Here we are checking the packet transfer only between PC1 and PC3

```
PC1> ping 100.0.0.2
84 bytes from 100.0.0.2 icmp_seq=1 ttl=61 time=105.701 ms
84 bytes from 100.0.0.2 icmp_seq=2 ttl=61 time=105.647 ms
84 bytes from 100.0.0.2 icmp_seq=3 ttl=61 time=106.054 ms
84 bytes from 100.0.0.2 icmp_seq=4 ttl=61 time=105.745 ms
84 bytes from 100.0.0.2 icmp_seq=5 ttl=61 time=106.300 ms

PC1>
```

Here we are checking the packet transfer only between router R1 to R4

```
R1#ping 30.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 30.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/58/64 ms
R1#
```

Here we are checking the packet transfer only between router R2 to R3

```
R2#ping 50.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 50.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/60/72 ms
R2#
```

Here we are checking the packet transfer only between router R3 to R2

```
R3#ping 30.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 30.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/59/60 ms
R3#
```

Here we are checking the packet transfer only between router R4 to R1

```
R4#ping 20.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/60/68 ms
R4#
```

Here we are checking the packet transfer only between router R5 to R3

```
R5#ping 50.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 50.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/60/68 ms
R5#
```