MODERN NETWORKING

A PRACTICAL REPORT
ON
MODERN NETWORKING

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UNDER THE GUIDANCE OF
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Department of Information Technology

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Certificate

This is to certify that Modern Networking Practicals performed at R.D & S.H National & S.W.A. Science College by Mr. **Mohd Kaif** holding Seat No. ________ studying Master of Science in Information Technology Semester – II has been satisfactorily completed as prescribed by the University of Mumbai, during the year 2022– 2023.

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College Stamp

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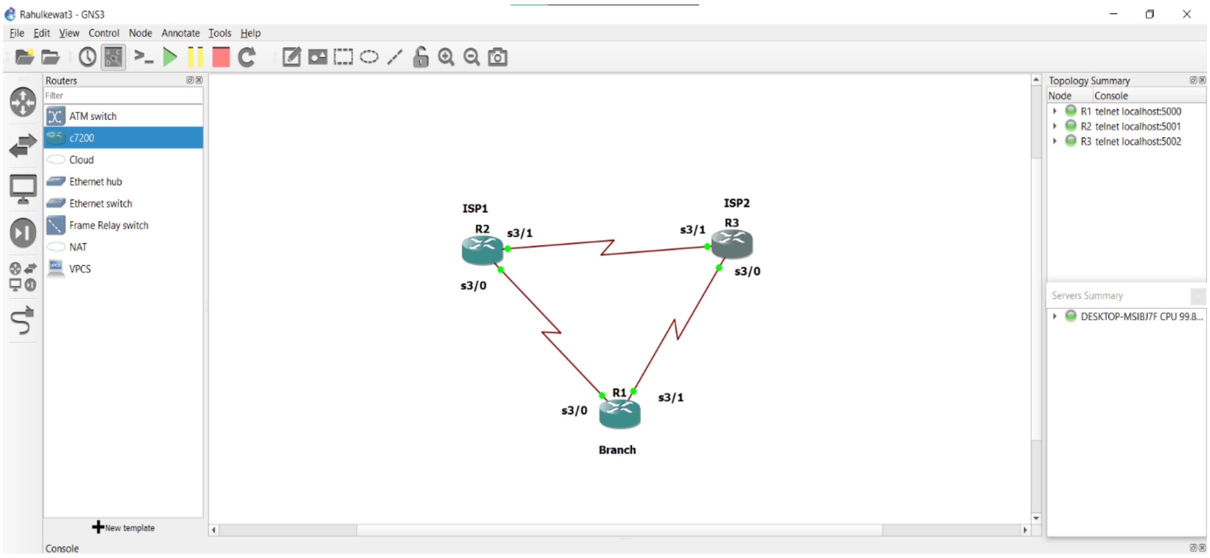
Practical 1

Aim: **Configure IP SLA Tracking and Path Control**

Writeup:

Step 0: Topology



Step 1:

Prepare the routers and configure the router hostname and interface addresses.

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

Router R1

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface Loopback 0
R1(config-if)#
*Mar 26 13:49:38.599: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial 3/0
R1(config-if)# description R1 --> ISP1
R1(config-if)# ip address 209.165.201.2 255.255.255.252
R1(config-if)# clock rate 128000
R1(config-if)# bandwidth 128
R1(config-if)# no shutdown
R1(config-if)#
R1(config-if)#interface Serial 3/1
R1(config-if)# description R1 --> ISP2
R1(config-if)# ip address 209.165.202.130 255.255.255.252
R1(config-if)# bandwidth 128
R1(config-if)# no shutdown
*Mar 26 13:52:01.207: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
```

Router ISP1 (R2)

```
ISP1(config)#interface Loopback0
ISP1(config-if)#description Simulated Internet Web Server
ISP1(config-if)#ip address 209.165.200.254 255.255.255.255
ISP1(config-if)#interface Loopback1
ISP1(config-if)#description ISP1 DNS Server
ISP1(config-if)#ip address 209.165.201.30 255.255.255.255
ISP1(config-if)#interface Serial 3/0
ISP1(config-if)# description ISP1 --> R1
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)#interface Serial 3/1
ISP1(config-if)# description ISP1 --> ISP2
ISP1(config-if)# ip address 209.165.200.225 255.255.255.252
ISP1(config-if)# clock rate 128000
ISP1(config-if)# bandwidth 128
ISP1(config-if)# no shutdown
*Mar 26 14:02:50.491: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
ISP1(config-if)# no shutdown
*Mar 26 14:02:51.499: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
ISP1(config-if)# no shutdown
*Mar 26 14:04:56.571: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP1(config-if)# no shutdown
```

Router ISP2 (R3)

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname ISP2
ISP2(config)#interface Loopback0
ISP2(config-if)# description Simulated Internet Web Server
ISP2(config-if)# ip address 209.165.200.254 255.255.255.255
ISP2(config-if)#
ISP2(config-if)#interface Loopback1
ISP2(config-if)# description ISP2 DNS Server
ISP2(config-if)# ip address 209.165.202.158 255.255.255.255
ISP2(config-if)#
ISP2(config-if)#interface Serial 3/0
ISP2(config-if)# description ISP2 --> R1
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)#
ISP2(config-if)#interface Serial 3/1
ISP2(config-if)# description ISP2 --> ISP1
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 26 14:04:49.467: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
*Mar 26 14:04:49.691: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
ISP2(config-if)#
*Mar 26 14:04:52.051: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
*Mar 26 14:04:52.191: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
ISP2(config-if)#
*Mar 26 14:04:53.059: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
*Mar 26 14:04:53.199: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP2(config-if)#
*Mar 26 14:05:16.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
ISP2(config-if)#
*Mar 26 14:09:46.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
```

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

R1# show interfaces description

```
R1#show interfaces description | include up
Se3/0                          up             up       R1 --> ISP1
Se3/1                          up             up       R1 --> ISP2
Lo0                            up             up
```

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 address pools.
• ISP1 and ISP2 both have static routes back to the ISP LAN.

Router R1
ip route 0.0.0.0 0.0.0.0 209.165.201.1

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1
```

Router ISP1 (R2)
router eigrp 1
network 209.165.200.224 0.0.0.3
network 209.165.201.0 0.0.0.31
no auto-summary
ip route 192.168.1.0 255.255.255.0 209.165.201.2

```
ISP1(config)#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)#exit
ISP1(config)#
ISP1(config)#end
ISP1#
*Mar 26 14:13:49.779: %SYS-5-CONFIG_I: Configured from console by console
ISP1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
ISP1(config)#ip route 192.168.1.0 255.255.255.0 209.165.201.2
```

Router ISP2 (R3)
router eigrp 1
network 209.165.200.224 0.0.0.3
network 209.165.202.128 0.0.0.31
no auto-summary
ip route 192.168.1.0 255.255.255.0 209.165.202.130

```
ISP2(config)#router eigrp 1
ISP2(config-router)#network 209.165.200.224 0.0.0.3
ISP2(config-router)#
*Mar 26 14:15:18.343: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 209.165.200.225 (Serial3/1) is up: new adjacency
ISP2(config-router)#network 209.165.202.128 0.0.0.31
ISP2(config-router)#no auto-summary
ISP2(config-router)# exit
ISP2(config)#
ISP2(config)#ip route 192.168.1.0 255.255.255.0 209.165.202.130
ISP2(config)#
```

Step 2:
Verify server reachability.

The Cisco IOS IP SLA feature enables an administrator to monitor network performance between Cisco devices (switches or routers) or from a Cisco device to a remote IP device. IP SLA probes continuously check the reachability of a specific destination, such as a provider edge router interface, the DNS server of the ISP, or any other specific destination, and can conditionally announce a default route only if the connectivity is verified**.**

a. Before implementing the Cisco IOS 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.

foreach address {
209.165.200.254
209.165.201.30
209.165.202.158
} {
ping $address source 192.168.1.1
}

```
R1#tclsh
R1(tcl)#foreach address {
+>(tcl)#209.165.200.254
+>(tcl)#209.165.201.30
+>(tcl)#209.165.202.158
+>(tcl)#} {
+>(tcl)#ping $address source 192.168.1.1
+>(tcl)#}
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 = 16/31/44 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
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/28/44 ms
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
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/34/44 ms
```

b. Trace the path taken to the web server, ISP1 DNS server, and ISP2 DNS server.

foreach address {
209.165.200.254
209.165.201.30
209.165.202.158
} {
trace $address source 192.168.1.1
}

```
R1(tcl)#foreach address {
+>(tcl)#209.165.200.254
+>(tcl)#209.165.201.30
+>(tcl)#209.165.202.158
+>(tcl)#} {
+>(tcl)#trace $address source 192.168.1.1
+>(tcl)#}
Type escape sequence to abort.
Tracing the route to 209.165.200.254
VRF info: (vrf in name/id, vrf out name/id)
  1 209.165.201.1 16 msec 32 msec 20 msec
Type escape sequence to abort.
Tracing the route to 209.165.201.30
VRF info: (vrf in name/id, vrf out name/id)
  1 209.165.201.1 24 msec 24 msec 28 msec
Type escape sequence to abort.
Tracing the route to 209.165.202.158
VRF info: (vrf in name/id, vrf out name/id)
  1 209.165.201.1 24 msec 28 msec 28 msec
  2 209.165.200.226 36 msec 44 msec 40 msec
```

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 command.

R1(config)# ip sla 11
R1(config-ip-sla)# icmp-echo 209.165.201.30
R1(config-ip-sla-echo)# frequency 10
R1(config-ip-sla-echo)# exit
R1(config)# ip sla schedule 11 life forever start-time now

```
R1(config)#ip sla 11
R1(config-ip-sla)#icmp-echo 209.165.201.30
R1(config-ip-sla-echo)#frequency 10
R1(config-ip-sla-echo)#exit
R1(config)#
R1(config)#ip sla schedule 11 life forever start-time now
```

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.

R1# show ip sla configuration 11

```
R1#show ip sla configuration 11
IP SLAs Infrastructure Engine-III
Entry number: 11
Owner:
Tag:
Operation timeout (milliseconds): 5000
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.201.30/0.0.0.0
Type Of Service parameter: 0x0
Request size (ARR data portion): 28
Verify data: No
Vrf Name:
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): 20
Enhanced History:
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
```

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.

R1# show ip sla statistics

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

IPSLA operation id: 11
        Latest RTT: 20 milliseconds
Latest operation start time: 14:27:07 UTC Sun Mar 26 2023
Latest operation return code: OK
Number of successes: 12
Number of failures: 0
Operation time to live: Forever
```

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.
ip sla 22
icmp-echo 209.165.202.158
frequency 10
exit
ip sla schedule 22 life forever start-time now

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip sla 22
R1(config-ip-sla)#icmp-echo 209.165.202.158
R1(config-ip-sla-echo)#frequency 10
R1(config-ip-sla-echo)#exit
R1(config)#
R1(config)#ip sla schedule 22 life forever start-time now
```

e. Verify the new probe using the **show ip sla configuration and show ip sla statistics** commands.
R1# show ip sla configuration 22

```
R1#show ip sla configuration 22
IP SLAs Infrastructure Engine-III
Entry number: 22
Owner:
Tag:
Operation timeout (milliseconds): 5000
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.202.158/0.0.0.0
Type Of Service parameter: 0x0
Request size (ARR data portion): 28
Verify data: No
Vrf Name:
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
```

```
   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): 20
Enhanced History:
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
```

R1# show ip sla statistics 22

```
R1#show ip sla statistics 22
IPSLAs Latest Operation Statistics

IPSLA operation id: 22
        Latest RTT: 60 milliseconds
Latest operation start time: 14:30:54 UTC Sun Mar 26 2023
Latest operation return code: OK
Number of successes: 12
Number of failures: 0
Operation time to live: Forever
```

The output lists the details of the configuration of operation 22. The operation is an ICMP echo to 209.165.202.158, with a frequency of 10 seconds, and it has already started (the start time has already passed). The statistics also prove that operation 22 is active.

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.
R1(config)# no ip route 0.0.0.0 0.0.0.0 209.165.201.1
R1(config)# ip route 0.0.0.0 0.0.0.0 209.165.201.1 5
R1(config)# exit

```
R1(config)#no ip route 0.0.0.0 0.0.0.0 209.165.201.1
R1(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1 5
R1(config)#exit
R1#
```

b. Verify the routing table.
R1# show ip route

```
R1#show ip route | begin Gateway
Gateway of last resort is 209.165.201.1 to network 0.0.0.0

S*    0.0.0.0/0 [5/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial3/0
L        209.165.201.2/32 is directly connected, Serial3/0
      209.165.202.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.202.128/30 is directly connected, Serial3/1
L        209.165.202.130/32 is directly connected, Serial3/1
```

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

R1(config)# track 1 ip sla 11 reachability
R1(config-track)#

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#track 1 ip sla 11 reachability
```

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.

R1(config-track)# delay down 10 up 1
R1(config-track)# exit
R1(config)#

```
R1(config-track)#delay down 10 up 1
R1(config-track)#exit
```

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).

R1# debug ip routing

```
R1#debug ip routing
IP routing debugging is on
```

R1(config)# ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1

```
R1(config)#ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1
R1(config)#
*Mar 26 14:35:24.811: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:35:24.811: RT: closer admin distance for 0.0.0.0, flushing 1 routes
*Mar 26 14:35:24.811: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [2/0]
*Mar 26 14:35:24.811: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:35:24.811: RT: rib update return code: 17
*Mar 26 14:35:24.811: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:35:24.811: RT: rib update return code: 17
```

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.

track 2 ip sla 22 reachability
delay down 10 up 1
exit
ip route 0.0.0.0 0.0.0.0 209.165.202.129 3 track 2

```
R1(config)#track 2 ip sla 22 reachability
R1(config-track)#delay down 10 up 1
R1(config-track)#exit
R1(config)#ip route 0.0.0.0 0.0.0.0 209.165.202.129 3 track 2
```

g.
Verify the routing table again.

R1# show ip route

```
R1#show ip route | begin Gateway
Gateway of last resort is 209.165.201.1 to network 0.0.0.0

S*    0.0.0.0/0 [2/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial3/0
L        209.165.201.2/32 is directly connected, Serial3/0
      209.165.202.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.202.128/30 is directly connected, Serial3/1
L        209.165.202.130/32 is directly connected, Serial3/1
R1#
*Mar 26 14:40:58.307: %TRACKING-5-STATE: 1 ip sla 11 reachability Up->Down
*Mar 26 14:40:58.311: RT: del 0.0.0.0 via 209.165.201.1, static metric [2/0]
*Mar 26 14:40:58.311: RT: delete network route to 0.0.0.0/0
*Mar 26 14:40:58.315: RT: default path has been cleared
*Mar 26 14:40:58.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.202.129   1048578

*Mar 26 14:40:58.315: RT: add 0.0.0.0/0 via 209.165.202.129, static metric [3/0]
*Mar 26 14:40:58.315: RT: default path is now 0.0.0.0 via 209.165.202.129
*Mar 26 14:40:58.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:40:58.315: RT: rib update return code: 17
*Mar 26 14:40:58.331: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.202.129   1048578

R1#
*Mar 26 14:40:58.339: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578
```

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)# interface loopback 1
ISP1(config-if)# shutdown
ISP1(config-if)#

```
ISP1(config)#int lo1
ISP1(config-if)#shutdown
ISP1(config-if)#
*Mar 26 14:40:39.719: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to down
*Mar 26 14:40:39.723: %LINK-5-CHANGED: Interface Loopback1, changed state to administratively down
```

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

b. Verify the routing table.

```
R1#show ip route | begin Gateway
Gateway of last resort is 209.165.202.129 to network 0.0.0.0

S*    0.0.0.0/0 [3/0] via 209.165.202.129
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial3/0
```

```
S*    0.0.0.0/0 [3/0] via 209.165.202.129
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial3/0
L        209.165.201.2/32 is directly connected, Serial3/0
      209.165.202.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.202.128/30 is directly connected, Serial3/1
L        209.165.202.130/32 is directly connected, Serial3/1
```

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.

R1# show ip sla statistics

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

IPSLA operation id: 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: 14:42:37 UTC Sun Mar 26 2023
Latest operation return code: Timeout
Number of successes: 92
Number of failures: 13
Operation time to live: Forever


IPSLA operation id: 22
        Latest RTT: 24 milliseconds
Latest operation start time: 14:42:34 UTC Sun Mar 26 2023
Latest operation return code: OK
Number of successes: 81
Number of failures: 1
Operation time to live: Forever
```

d. Initiate a trace to the web server from the internal LAN IP address.
R1# trace 209.165.200.254 source 192.168.1.1

```
R1#trace 209.165.200.254 source 192.168.1.1
Type escape sequence to abort.
Tracing the route to 209.165.200.254
VRF info: (vrf in name/id, vrf out name/id)
  1 209.165.202.129 20 msec 28 msec 20 msec
R1#
*Mar 26 14:44:49.315: %TRACKING-5-STATE: 1 ip sla 11 reachability Down->Up
*Mar 26 14:44:49.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:44:49.315: RT: closer admin distance for 0.0.0.0, flushing 1 routes
*Mar 26 14:44:49.315: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [2/0]
*Mar 26 14:44:49.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.202.129   1048578

*Mar 26 14:44:49.315: RT: rib update return code: 17
```

```
    via 209.165.202.129   1048578

*Mar 26 14:44:49.315: RT: rib update return code: 17
*Mar 26 14:44:49.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.202.129   1048578

*Mar 26 14:44:49.315: RT: rib update return code: 17
*Mar 26 14:44:49.315: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar 26 14:44:49.315: RT:
R1#rib update return code: 17
```

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.

ISP1(config-if)# no shutdown

```
ISP1(config-if)# no shutdown
ISP1(config-if)#
*Mar 26 14:44:38.999: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
ISP1(config-if)#
*Mar 26 14:44:39.003: %LINK-3-UPDOWN: Interface Loopback1, changed state to up
ISP1(config-if)#
```

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

```
R1#debug ip routing
IP routing debugging is on
```

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

f. Again examine the IP SLA statistics.

R1# show ip sla statistics

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

IPSLA operation id: 11
        Latest RTT: 24 milliseconds
Latest operation start time: 14:45:57 UTC Sun Mar 26 2023
Latest operation return code: OK
Number of successes: 100
Number of failures: 25
Operation time to live: Forever



IPSLA operation id: 22
        Latest RTT: 56 milliseconds
Latest operation start time: 14:45:54 UTC Sun Mar 26 2023
Latest operation return code: OK
Number of successes: 101
Number of failures: 1
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.

R1# show ip route

```
R1# show ip route | begin Gateway
Gateway of last resort is 209.165.201.1 to network 0.0.0.0

S*    0.0.0.0/0 [2/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial3/0
L        209.165.201.2/32 is directly connected, Serial3/0
      209.165.202.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.202.128/30 is directly connected, Serial3/1
L        209.165.202.130/32 is directly connected, Serial3/1
```

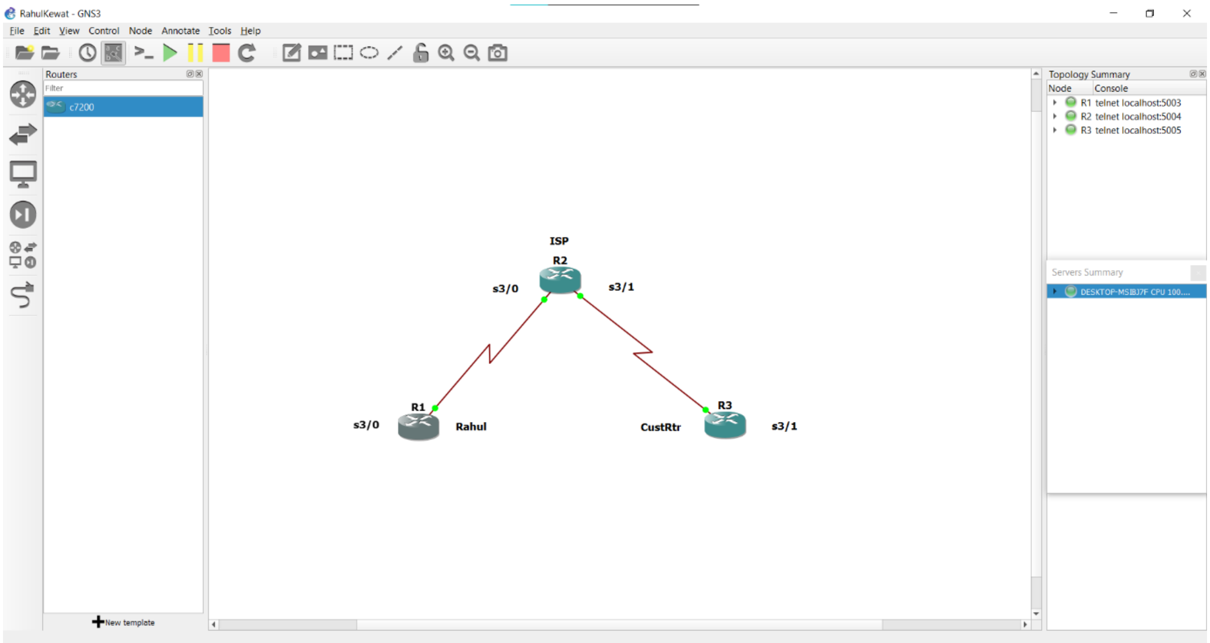
The default static through ISP1 with an administrative distance of 2 is reestablished.

Practical 2

Aim: **Using the AS_PATH Attribute**

Writeup:

Topology



Step 0: Suggested starting configurations

a. Apply the following configuration to each router along with the appropriate **hostname.** The **exec-timeout 0 0** command should only be used in a lab environment.

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname Rahul
Rahul(config)#no ip domain-lookup
Rahul(config)#line con 0
Rahul(config-line)#logging synchronous
Rahul(config-line)#exec-timeout 0 0
Rahul(config-line)#exit
Rahul(config)#
```

```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP
ISP(config)#no ip domain-lookup
ISP(config)#line con 0
ISP(config-line)#logging synchronous
ISP(config-line)#exec-timeout 0 0
ISP(config-line)#exit
ISP(config)#
```

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname CustRtr
CustRtr(config)#no ip domain-lookup
CustRtr(config)#line con 0
CustRtr(config-line)#logging synchronous
CustRtr(config-line)#exec-timeout 0 0
CustRtr(config-line)#exit
CustRtr(config)#
```

Step 1: Prepare the routers for the lab.

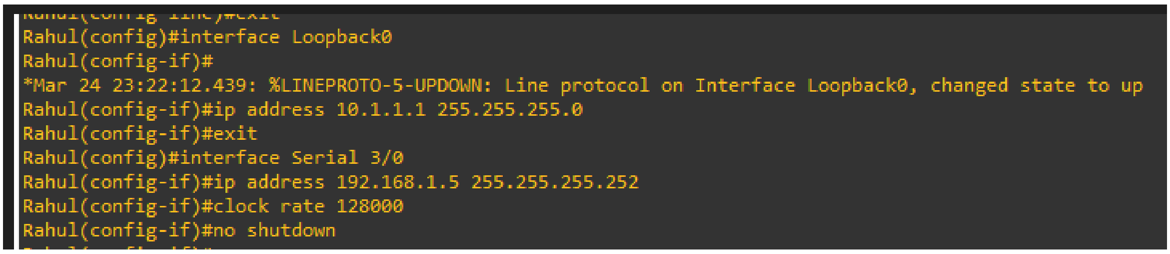
Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear previous configurations.

Step 2: Configure the hostname and interface addresses.

a. You can copy and paste the following configurations into your routers to begin.

Router R1 (hostname Rahul)

hostname Rahul
!
interface Loopback0
ip address 10.1.1.1 255.255.255.0
!
interface Serial 3/0
ip address 192.168.1.5 255.255.255.252
clock rate 128000
no shutdown



Router R2 (hostname ISP)
hostname ISP
!
interface Loopback0
ip address 10.2.2.1 255.255.255.0
!
interface Serial0 3/0
ip address 192.168.1.6 255.255.255.252
no shutdown
!
interface Serial 3/1
ip address 172.24.1.17 255.255.255.252
clock rate 128000
no shutdown

```
ISP(config-if)#
*Mar 24 23:28:32.119: %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)#interface Serial 3/0
ISP(config-if)#ip address 192.168.1.6 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#
*Mar 24 23:30:50.963: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
ISP(config-if)#
*Mar 24 23:30:51.971: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
ISP(config-if)#exit
ISP(config)#interface Serial 3/1
ISP(config-if)#ip address 172.24.1.17 255.255.255.252
ISP(config-if)#clock rate 128000
ISP(config-if)#no shutdown
ISP(config-if)#
*Mar 24 23:32:25.711: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
ISP(config-if)#
*Mar 24 23:32:26.715: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP(config-if)#end
ISP#
*Mar 24 23:32:45.379: %SYS-5-CONFIG_I: Configured from console by console
ISP#
*Mar 24 23:32:48.095: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
ISP#
```

Router R3 (hostname CustRtr)

hostname CustRtr
!
interface Loopback0
ip address 10.3.3.1 255.255.255.0
!
interface Serial 3/1
ip address 172.24.1.18 255.255.255.252
no shutdown

```
CustRtr(config)#interface Loopback0
CustRtr(config-if)#
*Mar 24 23:34:20.947: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
CustRtr(config-if)#ip address 10.3.3.1 255.255.255.0
CustRtr(config-if)#exit
CustRtr(config)#interface Serial 3/1
CustRtr(config-if)#ip address 172.24.1.18 255.255.255.252
CustRtr(config-if)#no shutdown
CustRtr(config-if)#
*Mar 24 23:35:49.751: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
CustRtr(config-if)#
*Mar 24 23:35:50.763: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
CustRtr(config-if)#end
CustRtr#
*Mar 24 23:36:05.727: %SYS-5-CONFIG_I: Configured from console by console
CustRtr#
```

b. Use ping to test the connectivity between the directly connected routers.

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.

Rahul(config)# router bgp 100
Rahul(config-router)# neighbor 192.168.1.6 remote-as 300
Rahul(config-router)# network 10.1.1.0 mask 255.255.255.0

```
Rahul#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
Rahul(config)#router bgp 100
Rahul(config-router)#neighbor 192.168.1.6 remote-as 300
Rahul(config-router)#network 10.1.1.0 mask 255.255.255.0
Rahul(config-router)#
```

ISP(config)# router bgp 300
ISP(config-router)# neighbor 192.168.1.5 remote-as 100
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#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
ISP(config)#router bgp 300
ISP(config-router)#neighbor 192.168.1.5 remote-as 100
ISP(config-router)#
*Mar 24 23:41:02.939: %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)#
```

CustRtr(config)# router bgp 65000
CustRtr(config-router)# neighbor 172.24.1.17 remote-as 300
CustRtr(config-router)# network 10.3.3.0 mask 255.255.255.0

```
CustRtr#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
CustRtr(config)#router bgp 65000
CustRtr(config-router)#neighbor 172.24.1.17 remote-as 300
CustRtr(config-router)#
*Mar 24 23:43:52.915: %BGP-5-ADJCHANGE: neighbor 172.24.1.17 Up
CustRtr(config-router)#network 10.3.3.0 mask 255.255.255.0
CustRtr(config-router)#
```

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

```
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 00:02:38
  Last read 00:00:15, last write 00:00:11, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                4          2
    Keepalives:             4          4
    Route Refresh:          0          0
    Total:                 11          7
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  Session: 172.24.1.18
  BGP table version 4, neighbor version 4/0
  Output queue size : 0
  Index 1, Advertise bit 0
  1 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               3          1 (Consumes 80 bytes)
    Prefixes Total:                 4          1
    Implicit Withdraw:              1          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          1
    Used as multipath:            n/a          0

                                   Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Bestpath from this peer:              1        n/a
    Total:                                1          0
  Number of NLRIs in the update sent: max 1, min 0
  Last detected as dynamic slow peer: never
  Dynamic slow peer recovered: never
```

```
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          1
    Used as multipath:            n/a          0

                               Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Bestpath from this peer:            1        n/a
    Total:                              1          0
  Number of NLRIs in the update sent: max 1, min 0
  Last detected as dynamic slow peer: never
  Dynamic slow peer recovered: never
  Refresh Epoch: 1
  Last Sent Refresh Start-of-rib: never
  Last Sent Refresh End-of-rib: never
  Last Received Refresh Start-of-rib: never
  Last Received Refresh End-of-rib: never
                                    Sent       Rcvd
        Refresh activity:           ----       ----
          Refresh Start-of-RIB         0          0
          Refresh End-of-RIB           0          0

  Address tracking is enabled, the RIB does have a route to 192.168.1.5
  Connections established 1; dropped 0
  Last reset never
  Transport(tcp) path-mtu-discovery is enabled
  Graceful-Restart is disabled
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled
Mininum incoming TTL 0, Outgoing TTL 1
Local host: 192.168.1.6, Local port: 179
Foreign host: 192.168.1.5, Foreign port: 32436
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x250CF4):
Timer          Starts    Wakeups            Next
Retrans             9          0             0x0
TimeWait            0          0             0x0
AckHold             8          6             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0

iss:  631997624  snduna:  631997924  sndnxt:  631997924     sndwnd:  16085
irs: 2660362310  rcvnxt: 2660362578  rcvwnd:      16117  delrcvwnd:    267

SRTT: 225 ms, RTTO: 978 ms, RTV: 753 ms, KRTT: 0 ms
minRTT: 108 ms, maxRTT: 444 ms, ACK hold: 200 ms
Status Flags: passive open, gen tcbs
Option Flags: nagle, path mtu capable

Datagrams (max data segment is 1460 bytes):
Rcvd: 18 (out of order: 0), with data: 9, total data bytes: 267
Sent: 17 (retransmit: 0 fastretransmit: 0),with data: 10, total data bytes: 299
```

Step 4: Remove the private AS.

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

Rahul# show ip route

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

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C        10.1.1.0/24 is directly connected, Loopback0
L        10.1.1.1/32 is directly connected, Loopback0
B        10.2.2.0/24 [20/0] via 192.168.1.6, 00:10:21
B        10.3.3.0/24 [20/0] via 192.168.1.6, 00:07:32
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.4/30 is directly connected, Serial3/0
L        192.168.1.5/32 is directly connected, Serial3/0
Rahul#
```

b. Ping the 10.3.3.1 address from Rahul.

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

```
Rahul#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 = 124/165/224 ms
Rahul#
```

d. Check the BGP table from Rahul 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.

Rahul# show ip bgp

```
Success rate is 100 percent (5/5), round-trip min/avg/max = 124/165/224 ms
Rahul#show ip bgp
BGP table version is 4, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.1.1.0/24      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 65000 i
Rahul#
```

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

ISP(config)# router bgp 300
ISP(config-router)# neighbor 192.168.1.5 remove-private-as

```
ISP#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
ISP(config)#router bgp 300
ISP(config-router)#neighbor 192.168.1.5 remove-private-as
```

f. After issuing these commands, use the **clear ip bgp** * command on ISP to reestablish the BGP relationship between the three routers. Wait several seconds and then return to Rahul to check its routing table.

```
ISP#clear ip bgp *
ISP#
*Mar 25 00:04:09.675: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Down User reset
*Mar 25 00:04:09.675: %BGP_SESSION-5-ADJCHANGE: neighbor 172.24.1.18 IPv4 Unicast topology base removed from session  User reset
*Mar 25 00:04:09.679: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar 25 00:04:09.683: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicast topology base removed from session  User reset
*Mar 25 00:04:10.459: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
*Mar 25 00:04:10.471: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Up
ISP#
```

Rahul should be able to ping 10.3.3.1 using its loopback 0 interface as the source of the ping.
Rahul# ping 10.3.3.1 source lo0

```
Rahul#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 = 140/198/300 ms
Rahul#
```

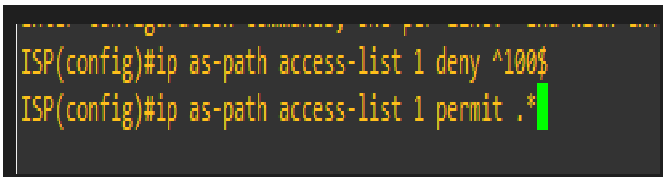
g. Now check the BGP table on Rahul. The AS_ PATH to the 10.3.3.0 network should be AS 300. It no longer has the private AS in the path.
Rahul# show ip bgp

```
Rahul#show ip bgp
BGP table version is 8, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  10.1.1.0/24      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
Rahul#S
```

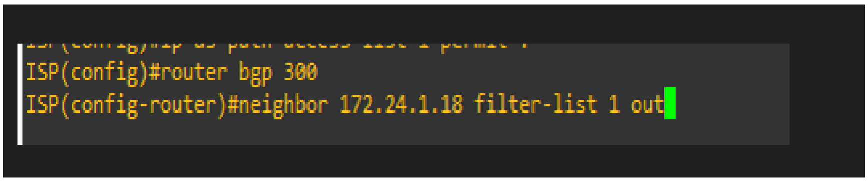
Step 5: Use the AS_PATH attribute to filter routes.

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.

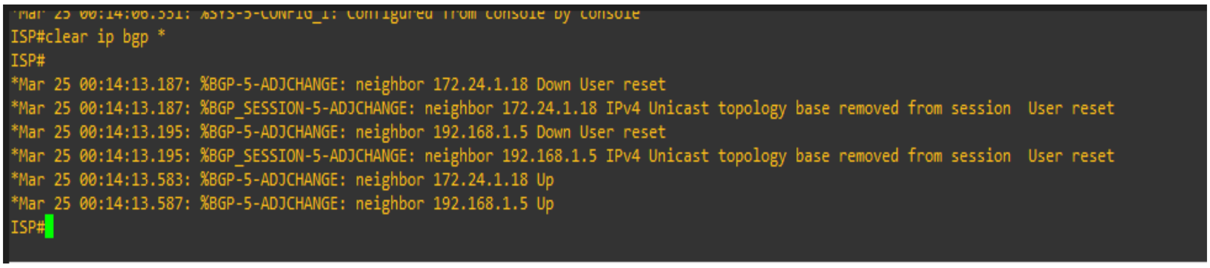
ISP(config)# ip as-path access-list 1 deny ^100$
ISP(config)# ip as-path access-list 1 permit .*


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

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 bgp 300
ISP(config-router)#neighbor 172.24.1.18 filter-list 1 out
```

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 to 10.1.1.0 should be in the routing table.


```
ISP#clear ip bgp *
ISP#
*Mar 25 00:14:13.187: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Down User reset
*Mar 25 00:14:13.187: %BGP_SESSION-5-ADJCHANGE: neighbor 172.24.1.18 IPv4 Unicast topology base removed from session  User reset
*Mar 25 00:14:13.195: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar 25 00:14:13.195: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicast topology base removed from session  User reset
*Mar 25 00:14:13.583: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Up
*Mar 25 00:14:13.587: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
ISP#
```

ISP# show ip route

```
*Mar 25 00:14:13.587: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
ISP#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
B        10.1.1.0/24 [20/0] via 192.168.1.5, 00:01:24
C        10.2.2.0/24 is directly connected, Loopback0
L        10.2.2.1/32 is directly connected, Loopback0
B        10.3.3.0/24 [20/0] via 172.24.1.18, 00:01:24
      172.24.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.24.1.16/30 is directly connected, Serial3/1
L        172.24.1.17/32 is directly connected, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.4/30 is directly connected, Serial3/0
L        192.168.1.6/32 is directly connected, Serial3/0
ISP#
```

d. Check the routing table for **CustRtr.** It should not have a route to 10.1.1.0 in its routing table.
CustRtr# show ip route

```
*Mar 25 00:17:56.643: %SYS-5-CONFIG_I: Configured from console by console
CustRtr#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
B        10.2.2.0/24 [20/0] via 172.24.1.17, 00:03:13
C        10.3.3.0/24 is directly connected, Loopback0
L        10.3.3.1/32 is directly connected, Loopback0
      172.24.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.24.1.16/30 is directly connected, Serial3/1
L        172.24.1.18/32 is directly connected, Serial3/1
CustRtr#
```

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$

```
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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

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

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 **CustRtr.**

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

ISP# tclsh
foreach address {
10.1.1.1
10.2.2.1
10.3.3.1
192.168.1.5
192.168.1.6
172.24.1.17
172.24.1.18
} {
ping $address }

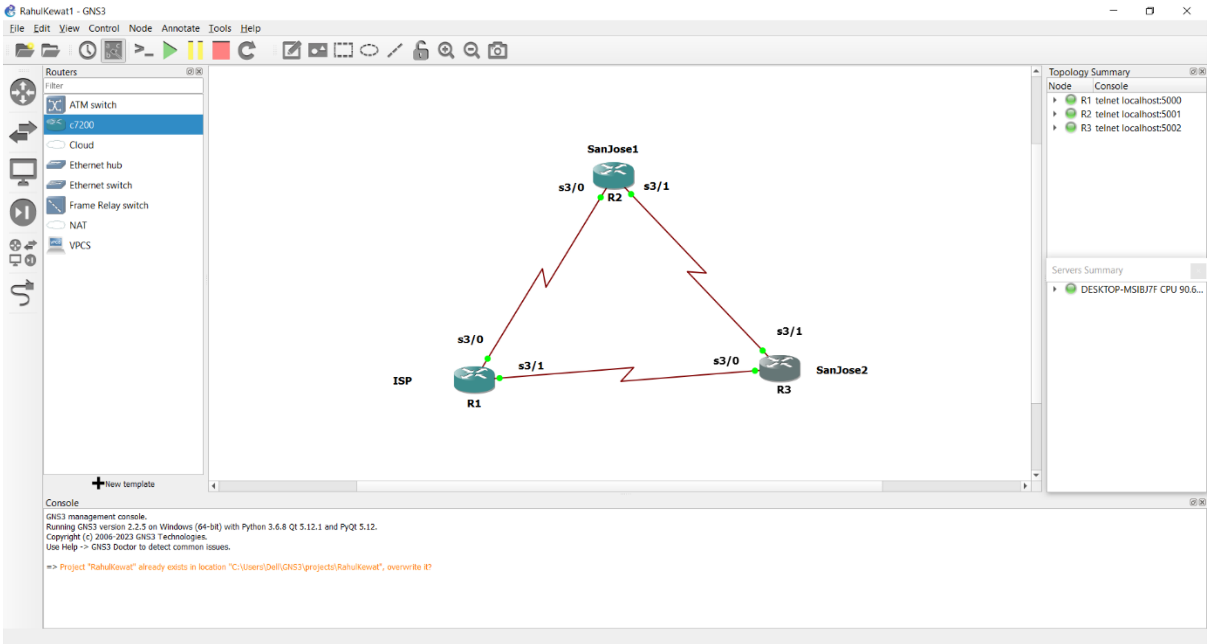
```
ISP#tclsh
ISP(tcl)#foreach address {
+>10.1.1.1
+>10.2.2.1
+>10.3.3.1
+>192.168.1.5
+>192.168.1.6
+>172.24.1.17
+>172.24.1.18
+>} {
+>ping $address }
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/83/132 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 = 1/3/8 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/56/92 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 = 36/60/84 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 = 64/104/156 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.24.1.17, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/101/140 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.24.1.18, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/51/64 ms
ISP(tcl)#
```

Practical 3

Aim: **Configuring IBGP and EBGP Sessions, Local Preference and MED**

Writeup:

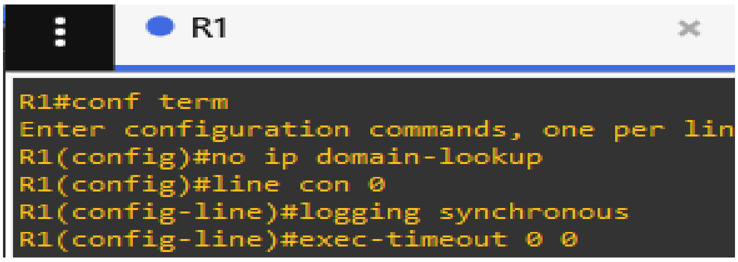
Topology

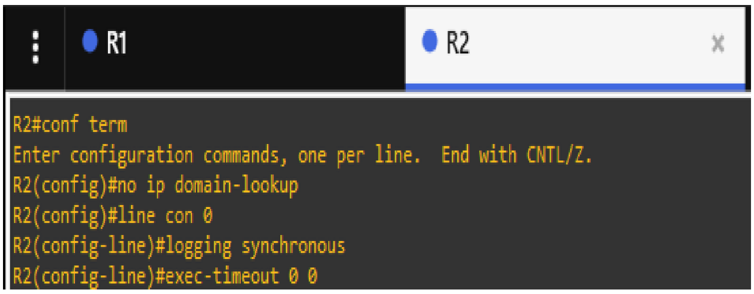


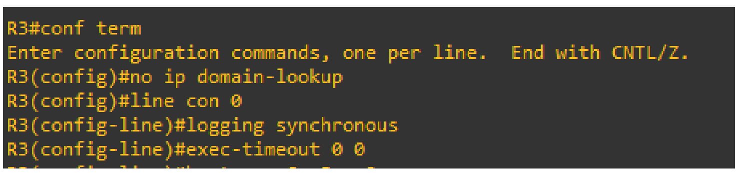
Step 0: Suggested starting configurations.

Apply the following configuration to each router along with the appropriate **hostname**. The **exec-timeout 0 0** command should only be used in a lab environment.

```
Router(config)# no ip domain-lookup
Router(config)# line con 0
Router(config-line)# logging synchronous
Router(config-line)# exec-timeout 0 0
```





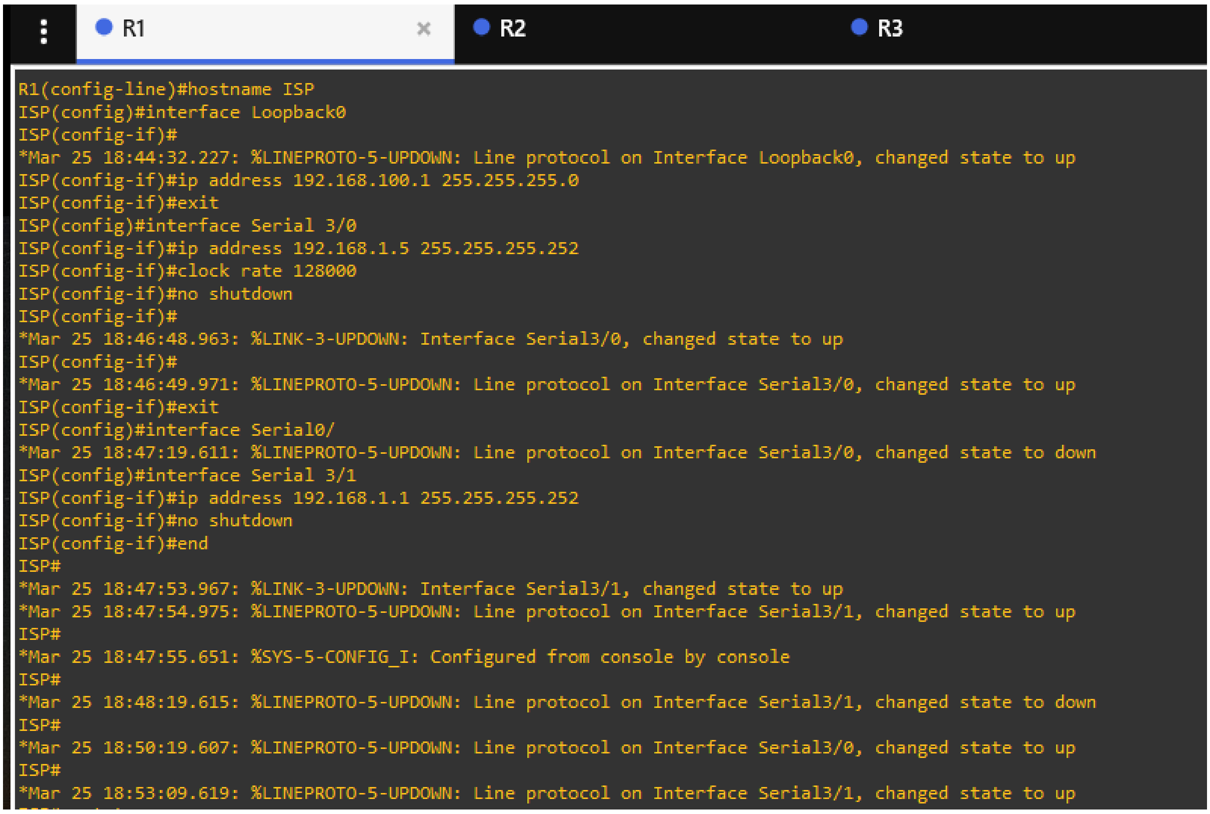


Step 1: Configure interface addresses.

a.Using the addressing scheme in the diagram, create the loopback interfaces and apply IPv4 addresses to these and the serial interfaces on ISP (R1), SanJose1 (R2), and SanJose2 (R3).

Router R1 (hostname ISP)

```
ISP(config)# interface Loopback0
ISP(config-if)# ip address 192.168.100.1 255.255.255.0
ISP(config-if)# exit
ISP(config)# interface Serial 3/0
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)# exit
ISP(config)# interface Serial 3/1
ISP(config-if)# ip address 192.168.1.1 255.255.255.252
ISP(config-if)# no shutdown
ISP(config-if)# end
ISP#
```




```
R1(config-line)#hostname ISP
ISP(config)#interface Loopback0
ISP(config-if)#
*Mar 25 18:44:32.227: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
ISP(config-if)#ip address 192.168.100.1 255.255.255.0
ISP(config-if)#exit
ISP(config)#interface Serial 3/0
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)#
*Mar 25 18:46:48.963: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
ISP(config-if)#
*Mar 25 18:46:49.971: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
ISP(config-if)#exit
ISP(config)#interface Serial0/
*Mar 25 18:47:19.611: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
ISP(config)#interface Serial 3/1
ISP(config-if)#ip address 192.168.1.1 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#end
ISP#
*Mar 25 18:47:53.967: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
*Mar 25 18:47:54.975: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP#
*Mar 25 18:47:55.651: %SYS-5-CONFIG_I: Configured from console by console
ISP#
*Mar 25 18:48:19.615: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
ISP#
*Mar 25 18:50:19.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
ISP#
*Mar 25 18:53:09.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
```

Router R2 (hostname SanJose1)

```
SanJose1(config)# interface Loopback0
SanJose1(config-if)# ip address 172.16.64.1 255.255.255.0
SanJose1(config-if)# exit
```

```
SanJose1(config)# interface Serial 3/0
SanJose1(config-if)# ip address 192.168.1.6 255.255.255.252
SanJose1(config-if)# no shutdown
SanJose1(config-if)# exit
SanJose1(config)# interface Serial 3/1
SanJose1(config-if)# ip address 172.16.1.1 255.255.255.0
SanJose1(config-if)# clock rate 128000
SanJose1(config-if)# no shutdown
SanJose1(config-if)# end
SanJose1#
```

```
R2(config-line)#hostname SanJose1
SanJose1(config)#interface Loopback0
SanJose1(config-if)#
*Mar 25 18:49:05.387: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
SanJose1(config-if)#ip address 172.16.64.1 255.255.255.0
SanJose1(config-if)#exit
SanJose1(config)#interface Serial 3/0
SanJose1(config-if)#ip address 192.168.1.6 255.255.255.252
SanJose1(config-if)#no shutdown
SanJose1(config-if)#
*Mar 25 18:50:00.983: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
SanJose1(config-if)#
*Mar 25 18:50:01.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
SanJose1(config-if)#exit
SanJose1(config)#interface Serial 3/1
SanJose1(config-if)#ip address 172.16.1.1 255.255.255.0
SanJose1(config-if)#clock rate 128000
SanJose1(config-if)#no shutdown
SanJose1(config-if)#end
SanJose1#
*Mar 25 18:51:02.627: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
*Mar 25 18:51:03.315: %SYS-5-CONFIG_I: Configured from console by console
SanJose1#
*Mar 25 18:51:03.635: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
SanJose1#
*Mar 25 18:51:29.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
SanJose1#
*Mar 25 18:53:49.611: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
SanJose1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
```

Router R3 (hostname SanJose2)

```
SanJose2(config)# interface Loopback0
SanJose2(config-if)# ip address 172.16.32.1 255.255.255.0
SanJose2(config-if)# exit
SanJose2(config)# interface Serial 3/0
SanJose2(config-if)# ip address 192.168.1.2 255.255.255.252
SanJose2(config-if)# clock rate 128000
SanJose2(config-if)# no shutdown
SanJose2(config-if)# exit
SanJose2(config)# interface Serial 3/1
SanJose2(config-if)# ip address 172.16.1.2 255.255.255.0
SanJose2(config-if)# no shutdown
SanJose2(config-if)# end
SanJose2#
```

```
SanJose2(config)#interface Loopback0
SanJose2(config-if)#
*Mar 25 18:51:42.275: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
SanJose2(config-if)#ip address 172.16.32.1 255.255.255.0
SanJose2(config-if)#exit
SanJose2(config)#interface Serial 3/0
SanJose2(config-if)#ip address 192.168.1.2 255.255.255.252
SanJose2(config-if)#clock rate 128000
SanJose2(config-if)#no shutdown
SanJose2(config-if)#exit
SanJose2(config)#
*Mar 25 18:53:08.987: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
SanJose2(config)#
*Mar 25 18:53:09.995: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
SanJose2(config)#interface Serial 3/1
SanJose2(config-if)#ip address 172.16.1.2 255.255.255.0
SanJose2(config-if)#no shutdown
SanJose2(config-if)#end
SanJose2#
*Mar 25 18:53:46.959: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
SanJose2#
*Mar 25 18:53:47.363: %SYS-5-CONFIG_I: Configured from console by console
SanJose2#
*Mar 25 18:53:47.971: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
```

b.Use **ping** to test the connectivity between the directly connected routers. Both SanJose routers should be able to ping each other and their local ISP serial link IP address. The ISP router cannot reach the segment between SanJose1 and SanJose2.

Step 2: Configure EIGRP.

Configure EIGRP between the SanJose1 and SanJose2 routers. (Note: If using an IOS prior to 15.0, use the no auto-summary router configuration command to disable automatic summarization. This command is the default beginning with IOS 15.)

SanJose1(config)# **router eigrp 1**
SanJose1(config-router)# **network 172.16.0.0**

```
R1    R2    R3
SanJose1(config)#router eigrp 1
SanJose1(config-router)#network 172.16.0.0
SanJose1(config-router)#
*Mar 25 18:55:52.195: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.1.2 (Serial3/1) is up: new adjacency
```

SanJose2(config)# **router eigrp 1**
SanJose2(config-router)# **network 172.16.0.0**

```
SanJose2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose2(config)#router eigrp 1
SanJose2(config-router)#network 172.16.0.0
```

Step 3: Configure IBGP and verify BGP neighbors.

a.Configure IBGP between the SanJose1 and SanJose2 routers. On the SanJose1 router, enter the following configuration.

SanJose1(config)# **router bgp 64512**
SanJose1(config-router)# **neighbor 172.16.32.1 remote-as 64512**
SanJose1(config-router)# **neighbor 172.16.32.1 update-source lo0**

```
R1    R2    R3
SanJose1(config-router)#router bgp 64512
SanJose1(config-router)#neighbor 172.16.32.1 remote-as 64512
SanJose1(config-router)#neighbor 172.16.32.1 update-source lo0
SanJose1(config-router)#
*Mar 25 18:58:12.303: %BGP-5-ADJCHANGE: neighbor 172.16.32.1 Up
SanJose1(config-router)#end
SanJose1#
*Mar 25 19:04:46.499: %SYS-5-CONFIG_I: Configured from console by console
```

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 SanJose2 using the following commands.

SanJose2(config)# **router bgp 64512**
SanJose2(config-router)# **neighbor 172.16.64.1 remote-as 64512**
SanJose2(config-router)# **neighbor 172.16.64.1 update-source lo0**

```
SanJose2(config-router)#router bgp 64512
SanJose2(config-router)#neighbor 172.16.64.1 remote-as 64512
SanJose2(config-router)#
*Mar 25 18:58:12.311: %BGP-5-ADJCHANGE: neighbor 172.16.64.1 Up
SanJose2(config-router)#neighbor 172.16.64.1 update-source lo0
SanJose2(config-router)#end
```

c.Verify that SanJose1 and SanJose2 become BGP neighbors by issuing the **show ip bgp neighbors** command on SanJose1. View the following partial output. If the BGP state is not established, troubleshoot the connection.

SanJose2# **show ip bgp neighbors**

```
SanJose2#
*Mar 25 18:58:45.499: %SYS-5-CONFIG_I: Configured from console by console
SanJose2#show ip bgp neighbors
BGP neighbor is 172.16.64.1,  remote AS 64512, internal link
  BGP version 4, remote router ID 172.16.64.1
```

```
 BGP version 4, remote router ID 172.16.64.1
 BGP state = Established, up for 00:00:37
 Last read 00:00:37, last write 00:00:37, hold time is 180, keepalive interval is 60 seconds
 Neighbor sessions:
   1 active, is not multisession capable (disabled)
 Neighbor capabilities:
   Route refresh: advertised and received(new)
   Four-octets ASN Capability: advertised and received
   Address family IPv4 Unicast: advertised and received
   Enhanced Refresh Capability: advertised and received
   Multisession Capability:
   Stateful switchover support enabled: NO for session 1
 Message statistics:
   InQ depth is 0
   OutQ depth is 0

                        Sent       Rcvd
   Opens:                  1          1
   Notifications:          0          0
   Updates:                1          1
   Keepalives:             2          2
   Route Refresh:          0          0
   Total:                  4          4
 Default minimum time between advertisement runs is 0 seconds

For address family: IPv4 Unicast
 Session: 172.16.64.1
 BGP table version 1, neighbor version 1/0
 Output queue size : 0
 Index 1, Advertise bit 0
 1 update-group member
 Slow-peer detection is disabled
 Slow-peer split-update-group dynamic is disabled
                                Sent       Rcvd
 Prefix activity:               ----       ----
   Prefixes Current:               0          0
   Prefixes Total:                 0          0
   Implicit Withdraw:              0          0
   Explicit Withdraw:              0          0
   Used as bestpath:             n/a          0
   Used as multipath:            n/a          0

                                  Outbound    Inbound
 Local Policy Denied Prefixes:    --------    -------
   Total:                                0          0
 Number of NLRIs in the update sent: max 0, min 0
 Last detected as dynamic slow peer: never
 Dynamic slow peer recovered: never
```

```
  Dynamic slow peer recovered: never
  Refresh Epoch: 1
  Last Sent Refresh Start-of-rib: never
  Last Sent Refresh End-of-rib: never
  Last Received Refresh Start-of-rib: never
  Last Received Refresh End-of-rib: never
                                       Sent       Rcvd
        Refresh activity:              ----       ----
          Refresh Start-of-RIB          0          0
          Refresh End-of-RIB            0          0

  Address tracking is enabled, the RIB does have a route to 172.16.64.1
  Connections established 1; dropped 0
  Last reset never
  Transport(tcp) path-mtu-discovery is enabled
  Graceful-Restart is disabled
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled
Mininum incoming TTL 0, Outgoing TTL 255
Local host: 172.16.32.1, Local port: 179
Foreign host: 172.16.64.1, Foreign port: 56813
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x12115C):
Timer          Starts    Wakeups            Next
Retrans             3          0             0x0
TimeWait            0          0             0x0
AckHold             2          0             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0

iss: 2064679468  snduna: 2064679587  sndnxt: 2064679587     sndwnd:  16266
irs: 3194035864  rcvnxt: 3194035983  rcvwnd:      16266  delrcvwnd:    118

SRTT: 99 ms, RTTO: 1539 ms, RTV: 1440 ms, KRTT: 0 ms
minRTT: 36 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: passive open, gen tcbs
Option Flags: nagle, path mtu capable

Datagrams (max data segment is 1460 bytes):
Rcvd: 7 (out of order: 0), with data: 4, total data bytes: 118
Sent: 5 (retransmit: 0 fastretransmit: 0),with data: 4, total data bytes: 118
```

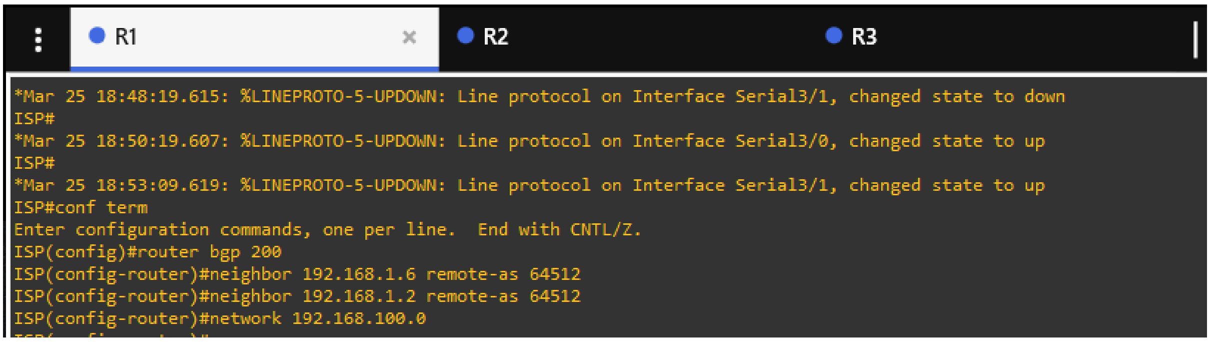
The link between SanJose1 and SanJose2 should be identified as an internal link indicating an IBGP peering relationship, as shown in the output.

Step 4: Configure EBGP and verify BGP neighbors.

a.Configure ISP to run EBGP with SanJose1 and SanJose2. 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**

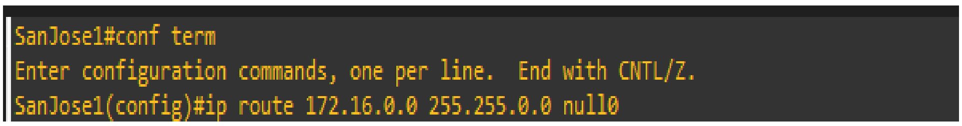


```
*Mar 25 18:48:19.615: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
ISP#
*Mar 25 18:50:19.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
ISP#
*Mar 25 18:53:09.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
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
```

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 a discard static route for the 172.16.0.0/16 network. Any packets that do not have a more specific match (longer match) for a 172.16.0.0 subnet will be dropped instead of sent to the ISP. Later in this lab we will configure a default route to the ISP.

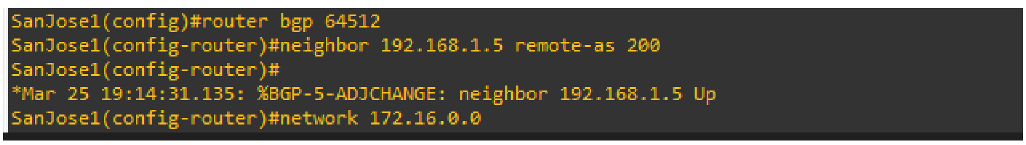
SanJose1(config)# **ip route 172.16.0.0 255.255.0.0 null0**



```
SanJose1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose1(config)#ip route 172.16.0.0 255.255.0.0 null0
```

c.Configure SanJose1 as an EBGP peer to ISP.

```
SanJose1(config)# router bgp 64512
SanJose1(config-router)# neighbor 192.168.1.5 remote-as 200
SanJose1(config-router)# network 172.16.0.0
```



```
SanJose1(config)#router bgp 64512
SanJose1(config-router)#neighbor 192.168.1.5 remote-as 200
SanJose1(config-router)#
*Mar 25 19:14:31.135: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
SanJose1(config-router)#network 172.16.0.0
```

d.Use the **show ip bgp neighbors** command to verify that SanJose1 and ISP have reached the established state. Troubleshoot if necessary.

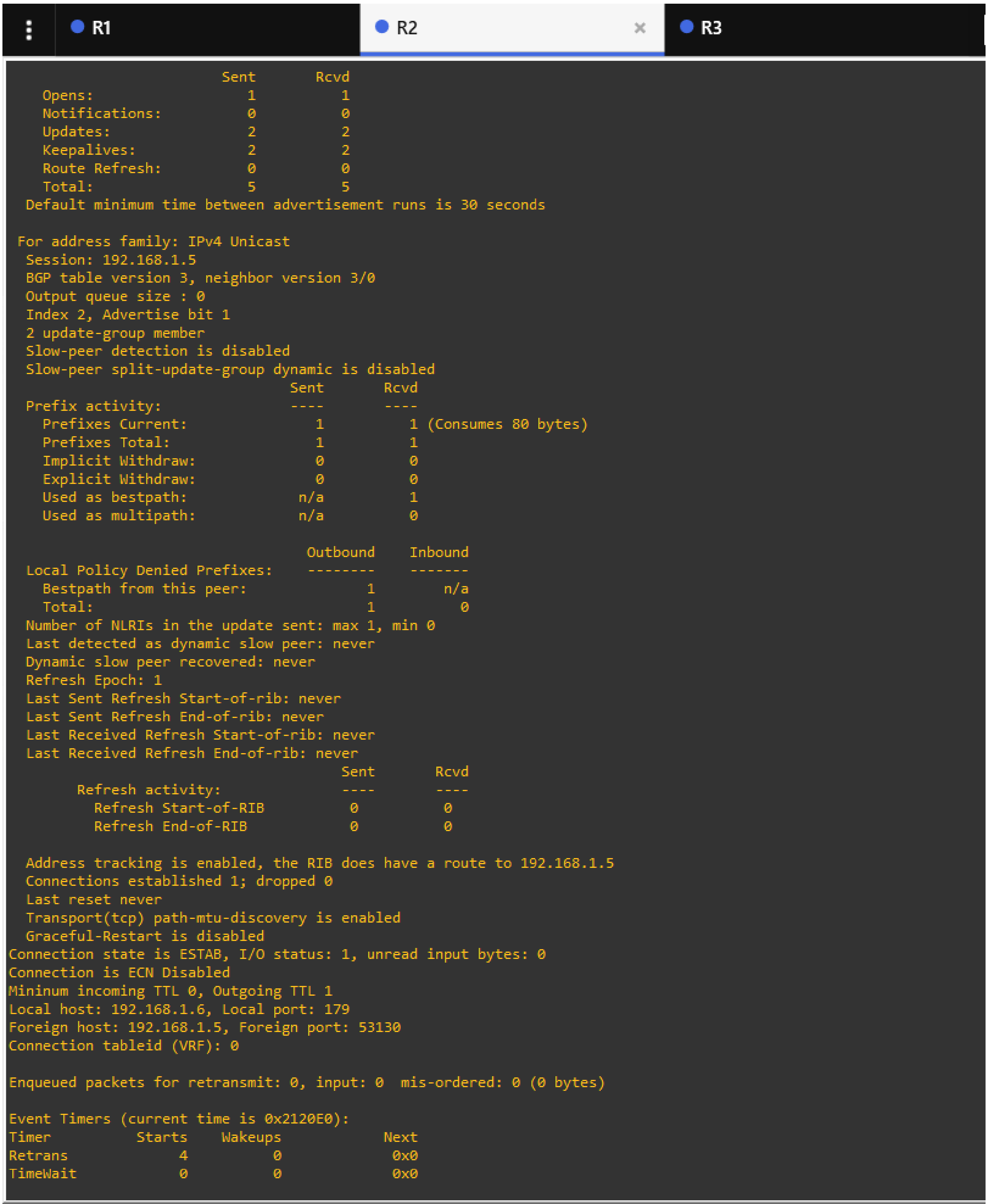
```
SanJose1# show ip bgp neighbors
```

R1 R2 R3

```
SanJose1#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 00:17:04
  Last read 00:00:07, last write 00:00:33, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                3          1
    Keepalives:            20         20
    Route Refresh:          0          0
    Total:                 24         22
  Default minimum time between advertisement runs is 0 seconds

 For address family: IPv4 Unicast
  Session: 172.16.32.1
  BGP table version 3, neighbor version 3/0
  Output queue size : 0
  Index 1, Advertise bit 0
  1 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               2          0
    Prefixes Total:                 2          0
    Implicit Withdraw:              0          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          0
    Used as multipath:            n/a          0

                                   Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Total:                                0          0
  Number of NLRIs in the update sent: max 1, min 0
  Last detected as dynamic slow peer: never
  Dynamic slow peer recovered: never
  Refresh Epoch: 1
  Last Sent Refresh Start-of-rib: never
  Last Sent Refresh End-of-rib: never
  Last Received Refresh Start-of-rib: never
  Last Received Refresh End-of-rib: never
                                       Sent       Rcvd
        Refresh activity:              ----       ----
          Refresh Start-of-RIB          0          0
          Refresh End-of-RIB            0          0

  Address tracking is enabled, the RIB does have a route to 172.16.32.1
```

R1 R2 R3

```
  Address tracking is enabled, the RIB does have a route to 172.16.32.1
  Connections established 1; dropped 0
  Last reset never
  Transport(tcp) path-mtu-discovery is enabled
  Graceful-Restart is disabled
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled
Mininum incoming TTL 0, Outgoing TTL 255
Local host: 172.16.64.1, Local port: 56813
Foreign host: 172.16.32.1, Foreign port: 179
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x2120D4):
Timer          Starts    Wakeups            Next
Retrans            25          2             0x0
TimeWait            0          0             0x0
AckHold            20         19             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger          754        753        0x2121A9
DeadWait            0          0             0x0
Linger              0          0             0x0

iss: 3194035864  snduna: 3194036440  sndnxt: 3194036440     sndwnd:  15809
irs: 2064679468  rcvnxt: 2064679929  rcvwnd:      15924  delrcvwnd:    460

SRTT: 284 ms, RTTO: 413 ms, RTV: 129 ms, KRTT: 0 ms
minRTT: 20 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: none
Option Flags: higher precendence, nagle, path mtu capable

Datagrams (max data segment is 1460 bytes):
Rcvd: 45 (out of order: 0), with data: 22, total data bytes: 460
Sent: 45 (retransmit: 2 fastretransmit: 0),with data: 24, total data bytes: 575


BGP neighbor is 192.168.1.5,  remote AS 200, external link
  BGP version 4, remote router ID 192.168.100.1
  BGP state = Established, up for 00:00:45
  Last read 00:00:45, last write 00:00:15, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          2
    Keepalives:             2          2
```




```
                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          2
    Keepalives:             2          2
    Route Refresh:          0          0
    Total:                  5          5
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  Session: 192.168.1.5
  BGP table version 3, neighbor version 3/0
  Output queue size : 0
  Index 2, Advertise bit 1
  2 update-group member
  Slow-peer detection is disabled
  Slow-peer split-update-group dynamic is disabled
                                 Sent       Rcvd
  Prefix activity:               ----       ----
    Prefixes Current:               1          1 (Consumes 80 bytes)
    Prefixes Total:                 1          1
    Implicit Withdraw:              0          0
    Explicit Withdraw:              0          0
    Used as bestpath:             n/a          1
    Used as multipath:            n/a          0

                                   Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Bestpath from this peer:              1        n/a
    Total:                                1          0
  Number of NLRIs in the update sent: max 1, min 0
  Last detected as dynamic slow peer: never
  Dynamic slow peer recovered: never
  Refresh Epoch: 1
  Last Sent Refresh Start-of-rib: never
  Last Sent Refresh End-of-rib: never
  Last Received Refresh Start-of-rib: never
  Last Received Refresh End-of-rib: never
                                       Sent       Rcvd
        Refresh activity:              ----       ----
          Refresh Start-of-RIB          0          0
          Refresh End-of-RIB            0          0

  Address tracking is enabled, the RIB does have a route to 192.168.1.5
  Connections established 1; dropped 0
  Last reset never
  Transport(tcp) path-mtu-discovery is enabled
  Graceful-Restart is disabled
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled
Mininum incoming TTL 0, Outgoing TTL 1
Local host: 192.168.1.6, Local port: 179
Foreign host: 192.168.1.5, Foreign port: 53130
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x2120E0):
Timer          Starts    Wakeups            Next
Retrans             4          0             0x0
TimeWait            0          0             0x0
```

R1 | R2 | R3

```
Foreign host: 192.168.1.5, Foreign port: 53130
Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x2120E0):
Timer          Starts    Wakeups            Next
Retrans             4          0             0x0
TimeWait            0          0             0x0
AckHold             3          1             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0

iss: 2783334713  snduna: 2783334885  sndnxt: 2783334885     sndwnd:  16213
irs: 2721959773  rcvnxt: 2721959946  rcvwnd:      16212  delrcvwnd:    172

SRTT: 124 ms, RTTO: 1405 ms, RTV: 1281 ms, KRTT: 0 ms
minRTT: 20 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: passive open, gen tcbs
Option Flags: nagle, path mtu capable

Datagrams (max data segment is 1460 bytes):
Rcvd: 8 (out of order: 0), with data: 4, total data bytes: 172
Sent: 7 (retransmit: 0 fastretransmit: 0),with data: 5, total data bytes: 171
```

```
SanJose1#
*Mar 25 19:22:44.487: %BGP-5-NBR_RESET: Neighbor 192.168.1.5 reset (Peer closed the session)
*Mar 25 19:22:44.499: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down Peer closed the session
*Mar 25 19:22:44.499: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicast topology base removed from session  Peer closed the session
*Mar 25 19:22:44.739: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
```

e.Configure a discard static route for 172.16.0.0/16 on SanJose2 and as an EBGP peer to ISP.

SanJose2(config)# **ip route 172.16.0.0 255.255.0.0 null0**
SanJose2(config)# **router bgp 64512**
SanJose2(config-router)# **neighbor 192.168.1.1 remote-as 200**
SanJose2(config-router)# **network 172.16.0.0**

```
SanJose2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose2(config)#ip route 172.16.0.0 255.255.0.0 null0
SanJose2(config)#router bgp 64512
SanJose2(config-router)#neighbor 192.168.1.1 remote-as 200
SanJose2(config-router)#
*Mar 25 19:18:57.419: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Up
SanJose2(config-router)#network 172.16.0.0
SanJose2(config-router)#end
SanJose2#
*Mar 25 19:19:32.187: %SYS-5-CONFIG_I: Configured from console by console
```

Step 5: View BGP summary output.

In Step 4, the **show ip bgp neighbors** command was used to verify that SanJose1 and ISP had reached the established state. A useful alternative command is **show ip bgp summary**. The output should be similar to the following.

SanJose2# **show ip bgp summary**

```
SanJose2#show ip bgp summary
BGP router identifier 172.16.32.1, local AS number 64512
BGP table version is 4, main routing table version 4
2 network entries using 288 bytes of memory
4 path entries using 320 bytes of memory
4/2 BGP path/bestpath attribute entries using 544 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
BGP using 1176 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      29      28        4    0    0 00:21:23        2
192.168.1.1     4          200       7       6        4    0    0 00:00:38        1
SanJose2#
*Mar 25 19:22:44.503: %BGP-5-NBR_RESET: Neighbor 192.168.1.1 reset (Peer closed the session)
*Mar 25 19:22:44.511: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Down Peer closed the session
*Mar 25 19:22:44.515: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.1 IPv4 Unicast topology base removed from session  Peer closed the session
*Mar 25 19:22:44.755: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Up
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
```

```
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:37:40, Serial3/1
      192.168.1.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/0
L        192.168.1.2/32 is directly connected, Serial3/0
B        192.168.1.4/30 [20/0] via 192.168.1.1, 00:00:44
 --More--
*Mar 25 19:36:39.567: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
*Mar 25 19:36:39.591: %BGP-5-NBR_RESET: Neighbor 192.168.1.1 reset (Interface flap)
*Mar 25 19:36:39.615: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Down Interface flap
*Mar 25 19:36:39.619: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.1 IPv4 Unicast topology base removed from session  Interface flap
B     192.168.100.0/24 [20/0] via 192.168.1.1, 00:09:48
SanJose2#show ip bgp
BGP table version is 13, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 * i                  172.16.64.1              0    100      0 i
 * i 192.168.100.0    192.168.1.5              0    100      0 200 i
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:41:19, Serial3/1
```

```
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:41:19, Serial3/1
```

Step 6: Verify which path the traffic takes.

f.Clear the IP BGP conversation with the **clear ip bgp** * command on ISP. Wait for the conversations to reestablish with each SanJose router.

ISP# **clear ip bgp ***

```
ISP#clear ip bgp *
ISP#
*Mar 25 19:22:44.475: %BGP-5-ADJCHANGE: neighbor 192.168.1.2 Down User reset
*Mar 25 19:22:44.475: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.2 IPv4 Unicast topology base removed from session  User reset
*Mar 25 19:22:44.483: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Down User reset
*Mar 25 19:22:44.483: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.6 IPv4 Unicast topology base removed from session  User reset
*Mar 25 19:22:44.747: %BGP-5-ADJCHANGE: neighbor 192.168.1.2 Up
*Mar 25 19:22:44.751: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Up
```

g.Test whether ISP can ping the loopback 0 address of 172.16.64.1 on SanJose1 and the serial link between SanJose1 and SanJose2, 172.16.1.1.

`ISP#` **`ping 172.16.64.1`**

```
ISP#ping 172.16.64.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.64.1, timeout is 2 seconds:
.....
```

`ISP#` **`ping 172.16.1.1`**

```
ISP#ping 172.16.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

h.Now ping from ISP to the loopback 0 address of 172.16.32.1 on SanJose2 and the serial link between SanJose1 and SanJose2, 172.16.1.2.

`ISP#` **`ping 172.16.32.1`**

```
ISP#ping 172.16.32.1
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 = 20/28/36 ms
```

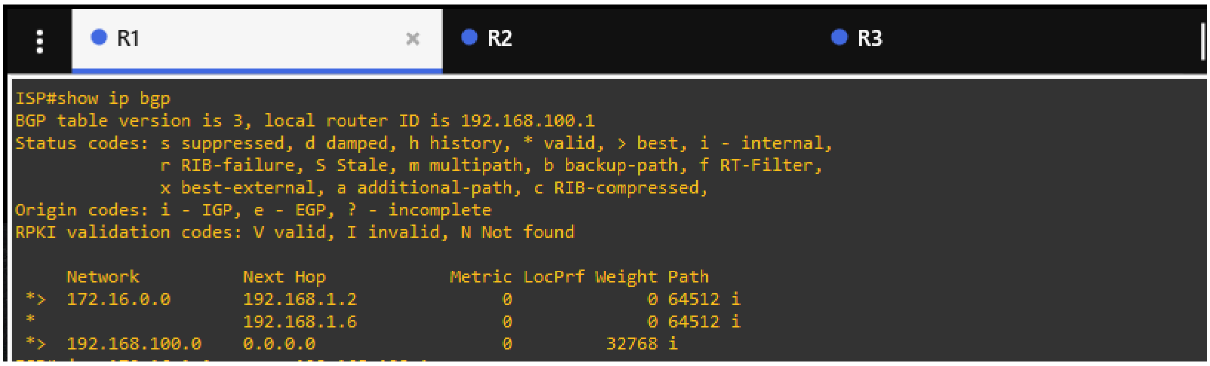
`ISP#` **`ping 172.16.1.2`**

```
ISP#ping 172.16.1.2
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 = 16/28/40 ms
```

You should see successful pings to each IP address on SanJose2 router. Ping attempts to 172.16.64.1 and 172.16.1.1 should fail. Why does this happen?

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

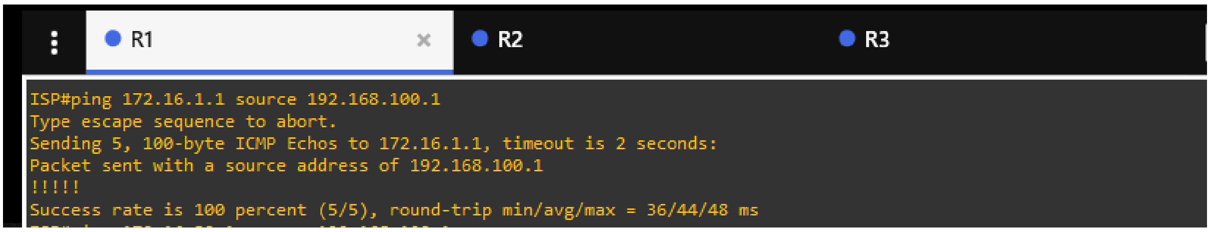
`ISP#` **`show ip bgp`**



```
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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

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

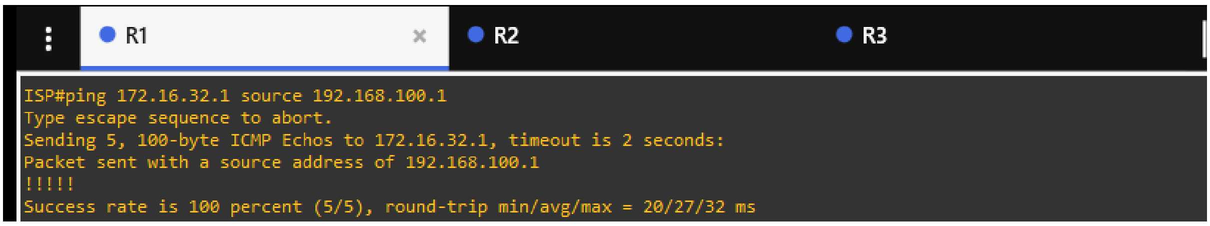
j.At this point, the ISP router should be able to get to each network connected to SanJose1 and SanJose2 from the loopback address 192.168.100.1. Use the extended **ping** command and specify the source address of ISP Lo0 to test.

ISP# **ping 172.16.1.1 source 192.168.100.1**



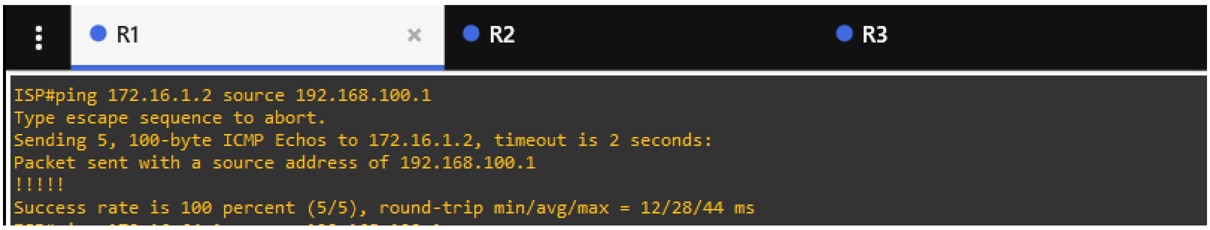
```
ISP#ping 172.16.1.1 source 192.168.100.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
Packet sent with a source address of 192.168.100.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/44/48 ms
```

ISP# **ping 172.16.32.1 source 192.168.100.1**



```
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 = 20/27/32 ms
```

ISP# **ping 172.16.1.2 source 192.168.100.1**



```
ISP#ping 172.16.1.2 source 192.168.100.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.2, 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 = 12/28/44 ms
```

ISP# **ping 172.16.64.1 source 192.168.100.1**

```
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 = 24/36/44 ms
```

You can also use the extended ping dialogue to specify the source address, as shown in this example.

```
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 = 20/20/24
ms
ISP#
```

```
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 = 32/42/48 ms
```

Complete reachability has been demonstrated between the ISP router and both SanJose1 and SanJose2.

Step 7: Configure the BGP next-hop-self feature.

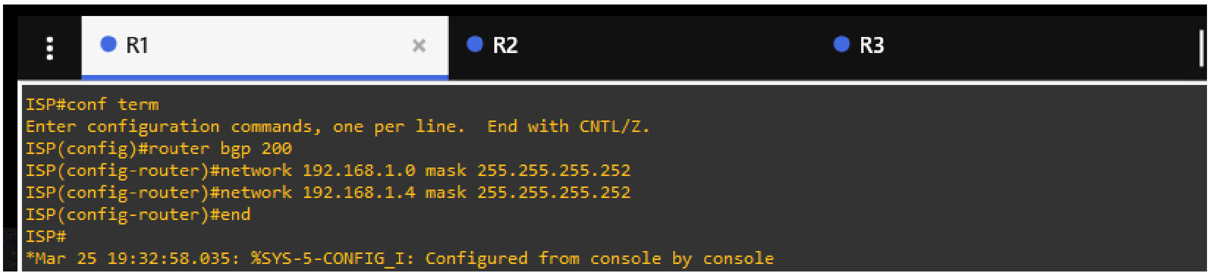
SanJose1 is unaware of the link between ISP and SanJose2, and SanJose2 is unaware of the link between ISP and SanJose1. Before ISP can successfully ping all the internal serial interfaces of AS

64512, these serial links should be advertised via BGP on the ISP router. This can also be resolved via EIGRP on each SanJose router. One method is for ISP to advertise these links.

a.Issue the following commands on the ISP router.

```
ISP(config)# router bgp 200
```

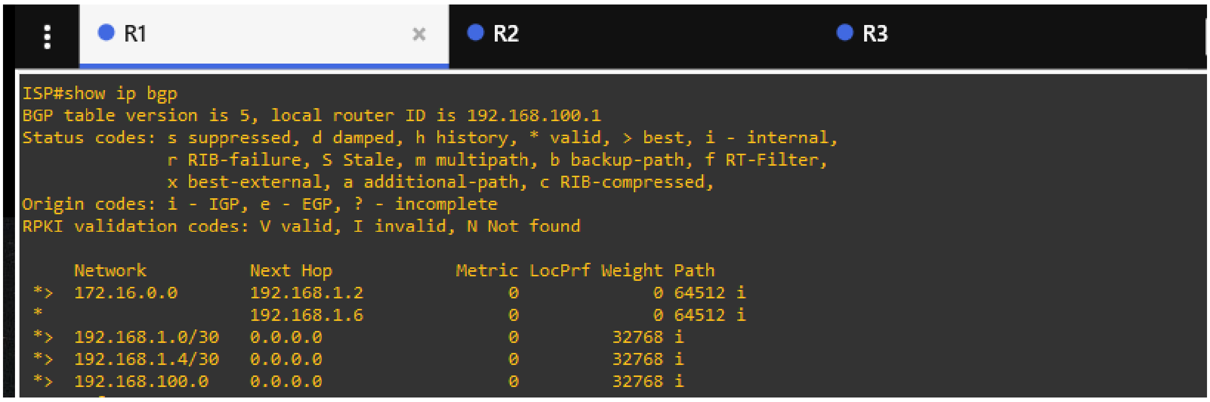
```
ISP(config-router)# network 192.168.1.0 mask 255.255.255.252
ISP(config-router)# network 192.168.1.4 mask 255.255.255.252
```




```
ISP#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
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)#end
ISP#
*Mar 25 19:32:58.035: %SYS-5-CONFIG_I: Configured from console by console
```

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
```




```
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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  172.16.0.0       192.168.1.2              0             0 64512 i
 *                    192.168.1.6              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
```

c.Verify on SanJose1 and SanJose2 that the opposite WAN link is included in the routing table. The output from SanJose2 is as follows.

```
SanJose2# show ip route
```

```
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:41:19, Serial3/1
```

```
      192.168.1.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/0
L        192.168.1.2/32 is directly connected, Serial3/0
B        192.168.1.4/30 [20/0] via 192.168.1.1, 00:00:44
 --More--
*Mar 25 19:36:39.567: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
*Mar 25 19:36:39.591: %BGP-5-NBR_RESET: Neighbor 192.168.1.1 reset (Interface flap)
*Mar 25 19:36:39.615: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Down Interface flap
*Mar 25 19:36:39.619: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.1 IPv4 Unicast topology base removed from session  Interface flap
B     192.168.100.0/24 [20/0] via 192.168.1.1, 00:09:48
```

d.To better understand the **next-hop-self** command we will remove ISP advertising its two WAN links and shutdown the WAN link between ISP and SanJose2. The only possible path from SanJose2 to ISP's 192.168.100.0/24 is through SanJose1.

```
ISP(config)# router bgp 200
ISP(config-router)# no network 192.168.1.0 mask 255.255.255.252
ISP(config-router)# no network 192.168.1.4 mask 255.255.255.252
ISP(config-router)# exit
ISP(config)# interface serial 0/0/1
ISP(config-if)# shutdown
ISP(config-if)#
```

```
R1    R2    R3
ISP#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
ISP(config)#router bgp 200
ISP(config-router)#no network 192.168.1.0 mask 255.255.255.252
ISP(config-router)#no network 192.168.1.4 mask 255.255.255.252
ISP(config-router)#exit
ISP(config)#interface serial 3/1
ISP(config-if)#shutdown
ISP(config-if)#
*Mar 25 19:36:06.963: %BGP-5-NBR_RESET: Neighbor 192.168.1.2 reset (Interface flap)
*Mar 25 19:36:06.983: %BGP-5-ADJCHANGE: neighbor 192.168.1.2 Down Interface flap
*Mar 25 19:36:06.987: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.2 IPv4 Unicast topology base removed from session  Interface flap
```

e.Display SanJose2's BGP table using the **show ip bgp** command and the IPv4 routing table with **show ip route**.

```
SanJose2# show ip bgp
```

```
SanJose2#show ip bgp
BGP table version is 13, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 * i                  172.16.64.1              0    100      0 i
 * i 192.168.100.0    192.168.1.5              0    100      0 200 i
```

SanJose2# **show ip route**

```
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:41:19, Serial3/1
```

f.Issue the **next-hop-self** command on SanJose1 and SanJose2 to advertise themselves as the next hop to their IBGP peer.

SanJose1(config)# **router bgp 64512**
SanJose1(config-router)# **neighbor 172.16.32.1 next-hop-self**

```
SanJose1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose1(config)#router bgp 64512
SanJose1(config-router)#neighbor 172.16.32.1 next-hop-self
SanJose1(config-router)#end
SanJose1#
```

SanJose2(config)# **router bgp 64512**

SanJose2(config-router)# **neighbor 172.16.64.1 next-hop-self**

```
SanJose2(config)#router bgp 64512
SanJose2(config-router)#neighbor 172.16.64.1 next-hop-self
SanJose2(config-router)#
*Mar 25 19:39:51.187: %BGP-5-NBR_RESET: Neighbor 172.16.64.1 reset (Peer closed the session)
*Mar 25 19:39:51.195: %BGP-5-ADJCHANGE: neighbor 172.16.64.1 Down Peer closed the session
*Mar 25 19:39:51.195: %BGP_SESSION-5-ADJCHANGE: neighbor 172.16.64.1 IPv4 Unicast topology base removed from session  Peer closed the session
*Mar 25 19:39:51.971: %BGP-5-ADJCHANGE: neighbor 172.16.64.1 Up
SanJose2(config-router)#end
SanJose2#
*Mar 25 19:40:10.067: %SYS-5-CONFIG_I: Configured from console by console
```

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

```
SanJose1# clear ip bgp *
SanJose1#
```

```
SanJose1#clear ip bgp *
SanJose1#
*Mar 25 19:39:51.107: %BGP-5-ADJCHANGE: neighbor 172.16.32.1 Down User reset
*Mar 25 19:39:51.107: %BGP_SESSION-5-ADJCHANGE: neighbor 172.16.32.1 IPv4 Unicast topology base removed from session  User reset
*Mar 25 19:39:51.115: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar 25 19:39:51.115: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicast topology base removed from session  User reset
*Mar 25 19:39:51.895: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
*Mar 25 19:39:51.907: %BGP-5-ADJCHANGE: neighbor 172.16.32.1 Up
SanJose1#
*Mar 25 19:40:13.039: %BGP-5-NBR_RESET: Neighbor 172.16.32.1 reset (Peer closed the session)
*Mar 25 19:40:13.047: %BGP-5-ADJCHANGE: neighbor 172.16.32.1 Down Peer closed the session
*Mar 25 19:40:13.047: %BGP_SESSION-5-ADJCHANGE: neighbor 172.16.32.1 IPv4 Unicast topology base removed from session  Peer closed the session
*Mar 25 19:40:14.027: %BGP-5-ADJCHANGE: neighbor 172.16.32.1 Up
```

```
SanJose2# clear ip bgp *
SanJose2#
```

```
SanJose2#clear ip bgp *
SanJose2#
*Mar 25 19:40:13.075: %BGP-5-ADJCHANGE: neighbor 172.16.64.1 Down User reset
*Mar 25 19:40:13.075: %BGP_SESSION-5-ADJCHANGE: neighbor 172.16.64.1 IPv4 Unicast topology base removed from session  User reset
*Mar 25 19:40:14.031: %BGP-5-ADJCHANGE: neighbor 172.16.64.1 Up
```

h.After the routers have returned to established BGP speakers, issue the **show ip bgp** command on SanJose2 and notice that the next hop is now SanJose1 instead of ISP.

```
SanJose2# show ip bgp
```

```
SanJose2#show ip bgp
BGP table version is 1, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 * i 172.16.0.0       172.16.64.1              0    100      0 i
 * i 192.168.100.0    172.16.64.1              0    100      0 200 i
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
```

```
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:45:21, Serial3/1
SanJose2#
*Mar 25 19:42:59.567: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
```

i.The **show ip route** command on SanJose2 now displays the 192.168.100.0/24 network because SanJose1 is the next hop, 172.16.64.1, which is reachable from SanJose2.

SanJose2# **show ip route**

```
SanJose2#show ip route
*Mar 25 19:43:02.415: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Up
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:47:12, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/0
L        192.168.1.2/32 is directly connected, Serial3/0
B     192.168.100.0/24 [20/0] via 192.168.1.1, 00:00:02
```

j.Before configuring the next BGP attribute, restore the WAN link between ISP and SanJose3. This will change the BGP table and routing table on both routers. For example, SanJose2's routing table shows 192.168.100.0/24 will now have a better path through ISP.

ISP(config)# **interface serial 0/0/1**
ISP(config-if)# **no shutdown**
ISP(config-if)#

```
ISP(config)#interface serial 3/1
ISP(config-if)#no shutdown
ISP(config-if)#
*Mar 25 19:42:46.251: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
ISP(config-if)#
*Mar 25 19:42:47.259: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
ISP(config-if)#
*Mar 25 19:43:02.303: %BGP-5-ADJCHANGE: neighbor 192.168.1.2 Up
ISP(config-if)#end
ISP#
*Mar 25 19:48:44.507: %SYS-5-CONFIG_I: Configured from console by console
```

SanJose2# **show ip route**

```
SanJose2#show ip route
*Mar 25 19:43:02.415: %BGP-5-ADJCHANGE: neighbor 192.168.1.1 Up
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 00:47:12, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/0
L        192.168.1.2/32 is directly connected, Serial3/0
B     192.168.100.0/24 [20/0] via 192.168.1.1, 00:00:02
```

Step 8: Set BGP local preference.

a.Because the local preference value is shared between IBGP neighbors, configure a simple route map that references the local preference value on SanJose1 and SanJose2. This policy adjusts outbound traffic to prefer the link off the SanJose1 router instead of the metered T1 off SanJose2.

SanJose1(config)# **route-map PRIMARY_T1_IN permit 10**
SanJose1(config-route-map)# **set local-preference 150**
SanJose1(config-route-map)# **exit**
SanJose1(config)# **router bgp 64512**
SanJose1(config-router)# **neighbor 192.168.1.5 route-map PRIMARY_T1_IN in**

```
SanJose1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose1(config)#route-map PRIMARY_T1_IN permit 10
SanJose1(config-route-map)#set local-preference 150
SanJose1(config-route-map)#exit
SanJose1(config)#router bgp 64512
SanJose1(config-router)#neighbor 192.168.1.5 route-map PRIMARY_T1_IN in
```

SanJose2(config)# **route-map SECONDARY_T1_IN permit 10**
SanJose2(config-route-map)# **set local-preference 125**
SanJose1(config-route-map)# **exit**
SanJose2(config)# **router bgp 64512**
SanJose2(config-router)# **neighbor 192.168.1.1 route-map SECONDARY_T1_IN in**

```
SanJose2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose2(config)#route-map SECONDARY_T1_IN permit 10
SanJose2(config-route-map)#set local-preference 125
SanJose2(config-route-map)#exit
SanJose2(config)#router bgp 64512
SanJose2(config-router)#neighbor 192.168.1.1 route-map SECONDARY_T1_IN in
```

b.Use the **clear ip bgp * soft** command after configuring this new policy. When the conversations have been reestablished, issue the **show ip bgp** command on SanJose1 and SanJose2.

SanJose1# **clear ip bgp * soft**

```
SanJose1#clear ip bgp * soft
```

SanJose2# **clear ip bgp * soft**

```
*Mar 25 19:47:31.067: %SYS-5-CONFIG_I: Configured from console by console
SanJose2#clear ip bgp * soft
```

SanJose1# **show ip bgp**

```
SanJose1#show ip bgp
BGP table version is 5, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 * i 172.16.0.0       172.16.32.1              0    100      0 i
 *>                   0.0.0.0                  0         32768 i
```

```
 *>  192.168.100.0    192.168.1.5              0    150      0 200 i
```

SanJose2# **show ip bgp**

```
SanJose2#show ip bgp
BGP table version is 5, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 * i                  172.16.64.1              0    100      0 i
 *   192.168.100.0    192.168.1.1              0    125      0 200 i
 *>i                  172.16.64.1              0    150      0 200 i
```

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 SanJose1 and ISP. SanJose2's next hop to 192.168.100.0/24 is SanJose1 because both routers have been configured using the **next-hop-self** command.

Step 9: Set BGP MED.

a.In the previous step we saw that SanJose1 and SanJose2 will route traffic for 192.168.100.0/24 using the link between SanJose1 and ISP. Examine what the return path ISP takes to reach AS 64512. Notice that the return path is different from the original path. This is known as asymmetric routing and is not necessarily an unwanted trait.

```
ISP# show ip bgp
```

```
R1    R2    R3
ISP#show ip bgp
BGP table version is 11, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

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

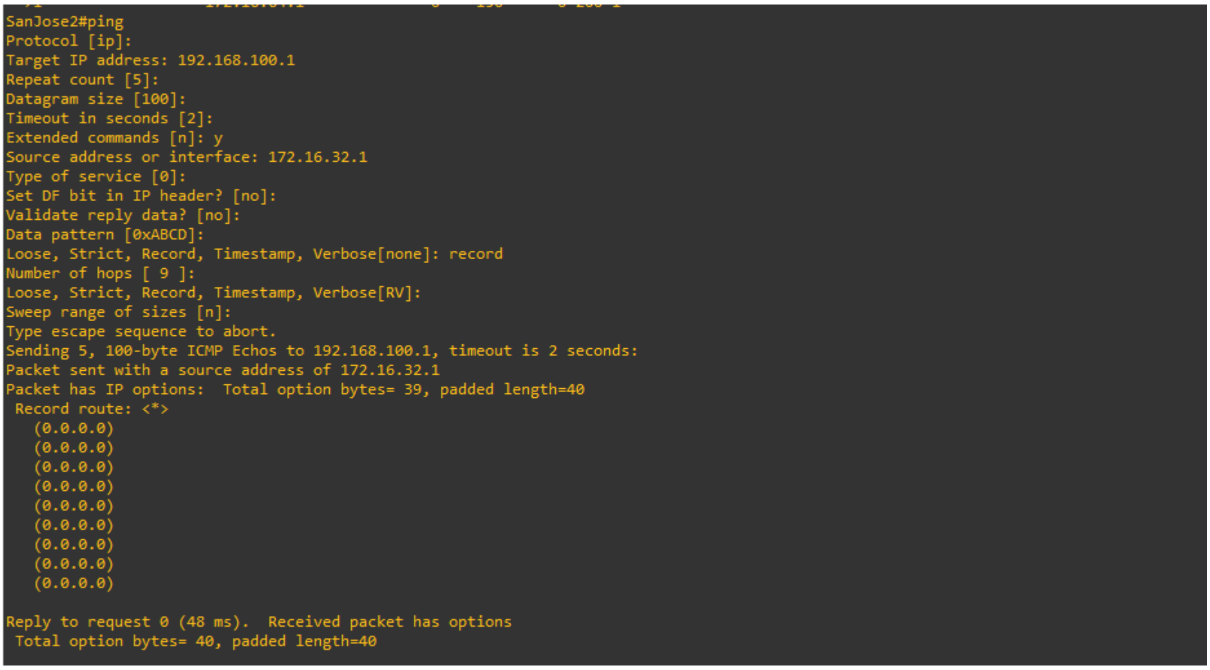
```
ISP# show ip route
```

```
R1    R2    R3
ISP#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

B     172.16.0.0/16 [20/0] via 192.168.1.6, 00:08:46
      192.168.1.0/24 is variably subnetted, 4 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/1
L        192.168.1.1/32 is directly connected, Serial3/1
C        192.168.1.4/30 is directly connected, Serial3/0
L        192.168.1.5/32 is directly connected, Serial3/0
      192.168.100.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.100.0/24 is directly connected, Loopback0
L        192.168.100.1/32 is directly connected, Loopback0
```

b.Use an extended **ping** command to verify this situation. Specify the **record** option and compare your output to the following. Notice the return path using the exit interface 192.168.1.1 to SanJose2.

```
SanJose2# ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]:
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 5, 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
```



```
SanJose2#ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]:
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 5, 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 (48 ms).  Received packet has options
 Total option bytes= 40, padded length=40
```

```
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 (48 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (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)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 2 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
```

```
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)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 2 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 3 (68 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 4 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
```

```
Reply to request 4 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Success rate is 100 percent (5/5), round-trip min/avg/max = 48/53/68 ms
```

b.Create a new policy to force the ISP router to return all traffic via SanJose1. Create a second route map utilizing the MED (metric) that is shared between EBGP neighbors.

```
SanJose1(config)#route-map PRIMARY_T1_MED_OUT permit 10
SanJose1(config-route-map)#set Metric 50
SanJose1(config-route-map)#exit
SanJose1(config)#router bgp 64512
SanJose1(config-router)#neighbor 192.168.1.5 route-map
PRIMARY_T1_MED_OUT out
```

```
SanJose1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose1(config)#route-map PRIMARY_T1_MED_OUT permit 10
SanJose1(config-route-map)#set Metric 50
SanJose1(config-route-map)#exit
SanJose1(config)#router bgp 64512
SanJose1(config-router)#neighbor 192.168.1.5 route-map PRIMARY_T1_MED_OUT out
```

```
SanJose2(config)#route-map SECONDARY_T1_MED_OUT permit 10
SanJose2(config-route-map)#set Metric 75
SanJose2(config-route-map)#exit
SanJose2(config)#router bgp 64512
SanJose2(config-router)#neighbor 192.168.1.1 route-map
SECONDARY_T1_MED_OUT out
```

```
SanJose2(config)#route-map SECONDARY_T1_MED_OUT permit 10
SanJose2(config-route-map)#set Metric 75
SanJose2(config-route-map)#exit
SanJose2(config)#router bgp 64512
SanJose2(config-router)#$2.168.1.1 route-map SECONDARY_T1_MED_OUT out
SanJose2(config-router)#end
```

c.Use the **clear ip bgp * soft** command after issuing this new policy. Issuing the **show ip bgp** command as follows on SanJose1 or SanJose2 does not indicate anything about this newly defined policy.

```
SanJose1# clear ip bgp * soft
```

```
SanJose1#clear ip bgp * soft
```

```
SanJose2# clear ip bgp * soft
```

```
SanJose2#clear ip bgp * soft
```

```
SanJose1# show ip bgp
```

```
SanJose1#show ip bgp
BGP table version is 5, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 * i 172.16.0.0       172.16.32.1              0    100      0 i
 *>                   0.0.0.0                  0         32768 i
 *>  192.168.100.0    192.168.1.5              0    150      0 200 i
```

```
SanJose2# show ip bgp
```

```
SanJose2#show ip bgp
BGP table version is 5, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 * i                  172.16.64.1              0    100      0 i
 *   192.168.100.0    192.168.1.1              0    125      0 200 i
 *>i                  172.16.64.1              0    150      0 200 i
```

d.Reissue an extended **ping** command with the **record** command. Notice the change in return path using the exit interface 192.168.1.5 to SanJose1.

```
SanJose2# ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]:
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 5, 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: <*>
```

```
SanJose2#ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 172.16.32.1
Type of service [0]:
```

```
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 5, 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 (60 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 1 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
```

```
Reply to request 1 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 2 (52 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 3 (44 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Reply to request 4 (64 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
```

```
Reply to request 4 (64 ms).  Received packet has options
 Total option bytes= 40, padded length=40
 Record route:
   (172.16.1.2)
   (192.168.1.6)
   (192.168.1.5)
   (192.168.1.5)
   (172.16.1.1)
   (172.16.1.2) <*>
   (0.0.0.0)
   (0.0.0.0)
   (0.0.0.0)
 End of list

Success rate is 100 percent (5/5), round-trip min/avg/max = 44/54/64 ms
```

```
ISP# show ip bgp
```

```
ISP#show ip bgp
BGP table version is 13, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *   172.16.0.0       192.168.1.2             75             0 64512 i
 *>                   192.168.1.6             50             0 64512 i
 *>  192.168.100.0    0.0.0.0                  0         32768 i
```

Step 10: Establish a default route.

a.Configure ISP to inject a default route to both SanJose1 and SanJose2 using BGP using the **default-originate** command. This command does not require the presence of 0.0.0.0 in the ISP router. Configure the 10.0.0.0/8 network which will not be advertised using BGP. This network will be used to test the default route on SanJose1 and SanJose2.

```
ISP(config)# router bgp 200
ISP(config-router)# neighbor 192.168.1.6 default-originate
ISP(config-router)# neighbor 192.168.1.2 default-originate
ISP(config-router)# exit
ISP(config)# interface loopback 10
ISP(config-if)# ip address 10.0.0.1 255.255.255.0
ISP(config-if)#
```

```
ISP(config)#router bgp 200
ISP(config-router)#neighbor 192.168.1.6 default-originate
ISP(config-router)#neighbor 192.168.1.2 default-originate
ISP(config-router)#exit
ISP(config)#interface loopback 10
ISP(config-if)#
*Mar 25 20:07:01.983: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback10, changed state to up
ISP(config-if)#ip address 10.0.0.1 255.255.255.0
```

b.Verify that both routers have received the default route by examining the routing tables on SanJose1 and SanJose2. Notice that both routers prefer the route between SanJose1 and ISP.

```
SanJose1# show ip route
```

```
SanJose1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.1.5 to network 0.0.0.0

B*    0.0.0.0/0 [20/0] via 192.168.1.5, 00:00:09
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.1/32 is directly connected, Serial3/1
D        172.16.32.0/24 [90/2297856] via 172.16.1.2, 01:11:57, Serial3/1
C        172.16.64.0/24 is directly connected, Loopback0
L        172.16.64.1/32 is directly connected, Loopback0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.1/32 is directly connected, Serial3/1
D        172.16.32.0/24 [90/2297856] via 172.16.1.2, 01:11:57, Serial3/1
C        172.16.64.0/24 is directly connected, Loopback0
L        172.16.64.1/32 is directly connected, Loopback0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.4/30 is directly connected, Serial3/0
L        192.168.1.6/32 is directly connected, Serial3/0
B     192.168.100.0/24 [20/0] via 192.168.1.5, 00:20:42
```

SanJose2# **show ip route**

```
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is 172.16.64.1 to network 0.0.0.0

B*    0.0.0.0/0 [200/0] via 172.16.64.1, 00:00:27
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.2/32 is directly connected, Serial3/1
C        172.16.32.0/24 is directly connected, Loopback0
L        172.16.32.1/32 is directly connected, Loopback0
D        172.16.64.0/24 [90/2297856] via 172.16.1.1, 01:12:15, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/30 is directly connected, Serial3/0
L        192.168.1.2/32 is directly connected, Serial3/0
B     192.168.100.0/24 [200/0] via 172.16.64.1, 00:21:00
```

c.The preferred default route is by way of SanJose1 because of the higher local preference attribute configured on SanJose1 earlier.

SanJose2# **show ip bgp**

```
SanJose2#show ip bgp
BGP table version is 7, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>i 0.0.0.0          172.16.64.1              0    150      0 200 i
 *                    192.168.1.1                   125      0 200 i
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 * i                  172.16.64.1              0    100      0 i
 *   192.168.100.0    192.168.1.1              0    125      0 200 i
 *>i                  172.16.64.1              0    150      0 200 i
SanJose2#traceroute 10.0.0.1
Type escape sequence to abort.
Tracing the route to 10.0.0.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.1.1 16 msec 28 msec 60 msec
  2 192.168.1.5 [AS 200] 68 msec 48 msec 60 msec
```

d.Using the traceroute command verify that packets to 10.0.0.1 is using the default route through SanJose1.

```
SanJose2# traceroute 10.0.0.1
```

```
SanJose2#traceroute 10.0.0.1
Type escape sequence to abort.
Tracing the route to 10.0.0.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.1.1 16 msec 28 msec 60 msec
  2 192.168.1.5 [AS 200] 68 msec 48 msec 60 msec
```

e.Next, test how BGP adapts to using a different default route when the path between SanJose1 and ISP goes down.

```
ISP(config)# interface serial 0/0/0
ISP(config-if)# shutdown
ISP(config-if)#
```

```
ISP#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
ISP(config)#interface serial 3/0
ISP(config-if)#shutdown
ISP(config-if)#
*Mar 25 20:10:12.115: %BGP-5-NBR_RESET: Neighbor 192.168.1.6 reset (Interface flap)
*Mar 25 20:10:12.139: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Down Interface flap
*Mar 25 20:10:12.143: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.6 IPv4 Unicast topology base removed from session  Interface flap
ISP(config-if)#
*Mar 25 20:10:14.091: %LINK-5-CHANGED: Interface Serial3/0, changed state to administratively down
*Mar 25 20:10:15.091: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
ISP(config-if)#
```

f.Verify that both routers are modified their routing tables with the default route using the path between SanJose2 and ISP.

```
SanJose1# show ip rout
```

```
SanJose1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.1.5 to network 0.0.0.0

B*    0.0.0.0/0 [20/0] via 192.168.1.5, 00:02:54
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
S        172.16.0.0/16 is directly connected, Null0
C        172.16.1.0/24 is directly connected, Serial3/1
L        172.16.1.1/32 is directly connected, Serial3/1
D        172.16.32.0/24 [90/2297856] via 172.16.1.2, 01:14:42, Serial3/1
C        172.16.64.0/24 is directly connected, Loopback0
L        172.16.64.1/32 is directly connected, Loopback0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.4/30 is directly connected, Serial3/0
L        192.168.1.6/32 is directly connected, Serial3/0
B     192.168.100.0/24 [20/0] via 192.168.1.5, 00:23:27
```

SanJose2# **show ip route**

```
anJose2#show ip route
odes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      E1 - OSPF external type 1, E2 - OSPF external type 2
      i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
      ia - IS-IS inter area, * - candidate default, U - per-user static route
      o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
      + - replicated route, % - next hop override

ateway of last resort is 192.168.1.1 to network 0.0.0.0

*     0.0.0.0/0 [20/0] via 192.168.1.1, 00:00:37
      172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
         172.16.0.0/16 is directly connected, Null0
         172.16.1.0/24 is directly connected, Serial3/1
         172.16.1.2/32 is directly connected, Serial3/1
         172.16.32.0/24 is directly connected, Loopback0
         172.16.32.1/32 is directly connected, Loopback0
         172.16.64.0/24 [90/2297856] via 172.16.1.1, 01:15:35, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
         192.168.1.0/30 is directly connected, Serial3/0
         192.168.1.2/32 is directly connected, Serial3/0
      192.168.100.0/24 [20/0] via 192.168.1.1, 00:00:37
anJose2#
```

gVerify the new path using the traceroute command to 10.0.0.1 from SanJose1. Notice the default route is now through SanJose2.

```
SanJose1# trace 10.0.0.1
Type escape sequence to abort.
Tracing the route to 10.0.0.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.1.2 8 msec 8 msec 8 msec
  2 192.168.1.1 [AS 200] 12 msec *  12 msec
SanJose1#
```

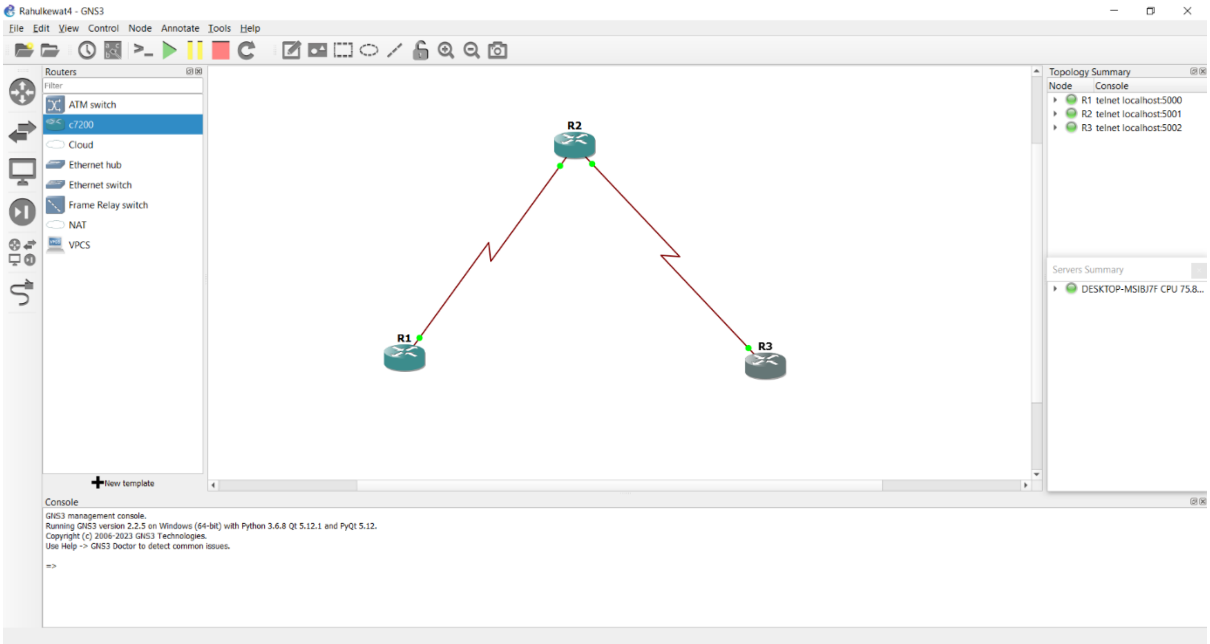
```
SanJose1#trace 10.0.0.1
Type escape sequence to abort.
Tracing the route to 10.0.0.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.1.2 28 msec 20 msec 40 msec
  2 192.168.1.1 [AS 200] 68 msec 56 msec 56 msec
SanJose1#
```

Practical 4

Aim: **Secure the Management Plane**

Writeup:

Topology

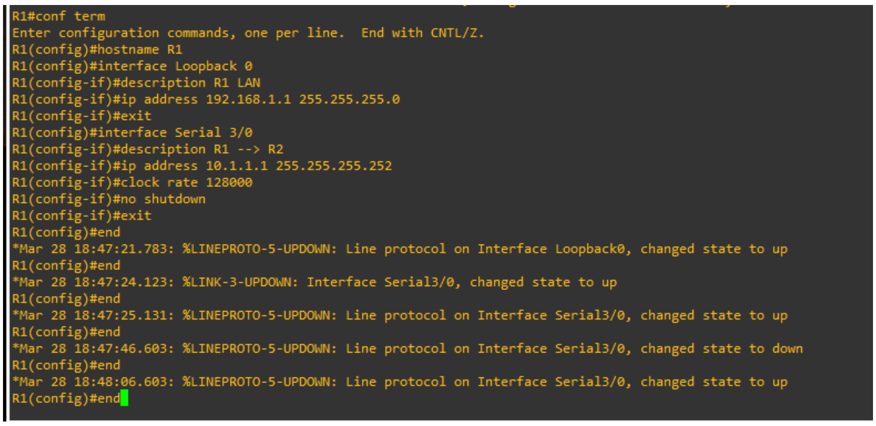


Step 1: Configure loopbacks and assign addresses.

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.

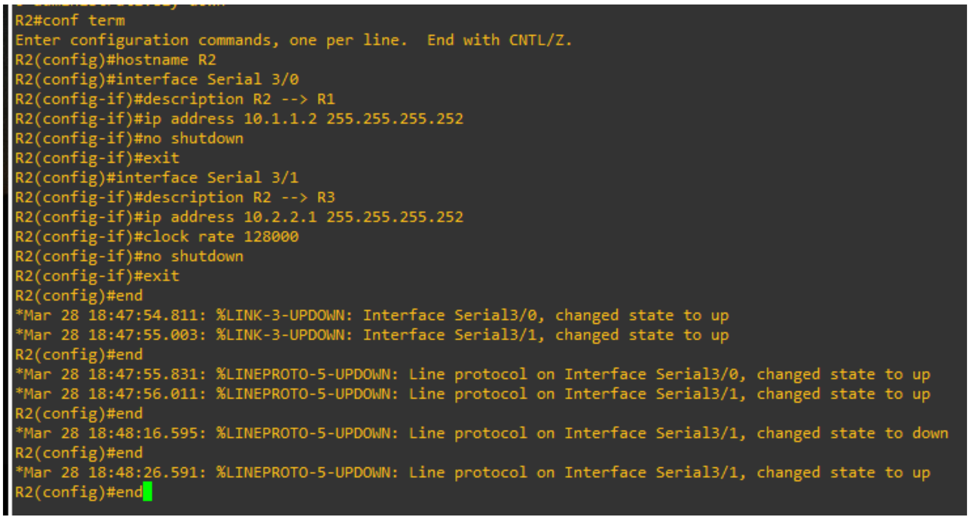
R1

```
hostname R1
interface Loopback 0
description R1 LAN
ip address 192.168.1.1 255.255.255.0
exit
interface Serial 3/0
description R1 --> R2
ip address 10.1.1.1 255.255.255.252
clock rate 128000
no shutdown
exit
end
```



R2

```
hostname R2
interface Serial 3/0
description R2 --> R1
ip address 10.1.1.2 255.255.255.252
no shutdown
exit
interface Serial 3/1
description R2 --> R3
ip address 10.2.2.1 255.255.255.252
clock rate 128000
no shutdown
exit
end
```



```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#interface Serial 3/0
R2(config-if)#description R2 --> R1
R2(config-if)#ip address 10.1.1.2 255.255.255.252
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#interface Serial 3/1
R2(config-if)#description R2 --> R3
R2(config-if)#ip address 10.2.2.1 255.255.255.252
R2(config-if)#clock rate 128000
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#end
*Mar 28 18:47:54.811: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
*Mar 28 18:47:55.003: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
R2(config)#end
*Mar 28 18:47:55.831: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
*Mar 28 18:47:56.011: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
R2(config)#end
*Mar 28 18:48:16.595: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
R2(config)#end
*Mar 28 18:48:26.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
R2(config)#end
```

R3

```
hostname R3
interface Loopback0
description R3 LAN
ip address 192.168.3.1 255.255.255.0
exit
interface Serial 3/1
description R3 --> R2
ip address 10.2.2.2 255.255.255.252
no shutdown
exit
end
```

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#interface Loopback0
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)#interface Serial 3/1
R3(config-if)#description R3 --> R2
R3(config-if)#ip address 10.2.2.2 255.255.255.252
R3(config-if)#no shutdown
R3(config-if)#exit!
R3(config)#end
*Mar 28 18:48:20.543: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config)#end
*Mar 28 18:48:22.935: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
*Mar 28 18:48:23.935: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
R3(config)#end
```

Step 2: Configure static routes.

[a]: On R1, configure a default static route to ISP.

R1(config)# **ip route 0.0.0.0 0.0.0.0 10.1.1.2**

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip route 0.0.0.0 0.0.0.0 10.1.1.2
R1(config)#
```

[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**

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#ip route 0.0.0.0 0.0.0.0 10.2.2.1
R3(config)#
```

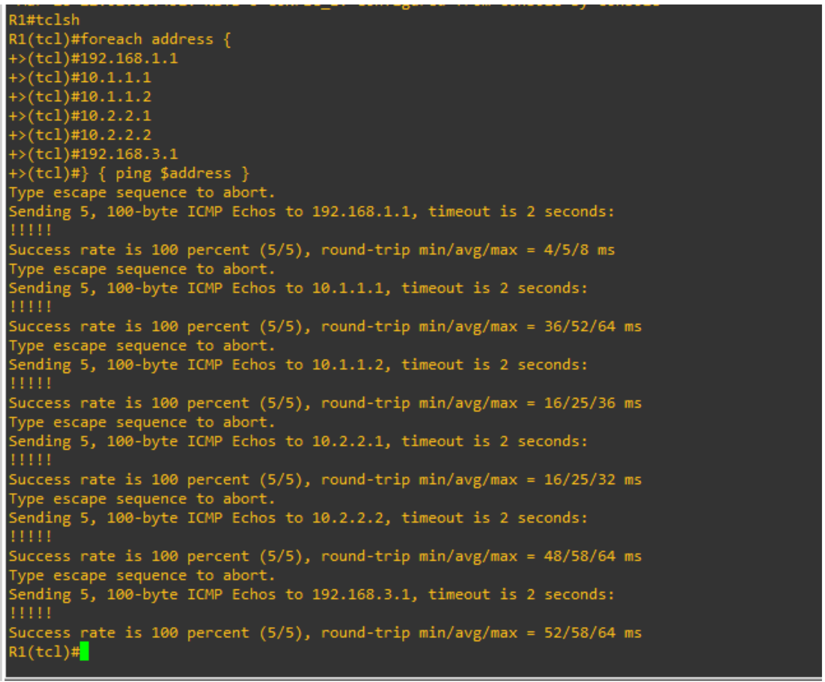
[c]: On R2, configure two static routes.

R2(config)# **ip route 192.168.1.0 255.255.255.0 10.1.1.1**
R2(config)# **ip route 192.168.3.0 255.255.255.0 10.2.2.2**

```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#ip route 192.168.1.0 255.255.255.0 10.1.1.1
R2(config)#ip route 192.168.3.0 255.255.255.0 10.2.2.2
```

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

```
foreach address {
192.168.1.1
10.1.1.1
10.1.1.2
10.2.2.1
10.2.2.2
192.168.3.1
} { ping $address }
```



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**

[b]: Configure the enable secret encrypted password on both routers.

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**

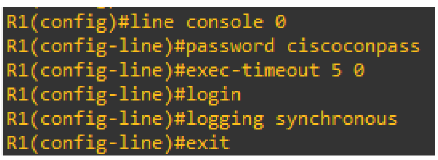
R1(config-line)# **exec-timeout 5 0**

R1(config-line)# **login**

R1(config-line)# **logging synchronous**

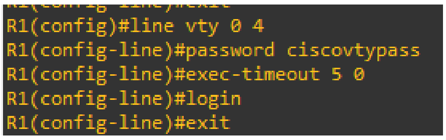
R1(config-line)# **exit**

R1(config)#



[d]: Configure the password on the vty lines for router R1.

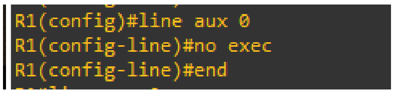
```
R1(config)# line vty 0 4
R1(config-line)# password ciscovtypass
R1(config-line)# exec-timeout 5 0
R1(config-line)# login
R1(config-line)# exit
R1(config)#
```



```
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
```

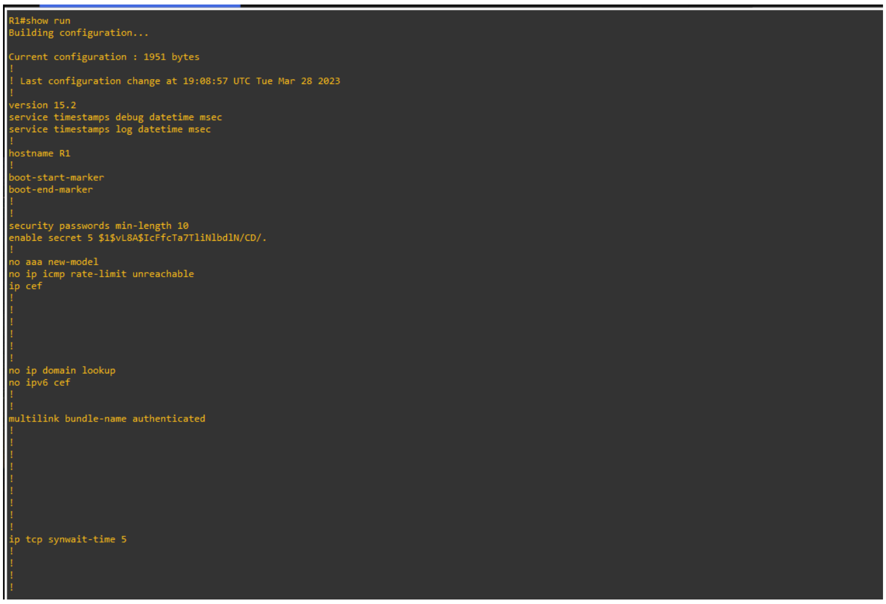
[e]: The aux port is a legacy port used to manage a router remotely using a modem and is hardly ever used. Therefore, disable the aux port.

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



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

[f]: Enter privileged EXEC mode and issue the **show run** command. Can you read the enable secret password? Why or why not?



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

Current configuration : 1951 bytes
!
! Last configuration change at 19:08:57 UTC Tue Mar 28 2023
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
!
hostname R1
!
boot-start-marker
boot-end-marker
!
!
security passwords min-length 10
enable secret 5 $1$vL8A$IcFfcTa7TliNlbdlN/CD/.
!
no aaa new-model
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
!
!
no ip domain lookup
no ipv6 cef
!
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
ip tcp synwait-time 5
!
!
!
!
```

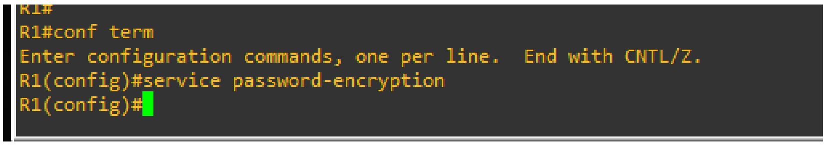
```
interface Loopback0
 description R1 LAN
 ip address 192.168.1.1 255.255.255.0
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex full
!
interface Serial1/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
```

```
 serial restart-delay 0
!
interface Serial3/0
 description R1 --> R2
 ip address 10.1.1.1 255.255.255.252
 serial restart-delay 0
 clock rate 128000
!
interface Serial3/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/3
 no ip address
 shutdown
 serial restart-delay 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
ip route 0.0.0.0 0.0.0.0 10.1.1.2
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 5 0
 privilege level 15
 password ciscoconpass
 logging synchronous
 login
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 no exec
```

```
ip route 0.0.0.0 0.0.0.0 10.1.1.2
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 5 0
 privilege level 15
 password ciscoconpass
 logging synchronous
 login
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 no exec
 stopbits 1
line vty 0 4
 exec-timeout 5 0
 password ciscovtypass
 login
!
!
end
```

[g]: Use the **service password-encryption** command to encrypt the line console and vty passwords.

```
R1(config)# service password-encryption
R1(config)#
```



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

[h]: Issue the **show run** command. Can you read the console, aux, and vty passwords? Why or why not?

```
*Mar 28 19:21:02.295: %SYS-5-CONFIG_I: Configured from console by console
R1#show run
Building configuration...

Current configuration : 2011 bytes
!
! Last configuration change at 19:21:02 UTC Tue Mar 28 2023
!
version 15.2
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 $1$vL8A$IcFfcTa7TliNlbdlN/CD/.
!
no aaa new-model
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
!
!
no ip domain lookup
no ipv6 cef
!
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
ip tcp synwait-time 5
!
 --More--
```

```
interface Loopback0
 description R1 LAN
 ip address 192.168.1.1 255.255.255.0
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex full
!
interface Serial1/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 --More--
```

```
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/0
 description R1 --> R2
 ip address 10.1.1.1 255.255.255.252
 serial restart-delay 0
 clock rate 128000
!
interface Serial3/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/3
 no ip address
 shutdown
 serial restart-delay 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
ip route 0.0.0.0 0.0.0.0 10.1.1.2
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 5 0
 privilege level 15
 password 7 060506324F410A160B0713181F
 --More--
```

```
line con 0
 exec-timeout 5 0
 privilege level 15
 password 7 060506324F410A160B0713181F
 logging synchronous
 login
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 no exec
 stopbits 1
line vty 0 4
 exec-timeout 5 0
 password 7 00071A1507541D1216314D5D1A
 login
!
!
end
```

[i]: 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(config)# **banner motd $Unauthorized access strictly prohibited!$**

R1(config)# **exit**

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

[j]: Issue the **show run** command. What does the $ convert to in the output?

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

Current configuration : 2066 bytes
!
! Last configuration change at 19:24:55 UTC Tue Mar 28 2023
!
version 15.2
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 $1$vL8A$IcFfcTa7TliNlbdlN/CD/.
!
no aaa new-model
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
!
!
no ip domain lookup
no ipv6 cef
!
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
ip tcp synwait-time 5
!
!
 --More--
```

```
interface Loopback0
 description R1 LAN
 ip address 192.168.1.1 255.255.255.0
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex full
!
interface Serial1/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 --More--
```

```
 serial restart-delay 0
!
interface Serial3/0
 description R1 --> R2
 ip address 10.1.1.1 255.255.255.252
 serial restart-delay 0
 clock rate 128000
!
interface Serial3/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial3/3
 no ip address
 shutdown
 serial restart-delay 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
ip route 0.0.0.0 0.0.0.0 10.1.1.2
!
!
!
!
control-plane
!
banner motd ^CUnauthorized access strictly prohibited!^C
!
line con 0
 exec-timeout 5 0
 privilege level 15
 password 7 060506324F410A160B0713181F
 logging synchronous
 login
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 --More--
```

```
line con 0
 exec-timeout 5 0
 privilege level 15
 password 7 060506324F410A160B0713181F
 logging synchronous
 login
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 no exec
 stopbits 1
line vty 0 4
 exec-timeout 5 0
 password 7 00071A1507541D1216314D5D1A
 login
!
!
end
```

[k]: Repeat the configuration portion of steps 3a through 3k on router R3.

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 command:

R1(config)# **username JR-ADMIN secret class12345**

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

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#username JR-ADMIN secret class12345
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**

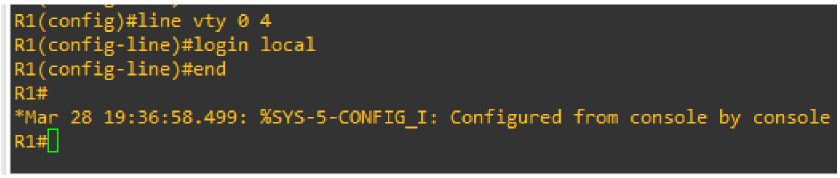
R1(config-line)# **exit**

R1(config)#

```
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
R1(config)#
```

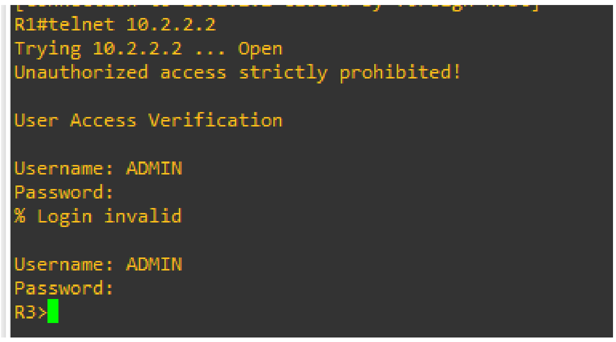


```
R1(config)#line vty 0 4
R1(config-line)#login local
R1(config-line)#end
R1#
*Mar 28 19:36:58.499: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

[d]: Repeat the steps 4a to 4c on R3.

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

```
R1# telnet 10.2.2.2
```



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

User Access Verification

Username: ADMIN
Password:
% Login invalid

Username: ADMIN
Password:
R3>
```

Step 5: Enabling AAA RADIUS Authentication with Local User for Backup.

Authentication, authorization, and accounting (AAA) is a standards-based framework that can be implemented to control who is permitted to access a network (authenticate), what they can do on that network (authorize), and audit what they did while accessing the network (accounting).

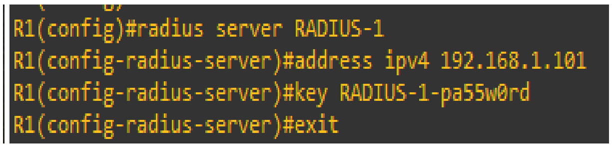
[a]: Always have local database accounts created before enabling AAA. Since we created two local database accounts in the previous step, then we can proceed and enable AAA on R1.

```
R1(config)# aaa new-model
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#aaa new-model
```

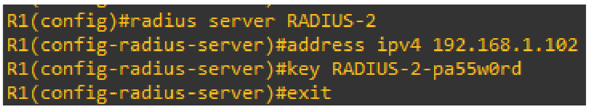
[b]: Configure the specifics for the first RADIUS server located at 192.168.1.101. Use **RADIUS-1-pa55w0rd** as the server password.

```
R1(config)# radius server RADIUS-1
R1(config-radius-server)# address ipv4 192.168.1.101
R1(config-radius-server)# key RADIUS-1-pa55w0rd
R1(config-radius-server)# exit
R1(config)#
```



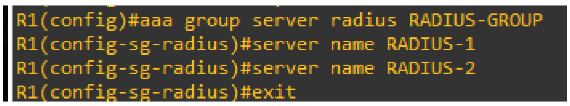
[c]: Configure the specifics for the second RADIUS server located at 192.168.1.102. Use **RADIUS-2-pa55w0rd** as the server password.

```
R1(config)# radius server RADIUS-2
R1(config-radius-server)# address ipv4 192.168.1.102
R1(config-radius-server)# key RADIUS-2-pa55w0rd
R1(config-radius-server)# exit
R1(config)#
```



[d]: Assign both RADIUS servers to a server group.

```
R1(config)# aaa group server radius RADIUS-GROUP
R1(config-sg-radius)# server name RADIUS-1
R1(config-sg-radius)# server name RADIUS-2
R1(config-sg-radius)# exit
R1(config)#
```



[e]: Enable the default AAA authentication login to attempt to validate against the server group. If they are not available, then authentication should be validated against the local database..

```
R1(config)# aaa authentication login default group RADIUS-GROUP local
R1(config)#
```

[f]: Enable the default AAA authentication Telnet login to attempt to validate against the server group. If they are not available, then authentication should be validated against a case sensitive local database.

```
R1(config)# aaa authentication login TELNET-LOGIN group RADIUS-GROUP
      local-case
```

```
R1(config)#
```

```
R1(config)#$ication login TELNET-LOGIN group RADIUS-GROUP local-case
```

[g]: Alter the VTY lines to use the TELNET-LOGIN AAA authentiaito0n method.

```
R1(config)# line vty 0 4
R1(config-line)# login authentication TELNET-LOGIN
R1(config-line)# exit
R1(config)#
```

```
R1(config)#line vty 0 4
R1(config-line)#login authentication TELNET-LOGIN
R1(config-line)#exit
R1(config)#
```

[h]: Repeat the steps 5a to 5g on R3.

[i]: To verify the configuration, telnet to R3 from R1 and login using the ADMIN local database account.

```
R1# telnet 10.2.2.2
```

```
R1#
*Mar 28 20:04:38.059: %SYS-5-CONFIG_I: Configured from console by console
R1#telnet 10.2.2.2
Trying 10.2.2.2 ... Open
Unauthorized access strictly prohibited!

User Access Verification

Username: ADMIN
Password:

R3>
```

Step 6: Enabling secure remote management using SSH.

Traditionally, remote access on routers was configured using Telnet on TCP port 23. However, Telnet was developed in the days when security was not an issue; therefore, all Telnet traffic is forwarded in plaintext.

Secure Shell (SSH) is a network protocol that establishes a secure terminal emulation connection to a router or other networking device. SSH encrypts all information that passes over the network link and provides authentication of the remote computer. SSH is rapidly replacing Telnet as the remote login tool of choice for network professionals.

[a]: SSH requires that a device name and a domain name be configured. Since the router already has a name assigned, configure the domain name.

```
R1(config)# ip domain-name ccnasecurity.com
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip domain-name ccnasecurity.com
R1(config)#
```

[b]: The router uses the RSA key pair for authentication and encryption of transmitted SSH data. Although optional it may be wise to erase any existing key pairs on the router.

R1(config)# **crypto key zeroize rsa**

```
R1(config)#crypto key zeroize rsa
% No Signature Keys found in configuration.

R1(config)#
```

[c]: Generate the RSA encryption key pair for the router. Configure the RSA keys with **1024** for the number of modulus bits. The default is 512, and the range is from 360 to 2048.

R1(config)# **crypto key generate rsa general-keys modulus 1024**

```
R1(config)#crypto key generate rsa general-keys modulus 1024
The name for the keys will be: R1.ccnasecurity.com

% The key modulus size is 1024 bits
% Generating 1024 bit RSA keys, keys will be non-exportable...
[OK] (elapsed time was 0 seconds)

R1(config)#
*Mar 28 20:11:13.735: %SSH-5-ENABLED: SSH 1.99 has been enabled
R1(config)#
```

[d]: Cisco routers support two versions of SSH:

R1(config)# **ip ssh version 2**

```
R1(config)#
*Mar 28 20:11:13.735: %SSH-5-ENABLED: SSH 1.99 has been enabled
R1(config)#ip ssh version 2
R1(config)#
```

[e]: Configure the vty lines to use only SSH connections.

R1(config)# **line vty 0 4**

R1(config-line)# **transport input ssh**

R1(config-line)# **end**

```
R1(config)#line vty 0 4
R1(config-line)#transport input ssh
R1(config-line)#end
```

[f]: Verify the SSH configuration using the **show ip ssh** command.

R1# **show ip ssh**

```
R1#show ip ssh
SSH Enabled - version 2.0
Authentication timeout: 120 secs; Authentication retries: 3
Minimum expected Diffie Hellman key size : 1024 bits
IOS Keys in SECSH format(ssh-rsa, base64 encoded):
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAAAgQC1th1UGOeHAfJrd4jQvbcAaSxkPby29yYxenYRH02Q
iXfNfzH/2/C/2vIZQ2ArG8UDw/ci+73pCLclURhyhc3FD28LcwNC2XzNYFDgRKMhUWSPcaWrsJYX7Am9
PyXm7MVHbijjbgfBugrHokZFOoNLxcPm2nf2pFfi+s+ahmS3vw==
R1#
```

[g]: Repeat the steps 6a to 6f on R3.

[h]: Although a user can SSH from a host using the SSH option of TeraTerm of PuTTY, a router can also SSH to another SSH enabled device. SSH to R3 from R1.

R1# **ssh -l ADMIN 10.2.2.2**

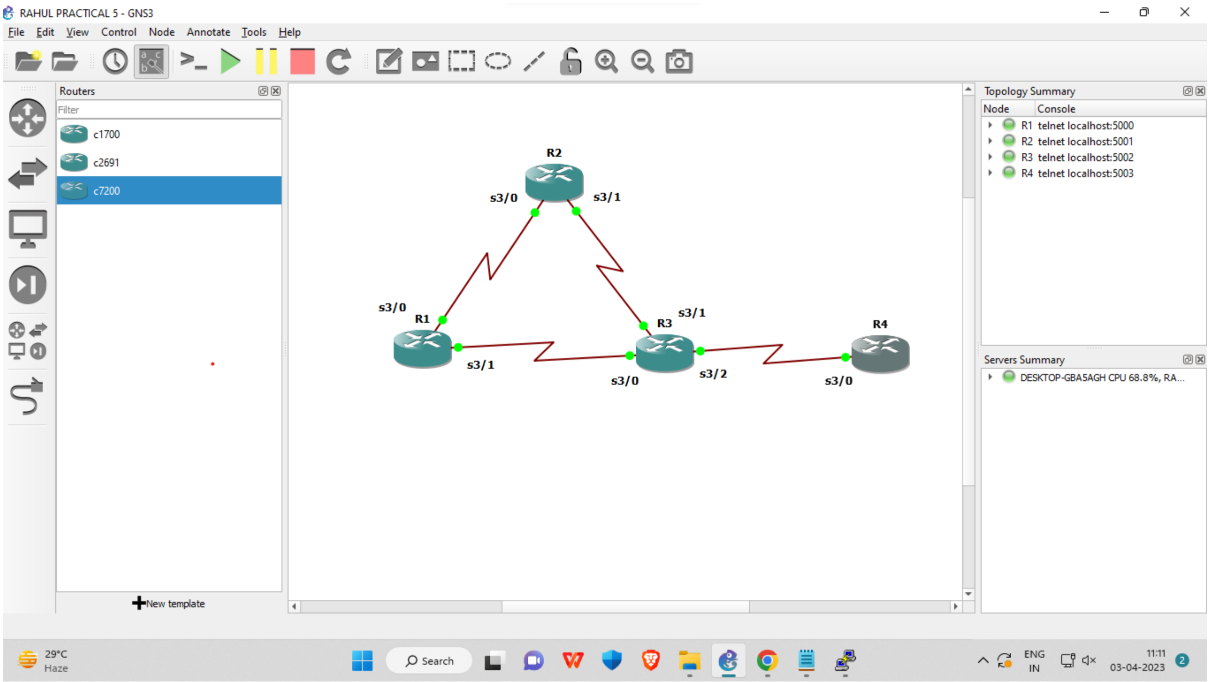
```
R1#ssh -l ADMIN 10.2.2.2
Password:
Unauthorized access strictly prohibited!R3>
R3>
R3>en
Password:
R3#
```

Practical 5

Aim: **Configure and Verify Path Control Using PBR**

Writeup:

Topology



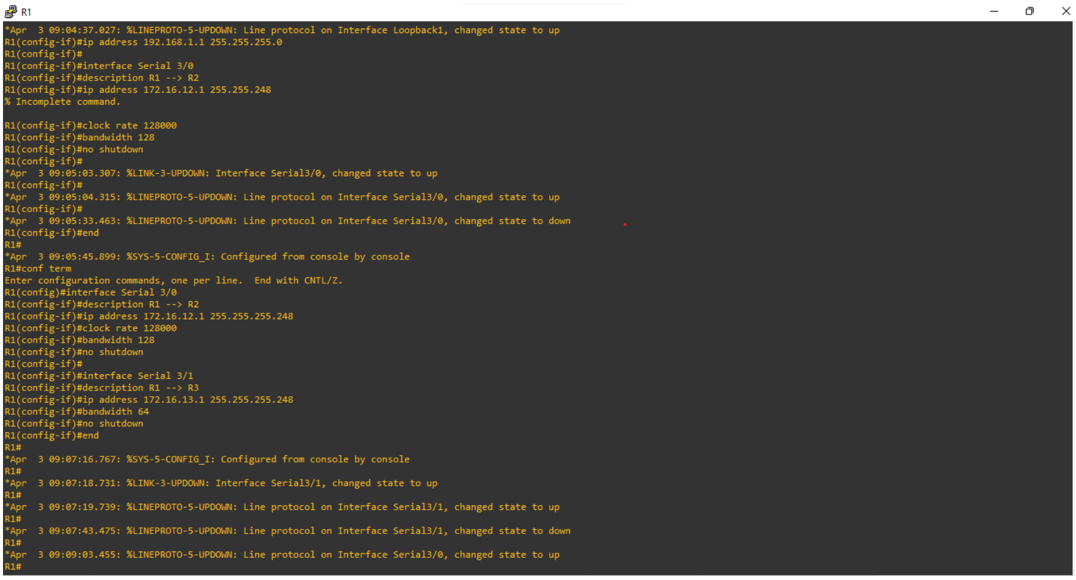
Step 1: Configure loopbacks and assign addresses.

[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.

Router R1

```
hostname R1
interface Lo1
description R1 LAN
ip address 192.168.1.1 255.255.255.0

interface Serial 3/0
description R1 --> R2
ip address 172.16.12.1 255.255.255.248
clock rate 128000
bandwidth 128
no shutdown

interface Serial 3/1
description R1 --> R3
ip address 172.16.13.1 255.255.255.248
bandwidth 64
no shutdown
end
```



```
R1
*Apr  3 09:04:37.027: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#
R1(config-if)#interface Serial 3/0
R1(config-if)#description R1 --> R2
R1(config-if)#ip address 172.16.12.1 255.255.248
% Incomplete command.

R1(config-if)#clock rate 128000
R1(config-if)#bandwidth 128
R1(config-if)#no shutdown
R1(config-if)#
*Apr  3 09:05:03.307: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
R1(config-if)#
*Apr  3 09:05:04.315: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
R1(config-if)#
*Apr  3 09:05:33.463: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to down
R1(config-if)#end
R1#
*Apr  3 09:05:45.899: %SYS-5-CONFIG_I: Configured from console by console
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface Serial 3/0
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 shutdown
R1(config-if)#
R1(config-if)#interface Serial 3/1
R1(config-if)#description R1 --> R3
R1(config-if)#ip address 172.16.13.1 255.255.255.248
R1(config-if)#bandwidth 64
R1(config-if)#no shutdown
R1(config-if)#end
R1#
*Apr  3 09:07:16.767: %SYS-5-CONFIG_I: Configured from console by console
R1#
*Apr  3 09:07:18.731: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
R1#
*Apr  3 09:07:19.739: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to up
R1#
*Apr  3 09:07:43.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/1, changed state to down
R1#
*Apr  3 09:09:03.455: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
R1#
```

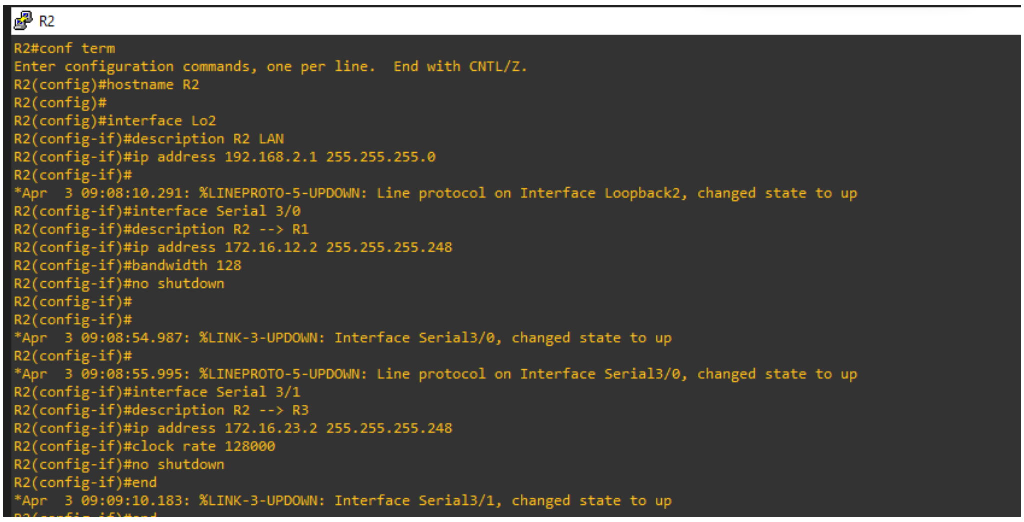
Router R2

hostname R2

interface Lo2
description R2 LAN
ip address 192.168.2.1 255.255.255.0

interface Serial 3/0
description R2 --> R1
ip address 172.16.12.2 255.255.255.248
bandwidth 128
no shutdown

interface Serial 3/1
description R2 --> R3
ip address 172.16.23.2 255.255.255.248
clock rate 128000
bandwidth 128
no shutdown
end



```
R2
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#
R2(config)#interface Lo2
R2(config-if)#description R2 LAN
R2(config-if)#ip address 192.168.2.1 255.255.255.0
R2(config-if)#
*Apr  3 09:08:10.291: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
R2(config-if)#interface Serial 3/0
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 shutdown
R2(config-if)#
R2(config-if)#
*Apr  3 09:08:54.987: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
R2(config-if)#
*Apr  3 09:08:55.995: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
R2(config-if)#interface Serial 3/1
R2(config-if)#description R2 --> R3
R2(config-if)#ip address 172.16.23.2 255.255.255.248
R2(config-if)#clock rate 128000
R2(config-if)#no shutdown
R2(config-if)#end
*Apr  3 09:09:10.183: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
```

Router R3

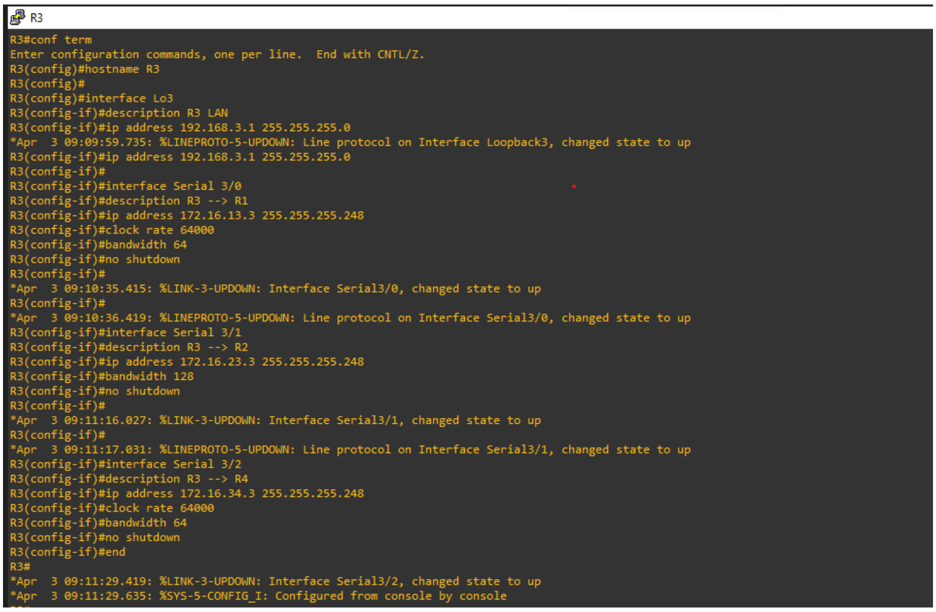
hostname R3

interface Lo3
description R3 LAN
ip address 192.168.3.1 255.255.255.0

interface Serial 3/0
description R3 --> R1
ip address 172.16.13.3 255.255.255.248
clock rate 64000
bandwidth 64
no shutdown

interface Serial 3/1
description R3 --> R2
ip address 172.16.23.3 255.255.255.248
bandwidth 128
no shutdown

interface Serial 3/2
description R3 --> R4
ip address 172.16.34.3 255.255.255.248
clock rate 64000
bandwidth 64
no shutdown
end



Router R4

hostname R4

interface Lo4
description R4 LAN A
ip address 192.168.4.1 255.255.255.128

interface Lo5
description R4 LAN B
ip address 192.168.4.129 255.255.255.128

interface Serial 3/0
description R4 --> R3
ip address 172.16.34.4 255.255.255.248
bandwidth 64
no shutdown
end

```
R4
R4#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#hostname R4
R4(config)#
R4(config)#interface Lo4
R4(config-if)#description R4 LAN A
R4(config-if)#ip address 192.168.4.1 255.255.255.128
R4(config-if)#
*Apr  3 09:12:02.543: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback4, changed state to up
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
*Apr  3 09:12:16.123: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback5, changed state to up
R4(config-if)#ip address 192.168.4.129 255.255.255.128
R4(config-if)#interface Serial 3/0
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 shutdown
R4(config-if)#end
R4#
*Apr  3 09:12:32.231: %SYS-5-CONFIG_I: Configured from console by console
R4#
*Apr  3 09:12:34.135: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
R4#
*Apr  3 09:12:35.139: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to up
```

[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**

```
R3
R3#show ip interface brief | include up
Serial3/0              172.16.13.3     YES manual up                    up
Serial3/1              172.16.23.3     YES manual up                    up
Serial3/2              172.16.34.3     YES manual up                    up
Loopback3              192.168.3.1     YES manual up                    up
```

R3# **show protocols**

```
R3#show protocols
Global values:
  Internet Protocol routing is enabled
FastEthernet0/0 is administratively down, line protocol is down
Serial1/0 is administratively down, line protocol is down
Serial1/1 is administratively down, line protocol is down
Serial1/2 is administratively down, line protocol is down
Serial1/3 is administratively down, line protocol is down
Serial2/0 is administratively down, line protocol is down
Serial2/1 is administratively down, line protocol is down
Serial2/2 is administratively down, line protocol is down
Serial2/3 is administratively down, line protocol is down
Serial3/0 is up, line protocol is up
  Internet address is 172.16.13.3/29
Serial3/1 is up, line protocol is up
  Internet address is 172.16.23.3/29
Serial3/2 is up, line protocol is up
  Internet address is 172.16.34.3/29
Serial3/3 is administratively down, line protocol is down
Loopback3 is up, line protocol is up
  Internet address is 192.168.3.1/24
```

R3# **show interfaces description | include up**

```
R3#show interfaces description | include up
Se3/0                          up             up       R3 --> R1
Se3/1                          up             up       R3 --> R2
Se3/2                          up             up       R3 --> R4
Lo3                            up             up       R3 LAN
R3#conf term
```

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.

Router R1

router eigrp 1
network 192.168.1.0
network 172.16.12.0 0.0.0.7
network 172.16.13.0 0.0.0.7
no auto-summary

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router eigrp 1
R1(config-router)#network 192.168.1.0
R1(config-router)#network 172.16.12.0 0.0.0.7
R1(config-router)#network 172.16.13.0 0.0.0.7
R1(config-router)#no auto-summary
R1(config-router)#
*Apr  3 09:24:44.367: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.12.2 (Serial3/0) is up: new adjacency
R1(config-router)#
*Apr  3 09:25:24.799: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.13.3 (Serial3/1) is up: new adjacency
R1(config-router)#end
R1#
*Apr  3 09:26:43.263: %SYS-5-CONFIG_I: Configured from console by console
```

Router R2

router eigrp 1
network 192.168.2.0
network 172.16.12.0 0.0.0.7
network 172.16.23.0 0.0.0.7
no auto-summary

```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
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)#network 172.16.23.0 0.0.0.7
R2(config-router)#no auto-summar
*Apr  3 09:24:44.763: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.12.1 (Serial3/0) is up: new adjacency
R2(config-router)#no auto-summar
*Apr  3 09:25:25.175: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.23.3 (Serial3/1) is up: new adjacency
R2(config-router)#no auto-summar
```

Router R3

router eigrp 1
network 192.168.3.0
network 172.16.13.0 0.0.0.7
network 172.16.23.0 0.0.0.7
network 172.16.34.0 0.0.0.7
no auto-summary

```
R3(config)#router eigrp 1
R3(config-router)#network 192.168.3.0
R3(config-router)#network 172.16.13.0 0.0.0.7
R3(config-router)#network 172.16.23.0 0.0.0.7
R3(config-router)#network 172.16.34.0 0.0.0.7
R3(config-router)#no auto-summary
R3(config-router)#
*Apr  3 09:25:24.559: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.13.1 (Serial3/0) is up: new adjacency
*Apr  3 09:25:24.559: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.23.2 (Serial3/1) is up: new adjacency
R3(config-router)#
*Apr  3 09:25:50.947: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.34.4 (Serial3/2) is up: new adjacency
R3(config-router)#
R3(config-router)#end
```

Router R4

router eigrp 1
network 192.168.4.0
network 172.16.34.0 0.0.0.7
no auto-summary

```
R4#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#router eigrp 1
R4(config-router)#network 192.168.4.0
R4(config-router)#network 172.16.34.0 0.0.0.7
R4(config-router)#no auto-summary
*Apr  3 09:25:51.179: %DUAL-5-NBRCHANGE: EIGRP-IPv4 1: Neighbor 172.16.34.3 (Serial3/0) is up: new adjacency
R4(config-router)#no auto-summary
R4(config-router)#end
R4#
*Apr  3 09:29:16.871: %SYS-5-CONFIG_I: Configured from console by console
```

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**

```
R1#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(1)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   172.16.13.3             Se3/1                    12 00:01:25   35  2340  0  9
0   172.16.12.2             Se3/0                    14 00:02:05   30  1170  0  8
```

R2# **show ip eigrp neighbors**

```
R2#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(1)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
1   172.16.23.3             Se3/1                    11 00:02:30   32   192  0  10
0   172.16.12.1             Se3/0                    14 00:03:11   30  1170  0  11
R2#
```

R3# **show ip eigrp neighbors**

```
R3
R3#
*Apr  3 09:28:26.939: %SYS-5-CONFIG_I: Configured from console by console
R3#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(1)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
2   172.16.34.4             Se3/2                    12 00:02:39   44  2340  0  3
1   172.16.23.2             Se3/1                    14 00:03:06   42  1170  0  9
0   172.16.13.1             Se3/0                    10 00:03:06   38  2340  0  10
```

R4# **show ip eigrp neighbors**

```
R4#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(1)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
0   172.16.34.3             Se3/0                    13 00:03:29   50  2340  0  11
```

[B]: Run the following Tcl script on all routers to verify full connectivity.

R1# **tclsh**

```
foreach address{
172.16.12.1
172.16.12.2
172.16.13.1
172.16.13.3
172.16.23.2
172.16.23.3
172.16.34.3
172.16.34.4
192.168.1.1
192.168.2.1
192.168.3.1
192.168.4.1
192.168.4.129
} { ping $address }
```

```
R1#tclsh
R1(tcl)#foreach address {
+>(tcl)#172.16.12.1
+>(tcl)#172.16.12.2
+>(tcl)#172.16.13.1
+>(tcl)#172.16.13.3
+>(tcl)#172.16.23.2
+>(tcl)#172.16.23.3
+>(tcl)#172.16.34.3
+>(tcl)#172.16.34.4
+>(tcl)#192.168.1.1
+>(tcl)#192.168.2.1
+>(tcl)#192.168.3.1
+>(tcl)#192.168.4.1
```

```
+>(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 = 48/58/64 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 = 20/27/40 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 = 48/60/68 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 = 16/26/32 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 = 16/27/32 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 = 48/56/68 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.34.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/27/36 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.34.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/60/64 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 = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/28/40 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 = 48/59/72 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 = 16/26/32 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 = 16/27/32 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 = 48/56/68 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.34.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/27/36 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.34.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/60/64 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 = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/28/40 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 = 48/59/72 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.4.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/59/68 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.4.129, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/58/68 ms
R1(tcl)#end
invalid command name "end"          ^
% Invalid input detected at '^' marker.

R1(tcl)#exit
R1#conf term
```

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# **show ip route | begin Gateway**

```
R1#
*Apr  3 09:32:38.395: %SYS-5-CONFIG_I: Configured from console by console
R1#show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 2 masks
C        172.16.12.0/29 is directly connected, Serial3/0
L        172.16.12.1/32 is directly connected, Serial3/0
C        172.16.13.0/29 is directly connected, Serial3/1
L        172.16.13.1/32 is directly connected, Serial3/1
D        172.16.23.0/29 [90/21024000] via 172.16.12.2, 00:07:17, Serial3/0
D        172.16.34.0/29 [90/41024000] via 172.16.13.3, 00:07:17, Serial3/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback1
L        192.168.1.1/32 is directly connected, Loopback1
D     192.168.2.0/24 [90/20640000] via 172.16.12.2, 00:07:17, Serial3/0
D     192.168.3.0/24 [90/21152000] via 172.16.12.2, 00:07:17, Serial3/0
      192.168.4.0/25 is subnetted, 2 subnets
D        192.168.4.0 [90/41152000] via 172.16.13.3, 00:06:50, Serial3/1
D        192.168.4.128 [90/41152000] via 172.16.13.3, 00:06:50, Serial3/1
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.

R4# **traceroute 192.168.1.1 source 192.168.4.1**

```
R4#traceroute 192.168.1.1 source 192.168.4.1
Type escape sequence to abort.
Tracing the route to 192.168.1.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.34.3 28 msec 36 msec 24 msec
  2 172.16.23.2 64 msec 56 msec 60 msec
  3 172.16.12.1 72 msec 80 msec 76 msec
R4#
```

R4# **traceroute 192.168.1.1 source 192.168.4.129**

```
R4#traceroute 192.168.1.1 source 192.168.4.129
Type escape sequence to abort.
Tracing the route to 192.168.1.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.34.3 16 msec 32 msec 28 msec
  2 172.16.23.2 56 msec 64 msec 60 msec
  3 172.16.12.1 56 msec 84 msec 72 msec
```

[C]: On R3, use the **show ip route** command and note that the preferred route from R3 to R1 LAN 192.168.1.0/24 is via R2 using the R3 exit interface S 3/1.

R3# **show ip route | begin Gateway**

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

      172.16.0.0/16 is variably subnetted, 7 subnets, 2 masks
D        172.16.12.0/29 [90/21024000] via 172.16.23.2, 00:09:38, Serial3/1
C        172.16.13.0/29 is directly connected, Serial3/0
L        172.16.13.3/32 is directly connected, Serial3/0
C        172.16.23.0/29 is directly connected, Serial3/1
L        172.16.23.3/32 is directly connected, Serial3/1
C        172.16.34.0/29 is directly connected, Serial3/2
L        172.16.34.3/32 is directly connected, Serial3/2
D     192.168.1.0/24 [90/21152000] via 172.16.23.2, 00:09:38, Serial3/1
D     192.168.2.0/24 [90/20640000] via 172.16.23.2, 00:09:38, Serial3/1
      192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.3.0/24 is directly connected, Loopback3
L        192.168.3.1/32 is directly connected, Loopback3
      192.168.4.0/25 is subnetted, 2 subnets
D        192.168.4.0 [90/40640000] via 172.16.34.4, 00:09:12, Serial3/2
D        192.168.4.128 [90/40640000] via 172.16.34.4, 00:09:12, Serial3/2
```

[D]: On R3, use the **show interfaces serial 3/0** and **show interfaces s 3/1** commands.

R3# **show interfaces serial 3/0**

```
R3
R3#show interfaces serial 3/0
Serial3/0 is up, line protocol is up
  Hardware is M4T
  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, crc 16, loopback not set
  Keepalive set (10 sec)
  Restart-Delay is 0 secs
  Last input 00:00:03, output 00:00:01, 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
     401 packets input, 29728 bytes, 0 no buffer
     Received 187 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     377 packets output, 28344 bytes, 0 underruns
     0 output errors, 0 collisions, 2 interface resets
     0 unknown protocol drops
     0 output buffer failures, 0 output buffers swapped out
     2 carrier transitions     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up
```

R3# **show interfaces serial0/0/0 | include BW**

```
R3#
R3#show interfaces serial 3/0 | include BW
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
```

R3# **show interfaces serial0/0/1 | include BW**

```
R3#show interfaces serial 3/1 | include BW
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
```

[E]: Confirm that R3 has a valid route to reach R1 from its serial 0/0/0 interface using the **show ip eigrp topology 192.168.1.0** command.

R3# **show ip eigrp topology 192.168.1.0**

```
R3#show ip eigrp topology 192.168.1.0
EIGRP-IPv4 Topology Entry for AS(1)/ID(192.168.3.1) for 192.168.1.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 21152000
  Descriptor Blocks:
  172.16.23.2 (Serial3/1), 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
        Originating router is 192.168.1.1
  172.16.13.1 (Serial3/0), 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
        Originating router is 192.168.1.1
```

Step 6: Configure PBR to provide path control.

[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**
R3(config)#

```
R3# conf term
Enter configuration commands, one per line.  End with CNTL/Z.
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
R3(config)#
```

[B]: Create a route map called **R3-to-R1** that matches PBR-ACL and sets the next-hop interface to the R1 serial 3/1 interface.

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)#

```
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)#
```

[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 S 3/2.

R3(config)# **interface s 3/2**
R3(config-if)# **ip policy route-map R3-to-R1**
R3(config-if)# **end**
R3#

```
R3(config)#
R3(config)#interface s3/2
R3(config-if)#ip policy route-map R3-to-R1
R3(config-if)#end
R3#
*Apr  3 09:48:10.843: %SYS-5-CONFIG_I: Configured from console by console
```

[D]: On R3, display the policy and matches using the **show route-map** command.

R3# **show route-map**

```
R3
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
```

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.

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#conf term
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)#exitaccess-list 1 permit 192.168.4.0 0.0.0.255
```

[B]: Enable PBR debugging only for traffic that matches the R4 LANs.

R3# **debug ip policy ?**

```
R3#debug ip policy ?
  <1-199>  Access list
  dynamic  dynamic PBR
  early    Early PBR
  <cr>
```

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

```
R3
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**

```
R4#traceroute 192.168.1.1 source 192.168.4.1
Type escape sequence to abort.
Tracing the route to 192.168.1.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.34.3 20 msec 32 msec 28 msec
  2 172.16.23.2 60 msec 64 msec 52 msec
  3 172.16.12.1 72 msec 80 msec 72 msec
```

```
R3#
*Apr  3 09:52:36.419: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.455: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.491: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.507: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.575: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.635: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1
R3#, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.703: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.783: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.859: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
R3#
*Apr  3 10:15:55.047: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.047: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.047: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.047: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.079: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.079: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.079: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.079: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.099: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.103: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.103: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.107: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.123: IP: s=192
R3#.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.123: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.127: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Apr  3 10:15:55.199: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.199: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.203: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
```

[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**

```
R4#traceroute 192.168.1.1 source 192.168.4.129
Type escape sequence to abort.
Tracing the route to 192.168.1.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.34.3 20 msec 28 msec 40 msec
  2 172.16.13.1 52 msec 60 msec 60 msec
R4#
```


```
R3#
*Apr  3 09:52:36.419: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.455: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.491: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, policy rejected -- normal forwarding
*Apr  3 09:52:36.507: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.575: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.635: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1
R3#, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.703: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.783: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
*Apr  3 09:52:36.859: IP: s=192.168.4.1 (Serial3/2), d=192.168.1.1, len 28, FIB policy rejected(no match) - normal forwarding
R3#
*Apr  3 10:15:55.047: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.047: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.047: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.047: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.079: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.079: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.079: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.079: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.099: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, policy match
*Apr  3 10:15:55.103: IP: route map R3-to-R1, item 10, permit
*Apr  3 10:15:55.103: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1 (Serial3/0), len 28, policy routed
*Apr  3 10:15:55.107: IP: Serial3/2 to Serial3/0 172.16.13.1
*Apr  3 10:15:55.123: IP: s=192
R3#.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.123: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.127: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Apr  3 10:15:55.199: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.199: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.203: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, g=172.16.13.1, len 28, FIB policy routed
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, FIB policy match
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), d=192.168.1.1, len 28, PBR Counted
*Apr  3 10:15:55.263: IP: s=192.168.4.129 (Serial3/2), 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**

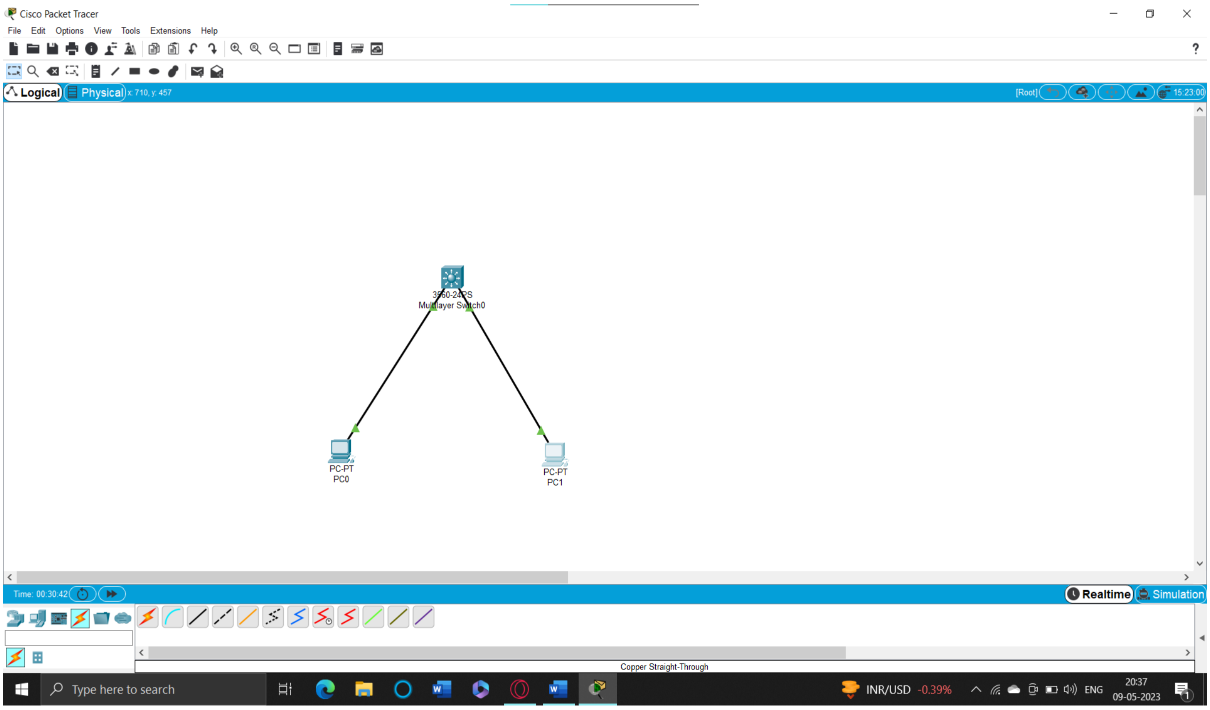
```
R3#show route-map
route-map R3-to-R1, permit, sequence 10
  Match clauses:
    ip address (access-lists): PBR-ACL
  Set clauses:
    ip next-hop 172.16.13.1
Nexthop tracking current: 0.0.0.0
172.16.13.1, fib_nh:0,oce:0,status:0

  Policy routing matches: 6 packets, 192 bytes
R3#A
```

Practical 6

Aim: **To Study the Inter-VLAN routing on a layer-3 switch**

Writeup:

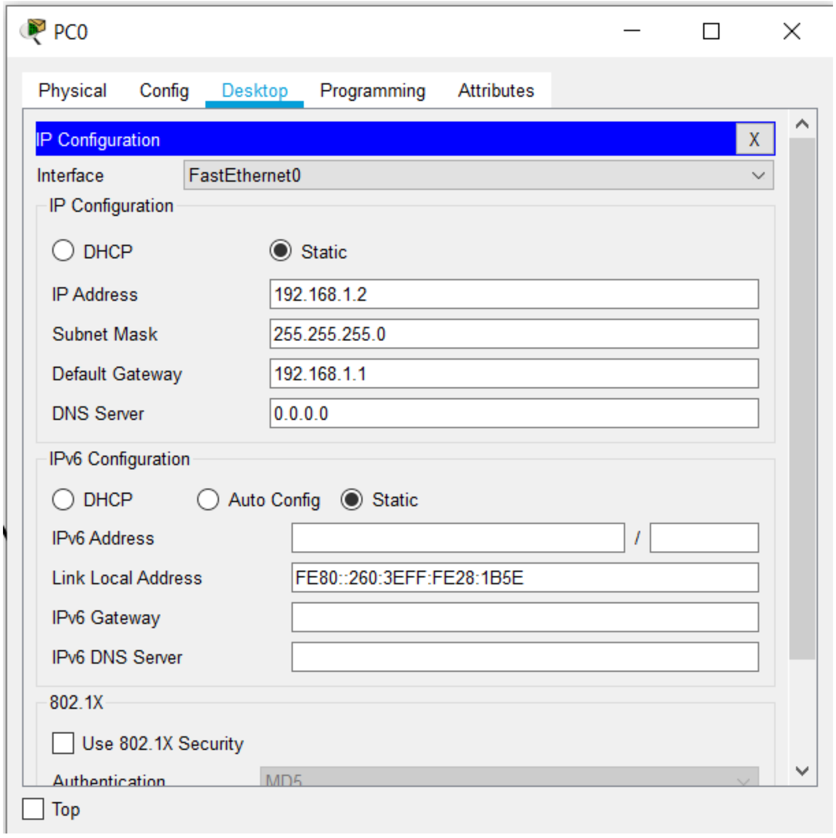
Topology



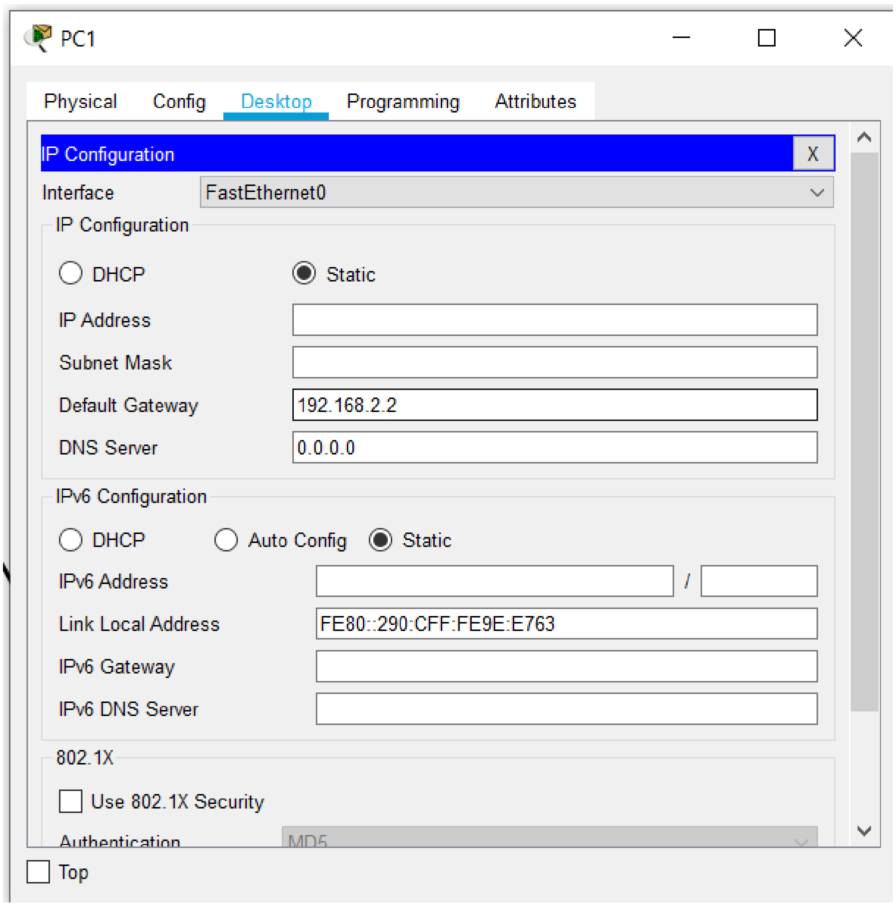
STEP 1

We Configure the IP addresses on the PC

PC0 :

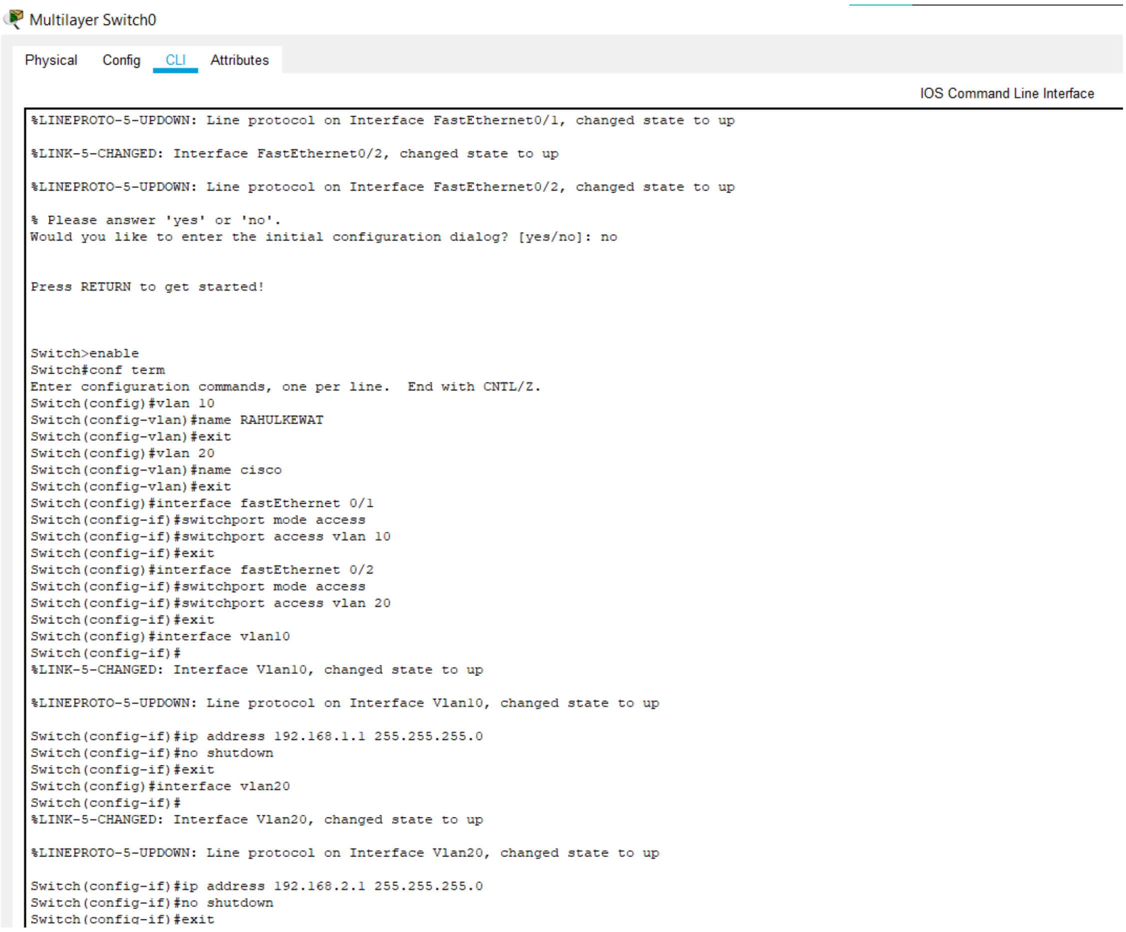

PC0
Physical
Config
Desktop
Programming
Attributes
IP Configuration
X
Interface
FastEthernet0
IP Configuration
DHCP
Static
IP Address
192.168.1.2
Subnet Mask
255.255.255.0
Default Gateway
192.168.1.1
DNS Server
0.0.0.0
IPv6 Configuration
DHCP
Auto Config
Static
IPv6 Address
/
Link Local Address
FE80::260:3EFF:FE28:1B5E
IPv6 Gateway
IPv6 DNS Server
802.1X
Use 802.1X Security
Authentication
MD5
Top

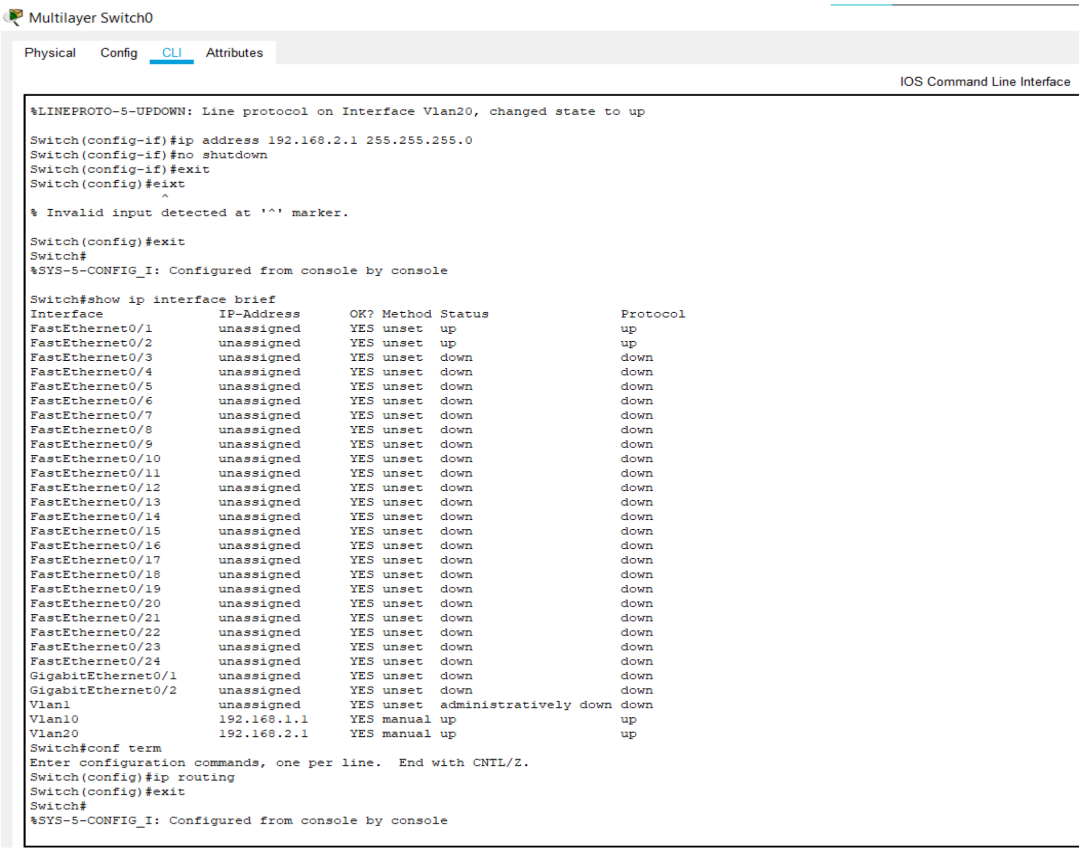
PC1 :


PC1
Physical
Config
Desktop
Programming
Attributes
IP Configuration
X
Interface
FastEthernet0
IP Configuration
DHCP
Static
IP Address
Subnet Mask
Default Gateway
192.168.2.2
DNS Server
0.0.0.0
IPv6 Configuration
DHCP
Auto Config
Static
IPv6 Address
/
Link Local Address
FE80::290:CFF:FE9E:E763
IPv6 Gateway
IPv6 DNS Server
802.1X
Use 802.1X Security
Authentication
MD5
Top

STEP 2:

Now we configure the Multilayer switch using the following command in the CLI mode

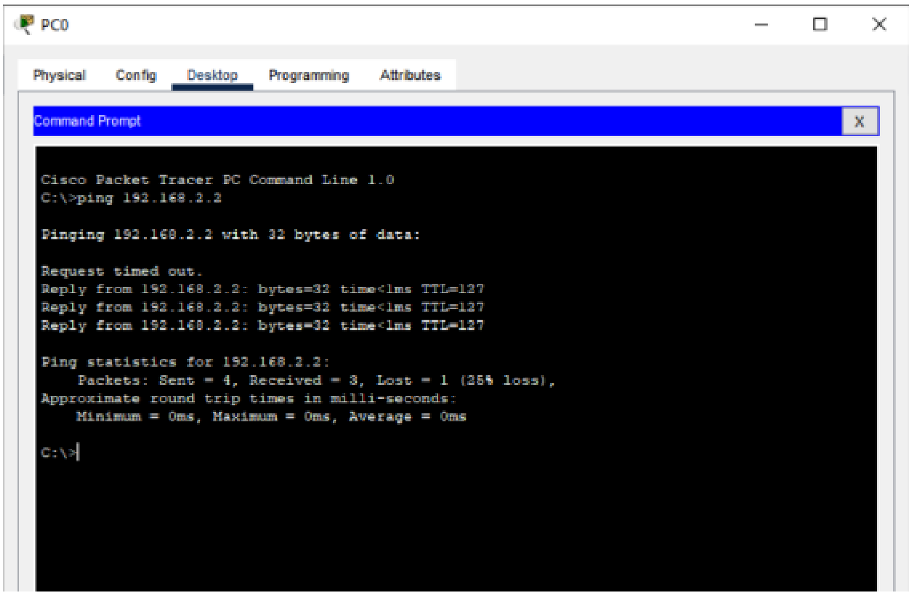





```
%LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan20, changed state to up

Switch(config-if)#ip address 192.168.2.1 255.255.255.0
Switch(config-if)#no shutdown
Switch(config-if)#exit
Switch(config)#eixt
                ^
% Invalid input detected at '^' marker.

Switch(config)#exit
Switch#
%SYS-5-CONFIG_I: Configured from console by console

Switch#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/1        unassigned      YES unset  up                    up
FastEthernet0/2        unassigned      YES unset  up                    up
FastEthernet0/3        unassigned      YES unset  down                  down
FastEthernet0/4        unassigned      YES unset  down                  down
FastEthernet0/5        unassigned      YES unset  down                  down
FastEthernet0/6        unassigned      YES unset  down                  down
FastEthernet0/7        unassigned      YES unset  down                  down
FastEthernet0/8        unassigned      YES unset  down                  down
FastEthernet0/9        unassigned      YES unset  down                  down
FastEthernet0/10       unassigned      YES unset  down                  down
FastEthernet0/11       unassigned      YES unset  down                  down
FastEthernet0/12       unassigned      YES unset  down                  down
FastEthernet0/13       unassigned      YES unset  down                  down
FastEthernet0/14       unassigned      YES unset  down                  down
FastEthernet0/15       unassigned      YES unset  down                  down
FastEthernet0/16       unassigned      YES unset  down                  down
FastEthernet0/17       unassigned      YES unset  down                  down
FastEthernet0/18       unassigned      YES unset  down                  down
FastEthernet0/19       unassigned      YES unset  down                  down
FastEthernet0/20       unassigned      YES unset  down                  down
FastEthernet0/21       unassigned      YES unset  down                  down
FastEthernet0/22       unassigned      YES unset  down                  down
FastEthernet0/23       unassigned      YES unset  down                  down
FastEthernet0/24       unassigned      YES unset  down                  down
GigabitEthernet0/1     unassigned      YES unset  down                  down
GigabitEthernet0/2     unassigned      YES unset  down                  down
Vlan1                  unassigned      YES unset  administratively down down
Vlan10                 192.168.1.1     YES manual up                    up
Vlan20                 192.168.2.1     YES manual up                    up
Switch#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)#ip routing
Switch(config)#exit
Switch#
%SYS-5-CONFIG_I: Configured from console by console
```

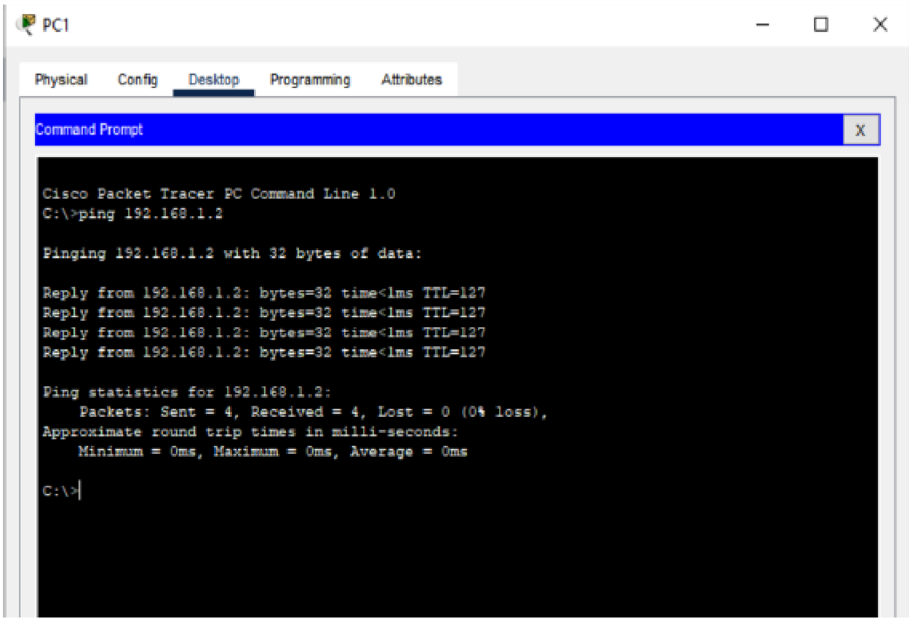
Output:

Now we ping PC1 from PC0 to check the connectivity




```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 192.168.2.2

Pinging 192.168.2.2 with 32 bytes of data:

Request timed out.
Reply from 192.168.2.2: bytes=32 time<1ms TTL=127
Reply from 192.168.2.2: bytes=32 time<1ms TTL=127
Reply from 192.168.2.2: bytes=32 time<1ms TTL=127

Ping statistics for 192.168.2.2:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\>
```

Similarly ping PC0 from PC1

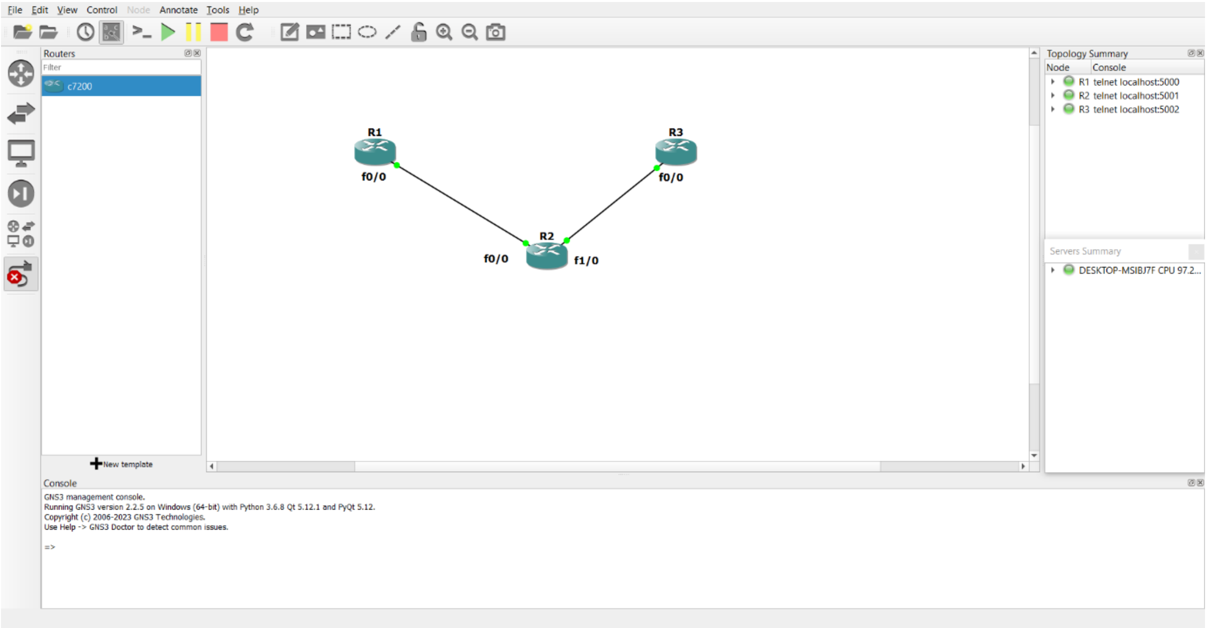

PC1
Physical
Config
Desktop
Programming
Attributes
Command Prompt
X
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 192.168.1.2
Pinging 192.168.1.2 with 32 bytes of data:
Reply from 192.168.1.2: bytes=32 time<1ms TTL=127
Reply from 192.168.1.2: bytes=32 time<1ms TTL=127
Reply from 192.168.1.2: bytes=32 time<1ms TTL=127
Reply from 192.168.1.2: bytes=32 time<1ms TTL=127
Ping statistics for 192.168.1.2:
Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
Minimum = 0ms, Maximum = 0ms, Average = 0ms
C:\>

Practical 7

Aim: **: Simulating MPLS Environment.**

Writeup:

Topology:



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.

Router R1:

```
hostname R1
int lo0
ip add 1.1.1.1 255.255.255.255
ip ospf 1 area 0
int f0/0
ip add 10.0.0.1 255.255.255.0
no shut
ip ospf 1 area 0
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#int lo0
R1(config-if)#
*May 18 09:48:49.307: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip add 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 add 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#ip o
*May 18 09:50:11.411: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*May 18 09:50:12.411: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config-if)#ip ospf 1 area 0
R1(config-if)#
*May 18 09:52:43.691: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading Done
```

Router R2:

```
hostname R2
int lo0
ip add 2.2.2.2 255.255.255.255
ip ospf 1 area 0
int f0/0
ip add 10.0.0.2 255.255.255.0
no shut
ip ospf 1 area 0
int f0/1
ip add 10.0.1.2 255.255.255.0
no shut
ip ospf 1 area 0
```

```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#int lo0
R2(config-if)#
*May 18 09:51:05.287: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip add 2.2.2.2 255.255.255.255
R2(config-if)#ip ospf 1 area 0
R2(config-if)#int f0/0
R2(config-if)#ip add 10.0.0.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#
*May 18 09:52:19.251: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*May 18 09:52:20.251: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#int f1/0
R2(config-if)#i
*May 18 09:52:43.727: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
R2(config-if)#ip add 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#
*May 18 09:53:17.931: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*May 18 09:53:18.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
*May 18 09:55:51.243: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on FastEthernet1/0 from LOADING to FULL, Loading Done
```

Router R3:

```
hostname R3
int lo0
ip add 3.3.3.3 255.255.255.255
ip ospf 1 are 0
int f0/0
ip add 10.0.1.3 255.255.255.0
no shut
ip ospf 1 area 0
```

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#int lo0
R3(config-if)#
*May 18 09:54:01.247: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip add 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 are 0
R3(config-if)#int f0/0
R3(config-if)#ip add 10.0.1.3 255.255.255.0
R3(config-if)#no shut
R3(config-if)#ip o
*May 18 09:55:34.523: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*May 18 09:55:35.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
*May 18 09:55:51.215: %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 lo0

```
R1#ping 3.3.3.3 source lo0
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 = 44/60/80 ms
```

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, we will be using the second option, so go into 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

router ospf 1
mpls ldp autoconfig
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#mpls ldp autoconfig
R1(config-router)#
*May 18 09:57:16.627: %PARSE_RC-3-PRC_INVALID_BLOCK_PTR:
R1(config-router)#
*May 18 09:58:35.263: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
```

```
R2

router ospf 1
mpls ldp autoconfig
```

```
R2#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#router ospf 1
R2(config-router)#mpls ldp autoconfig
R2(config-router)#
*May 18 09:58:35.031: %PARSE_RC-3-PRC_INVALID_BLOCK_PTR:
*May 18 09:58:35.063: %PARSE_RC-3-PRC_INVALID_BLOCK_PTR:
R2(config-router)#
*May 18 09:58:35.263: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
R2(config-router)#
*May 18 10:00:36.719: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is UP
```

R3

```
router ospf 1
mpls ldp autoconfig
```

```
R3(config-if)#
*May 18 09:55:51.215: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading Done
R3(config-if)#router ospf 1
R3(config-router)#mpls ldp autoconfig
R3(config-router)#
*May 18 10:00:36.459: %PARSE_RC-3-PRC_INVALID_BLOCK_PTR:
R3(config-router)#
*May 18 10:00:36.667: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) is UP
```

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

```
R2#show mpls interface
Interface              IP            Tunnel   BGP Static Operational
FastEthernet0/0        Yes (ldp)     No       No  No     Yes
FastEthernet1/0        Yes (ldp)     No       No  No     Yes
```

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

R2#sh mpls ldp neigh

```
R2#show 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 - 2.2.2.2.55472
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:03:33
        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: 3.3.3.3.16417 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 9/9; Downstream
        Up time: 00:01:32
        LDP discovery sources:
          FastEthernet1/0, 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

```
*May 18 10:02:22.575: %SYS-5-CONFIG_I: Configured from console by console
R1#trace 3.3.3.3
Type escape sequence to abort.
Tracing the route to 3.3.3.3
VRF info: (vrf in name/id, vrf out name/id)
  1 10.0.0.2 [MPLS: Label 17 Exp 0] 28 msec 40 msec 24 msec
  2 10.0.1.3 60 msec 52 msec 76 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 R3

We need to establish a MultiProtocol BGP session between R1 and R3 this is done by configuring the vpnv4 address family as below

Router R1:

```
router bgp 1
neighbor 3.3.3.3 remote-as 1
neighbor 3.3.3.3 update-source Loopback0
no auto-summary
address-family vpnv4
neighbor 3.3.3.3 activate
```

```
R1#conf term
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 activate
R1(config-router-af)#
*May 18 10:06:10.535: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 VPNv4 Unicast topology base removed from session  Capabilit
y changed
*May 18 10:06:10.535: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
R1(config-router-af)#
*May 18 10:07:39.699: %BGP-5-NBR_RESET: Neighbor 3.3.3.3 reset (Peer closed the session)
*May 18 10:07:39.699: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Down Peer closed the session
*May 18 10:07:39.699: %BGP_SESSION-5-ADJCHANGE: neighbor 3.3.3.3 IPv4 Unicast topology base removed from session  Peer close
d the session
*May 18 10:07:40.607: %BGP-5-ADJCHANGE: neighbor 3.3.3.3 Up
R1(config-router-af)#end
R1#
*May 18 10:07:50.267: %SYS-5-CONFIG_I: Configured from console by console
```

Router R3:

```
router bgp 1
neighbor 1.1.1.1 remote-as 1
neighbor 1.1.1.1 update-source Loopback0
no auto-summary
address-family vpnv4
neighbor 1.1.1.1 activate
```

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router bgp 1
R3(config-router)#neighbor 1.1.1.1 remote-as 1
R3(config-router)#
*May 18 10:06:10.595: %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)#
*May 18 10:07:39.623: %BGP-5-NBR_RESET: Neighbor 1.1.1.1 reset (Capability changed)
```

You should see log messages showing the BGP sessions coming up.

To verify the BGP session between R1 and R3 issue the command sh bgp vpnv4 unicast all summary

R1#sh bgp vpnv4 unicast all summary

```
R1#show 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       5       5        1    0    0 00:00:45        0
```

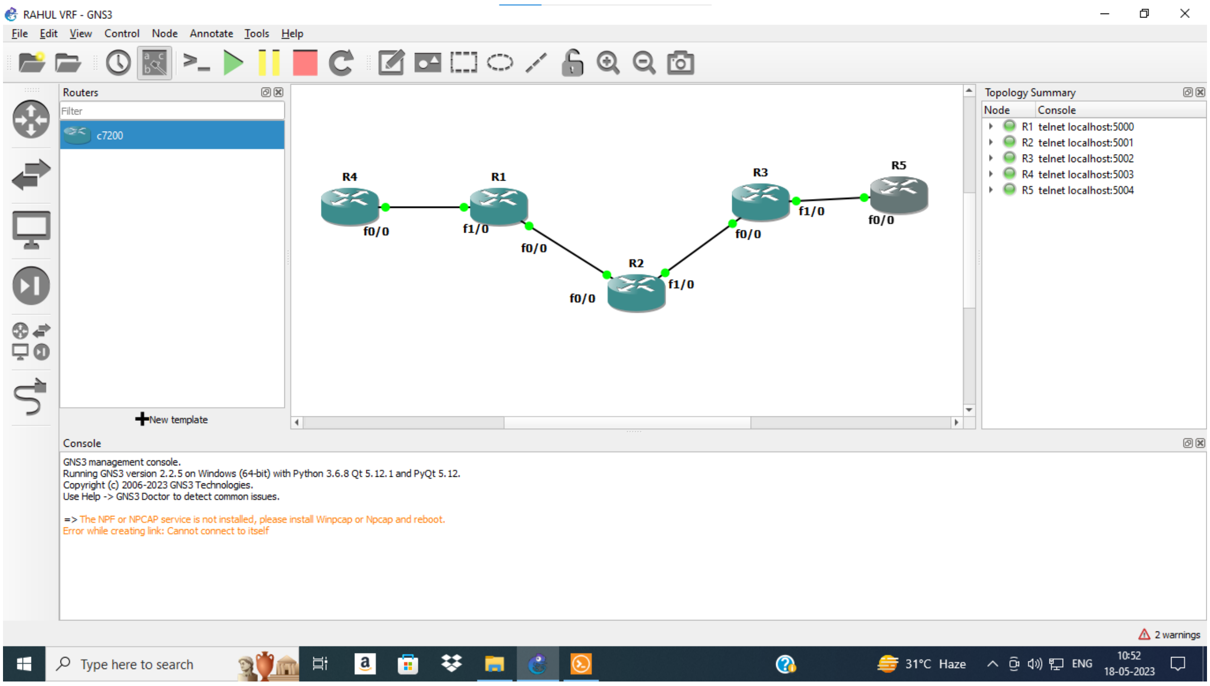
You can see here that we do have a bgp vpnv4 peering to R3 – looking at the PfxRcd you can see it says 0 this is because we have not got any routes in BGP. We are now going to add two more routers to the topology. These will be the customer sites connected to R1 and R3. We will then create a VRF on each router and put the interfaces connected to each site router into that VRF.

Practical 8

Aim: **: Simulating VRF.**

Writeup:

Step 1: In practical 7 topology diagram add two routers, create VRF



Router 4 will peer OSPF using process number 2 to a VRF configured on R1. It will use the local site addressing of 192.168.1.0/24.

Router R4:

```
int lo0
ip add 4.4.4.4 255.255.255.255
ip ospf 2 area 2
int f0/0
ip add 192.168.1.4 255.255.255.0
ip ospf 2 area 2
no shut
```

```
R4#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#int lo0
R4(config-if)#
*May 18 10:09:16.783: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R4(config-if)#ip add 4.4.4.4 255.255.255.255
R4(config-if)#ip ospf 2 area 2
R4(config-if)#int f0/0
R4(config-if)#ip add 192.168.1.4 255.255.255.0
R4(config-if)#ip ospf 2 area 2
R4(config-if)#no shut
R4(config-if)#
*May 18 10:11:02.931: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*May 18 10:11:03.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R4(config-if)#
*May 18 10:17:54.911: %OSPF-5-ADJCHG: Process 2, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
```

Router R1:

```
int f0/1
no shut
ip add 192.168.1.1 255.255.255.0
```

```
R1(config)#int f1/0
R1(config-if)#no shut
R1(config-if)#ip add
*May 18 10:11:32.643: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*May 18 10:11:33.643: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
R1(config-if)#ip add 192.168.1.1 255.255.255.0
```

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

For this mpls tutorial I will be using VRF RED
Router R1:

```
ip vrf RED
rd 4:4
route-target both 4:4
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#end
R1#
*May 18 10:13:22.199: %SYS-5-CONFIG_I: Configured from console by console
```

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 F1/0 into that VRF
Router R1:

```
int f0/1
ip vrf forwarding RED
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f1/0
R1(config-if)#ip vrf forwarding RED
% Interface FastEthernet1/0 IPv4 disabled and address(es) removed due to enabling VRF RED
```

Now notice what happens when you do that – the IP address is removed.

You just need to re-apply it.
Router R1:

```
int f0/1
ip address 192.168.1.1 255.255.255.0
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f1/0
R1(config-if)#ip address 192.168.1.1 255.255.255.0
```

Now if we view the config on R1 int f1/0 you can see the VRF configured.

R1#sh run int f1/0

```
R1#sh run int f1/0
Building configuration...

Current configuration : 119 bytes
!
interface FastEthernet1/0
```

```
interface FastEthernet1/0
 ip vrf forwarding RED
 ip address 192.168.1.1 255.255.255.0
 speed auto
 duplex auto
end
```

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

- The Global Routing Table
- The Routing Table for VRF RED

If you issue the command sh ip route this shows the routes in the global table and you will notice that you do not see 192.168.1.0/24.
R1#sh ip route

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

Gateway of last resort is not set

      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 [110/2] via 10.0.0.2, 00:23:32, FastEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/3] via 10.0.0.2, 00:20:24, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
O        10.0.1.0/24 [110/2] via 10.0.0.2, 00:22:45, FastEthernet0/0
```

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

```
R1#show ip route vrf RED

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

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet1/0
L        192.168.1.1/32 is directly connected, FastEthernet1/0
```

We just need to enable OSPF on this interface and get the loopback address for R4 in the VRF RED routing table before proceeding.

Router R1:

```
int f0/1
ip ospf 2 area 2
```

```
R1#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f1/0
R1(config-if)#ip ospf 2 area 2
R1(config-if)#
*May 18 10:17:55.487: %OSPF-5-ADJCHG: Process 2, Nbr 4.4.4.4 on FastEthernet1/0 from LOADING to FULL, Loading Done
```

You should see a log message showing the OSPF neighbor come up.

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

```
R1#show ip route vrf RED

Routing Table: RED
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
```

```
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/2] via 192.168.1.4, 00:10:14, FastEthernet1/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet1/0
L        192.168.1.1/32 is directly connected, FastEthernet1/0
```

We now need to repeat this process for R3 & R6.

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.

Router R5:

int lo0
ip add 5.5.5.5 255.255.255.255
ip ospf 2 area 2
int f0/0
ip add 192.168.2.6 255.255.255.0
ip ospf 2 area 2 no shut

```
R5(config)#int lo0
R5(config-if)#
*May 18 10:19:14.535: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R5(config-if)#ip add 5.5.5.5 255.255.255.255
R5(config-if)#ip ospf 2 area 2
R5(config-if)#int f0/0
R5(config-if)#ip add 192.168.2.6 255.255.255.0
R5(config-if)#ip ospf 2 area 2
R5(config-if)#no shut
R5(config-if)#
*May 18 10:20:51.995: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*May 18 10:20:52.995: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R5(config-if)#
*May 18 10:26:26.603: %OSPF-5-ADJCHG: Process 2, Nbr 192.168.2.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
R5(config-if)#end
```

Router R3:

int f1/0
no shut
ip add 192.168.2.3 255.255.255.0

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f1/0
R3(config-if)#no shut
R3(config-if)#
*May 18 10:21:29.851: %LINK-3-UPDOWN: Interface FastEthernet1/0, changed state to up
*May 18 10:21:30.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/0, changed state to up
R3(config-if)#ip add 192.168.2.3 255.255.255.255.0
                                               ^
% Invalid input detected at '^' marker.

R3(config-if)#ip add 192.168.2.3 255.255.255.0
```

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

Router R3:

ip vrf RED

rd 4:4
route-target both 4:4

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#ip vrf RED
R3(config-vrf)#rd 4:4
R3(config-vrf)#route-target both 4:4
R3(config-vrf)#end
```

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

int f1/0
ip vrf forwarding RED

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f1/0
R3(config-if)#ip vrf forwarding RED
% Interface FastEthernet1/0 IPv4 disabled and address(es) removed due to enabling VRF RED
R3(config-if)#end
```

Now notice what happens when you do that – the IP address is removed.

You just need to re-apply it.
Router R3:

int f1/0
ip address 192.168.2.1 255.255.255.0

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f1/0
R3(config-if)#ip address 192.168.2.1 255.255.255.0
R3(config-if)#end
```

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

R3#sh run int f1/0

```
R3#sh run int f1/0
Building configuration...

Current configuration : 119 bytes
!
interface FastEthernet1/0
 ip vrf forwarding RED
 ip address 192.168.2.1 255.255.255.0
 speed auto
 duplex auto
end
```

Finally we just need to enable OSPF on that interface and verify the routes are in the RED routing table.
Router R3:

int f1/0
ip ospf 2 area 2

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f1/0
R3(config-if)#ip ospf 2 area 2
R3(config-if)#end
R3#sh
*May 18 10:26:26.271: %SYS-5-CONFIG_I: Configured from console by console
*May 18 10:26:27.219: %OSPF-5-ADJCHG: Process 2, Nbr 5.5.5.5 on FastEthernet1/0 from LOADING to FULL, Loading Done
```

Check the routes in vrf RED

R3#sh ip route vrf RED

```
R3#sh ip route vrf RED

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

```
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      5.0.0.0/32 is subnetted, 1 subnets
O        5.5.5.5 [110/2] via 192.168.2.6, 00:00:12, FastEthernet1/0
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, FastEthernet1/0
L        192.168.2.1/32 is directly connected, FastEthernet1/0
```

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.

Check the routes on R4

R4#sh ip route

```
R4#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      4.0.0.0/32 is subnetted, 1 subnets
C        4.4.4.4 is directly connected, Loopback0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet0/0
L        192.168.1.4/32 is directly connected, FastEthernet0/0
```

As expected we have the local interface and the loopback address

When we are done we want to see 5.5.5.5 in there so we can ping across the MPLS
Check the routes on R1

R1#sh ip route

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

Gateway of last resort is not set

      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 [110/2] via 10.0.0.2, 00:23:32, FastEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/3] via 10.0.0.2, 00:20:24, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.0.0.0/24 is directly connected, FastEthernet0/0
L        10.0.0.1/32 is directly connected, FastEthernet0/0
O        10.0.1.0/24 [110/2] via 10.0.0.2, 00:22:45, FastEthernet0/0
```

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

```
R1#show ip route vrf RED

Routing Table: RED
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
```

```
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/2] via 192.168.1.4, 00:10:14, FastEthernet1/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet1/0
L        192.168.1.1/32 is directly connected, FastEthernet1/0
```

Here you can see the 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 R1
• Redistribute OSPF into MP-BGP on R3
• Redistribute MP-BGP into OSPF on R3

Redistribute OSPF into MP-BGP on R1
Router R1:
router bgp 1
address-family ipv4 vrf RED
redistribute ospf 2

```
R1#conf term
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)#end
```

Redistribute OSPF into MP-BGP on R3
Router R3:

router bgp 1
address-family ipv4 vrf RED
redistribute ospf 2

```
R3#conf term
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)#end
```

This has enabled redistribution of the OSPF routes into BGP. We can check the routes from R4 and R5 are now showing in the BGP table for their VRF with this command

R1#sh ip bgp vpnv4 vrf RED

```
R1#sh ip bgp vpnv4 vrf RED
BGP table version is 7, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
 *>  4.4.4.4/32       192.168.1.4              2         32768 ?
 *>i 5.5.5.5/32       3.3.3.3                  2    100      0 ?
 *>  192.168.1.0      0.0.0.0                  0         32768 ?
 *>i 192.168.2.0      3.3.3.3                  0    100      0 ?
```

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 5.5.5.5 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

```
R3#sh ip bgp vpnv4 vrf RED
BGP table version is 7, 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, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
 *>i 4.4.4.4/32       1.1.1.1                  2    100      0 ?
 *>  5.5.5.5/32       192.168.2.6              2         32768 ?
 *>i 192.168.1.0      1.1.1.1                  0    100      0 ?
 *>  192.168.2.0      0.0.0.0                  0         32768 ?
```

5.5.5.5 is now in the BGP table in VRF RED on R3 with a next hop of 192.168.2.6 (R5) 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 come across the MPLS back into OSPF and then we can get end to end connectivity

Router R1:

router ospf 2
redistribute bgp 1 subnets

```
R1#conf term
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)#
```

Router R3:
router ospf 2
redistribute bgp 1 subnets

```
R3#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
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 5.5.5.5 from R4.

Before we do let's see what the routing table looks like on R4.
R4#sh ip route

```
R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      4.0.0.0/32 is subnetted, 1 subnets
C        4.4.4.4 is directly connected, Loopback0
      5.0.0.0/32 is subnetted, 1 subnets
O IA     5.5.5.5 [110/3] via 192.168.1.1, 00:00:54, FastEthernet0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet0/0
L        192.168.1.4/32 is directly connected, FastEthernet0/0
O IA  192.168.2.0/24 [110/2] via 192.168.1.1, 00:00:54, FastEthernet0/0
```

Also check the routing table on R5

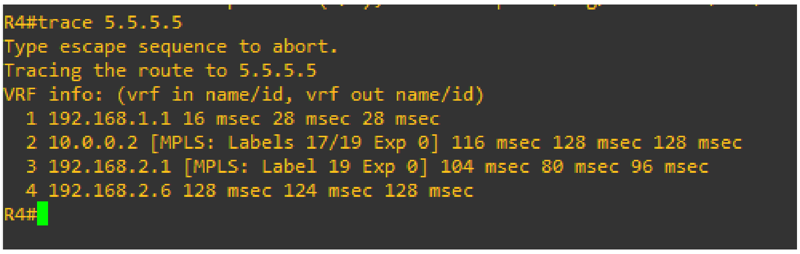
R5#sh ip route

```
R5#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      4.0.0.0/32 is subnetted, 1 subnets
O IA     4.4.4.4 [110/3] via 192.168.2.1, 00:00:36, FastEthernet0/0
      5.0.0.0/32 is subnetted, 1 subnets
C        5.5.5.5 is directly connected, Loopback0
O IA  192.168.1.0/24 [110/2] via 192.168.2.1, 00:00:36, FastEthernet0/0
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, FastEthernet0/0
L        192.168.2.6/32 is directly connected, FastEthernet0/0
R5#
```

R4#ping 5.5.5.5

```
R4#ping 5.5.5.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 5.5.5.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 108/124/132 ms
```

Which we can – to prove this is going over the MPLS and be label switched and not routed, let's do a trace
R4#trace 5.5.5.5



Evolution of Cellular Network Generations: From 1G to 5G

Evolution of Cellular Network Generations: From 1G to 5G

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INTRODUCTION

Cellular networks have evolved significantly over the years, progressing through multiple generations from 1G to the latest 5G. Each generation represents a significant leap in technology and capabilities, bringing about advancements in speed, capacity, and functionality. Cellular network generations have evolved from 1G to 5G, bringing significant advancements in speed, capacity, and functionality. Each generation has contributed to the progress of mobile communication, paving the way for the increasingly connected and technologically advanced world we live in today.

First Generation (1G)

1G, introduced in 1979, marked the advent of cellular networks. It utilized analog technology, offering voice-only communication. While it brought wireless communication and improved mobility, it had limitations such as limited capacity and poor call quality.

- Key Features and Technologies
  1. Analog technology
  2. Voice-only communication
  3. Low capacity and quality
- Advantages: Wireless communication, improved mobility
- Limitations: Limited capacity, poor call quality
- Historical Context and Deployment: First commercial 1G network launched in Japan in 1979

Second Generation (2G)

- Introduction to 2G
  - Year of Introduction: Late 1980s/Early 1990s
- Key Features and Technologies
  - Digital technology (GSM, CDMA)
  - Introduction of SMS (Short Message Service)
  - Enhanced voice quality and capacity
- Advancements over 1G
  - Digital encryption for increased security
  - Introduction of data services (e.g., WAP)
- Advantages and Limitations
  - Advantages: Digital communication, improved voice quality
  - Limitations: Limited data speeds, basic internet capabilities
- Historical Context and Deployment
  - Global deployment in the late 1990s

Third Generation (3G)

- Introduction to 3G
  - Year of Introduction: Early 2000s
- Key Features and Technologies
  - High-speed data transmission
  - Enhanced multimedia capabilities
  - Introduction of video calling and mobile internet
- Advancements over 2G
  - Higher data speeds (up to Mbps)
  - Enhanced voice quality and capacity
- Advantages and Limitations
  - Advantages: Mobile internet access, improved data transmission
  - Limitations: Limited coverage, higher infrastructure costs
- Historical Context and Deployment
  - Global deployment in the early 2000s

Fourth Generation (4G)

- Introduction to 4G
  - Year of Introduction: Late 2000s/Early 2010s
- Key Features and Technologies
  - All-IP network architecture
  - High-speed data transmission (up to Mbps)
  - Seamless multimedia streaming and gaming
- Advancements over 3G
  - Higher data speeds and capacity
  - Lower latency for real-time applications
- Advantages and Limitations
  - Advantages: Faster data speeds, improved multimedia experience
  - Limitations: Limited coverage in rural areas
- Historical Context and Deployment
  - Global deployment in the early 2010s

4G LTE - Long-Term Evolution

- Introduction to 4G LTE
  - Year of Introduction: Late 2000s/Early 2010s
- Key Features and Technologies
  - LTE (Long-Term Evolution) as a standard
  - Increased data transmission rates (up to Mbps)
  - Advanced multimedia capabilities
- Advancements over 4G
  - Higher data speeds and capacity
  - Improved network efficiency
- Advantages and Limitations
  - Advantages: Faster data speeds, lower latency
  - Limitations: Limited coverage in remote areas
- Historical Context and Deployment
  - Global deployment in the early 2010s

Fifth Generation (5G)

- Introduction to 5G
  - Year of Introduction: 2019 (commercially available)
- Key Features and Technologies
  - Ultra-fast data transmission (up to Gbps)
  - Low latency (less than milliseconds)
  - Massive device connectivity
- Advancements over 4G LTE
  - Higher data speeds and capacity
  - Lower latency for real-time applications
- Key Benefits and Use Cases
  - Enhanced mobile broadband, virtual reality, and augmented reality
  - Internet of Things (IoT) connectivity, smart cities, and autonomous vehicles
- Historical Context and Deployment
  - Ongoing global deployment since 2019

5G Architecture and Components

With its higher speeds, lower latency, and increased capacity, 5G is expected to revolutionize various industries and enable innovative applications that were not feasible before. It is also driving the development of technologies like network slicing, virtualization, small cells, and massive MIMO to support the diverse requirements of different use cases.

- Overview of 5G Network Architecture
    - Core Network and Radio Access Network (RAN)
    - Network Slicing and Virtualization
    - Small Cells and Massive MIMO

Challenges and Overview

- Challenges in Deploying and Adopting 5G
    - Spectrum Availability and Interference
    - Security and Privacy Concerns

- Overview of 5G Applications
    - Enhanced Mobile Broadband (eMBB)
    - Ultra-Reliable Low-Latency Communications (URLLC)
    - Massive Machine-Type Communications (mMTC)
    - Internet of Things (IoT) Connectivity

Thank you.