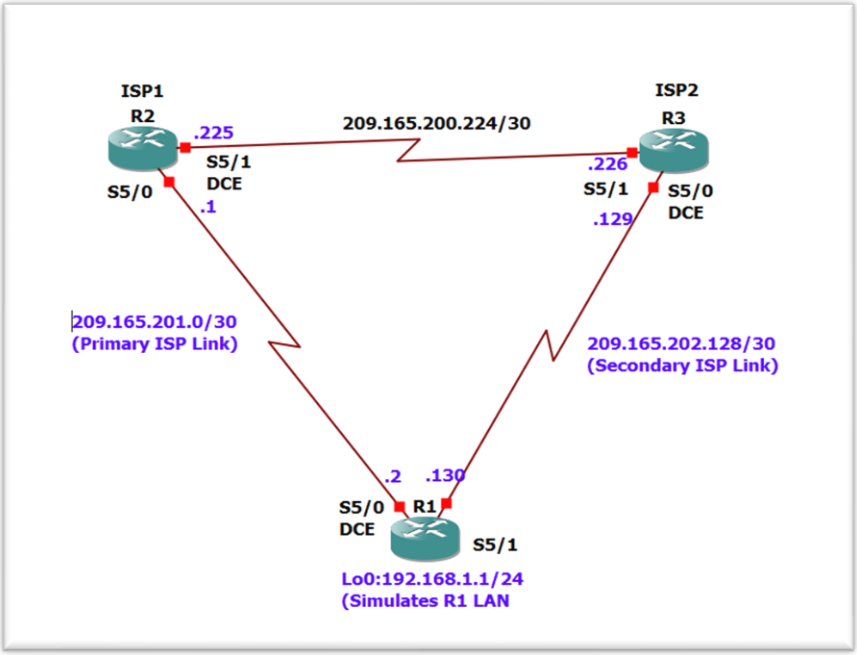
INDEX

PRACTICAL NO: 01

AIM: Configure Ip Sla Tracking And Path Control



Objectives:
Configure and verify the IP SLA feature.
Test the IP SLA tracking feature.
Verify the configuration and operation using show and debug commands.
Use IO router c7200

Step 1: Configure loopbacks and assign addresses.

Router R1

hostname R1

interface Loopback 0
description R1 LAN
ip address 192.168.1.1 255.255.255.0

interface Serial3/0
description R1 → ISP1
ip address 209.165.201.2 255.255.255.252
clock rate 128000
bandwidth 128
no shutdown

interface Serial3/1
description R1 → ISP2
ip address 209.165.202.130 255.255.255.252
bandwidth 128
no shutdown

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#description R1 --> ISP1
                ^
% Invalid input detected at '^' marker.

R1(config)#end
R1#
*Mar  6 12:03:34.175: %SYS-5-CONFIG_I: Configured from console by console
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface Loopback 0
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial3/0
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)#
*Mar  6 12:05:27.659: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
*Mar  6 12:05:28.659: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0,
 changed state to up
R1(config-if)#interface Serial3/1
R1(config-if)#description R1 --?
LINE    <cr>

R1(config-if)#description R1 -
*Mar  6 12:05:51.835: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0,
 changed state to down
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
```

Router ISP1 (R2)

hostname ISP1

interface Loopback0
description Simulated Internet Web Server
ip address 209.165.200.254 255.255.255.255

interface Loopback1
description ISP1 DNS Server
ip address 209.165.201.30 255.255.255.255

interface Serial3/0
description ISP1 → R1
ip address 209.165.201.1 255.255.255.252
bandwidth 128
no shutdown

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP1
ISP1(config)#
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)#
*Mar  6 12:07:55.159: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state
 to up
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)#
*Mar  6 12:08:11.943: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state
 to up
ISP1(config-if)#interface Serial3/0
ISP1(config-if)#description ISP --> R1
ISP1(config-if)#ip address 209.165.201.1 255.255.255.252
ISP1(config-if)#bandwidth 128
ISP1(config-if)#no shutdown
```

interface Serial3/1
description ISP1 → ISP2
ip address 209.165.200.225 255.255.255.252
clock rate 128000
bandwidth 128
no shutdown

```
ISP1(config)#interface Serial3/1
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
```

Router ISP2 (R3)

hostname ISP2
interface Loopback0
description Simulated Internet Web Server
ip address 209.165.200.254 255.255.255.255

interface Loopback1
description ISP2 DNS Server
ip address 209.165.202.158 255.255.255.255

interface Serial
description ISP2 → R1
ip address 209.165.202.129 255.255.255.252

clock rate 128000
bandwidth 128
no shutdown

interface Serial3/1
description ISP2 → ISP1
ip address 209.165.200.226 255.255.255.252
bandwidth 128
no shutdown

```
R3#CONF T
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)#
*Mar  6 12:14:03.687: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to u
p
*Mar  6 12:14:03.895: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to u
p
ISP2(config-if)#interface Serial3/0
ISP2(config-if)#description ISP2 --> R1
ISP2(config-if)#ip address 209.165.202.129 255.255.255.252
ISP2(config-if)#
ISP2(config-if)#clock rate 128000
ISP2(config-if)#bandwidth 128
ISP2(config-if)#no shutdown
ISP2(config-if)#
*Mar  6 12:14:54.155: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
ISP2(config-if)#
*Mar  6 12:14:55.159: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0, changed state to u
p
ISP2(config-if)#interface Serial3/1
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
```

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
Interface                      Status         Protocol Description
Fa0/0                          admin down     down
Gi1/0                          admin down     down
Se2/0                          admin down     down
Se2/1                          admin down     down
Se2/2                          admin down     down
Se2/3                          admin down     down
Se3/0                          up             up       R1 --> ISP1
Se3/1                          up             up       R1 --> ISP2
Se3/2                          admin down     down
Se3/3                          admin down     down
Se3/4                          admin down     down
Se3/5                          admin down     down
Se3/6                          admin down     down
Se3/7                          admin down     down
Et4/0                          admin down     down
Et4/1                          admin down     down
Et4/2                          admin down     down
Et4/3                          admin down     down
Et5/0                          admin down     down
Et5/1                          admin down     down
Et5/2                          admin down     down
 --More--
```

All three interfaces should be active.

Step 2: Configure static routing.

a) **Implement the routing policies on the respective routers. You can copy and paste the following configurations.**

Router R1

R1(config)# ip route 0.0.0.0 0.0.0.0 209.165.201.1
R1(config)#

```
R1#CONF T
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
R1(config)#
```

Router ISP1 (R2)

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

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

Router ISP2 (R3)

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

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

b) 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. You can copy the following Tcl script and paste it into R1.

R1#tclsh
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 0 percent (0/5)
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 0 percent (0/5)
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.202.158, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
.....
Success rate is 0 percent (0/5)
R1(tcl)#
```

c) Trace the path taken to the web server, ISP1 DNS server, and ISP2 DNS server. You can copy the following Tcl script and paste it into R1.

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 48 msec 32 msec 32 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 32 msec 28 msec 32 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 32 msec 32 msec 32 msec
  2 209.165.200.226 44 msec 48 msec 48 msec
R1(tcl)#
```

Step 3: Configure IP SLA probes.

Create an ICMP echo probe on R1 to the primary DNS server on ISP1 using the ip slacommand. the previous ip sla monitor command. In addition, the icmp-echo commandhas replaced the type echo protocol ipIcmpEcho command.

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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
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)#
```

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
 --More--
```

b. 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: 36 milliseconds
Latest operation start time: 12:42:36 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 34
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.

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
R1(config)# end

```
R1#CONF T
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)#ip sla schedule 22 life forever start-time now
R1(config)#end
R1#
*Mar  6 12:47:34.847: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

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
   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: 71 milliseconds
Latest operation start time: 12:51:02 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 24
Number of failures: 0
Operation time to live: Forever
```

Step 4: Configure tracking options.
Although PBR could be used, you will configure a floating static route that appears or disappears depending on the success or failure of the IP SLA.

a. On R1, remove the current default route 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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
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#
*Mar  6 12:53:08.815: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

h. Verify the routing table.
R1# show 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 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
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#
```

Notice that the default static route is now using the route with the administrative distance of 5. The first tracking object is tied to IP SLA object 11.

From global configuration mode on R1, 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)# delay down 10 up 1
R1(config-track)# exit

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#track 1 ip sla 11 reachability
R1(config-track)#delay down 10 up 1
R1(config-track)#exit
R1(config)#
```

To view routing table changes as they happen, first enable the debug ip routing command.
R1# debug ip routing

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

Configure the floating static route that will be implemented when tracking object 1 is active. Use the ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1 command to create a floating static default route via 209.165.201.1 (ISP1). Notice that this command references the tracking object number 1, which in turn references IP SLA operation number 11.

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

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#track 1 ip sla 11 reachability
R1(config-track)#delay down 10 up 1
R1(config-track)#exit
R1(config)#EXIT
R1#
*Mar  6 12:59:01.551: %SYS-5-CONFIG_I: Configured from console by console
R1#debug ip routing
IP routing debugging is on
R1#CONF T
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 2 track 1
R1(config)#
*Mar  6 13:00:34.871: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar  6 13:00:34.871: RT: closer admin distance for 0.0.0.0, flushing 1 routes
*Mar  6 13:00:34.871: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [2/0]
*Mar  6 13:00:34.871: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar  6 13:00:34.871: RT: rib update return code: 17
*Mar  6 13:00:34.871: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar  6 13:00:34.871: RT: rib update return code: 17
R1(config)#
```

Repeat the steps for operation 22, track number 2, and assign the static route an admin distance higher than track 1 and lower than 5. On R1, copy the following configuration, which sets an admin distance of 3.
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

```
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
R1(config)#
*Mar  6 13:02:08.083: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar  6 13:02:08.087: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Mar  6 13:02:08.091: RT: rib update return code: 17
*Mar  6 13:02:08.095: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.202.129   1048578

*Mar  6 13:02:08.099: RT: rib update return code: 17
R1(config)#
```

Verify the routing table again.
R1# show 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 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#
```

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.

a. On ISP1, disable the loopback interface 1.

ISP1(config-if)# int lo1

ISP1(config-if)# shutdown

```
R1(config)#int lo1
R1(config-if)#shutdown
R1(config-if)#
*Mar  6 13:07:08.015: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state
 to down
*Mar  6 13:07:08.019: %LINK-5-CHANGED: Interface Loopback1, changed state to administratively
down
R1(config-if)#
```

R1# show 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 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#
```

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: 44 milliseconds
Latest operation start time: 13:10:56 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 204
Number of failures: 0
Operation time to live: Forever


IPSLA operation id: 22
        Latest RTT: 72 milliseconds
Latest operation start time: 13:10:52 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 142
Number of failures: 1
Operation time to live: Forever
```

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)
  1 209.165.201.1 20 msec 28 msec 28 msec
R1#
```

R1# (config)# int lo1
ISP1(config-if)# no shutdown

```
R1(config)#int lo1
R1(config-if)#no shutdown
R1(config-if)#
*Mar  6 13:15:15.975: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed s
 to up
R1(config-if)#
*Mar  6 13:15:15.975: %LINK-3-UPDOWN: Interface Loopback1, changed state to up
R1(config-if)#
```

R1# show ip sla statistics

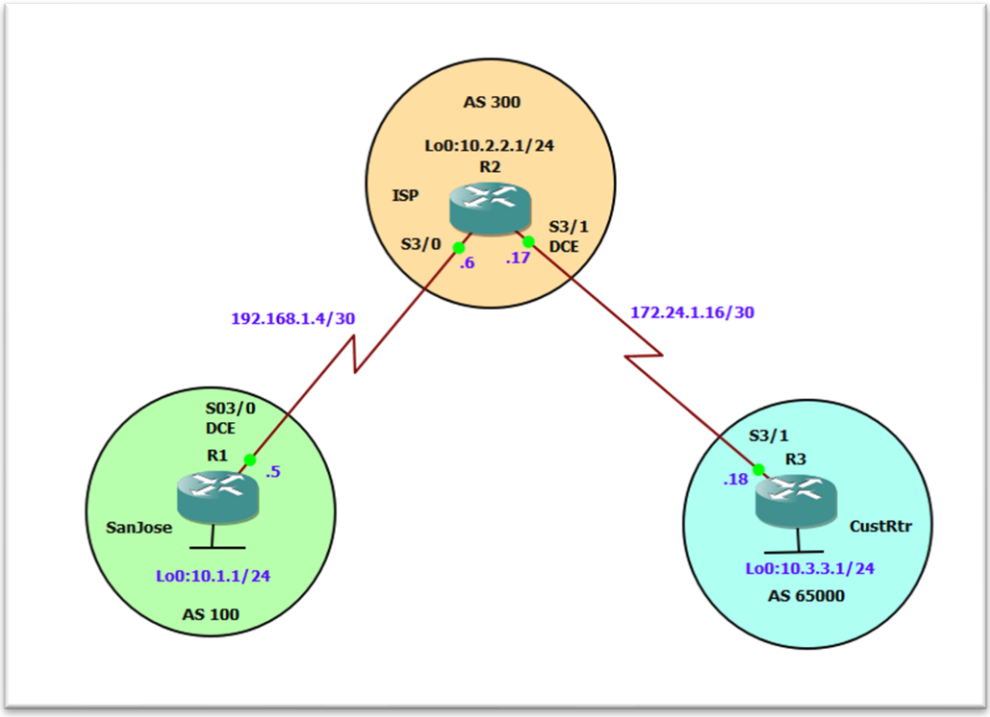
```
R1#show ip sla statistics
IPSLAs Latest Operation Statistics

IPSLA operation id: 11
        Latest RTT: 40 milliseconds
Latest operation start time: 13:18:06 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 247
Number of failures: 0
Operation time to live: Forever


IPSLA operation id: 22
        Latest RTT: 68 milliseconds
Latest operation start time: 13:18:02 UTC Mon Mar 6 2023
Latest operation return code: OK
Number of successes: 185
Number of failures: 1
Operation time to live: Forever
```

R1# show 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 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#
```

PRACTICAL NO: 02

AIM: Using The As_Path Attribute



Objectives:
Use BGP commands to prevent private AS numbers from being advertised to the outside world.
Use the AS_PATH attribute to filter BGP routes based on their source AS number
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.
You can copy and paste the following configurations into your routers to begin.

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.
Router R1 (hostname SanJose)

```
R1#CONF T
R1(config)#hostname SanJose
SanJose(config)#interface Loopback0
SanJose(config-if)#ip address 10.1.1.1 255.255.255.0
SanJose(config-if)#interface Serial3/0
SanJose(config-if)#ip address 192.168.1.5 255.255.255.252
SanJose(config-if)#clock rate 128000
SanJose(config-if)#no shutdown
SanJose(config-if)#
```

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname SanJose
SanJose(config)#interface Loopback0
SanJose(config-if)#ip address 10.1.1.1 255.255.255.0
SanJose(config-if)#interface Serial3/0
SanJose(config-if)#ip address 192.168.1.5 255.255.255.252
SanJose(config-if)#clock rate 128000
SanJose(config-if)#no shutdown
```

Router R2 (hostname ISP)

R2#CONF T
R2(config)#hostname ISP
ISP(config)#interface Loopback0
ISP(config-if)#ip address 10.2.2.1 255.255.255.0
ISP(config-if)#interface Serial3/0
ISP(config-if)#ip address 192.168.1.6 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#interface Serial3/1
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)#

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP
ISP(config)#interface Loopback0
ISP(config-if)#ip address 10.2.2.1 255.255.255.0
ISP(config-if)#interface Serial3/0
ISP(config-if)#ip address 192.168.1.6 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#interface Serial3/1
ISP(config-if)#ip address 172.24.1.17 255.255.255.252
ISP(config-if)#clock rate 128000
ISP(config-if)#no shutdown
*Mar 18 15:22:35.019: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
ISP(config-if)#no shutdown
```

Router R3 (hostname CustRtr)

R3#CONF T
R3(config)#hostname CustRtr
CustRtr(config)#interface Loopback0
CustRtr(config-if)#ip address 10.3.3.1 255.255.255.0
CustRtr(config-if)#interface Serial3/1
CustRtr(config-if)#ip address 172.24.1.18 255.255.255.252
CustRtr(config-if)#no shutdown
CustRtr(config-if)#

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname CustRtr
CustRtr(config)#interface Loopback0
CustRtr(config-if)#ip address 10.3.3.1 255.255.255.0
CustRtr(config-if)#interface Serial3/1
CustRtr(config-if)#ip address 172.24.1.18 255.255.255.252
CustRtr(config-if)#no shutdown
*Mar 18 15:27:18.447: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
CustRtr(config-if)#no shutdown
```

Step 3: Configure BGP.

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.

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

```
SanJose#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose(config)#router bgp 100
SanJose(config-router)#neighbor 192.168.1.6 remote-as 300
SanJose(config-router)#network 10.1.1.0 mask 255.255.255.0
SanJose(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 T
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)#neighbor 172.24.1.18 remote-as 65000
ISP(config-router)#network 10.2.2.0 mask 255.255.255.0
```

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 T
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)#network 10.3.3.0 mask 255.255.255.0
CustRtr(config-router)#
```

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
*Mar 18 15:52:00.027: %SYS-5-CONFIG_I: Configured from console by console
ISP#show ip bgp neighbors
BGP neighbor is 172.24.1.18,  remote AS 65000, external link
  BGP version 4, remote router ID 0.0.0.0
  BGP state = Idle
  Neighbor sessions:
    0 active, is not multisession capable (disabled)
    Stateful switchover support enabled: NO
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 3, neighbor version 1/3
  Output queue size : 0
  Index 0, Advertise bit 0
  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

 --More--
```

Step 4: Remove the private AS.

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

SanJose# show ip route

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

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.1.1.0/24 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, 00:03:49
      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
SanJose#
```

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

ping 10.3.3.1 source 10.1.1.1

```
SanJose#ping 10.3.3.1 source 10.1.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
Packet sent with a source address of 10.1.1.1
.....
Success rate is 0 percent (0/5)
SanJose#
```

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

SanJose# **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.

```
SanJose#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 0 percent (0/5)
SanJose#
```

Check the BGP table from SanJose 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.

SanJose# show ip bgp

```
SanJose#show ip bgp
BGP table version is 3, 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
SanJose#
```

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

ISP(config)# router bgp 300

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

```
ISP#CONF T
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
ISP(config-router)#
```

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 SanJose to check its routing table.

SanJose# ping 10.3.3.1 source lo0

```
SanJose#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 secon
ds:
Packet sent with a source address of 10.1.1.1
.....
Success rate is 0 percent (0/5)
SanJose#
```

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

SanJose# show ip bgp

```
SanJose#show ip bgp
BGP table version is 3, local router ID is 10.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - i
nternal,
              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
SanJose#
```

Step 5: Use the AS_PATH attribute to filter routes.

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 .*
ISP(config)#
```

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
ISP(config-router)#
```

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

ISP#clear ip bgp *
ISP# show ip route

```
ISP#clear ip bgp *
ISP#show ip route
*Mar 26 12:10:23.179: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar 26 12:10:23.183: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicas
t topology base removed from session  User reset
*Mar 26 12:10:24.111: %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, 2 subnets, 2 masks
C        10.2.2.0/24 is directly connected, Loopback0
L        10.2.2.1/32 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        172.24.1.17/32 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#
```

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

```
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, 2 subnets, 2 masks
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#
```

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 3, 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#
```

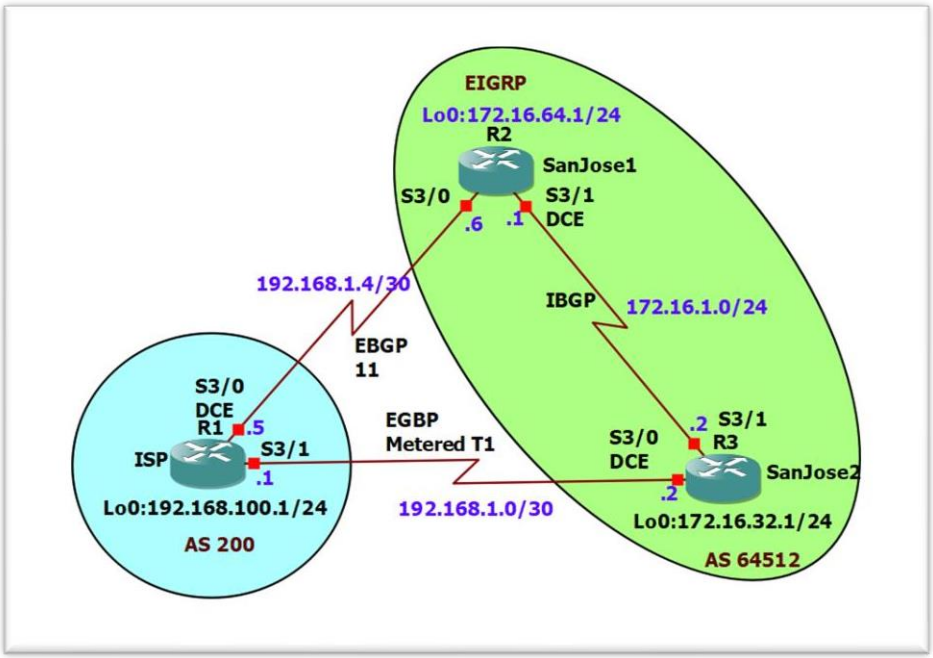
Run the following Tcl script on all routers to verify whether there is connectivity. All pings from ISP should be successful. SanJose should not be able to ping the CustRtr loopback 10.3.3.1 or the WAN link 172.24.1.16/30. CustRtr should not be able to ping the SanJose loopback 10.1.1.1 or the WAN link 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 = 20/28/36 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 = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
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 = 44/62/88 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 = 52/65/72 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 = 52/60/76 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 = 28/44/92 ms
ISP(tcl)#
```

PRACTICAL NO: 03

AIM: Configuring Ibgp And Ebgp Sessions, Local Preference, And Med



Step 0: Suggested starting configurations.

Router R1

no ip domain-lookup
line con 0
logging synchronous
exec-timeout 0 0

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

Router R2

no ip domain-lookup
line con 0
logging synchronous
exec-timeout 0 0

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

Router R3

no ip domain-lookup
line con 0
logging synchronous

exec-timeout 0 0

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

Step 1: Configure interface addresses.

Router R1 (hostname ISP)

R1(config)#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 Serial3/0
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 Serial3/1
ISP(config-if)#ip address 192.168.1.1 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#end

```
R1(config)#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 Serial3/0
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 Serial3/1
ISP(config-if)#ip address 192.168.1.1 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#end
ISP#
```

Router R2 (hostname SanJose1)
R2#CONF T
R2(config)#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 Serial3/0
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 Serial3/1
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

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname SanJose1
SanJose1(config)#interface Loopback0
SanJose1(config-if)#
*Mar 15 14:59:06.395: %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 Serial3/0
SanJose1(config-if)#ip address 192.168.1.6 255.255.255.252
SanJose1(config-if)#no shutdown
SanJose1(config-if)#exit
*Mar 15 14:59:40.627: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
SanJose1(config-if)#exit
SanJose1(config)#
*Mar 15 14:59:41.635: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0,
 changed state to up
SanJose1(config)#interface Serial3/1
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
*Mar 15 15:00:15.183: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
SanJose1(config-if)#end
SanJose1#
```

Router R3 (hostname SanJose2)

R3#CONF T
R3(config)#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 Serial3/0
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 Serial3/1
SanJose2(config-if)#ip address 172.16.1.2 255.255.255.0
SanJose2(config-if)#no shutdown
SanJose2(config-if)#end

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname SanJose2
SanJose2(config)#interface Loopback0
SanJose2(config-if)#
*Mar 15 15:02:56.415: %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 Serial3/0
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
*Mar 15 15:03:37.571: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
SanJose2(config-if)#exit
SanJose2(config)#
*Mar 15 15:03:38.579: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0,
 changed state to up
SanJose2(config)#interface Serial3/1
SanJose2(config-if)#ip address 172.16.1.2 255.255.255.0
SanJose2(config-if)#no shutdown
SanJose2(config-if)#end
*Mar 15 15:04:04.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial3/0,
 changed state to down
SanJose2(config-if)#end
*Mar 15 15:04:05.851: %LINK-3-UPDOWN: Interface Serial3/1, changed state to up
SanJose2(config-if)#end
SanJose2#
```

Step 2: Configure EIGRP.

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

```
SanJose1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
SanJose1(config)#router eigrp 1
SanJose1(config-router)#network 172.16.0.0
SanJose1(config-router)#
```

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

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

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

```
SanJose1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
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
SanJose1(config-router)#
```

c. 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 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)#
```

d. 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#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 state = Established, up for 00:01:10
  Last read 00:00:20, last write 00:00:17, 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:             3          3
--More--
```

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

```
ISp#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
ISp(config)#hostname ISP
ISP(config)#router bgp 200
ISP(config-router)#neighbor 192.168.1.6 remote-as 64512
ISP(config-router)#neighbor 192.168.1.2 remote-as 64512
ISP(config-router)#network 192.168.100.0
ISP(config-router)#
```

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

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

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

```
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 00:15:49
  Last read 00:00:14, last write 00:00:46, 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:            19         19
  --More--
```

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 T
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)#network 172.16.0.0
SanJose2(config-router)#
```

Step 5: View BGP summary output.

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 3, main routing table version 3
2 network entries using 288 bytes of memory
3 path entries using 240 bytes of memory
3/1 BGP path/bestpath attribute entries using 408 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 960 total bytes of memory
BGP activity 2/0 prefixes, 3/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
172.16.64.1     4        64512       9       9        3    0    0 00:05:00        2
192.168.1.1     4          200       0       0        1    0    0 never    Idle
SanJose2#
```

Step 6: Verify which path the traffic takes.

ISP#clear ip bgp *

```
ISP#clear ip bgp *
ISP#
*Mar 16 12:54:33.471: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Down User reset
*Mar 16 12:54:33.471: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.6 IPv4 Unicast topology base removed from
ion  User reset
*Mar 16 12:54:34.079: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Up
ISP#
```

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:
.....
Success rate is 0 percent (0/5)
ISP#
```

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 100 percent (5/5), round-trip min/avg/max = 28/32/36 ms
ISP#
```

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:
UUUUU
Success rate is 0 percent (0/5)
ISP#
```

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 0 percent (0/5)
ISP#
```

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       192.168.1.6              0             0 64512 i
 *>  192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

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

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
UUUUU
Success rate is 0 percent (0/5)
ISP#
```

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 0 percent (0/5)
ISP#
```

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 = 20/30/40 ms
ISP#
```

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 = 28/31/32 ms
ISP#
```

Step 7: Configure the BGP next-hop-self feature.
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 T
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)#
```

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 4, 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       192.168.1.6              0             0 64512 i
 *>  192.168.1.4/30   0.0.0.0                  0         32768 i
 *>  192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

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, 5 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
SanJose2#
```

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#CONF T
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)#
```

SanJose2# show ip bgp

```
SanJose2#show ip bgp
BGP table version is 2, 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
SanJose2#
```

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, 5 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
SanJose2#
```

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
SanJose2(config)# router bgp 64512
SanJose2(config-router)# neighbor 172.16.64.1 next-hop-self

```
SanJose1#CONF T
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)#router bgp 64512
SanJose1(config-router)#neighbor 172.16.64.1 next-hop-self
```

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

SanJose1# clear ip bgp *
SanJose1#

```
SanJose1#clear ip bgp *
SanJose1#
*Mar 17 12:22:40.999: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
*Mar 17 12:22:41.003: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.5 IPv4 Unicas
t topology base removed from session  User reset
*Mar 17 12:22:41.179: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
SanJose1#
```

SanJose2# clear ip bgp *
SanJose2#

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

SanJose2# show ip bgp

```
SanJose2#show ip bgp
BGP table version is 2, 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
SanJose2#
```

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, 5 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
SanJose2#
```

ISP(config)# interface serial 3/1
ISP(config-if)# no shutdown
ISP(config-if)#

```
ISP(config)#interface serial 3/1
ISP(config-if)#no shutdown
ISP(config-if)#
```

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, 5 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
SanJose2#
```

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 T
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
SanJose1(config-router)#
```

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 T
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
SanJose2(config-router)#
```

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
SanJose1#
```

SanJose2# clear ip bgp * soft

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

SanJose1# show ip bgp

```
SanJose1#show ip bgp
BGP table version is 4, 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
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 *>  192.168.100.0    192.168.1.5              0    150      0 200 i
SanJose1#
```

SanJose2# show ip bgp

```
SanJose2#show ip bgp
BGP table version is 2, 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
SanJose2#
```

Step 9: Set BGP MED.

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

```
ISP#show ip bgp
BGP table version is 7, 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       192.168.1.6              0             0 64512 i
 *>  192.168.100.0    0.0.0.0                  0         32768 i
ISP#
```

ISP# show ip route

```
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, 00:17:20
      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
      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
ISP#
```

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)

Request 0 timed out
Request 1 timed out
Request 2 timed out
Request 3 timed out
Request 4 timed out
Success rate is 0 percent (0/5)
SanJose2#
```

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 T
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
SanJose1(config-router)#
```

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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
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)#
```

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
SanJose1#
```

SanJose2# clear ip bgp * soft

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

SanJose1# show ip bgp

```
SanJose1#show ip bgp
BGP table version is 4, 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
 *>  172.16.0.0       0.0.0.0                  0         32768 i
 *>  192.168.100.0    192.168.1.5              0    150      0 200 i
SanJose1#
```

SanJose2# show ip bgp

```
SanJose2#clear ip bgp * soft
SanJose2#show ip bgp
BGP table version is 2, 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
SanJose2#
```

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: <*>
(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)

```
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)

Request 0 timed out
Request 1 timed out
Request 2 timed out
Request 3 timed out
Request 4 timed out
Success rate is 0 percent (0/5)
SanJose2#
```

ISP# show ip bgp

```
ISP#show ip bgp
BGP table version is 8, 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       192.168.1.6              50             0 64512 i
 *>  192.168.100.0    0.0.0.0                   0         32768 i
ISP#
```

Step 10: Establish a default route.

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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
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
*Mar 17 12:59:38.343: %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
ISP(config-if)#
```

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 not set

      172.16.0.0/16 is variably subnetted, 5 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
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, 00:23:38
SanJose1#
```

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, 5 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
SanJose2#
```

SanJose2# show ip bgp

```
SanJose2#show ip bgp
BGP table version is 2, 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
SanJose2#
```

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  *  *  *
  2  *  *  *
  3  *  *  *
  4  *  *  *
  5  *  *  *
  6  *  *  *
  7  *  *  *
  8  *  *  *
  9  *  *  *
 10  *  *  *
 11  *  *  *
 12  *  *  *
 13  *  *  *
 14  *  *  *
 15  *  *  *
 16  *  *  *
 17  *  *  *
 18  *  *  *
 19  *  *  *
 20  *  *  *
 21  *  *  *
 22  *  *  *
 23  *  *  *
 24  *  *  *
 25  *  *  *
 26  *  *  *
 27  *  *  *
 28  *  *  *
 29  *  *  *
 30  *  *  *
SanJose2#
```

ISP(config)# interface serial 3/0
ISP(config-if)# shutdown

```
ISP(config-if)#shutdown
ISP(config-if)#
*Mar 17 13:02:36.151: %BGP-5-NBR_RESET: Neighbor 192.168.1.6 reset (Interface fl
ap)
*Mar 17 13:02:36.167: %BGP-5-ADJCHANGE: neighbor 192.168.1.6 Down Interface flap
*Mar 17 13:02:36.167: %BGP_SESSION-5-ADJCHANGE: neighbor 192.168.1.6 IPv4 Unicas
t topology base removed from session  Interface flap
ISP(config-if)#
*Mar 17 13:02:38.127: %LINK-5-CHANGED: Interface Serial3/0, changed state to adm
inistratively down
ISP(config-if)#
```

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, 00:02:20
      172.16.0.0/16 is variably subnetted, 5 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
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, 00:26:36
SanJose1#
```

SanJose2# show ip route

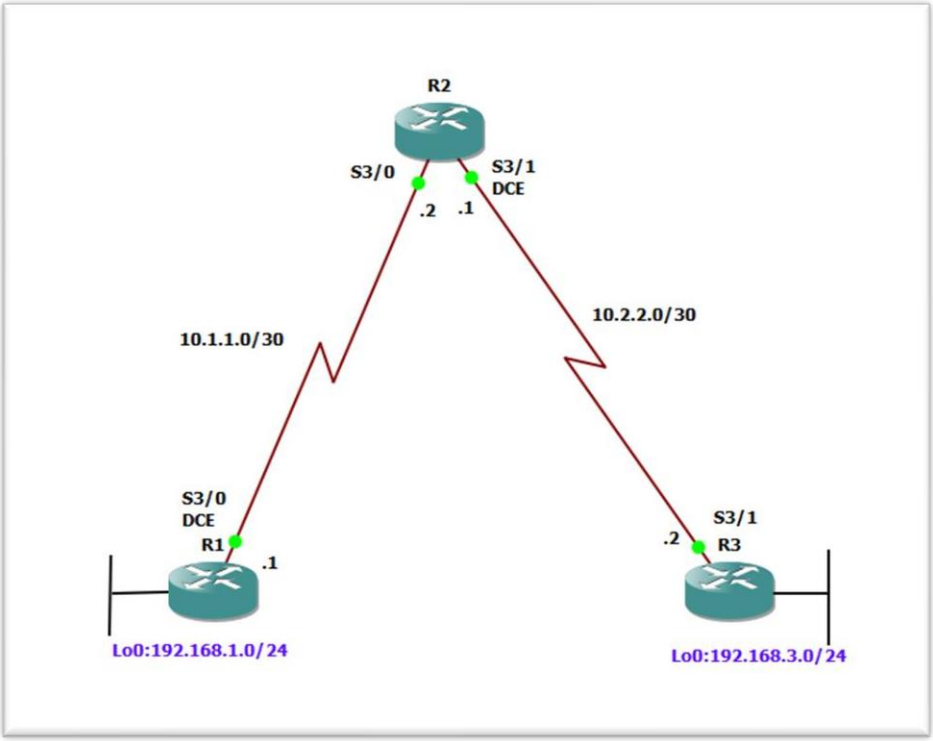
```
SanJose2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-
       ia - IS-IS inter area, * - candidate default, U - per-user static ro
       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, 5 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
SanJose2#
```

SanJose1# trace 10.0.0.1

```
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  *  *  *
  2  *  *  *
  3  *  *  *
  4  *  *  *
  5  *  *  *
  6  *  *  *
  7  *  *  *
  8  *  *  *
  9  *  *  *
 10  *  *  *
 11  *  *  *
 12  *  *  *
 13  *  *  *
 14  *  *  *
 15  *  *  *
 16  *  *  *
 17  *  *  *
 18  *  *  *
 19  *  *  *
 20  *  *  *
 21  *  *  *
 22  *  *  *
 23  *  *  *
 24  *  *  *
 25  *  *  *
 26  *  *  *
 27  *  *  *
 28  *  *  *
 29  *  *  *
 30  *  *  *
SanJose1#
```

PRACTICAL NO: 04

AIM: Secure The Management Plane



Objective:

- Secure management access.
- Configure enhanced username password security.
- Enable AAA RADIUS authentication.
- Enable secure remote management.

Required Resourse

- 3 routers (Cisco IOS Release 15.2 or comparable)
- Serial and Ethernet cables

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.

Router R1

```
R1#CONF T
R1(config)#hostname R1
R1(config)#interface Loopback 0
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#
R1(config-if)#EXIT
R1(config)#interface Serial3/0
R1(config-if)#description R1 --> R2
```

R1(config-if)#ip address 10.1.1.1 255.255.255.252
R1(config-if)#clock rate 128000
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#end

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface Loopback 0
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#
*Mar 20 12:28:52.843: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 changed state to up
R1(config-if)#EXIT
R1(config)#interface Serial3/0
R1(config-if)#description R1 --> R2
R1(config-if)#ip address 10.1.1.1 255.255.255.252
R1(config-if)#clock rate 128000
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#end
*Mar 20 12:29:22.243: %LINK-3-UPDOWN: Interface Serial3/0, changed state to up
R1(config)#end
```

Router R2
R2#CONF T
R2(config)#hostname R2
R2(config)#interface Serial3/0
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 Serial3/1
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

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#interface Serial3/0
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 Serial3/1
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
R2#
```

Router R3
R3#CONF T
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 Serial3/1

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

```
R3#CONF T
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 Serial3/1
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 20 12:39:35.323: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
 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 T
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 T
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 T
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
R2(config)#
```

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

R1#tclsh
R1(tcl)#foreach address {
+>(tcl)#192.168.1.1
+>(tcl)#10.1.1.1
+>(tcl)#10.1.1.2
+>(tcl)#10.2.2.1
+>(tcl)#10.2.2.2
+>(tcl)#192.168.3.1
+>(tcl)#} { ping $address }

```
R1#tclsh
R1(tcl)#foreach address {
+>(tcl)#192.168.1.1
+>(tcl)#10.1.1.1
+>(tcl)#10.1.1.2
+>(tcl)#10.2.2.1
+>(tcl)#10.2.2.2
+>(tcl)#192.168.3.1
+>(tcl)#} { ping $address }
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/7/8 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/61/72 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/28/40 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 = 20/30/40 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.2.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/62/64 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 = 60/63/64 ms
R1(tcl)#
R1#
*Mar 20 12:49:58.719: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

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

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#security passwords min-length 10
R1(config)#enable secret class12345
R1(config)#
```

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)#

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

Use the service password-encryption command to encrypt the line console and vty passwords.
R1(config)# service password-encryption

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

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(config)#service password-encryption
R1(config)#banner motd $Unauthorized access strictly prohibited!$
R1(config)#exit
R1#
```

Step 4: Configure enhanced username password security.

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

a. To create local database entry encrypted to level 4 (SHA256), use the username name secret password global configuration command. In global configuration mode, enter the following command:
R1(config)# username JR-ADMIN secret class12345
R1(config)# username ADMIN secret class54321

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#username JR-ADMIN secret class12345
R1(config)#username ADMIN secret class54321
R1(config)#
```

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

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

d. 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:
R3(config)# username JR-ADMIN secret class12345
R3(config)# username ADMIN secret class54321

```
R3(config)#username JR-ADMIN secret class12345
R3(config)#username ADMIN secret class54321
R3(config)#
```

Set the console line to use the locally defined login accounts.
R3(config)# line console 0
R3(config-line)# login local
R3(config-line)# exit

```
R3(config)#line console 0
R3(config-line)#login local
R3(config-line)#exit
R3(config)#
```

Set the vty lines to use the locally defined login accounts.
R3(config)# line vty 0 4
R3(config-line)# login local
R3(config-line)# end

```
R3(config)#line vty 0 4
R3(config-line)#login local
R3(config-line)#end
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
Trying 10.2.2.2 ... Open
Unauthorized access strictly prohibited!
User Access Verification
Username: ADMIN
Password:
R3>

```
R1#telnet 10.2.2.2
Trying 10.2.2.2 ... Open


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

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

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

h. 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.
R3(config)# aaa new-model

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#aaa new-model
```

Configure the specifics for the first RADIUS server located at 192.168.1.101. Use RADIUS-1-pa55w0rd as the server password.
R3(config)# radius server RADIUS-1
R3(config-radius-server)# address ipv4 192.168.1.101
R3(config-radius-server)# key RADIUS-1-pa55w0rd
R3(config-radius-server)# exit

```
R3(config)#aaa new-model
R3(config)#radius server RADIUS-1
R3(config-radius-server)#address ipv4 192.168.1.101
R3(config-radius-server)#key RADIUS-1-pa55w0rd
R3(config-radius-server)#exit
R3(config)#
```

Configure the specifics for the second RADIUS server located at 192.168.1.102. Use RADIUS-2-pa55w0rd as the server password.
R3(config)# radius server RADIUS-2
R3(config-radius-server)# address ipv4 192.168.1.102
R3(config-radius-server)# key RADIUS-2-pa55w0rd
R3(config-radius-server)# exit

```
R3(config)#radius server RADIUS-2
R3(config-radius-server)#address ipv4 192.168.1.102
R3(config-radius-server)#key RADIUS-2-pa55w0rd
R3(config-radius-server)#exit
R3(config)#
```

Assign both RADIUS servers to a server group.
R3(config)# aaa group server radius RADIUS-GROUP
R3(config-sg-radius)# server name RADIUS-1
R3(config-sg-radius)# server name RADIUS-2
R3(config-sg-radius)# exit

```
R3(config)#aaa group server radius RADIUS-GROUP
R3(config-sg-radius)#server name RADIUS-1
R3(config-sg-radius)#server name RADIUS-2
R3(config-sg-radius)#exit
R3(config)#
```

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..

R3(config)# aaa authentication login default group RADIUS-GROUP local

```
R3(config)#aaa authentication login default group RADIUS-GROUP local
R3(config)#
```

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.
R3(config)# aaa authentication login TELNET-LOGIN group RADIUS-GROUP local-case

```
R3(config)#$ication login TELNET-LOGIN group RADIUS-GROUP local-case
R3(config)#
```

Alter the VTY lines to use the TELNET-LOGIN AAA authentiaito0n method.
R3(config)# line vty 0 4
R3(config-line)# login authentication TELNET-LOGIN
R3(config-line)# exit

```
R3(config)#line vty 0 4
R3(config-line)#login authentication TELNET-LOGIN
R3(config-line)#exit
```

i. To verify the configuration, telnet to R3 from R1 and login using the ADMIN local database account.
R1# telnet 10.2.2.2
Username: ADMIN
Password: class54321

```
R1#telnet 10.2.2.2
Trying 10.2.2.2 ... Open

User Access Verification

Username: ADMIN
Password:

% Authentication failed

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 t
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.
```

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 1 seconds)

R1(config)#
*Mar 21 12:42:14.439: %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)#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
R1#
```

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 AAAAB3NzaC1yc2EAAAADAQABAAAAgQDLPSfbpHMLEQXjxJDwWSoQ/NKG0D1NaDNCGPaldgl4
U/kGKDOT1WDLGbPewfqoeWTcLeL6VDyXcAX8XWJ3WffBn0/ywecW4gihhX8kqp7QuGEW0Vrb0iFCczIu
Tzv8o5TKbnmpgGDjzpnuOGC1LGHqgVO1ZXpDLdTL2q31NDAOsw==
R1#
```

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

R3(config)# ip domain-name ccnasecurity.com

```
R3(config)#ip domain-name ccnasecurity.com
```

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.

R3(config)# crypto key zeroize rsa

```
R3(config)#crypto key zeroize rsa
% No Signature Keys found in configuration.
```

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.

R3(config)# crypto key generate rsa general-keys modulus 1024

```
R3(config)#crypto key generate rsa general-keys modulus 1024
The name for the keys will be: R3.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)

R3(config)#
*Mar 21 12:50:29.823: %SSH-5-ENABLED: SSH 1.99 has been enabled
R3(config)#
```

Cisco routers support two versions of SSH:
R3(config)# ip ssh version 2

```
R3(config)#ip ssh version 2
R3(config)#
```

Configure the vty lines to use only SSH connections.
R3(config)# line vty 0 4
R3(config-line)# transport input ssh
R3(config-line)# end

```
R3(config)#line vty 0 4
R3(config-line)#transport input ssh
R3(config-line)#end
R3#
```

Verify the SSH configuration using the show ip ssh command.
R3# show ip ssh

```
R3#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 AAAAB3NzaC1yc2EAAAADAQABAAAAgQCU1lX1GjSlihj+LunLsKM28wu4RQOSUNqJ6i3
Tf6I0
8L5Z3dv2wnJkxkQ45s/3u3mv5Os5OF7nZ42filU+pGd5CrHxIytdNBuak/dbxFRPy76bW/bql4q
BLhcS
IAq3shHDd7vel3G2CPiK44ZHC41G5xxq85Al8BQR9GoV+8/rvw==
```

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
Password:
R3>
R3>en
% Error in authentication.
R3>

```
R1#ssh -l ADMIN 10.2.2.2
Password:
R3>
R3>en
% Error in authentication.

R3>
```

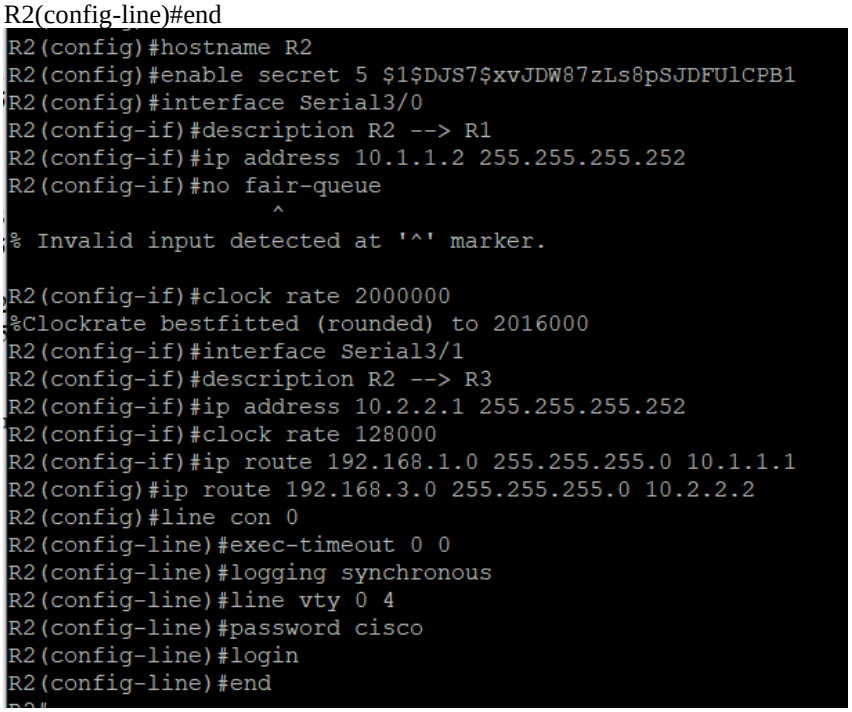
Router R1
R1#CONF T
R1(config)#service password-encryption
R1(config)#hostname R1
R1(config)#security passwords min-length 10

```
R1(config)#enable secret 5 $1$t6eK$FZ.JdmMLj8QSgNkpChyZz.
R1(config)#aaa new-model
R1(config)#aaa group server radius RADIUS-GROUP
R1(config-sg-radius)#server name RADIUS-1
R1(config-sg-radius)#server name RADIUS-2
R1(config-sg-radius)#$ication login default group RADIUS-GROUP local
R1(config)#$ication login TELNET-LOGIN group RADIUS-GROUP local-case
R1(config)#ip domain name ccnasecurity.com
R1(config)#username JR-ADMIN secret 5 $1$0u0q$lwimCZIAuQtV4C1ezXL1S0
R1(config)#username ADMIN secret 5 $1$NSVD$/YjzB7Auyes1sAt4qMfpd.
R1(config)#ip ssh version 2
R1(config)#interface Loopback0
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial3/0
R1(config-if)#description R1 --> R2
R1(config-if)#ip address 10.1.1.1 255.255.255.252
R1(config-if)#no fair-queue
R1(config-if)#ip route 0.0.0.0 0.0.0.0 10.1.1.2
R1(config)#radius server RADIUS-1
R1(config-radius-server)#$4 192.168.1.101 auth-port 1645 acct-port 1646
 R1(config-radius-server)#key 7 107C283D2C2221465D493A2A717D24653017
R1(config-radius-server)#radius server RADIUS-2
R1(config-radius-server)#$4 192.168.1.102 auth-port 1645 acct-port 1646
R1(config-radius-server)#key 7 03367A2F2F3A12011C44090442471C5C162E
R1(config-radius-server)#$ ^CUnauthorized access strictly prohibited!^C
R1(config)#line con 0
R1(config-line)#exec-timeout 5 0
R1(config-line)#password 7 070C285F4D061A0A19020A1F17
R1(config-line)#logging synchronous
R1(config-line)#line aux 0
R1(config-line)#no exec
R1(config-line)#password 7 060506324F411F0D1C0713181F
R1(config-line)#login authentication TELNET-LOGIN
R1(config-line)#transport input ssh
R1(config-line)#end
```

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#service password-encryption
R1(config)#hostname R1
R1(config)#security passwords min-length 10
R1(config)#enable secret 5 $1$t6eK$FZ.JdmMLj8QSgNkpChyZz.
R1(config)#aaa new-model
R1(config)#aaa group server radius RADIUS-GROUP
R1(config-sg-radius)#server name RADIUS-1
R1(config-sg-radius)#server name RADIUS-2
R1(config-sg-radius)#$ication login default group RADIUS-GROUP local
R1(config)#$ication login TELNET-LOGIN group RADIUS-GROUP local-case
R1(config)#ip domain name ccnasecurity.com
R1(config)#username JR-ADMIN secret 5 $1$0u0q$lwimCZIAuQtV4C1ezXL1S0
R1(config)#username ADMIN secret 5 $1$NSVD$/YjzB7Auyes1sAt4qMfpd.
R1(config)#ip ssh version 2
R1(config)#interface Loopback0
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial3/0
R1(config-if)#description R1 --> R2
R1(config-if)#ip address 10.1.1.1 255.255.255.252
R1(config-if)#no fair-queue
                ^
% Invalid input detected at '^' marker.

R1(config-if)#ip route 0.0.0.0 0.0.0.0 10.1.1.2
R1(config)#radius server RADIUS-1
R1(config-radius-server)#$4 192.168.1.101 auth-port 1645 acct-port 1646
R1(config-radius-server)#key 7 107C283D2C2221465D493A2A717D24653017
R1(config-radius-server)#radius server RADIUS-2
R1(config-radius-server)#$4 192.168.1.102 auth-port 1645 acct-port 1646
R1(config-radius-server)#key 7 03367A2F2F3A12011C44090442471C5C162E
R1(config-radius-server)#$ ^CUnauthorized access strictly prohibited!^C
R1(config)#line con 0
R1(config-line)#exec-timeout 5 0
R1(config-line)#password 7 070C285F4D061A0A19020A1F17
R1(config-line)#logging synchronous
R1(config-line)#line aux 0
R1(config-line)#no exec
R1(config-line)#password 7 060506324F411F0D1C0713181F
R1(config-line)#login authentication TELNET-LOGIN
R1(config-line)#transport input ssh
R1(config-line)#end
```

Router R2

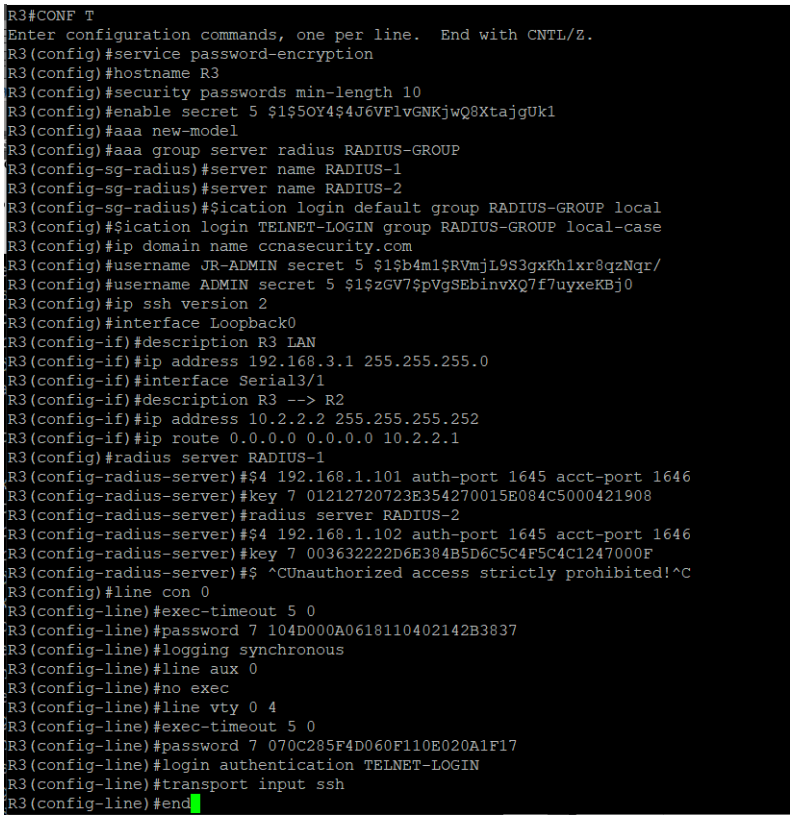
```
R2(config)#hostname R2
R2(config)#enable secret 5 $1$DJS7$xvJDW87zLs8pSJDFUlCPB1
R2(config)#interface Serial3/0
R2(config-if)#description R2 --> R1
R2(config-if)#ip address 10.1.1.2 255.255.255.252
R2(config-if)#no fair-queue
R2(config-if)#clock rate 2000000
R2(config-if)#interface Serial3/1
R2(config-if)#description R2 --> R3
R2(config-if)#ip address 10.2.2.1 255.255.255.252
R2(config-if)#clock rate 128000
R2(config-if)#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(config)#line con 0
R2(config-line)#exec-timeout 0 0
R2(config-line)#logging synchronous
R2(config-line)#line vty 0 4
R2(config-line)#password cisco
R2(config-line)#login
R2(config-line)#end
```



Router R3

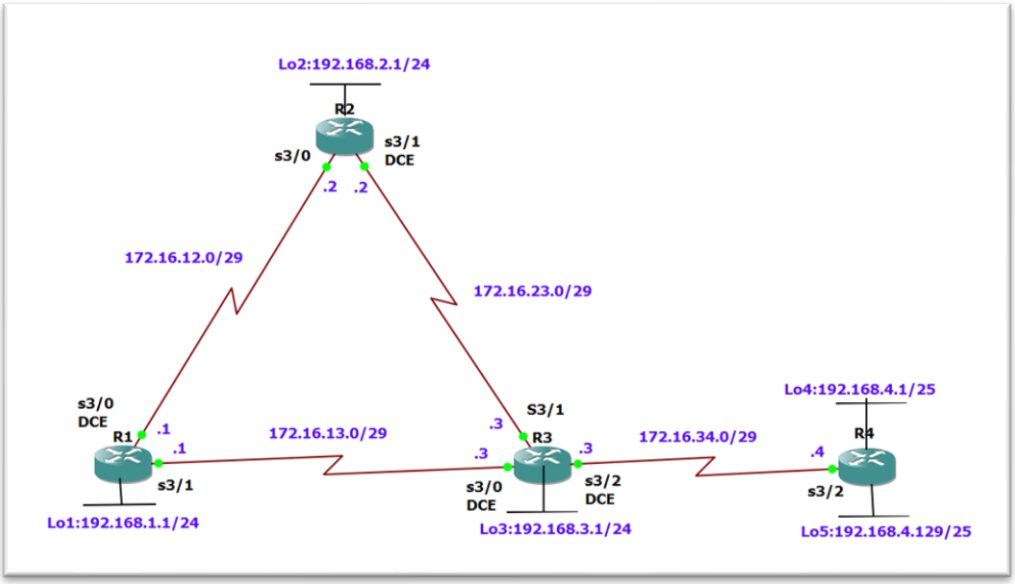
```
R3(config)#service password-encryption
R3(config)#hostname  R3
R3(config)#security passwords min-length 10
R3(config)#enable secret 5 $1$5OY4$4J6VFlvGNKjwQ8XtajgUk1
R3(config)#aaa new-model
R3(config)#aaa group server radius RADIUS-GROUP
R3(config-sg-radius)#server name RADIUS-1
R3(config-sg-radius)#server name RADIUS-2
R3(config-sg-radius)#$ication login default group RADIUS-GROUP local R3(config)#$ication login
TELNET-LOGIN group RADIUS-GROUP local-case R3(config)#ip domain name ccnasecurity.com
R3(config)#username JR-ADMIN secret 5 $1$b4m1$RVmjL9S3gxKh1xr8qzNqr/
R3(config)#username ADMIN secret 5 $1$zGV7$pVgSEbinvXQ7f7uyxeKBj0
R3(config)#ip ssh version 2
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)#interface Serial3/1
R3(config-if)#description R3 --> R2
R3(config-if)#ip address 10.2.2.2 255.255.255.252
R3(config-if)#ip route 0.0.0.0 0.0.0.0 10.2.2.1
R3(config)#radius server RADIUS-1
R3(config-radius-server)#$4 192.168.1.101 auth-port 1645 acct-port 1646
R3(config-radius-server)#key 7 01212720723E354270015E084C5000421908
R3(config-radius-server)#radius server RADIUS-2
R3(config-radius-server)#$4 192.168.1.102 auth-port 1645 acct-port 1646
R3(config-radius-server)#key 7 003632222D6E384B5D6C5C4F5C4C1247000F
R3(config-radius-server)#$ ^CUnauthorized access strictly prohibited!^C
R3(config)#line con 0
R3(config-line)#exec-timeout 5 0
R3(config-line)#password 7 104D000A0618110402142B3837
R3(config-line)#logging synchronous
R3(config-line)#line aux 0
R3(config-line)#no exec
R3(config-line)#line vty 0 4
R3(config-line)#exec-timeout 5 0
R3(config-line)#password 7 070C285F4D060F110E020A1F17
R3(config-line)#login authentication TELNET-LOGIN
R3(config-line)#transport input ssh
R3(config-line)#end
```



PRACTICAL NO: 05

AIM: Configure And Verify Path Control Using Pbr



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

```
R1#CONF T
R1(config)#hostname R1
R1(config)#interface Lo1
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial3/0
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)#interface Serial3/1
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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface Lo1
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface Serial3/0
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)#interface Serial3/1
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#
```

Router R2

R2#CONF T
R2(config)#hostname R2
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)#interface Serial3/0
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)#interface Serial3/1
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)#bandwidth 128
R2(config-if)#no shutdown
R2(config-if)#end

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
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)#interface Serial3/0
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)#interface Serial3/1
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)#bandwidth 128
R2(config-if)#no shutdown
R2(config-if)#end
```

Router R3

R3#CONF T
R3(config)#hostname R3
R3(config)#interface Lo3
R3(config-if)#description R3 LAN
R3(config-if)#ip address 192.168.3.1 255.255.255.0
R3(config-if)#interface Serial3/0

R3(config-if)#description R3 --> R1
R3(config-if)#ip address 172.16.13.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
R3(config-if)#no shutdown
R3(config-if)#interface Serial3/1
R3(config-if)#description R3 --> R2
R3(config-if)#ip address 172.16.23.3 255.255.255.248
R3(config-if)#bandwidth 128
R3(config-if)#no shutdown
R3(config-if)#interface Serial3/2
R3(config-if)#description R3 --> R4
R3(config-if)#ip address 172.16.34.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
R3(config-if)#no shutdown
R3(config-if)#end

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#interface Lo3
R3(config-if)#description R3 LAN
R3(config-if)#ip address 192.168.3.1 255.255.255.0
R3(config-if)#interface Serial3/0
R3(config-if)#description R3 --> R1
R3(config-if)#ip address 172.16.13.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
R3(config-if)#no shutdown
R3(config-if)#interface Serial3/1
R3(config-if)#description R3 --> R2
R3(config-if)#ip address 172.16.23.3 255.255.255.248
R3(config-if)#bandwidth 128
R3(config-if)#no shutdown
R3(config-if)#interface Serial3/2
R3(config-if)#description R3 --> R4
R3(config-if)#ip address 172.16.34.3 255.255.255.248
R3(config-if)#clock rate 64000
R3(config-if)#bandwidth 64
R3(config-if)#no shutdown
R3(config-if)#end
```

Router R4

R4#CONF T
Enter configuration commands, one per line. End with CNTL/Z.
R4(config)#hostname R4
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)#interface Lo5
R4(config-if)#description R4 LAN B
R4(config-if)#ip address 192.168.4.129 255.255.255.128
R4(config-if)#interface Serial3/2
R4(config-if)#description R4 --> R3
R4(config-if)#ip address 172.16.34.4 255.255.255.248
R4(config-if)#bandwidth 64
R4(config-if)#no shutdown
R4(config-if)#end

```
R4#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#hostname R4
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)#interface Lo5
R4(config-if)#description R4 LAN B
R4(config-if)#ip address 192.168.4.129 255.255.255.128
R4(config-if)#interface Serial3/2
R4(config-if)#description R4 --> R3
R4(config-if)#ip address 172.16.34.4 255.255.255.248
R4(config-if)#bandwidth 64
R4(config-if)#no shutdown
R4(config-if)#end
```

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

```
R3#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
GigabitEthernet2/0     unassigned      YES unset  administratively down down
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
Serial3/3              unassigned      YES unset  administratively down down
FastEthernet4/0        unassigned      YES unset  administratively down down
FastEthernet4/1        unassigned      YES unset  administratively down down
Ethernet5/0            unassigned      YES unset  administratively down down
Ethernet5/1            unassigned      YES unset  administratively down down
Ethernet5/2            unassigned      YES unset  administratively down down
Ethernet5/3            unassigned      YES unset  administratively down down
Ethernet6/0            unassigned      YES unset  administratively down down
Ethernet6/1            unassigned      YES unset  administratively down down
Ethernet6/2            unassigned      YES unset  administratively down down
Ethernet6/3            unassigned      YES unset  administratively down down
Ethernet6/4            unassigned      YES unset  administratively down down
Ethernet6/5            unassigned      YES unset  administratively down down
Ethernet6/6            unassigned      YES unset  administratively down down
Ethernet6/7            unassigned      YES unset  administratively down down
Loopback3              192.168.3.1     YES manual up                    up
R3#
```

R3# show protocols

```
R3#show protocols
Global values:
  Internet Protocol routing is enabled
FastEthernet0/0 is administratively down, line protocol is down
GigabitEthernet2/0 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
FastEthernet4/0 is administratively down, line protocol is down
FastEthernet4/1 is administratively down, line protocol is down
Ethernet5/0 is administratively down, line protocol is down
Ethernet5/1 is administratively down, line protocol is down
Ethernet5/2 is administratively down, line protocol is down
Ethernet5/3 is administratively down, line protocol is down
Ethernet6/0 is administratively down, line protocol is down
Ethernet6/1 is administratively down, line protocol is down
Ethernet6/2 is administratively down, line protocol is down
Ethernet6/3 is administratively down, line protocol is down
Ethernet6/4 is administratively down, line protocol is down
Ethernet6/5 is administratively down, line protocol is down
 --More--
```

R3# show interfaces description

```
R3#show interfaces description
Interface                      Status         Protocol Description
Fa0/0                          admin down     down
Gi2/0                          admin down     down
Se3/0                          up             up       R3 --> R1
Se3/1                          up             up       R3 --> R2
Se3/2                          up             up       R3 --> R4
Se3/3                          admin down     down
Fa4/0                          admin down     down
Fa4/1                          admin down     down
Et5/0                          admin down     down
Et5/1                          admin down     down
Et5/2                          admin down     down
Et5/3                          admin down     down
Et6/0                          admin down     down
Et6/1                          admin down     down
Et6/2                          admin down     down
Et6/3                          admin down     down
Et6/4                          admin down     down
Et6/5                          admin down     down
Et6/6                          admin down     down
Et6/7                          admin down     down
Lo3                            up             up       R3 LAN
R3#
```

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.

d. 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.

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 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)#
```

R2#conf t
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-summary

```
R2(config)#router eigrp 1
R2(config-router)#network 192.168.2.0
R2(config-router)#network 172.16.12.0 0.0.0.7
R2(config-router)#network 172.16.23.0 0.0.0.7
R2(config-router)#no auto-summary
```

R3(config)#router eigrp 1
R3(config-router)#network 192.168.3.0
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 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
```

R4#conf t
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

```
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
```

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 00:01:09   58  2340  0
10
0   172.16.12.2             Se3/0                    11 00:01:49   60  1170  0
9
R1#
```

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                    12 00:01:55   62  1170  0
11
0   172.16.12.1             Se3/0                    10 00:02:35   45  1170  0
11
R2#
```

R3# show ip eigrp neighbors

```
R3#show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(1)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Se
q
                                                   (sec)         (ms)       Cnt Nu
m
2   172.16.34.4             Se3/2                    10 00:02:08   73  2340  0  3
1   172.16.23.2             Se3/1                    14 00:02:38   48  1170  0  8
0   172.16.13.1             Se3/0                    10 00:02:38   54  2340  0  10
R3#
```

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             Se3/2                    10 00:02:40   54  2340  0
9
R4#
```

a. 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 = 56/88/136 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 = 36/56/72 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 = 76/112/144 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 = 20/44/72 ms
Type escape sequence to abort.
```

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

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

Gateway of last resort is not set

      172.16.0.0/16 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, 00:05:36, Serial3/0
D        172.16.34.0/29 [90/41024000] via 172.16.13.3, 00:05:36, 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, 00:05:36, Serial3/0
 --More--
```

e. 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 16 msec 28 msec 64 msec
  2 172.16.23.2 84 msec 148 msec 116 msec
  3 172.16.12.1 164 msec 156 msec 164 msec
```

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 40 msec 28 msec 60 msec
  2 172.16.23.2 124 msec 100 msec 144 msec
  3 172.16.12.1 152 msec 160 msec 160 msec
R4#
```

f. 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 S0/0/1.
R3# show ip route

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

Gateway of last resort is not set

      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, 00:07:39, 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, 00:07:39, Serial3/1
D     192.168.2.0/24 [90/20640000] via 172.16.23.2, 00:07:39, Serial3/1
      192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
 --More--
```

g. On R3, use the show interfaces serial 0/0/0 and show interfaces s0/0/1 commands.
R3# show interfaces serial3/2

```
R3#show interfaces serial3/2
Serial3/2 is up, line protocol is up
  Hardware is M4T
  Description: R3 --> R4
  Internet address is 172.16.34.3/29
  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 00:00:04, 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
     313 packets input, 22504 bytes, 0 no buffer
     Received 147 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
 --More--
```

R3# show interfaces serial3/0

```
R3#show interfaces serial3/0
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 00:00:00, 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
     364 packets input, 27064 bytes, 0 no buffer
     Received 145 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
 --More--
```

R3# show interfaces serial3/1

```
R3#show interfaces serial3/1
Serial3/1 is up, line protocol is up
  Hardware is M4T
  Description: R3 --> R2
  Internet address is 172.16.23.3/29
  MTU 1500 bytes, BW 128 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 00:00:03, 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 96 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     348 packets input, 25420 bytes, 0 no buffer
     Received 162 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
 --More--
```

h. 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
 --More--
```

Step 6: Configure PBR to provide path control.

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

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

The steps required to implement path control include the following:

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

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

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

a. On router R3, create a standard access list called PBR-ACL to identify the R4 LAN B network.
R3(config)# ip access-list standard PBR-ACL
R3(config-std-nacl)# remark ACL matches R4 LAN B traffic
R3(config-std-nacl)# permit 192.168.4.128 0.0.0.127
R3(config-std-nacl)# exit

```
R3#CONF T
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)#
```

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

j. 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 S3/2
R3(config)# interface s03/2
R3(config-if)# ip policy route-map R3-to-R1
R3(config-if)# end

```
R3(config)#interface s3/2
R3(config-if)#ip policy route-map R3-to-R1
R3(config-if)#end
R3#
```

k. 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
  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
R3(config)# access-list 1 permit 192.168.4.0 0.0.0.255
R3(config)# exit

```
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
```

l. 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

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

Policy routing debugging is on for access list 1 m. 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 52 msec 24 msec 52 msec
  2 172.16.23.2 104 msec 108 msec 104 msec
  3 172.16.12.1 84 msec 68 msec 128 msec
```

n. 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 40 msec 76 msec 52 msec
  2 172.16.13.1 132 msec 140 msec 128 msec
```

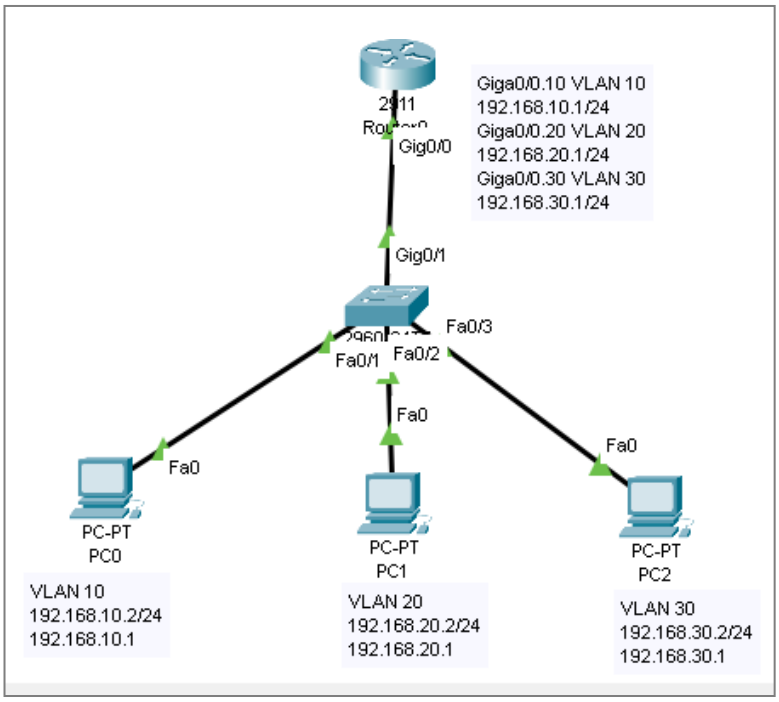
o. On R3, display the policy and matches using the show route-map command.
R3# show route-map

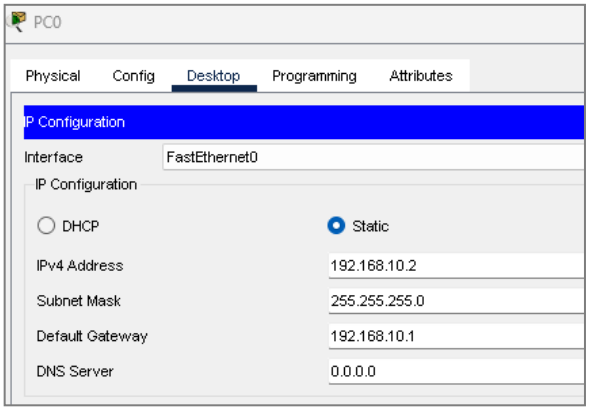
```
R3#show route-map
route-map R3-to-R1, permit, sequence 10
  Match clauses:
    ip address (access-lists): PBR-ACL
  Set clauses:
    ip next-hop 172.16.13.1
Nexthop tracking current: 0.0.0.0
172.16.13.1, fib_nh:0,oce:0,status:0

  Policy routing matches: 6 packets, 192 bytes
```

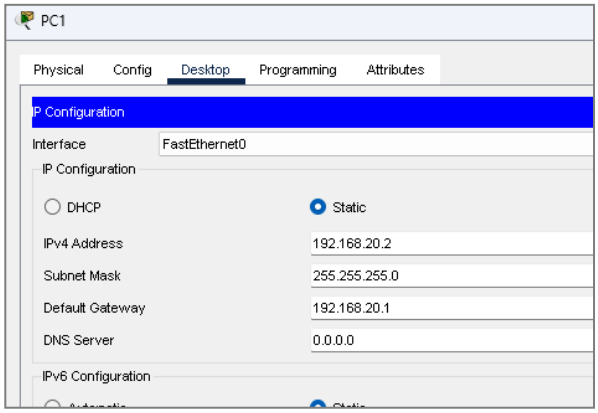
PRACTICAL NO: 07

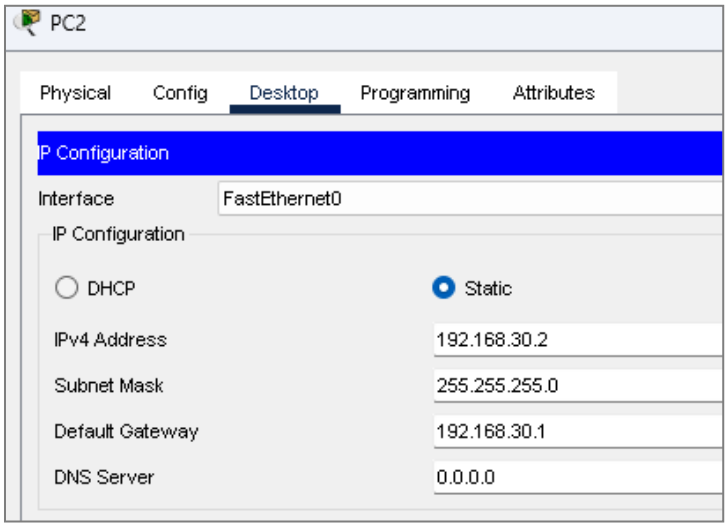
AIM: Inter-Vlan Routing

1) Assing the Address to PCs









2) Configure within the switch

- **VLAN**
- **Assign the specified interfaces to the specific VLANs**
- **Define Access ports and Trunk Ports**

Switch(config)# **VLAN 10**
Switch(config)# **exit**
Switch(config)# **VLAN 20**
Switch(config)# **exit**
Switch(config)# **VLAN 30**
Switch(config)# **exit**

Switch#**show vlan brief**

```
VLAN Name                              Status    Ports
---- --------------------------------- --------- -------------------------------
1    default                           active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                 Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                 Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                                 Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                                 Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                                 Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                                 Gig0/1, Gig0/2
10   VLAN0010                          active
20   VLAN0020                          active
30   VLAN0030                          active
1002 fddi-default                      active
1003 token-ring-default                active
1004 fddinet-default                   active
1005 trnet-default                     active
```

Switch# **configure terminal**
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#**interface fastethernet 0/1**
Switch(config-if)#**switchport access vlan 10**
Switch(config-if)#**switchport mode access**
Switch(config-if)#**exit**
Switch(config)#
Switch(config)#**interface fastethernet 0/2**

Switch(config-if)#**switchport access vlan 20**
Switch(config-if)#**switchport mode access**
Switch(config-if)#**exit**
Switch(config)#
Switch(config)#**interface fastethernet 0/3**
Switch(config-if)#**switchport access vlan 10**
Switch(config-if)#**switchport mode access**
Switch(config-if)#**end**
Switch#
%SYS-5-CONFIG_I: Configured from console by console

Switch#**show vlan brief**

VLAN	Name	Status	Ports
1	default	active	Fa0/4, Fa0/5, Fa0/6, Fa0/7 Fa0/8, Fa0/9, Fa0/10, Fa0/11 Fa0/12, Fa0/13, Fa0/14, Fa0/15 Fa0/16, Fa0/17, Fa0/18, Fa0/19 Fa0/20, Fa0/21, Fa0/22, Fa0/23 Fa0/24, Gig0/1, Gig0/2
10	VLAN0010	active	Fa0/1
20	VLAN0020	active	Fa0/2
30	VLAN0030	active	Fa0/3
1002	fddi-default	active	
1003	token-ring-default	active	
1004	fddinet-default	active	
1005	trnet-default	active	

Switch#**conf t**
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#**interface gigabitethernet 0/1**
Switch(config-if)#**no shutdown**
Switch(config-if)#
Switch(config-if)#**switchport mode trunk**
Switch(config-if)#**exit**
Switch(config)#**exit**
Switch#
%SYS-5-CONFIG_I: Configured from console by console

Switch#**show run**

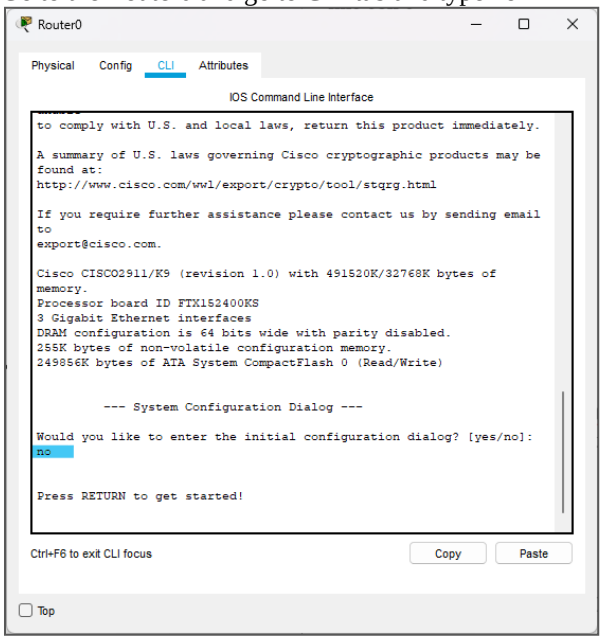
```
Switch#show run
Building configuration...

Current configuration : 1256 bytes
!
version 15.0
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname Switch
!
!
!
!
!
!
spanning-tree mode pvst
spanning-tree extend system-id
!
interface FastEthernet0/1
 switchport access vlan 10
 switchport mode access
!
interface FastEthernet0/2
 switchport access vlan 20
 switchport mode access
!
interface FastEthernet0/3
 switchport access vlan 30
 switchport mode access
!
interface FastEthernet0/4
!
interface FastEthernet0/5
!
interface FastEthernet0/6
!
interface FastEthernet0/7
!
interface FastEthernet0/8
!
interface FastEthernet0/9
!
interface FastEthernet0/10
!
interface FastEthernet0/11
!
interface FastEthernet0/12
!
interface FastEthernet0/13
!
interface FastEthernet0/14
!
interface FastEthernet0/15
!
interface FastEthernet0/16
!
interface FastEthernet0/17
!
interface FastEthernet0/18
!
interface FastEthernet0/19
!
interface FastEthernet0/20
!
interface FastEthernet0/21
!
interface FastEthernet0/22
!
interface FastEthernet0/23
!
interface FastEthernet0/24
```

```
interface GigabitEthernet0/1
 switchport mode trunk
!
interface GigabitEthernet0/2
!
interface Vlan1
 no ip address
 shutdown
!
!
!
!
line con 0
!
line vty 0 4
 login
line vty 5 15
 login
!
!
!
!
end
```

Switch#**copy running-config startup-config**
Destination filename [startup-config]?
Building configuration...
[OK]
Switch#

3) Configure router with dot1Q encapsulation by making each of sub-interfaces

Go to the Router0 and go to CLI tab and type no



```
Router>enable
Router#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#interface gigabitEthernet 0/0
Router(config-if)#no shutdown

Router(config-if)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to up

Router(config-if)#exit
Router(config)#interface gigabitEthernet 0/0.10
Router(config-subif)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0.10, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0.10, changed state to up

Router(config-subif)#encapsulation dot1Q 10
Router(config-subif)#ip address 192.168.10.1 255.255.255.0
Router(config-subif)#exit
Router(config)#interface gigabitEthernet 0/0.20
Router(config-subif)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0.20, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0.20, changed state to up

Router(config-subif)#encapsulation dot1Q 20
Router(config-subif)#ip address 192.168.20.1 255.255.255.0
Router(config-subif)#exit
Router(config)#interface gigabitEthernet 0/0.30
Router(config-subif)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0.30, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0.30, changed state to up

Router(config-subif)#encapsulation dot1Q 30
Router(config-subif)#ip address 192.168.30.1 255.255.255.0
Router(config-subif)#
Router(config-subif)#encapsulation dot1Q 10

%Configuration of multiple subinterfaces of the same main
interface with the same VID (10) is not permitted.
This VID is already configured on GigabitEthernet0/0.10.

Router(config-subif)#shutdown
Router(config-subif)#
%LINK-5-CHANGED: Interface GigabitEthernet0/0.30, changed state to administratively down

%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0.30, changed state to down

Router(config-subif)#
Router(config-subif)#exit
Router(config)#no interface gigabitethernet 0/0.30
Router(config)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console
Router#show run
```

```
Router#show run
Building configuration...

Current configuration : 875 bytes
!
version 15.1
no service timestamps log datetime msec
no service timestamps debug datetime msec
no service password-encryption
!
hostname Router
!
!
!
!
!
!
!
!
ip cef
no ipv6 cef
!
!
!
!
license udi pid CISCO2911/K9 sn FTX1524JG2W-
!
!
!
!
!
!
!
!
!
!
!
!
spanning-tree mode pvst
!
!
!
!
!
!
interface GigabitEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface GigabitEthernet0/0.10
 encapsulation dot1Q 10
 ip address 192.168.10.1 255.255.255.0
!
interface GigabitEthernet0/0.20
 encapsulation dot1Q 20
 ip address 192.168.20.1 255.255.255.0
!
interface GigabitEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface GigabitEthernet0/0.10
 encapsulation dot1Q 10
 ip address 192.168.10.1 255.255.255.0
!
interface GigabitEthernet0/0.20
 encapsulation dot1Q 20
 ip address 192.168.20.1 255.255.255.0
!
interface GigabitEthernet0/1
 no ip address
 duplex auto
 speed auto
 shutdown
!
interface GigabitEthernet0/2
 no ip address
 duplex auto
 speed auto
 shutdown
!
interface Vlan1
 no ip address
 shutdown
!
ip classless
!
ip flow-export version 9
!
!
!
!
!
!
!
!
line con 0
!
line aux 0
!
line vty 0 4
 login
!
!
!
end
```

Router#show ip route

```
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0.10
L       192.168.10.1/32 is directly connected, GigabitEthernet0/0.10
     192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.20.0/24 is directly connected, GigabitEthernet0/0.20
L       192.168.20.1/32 is directly connected, GigabitEthernet0/0.20
```

Switch>enable
Switch#show vlan brief

```
Switch>
Switch>enable
Switch#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/4, Fa0/5, Fa0/6, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gig0/2
10   VLAN0010                         active    Fa0/1, Fa0/3
20   VLAN0020                         active    Fa0/2
30   VLAN0030                         active
1002 fddi-default                     active
1003 token-ring-default               active
1004 fddinet-default                  active
1005 trnet-default                    active
Switch#
```

Switch#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Switch(config)#vlan 30
Switch(config-vlan)#exit
Switch(config)#
Switch(config)#interface fastethernet 0/3
Switch(config-if)#switchport access vlan 30
Switch(config-if)#switchport mode access
Switch(config-if)#exit
Switch(config)#exit
Switch#

Switch#**show vlan brief**

```
Switch#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/4, Fa0/5, Fa0/6, Fa0/7
                                                Fa0/8, Fa0/9, Fa0/10, Fa0/11
                                                Fa0/12, Fa0/13, Fa0/14, Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                                Fa0/24, Gig0/2
10   VLAN0010                         active    Fa0/1
20   VLAN0020                         active    Fa0/2
30   VLAN0030                         active    Fa0/3
1002 fddi-default                     active
1003 token-ring-default               active
1004 fddinet-default                  active
1005 trnet-default                    active
Switch#
```

Router#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#interface gigabitethernet 0/0.30
Router(config-subif)#
Router(config-subif)#encapsulation dot1Q 30
Router(config-subif)#ip address 192.168.30.1 255.255.255.0
Router(config-subif)#exit
Router(config)#exit
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#show ip route

```
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0.10
L       192.168.10.1/32 is directly connected, GigabitEthernet0/0.10
     192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.20.0/24 is directly connected, GigabitEthernet0/0.20
L       192.168.20.1/32 is directly connected, GigabitEthernet0/0.20
     192.168.30.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.30.0/24 is directly connected, GigabitEthernet0/0.30
L       192.168.30.1/32 is directly connected, GigabitEthernet0/0.30
```

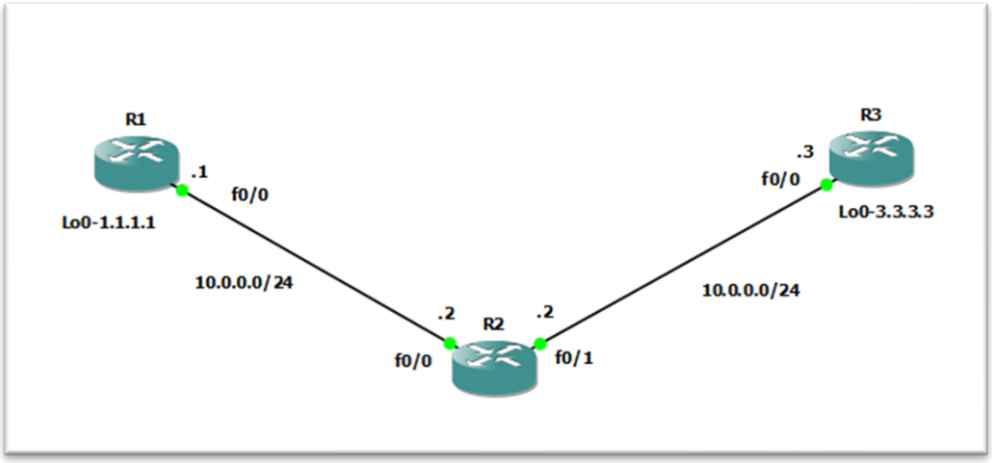
Switch#copy running-config startup-config

```
Switch#copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
Switch#
```

PRACTICAL NO: 08

AIM: Simulating Mpls Environment

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
R1#conf t
R1(config)#int lo0
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 ospf 1 area 0

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int lo0
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 ospf 1 area 0
```

Router R2
R2#CONF T
R2(config)#int lo0
R2(config-if)#ip add 2.2.2.2 255.255.255.255
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
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)#ip ospf 1 area 0
R2(config)#int f0/1
R2(config-if)#ip add 10.0.1.2 255.255.255.0
R2(config-if)#no shut

R2(config-if)#ip ospf 1 area 0

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int lo0
R2(config-if)#ip add 2.2.2.2 255.255.255.255
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
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)#ip ospf 1 area 0
R2(config-if)#
R2(config-if)#int f0/1
R2(config-if)#ip add 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#ip ospf 1 area 0
```

Router R3

R3(config)#CONF T
R3(config)#int lo0
R3(config-if)#ip add 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
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 ospf 1 area 0

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int lo0
R3(config-if)#ip add 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
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 ospf 1 area 0
```

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 = 60/62/64 ms
R1#
```

Step 2 – Configure LDP on all the interfaces in the MPLS Core

In order to run MPLS you need to enable it, there are two ways to do this.

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

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

Router R1

R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#router ospf 1

R1(config-router)#mpls ldp autoconfig

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#mpls ldp autoconfig
R1(config-router)#
```

Router R2

R2(config)#router ospf 1
R2(config-router)#mpls ldp autoconfig

```
R2#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#router ospf 1
R2(config-router)#mpls ldp autoconfig
R2(config-router)#
```

Router R3

R3(config)#router ospf 1
R3(config-router)#mpls ldp autoconfig

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router ospf 1
R3(config-router)#mpls ldp autoconfig
R3(config-router)#
```

You should see log messages coming up showing the LDP neighbors are up.

```
*Mar  1 00:14:42.787: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
R2(config-router)#
R2#
*Mar  1 00:14:57.659: %SYS-5-CONFIG_I: Configured from console by console
R2#
*Mar  1 00:15:28.615: %LDP-5-NBRCHG: LDP Neighbor 3.3.3.3:0 (2) is UP
R2#
```

To verify the mpls interfaces the command is very simple – sh mpls Interface This is done on R2 and you can see that both interfaces are running mpls and using LDP

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

You can also verify the LDP neighbors with the sh mpls ldp neighbors command.
R2#sh mpls ldp neigh

```
R2#sh mpls ldp neigh
    Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 1.1.1.1.646 - 2.2.2.2.37982
        State: Oper; Msgs sent/rcvd: 13/12; Downstream
        Up time: 00:04:31
        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: 3.3.3.3.34804 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:03:45
        LDP discovery sources:
          FastEthernet0/1, Src IP addr: 10.0.1.3
        Addresses bound to peer LDP Ident:
          10.0.1.3        3.3.3.3
R2#
```

One more verification to confirm LDP is running ok is to do a trace between R1 and R3 and verify if you get MPLS Labels show up in the trace.
R1#trace 3.3.3.3

```
R1#trace 3.3.3.3

Type escape sequence to abort.
Tracing the route to 3.3.3.3

  1 10.0.0.2 [MPLS: Label 17 Exp 0] 52 msec 64 msec 60 msec
  2 10.0.1.3 64 msec 68 msec 68 msec
R1#
```

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

Step 3 – MPLS BGP Configuration between R1 and R3
We need to establish a Multi Protocol BGP session between R1 and R3 this is done by configuring the vpnv4 address family as below

R1(config)#router bgp 1
R1(config-router)#neighbor 3.3.3.3 remote-as 1
R1(config-router)#neighbor 3.3.3.3 update-source Loopback0
R1(config-router)#no auto-summary
R1(config-router)#address-family vpnv4
R1(config-router-af)#neighbor 3.3.3.3 activate

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router bgp 1
R1(config-router)#neighbor 3.3.3.3 remote-as 1
R1(config-router)#neighbor 3.3.3.3 update-source Loopback0
R1(config-router)#no auto-summary
R1(config-router)#address-family vpnv4
R1(config-router-af)#neighbor 3.3.3.3 activate
R1(config-router-af)#
```

R3(config)#router bgp 1
R3(config-router)#neighbor 1.1.1.1 remote-as 1
R3(config-router)#neighbor 1.1.1.1 update-source Loopback0
R3(config-router)#no auto-summary
R3(config-router)#address-family vpnv4
R3(config-router-af)#neighbor 1.1.1.1 activate

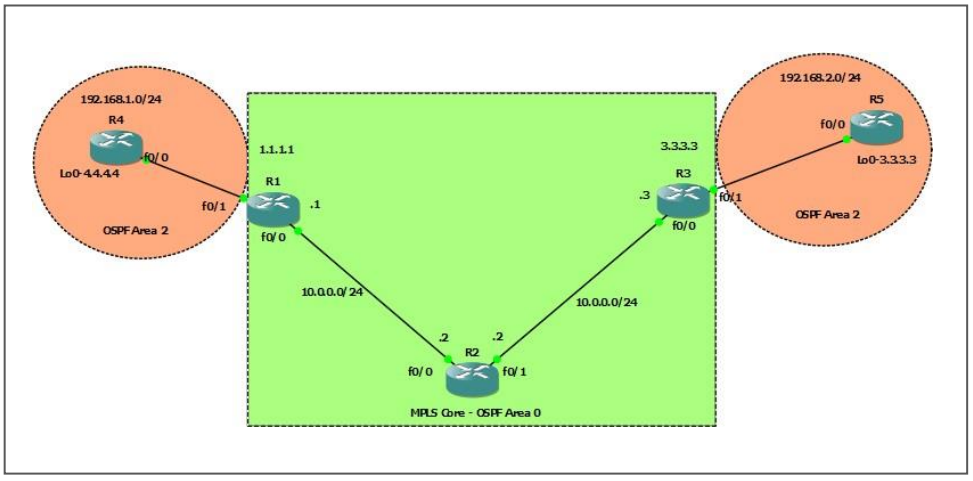
```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router bgp 1
R3(config-router)#neighbor 1.1.1.1 remote-as 1
R3(config-router)#neighbor 1.1.1.1 update-source Loopback0
R3(config-router)#no auto-summary
R3(config-router)#address-family vpnv4
R3(config-router-af)#neighbor 1.1.1.1 activate
R3(config-router-af)#
*Mar  1 00:24:35.327: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
R3(config-router-af)#
```

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

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
3.3.3.3         4     1       4       4        1    0    0 00:01:28        0
R1#
```

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.

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



R4#conf t
R4(config)#int lo0
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#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#int lo0
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
```

R1#conf t
R1(config)#int f0/1
R1(config-if)#no shut
R1(config-if)#ip add 192.168.1.1 255.255.255.0

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f0/1
R1(config-if)#no shut
R1(config-if)#ip add 192.168.1.1 255.255.255.0
```

R1(config)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4

```
R1#CONF T
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)#int f0/1
R1(config-if)#ip vrf forwarding RED
R1(config-if)#ip vrf fo
R1(config-if)#ip vrf forwarding RED

```
R1(config)#int f0/1
R1(config-if)#ip vrf forwarding RED
% Interface FastEthernet0/1 IP address 192.168.1.1 removed due to enabling VRF
RED
```

R1(config)#int f0/1
R1(config-if)#ip address 192.168.1.1 255.255.255.0

```
R1(config)#int f0/1
R1(config-if)#ip address 192.168.1.1 255.255.255.0
```

R1#sh run int f0/1

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

Current configuration : 119 bytes
!
interface FastEthernet0/1
 ip vrf forwarding RED
 ip address 192.168.1.1 255.255.255.0
 duplex auto
 speed auto
end
```

R1#sh ip route

```
R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 10.0.0.2, 00:17:49, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/21] via 10.0.0.2, 00:17:23, FastEthernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
O       10.0.1.0 [110/20] via 10.0.0.2, 00:17:33, FastEthernet0/0
```

R1#sh ip route vrf red

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

R1#sh ip route vrf RED

```
R1#sh ip route vrf RED

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

Gateway of last resort is not set

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

R1(config)#int f0/1
R1(config-if)#ip ospf 2 area 2

```
R1#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f0/1
R1(config-if)#ip ospf 2 area 2
R1(config-if)#
*Mar  1 00:23:14.423: %OSPF-5-ADJCHG: Process 2, Nbr 4.4.4.4 on FastEthernet0/1 from LOADING to FULL, Loading Done
R1(config-if)#
R1#
*Mar  1 00:23:36.811: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

R1#sh ip route vrf RED

```
R1#sh ip route vrf RED

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.1.4, 00:01:18, FastEthernet0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/1
R1#
```

R5(config)#int lo0

R5(config-if)#ip add 6.6.6.6 255.255.255.255
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#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R5(config)#int lo0
R5(config-if)#ip add 6.6.6.6 255.255.255.255
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
```

R3(config)#int f0/1
R3(config-if)#no shut
R3(config-if)#ip add 192.168.2.3 255.255.255.0

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/1
R3(config-if)#no shut
R3(config-if)#ip add 192.168.2.3 255.255.255.0
```

R3(config)#ip vrf RED
R3(config-vrf)#rd 4:4
R3(config-vrf)#route-target both 4:4

```
R3#CONF T
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)#int f0/1
R3(config-if)#ip vrf forwarding RED

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/1
R3(config-if)#ip vrf forwarding RED
% Interface FastEthernet0/1 IP address 192.168.2.3 removed due to enabling VRF R
ED
R3(config-if)#
```

R3(config)#int f0/1
R3(config-if)#ip address 192.168.2.1 255.255.255.0

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/1
R3(config-if)#ip address 192.168.2.1 255.255.255.0
R3(config-if)#
```

R3#sh run int f0/1

```
R3#sh run int f0/1
Building configuration...

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

R3#
```

R3(config)#int f0/1
R3(config-if)#ip ospf 2 area 2

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/1
R3(config-if)#ip ospf 2 area 2
R3(config-if)#
```

R3#sh ip route vrf RED

```
R3#sh ip route vrf RED

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

Gateway of last resort is not set

     6.0.0.0/32 is subnetted, 1 subnets
O       6.6.6.6 [110/11] via 192.168.2.6, 00:00:37, FastEthernet0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/1
R3#
```

R4#sh ip route

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
C       4.4.4.4 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
R4#
```

R1#sh ip route

```
R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 10.0.0.2, 00:32:11, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/21] via 10.0.0.2, 00:31:45, FastEthernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
O       10.0.1.0 [110/20] via 10.0.0.2, 00:31:55, FastEthernet0/0
R1#
```

R1#sh ip route vrf RED

```
R1#sh ip route vrf RED

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.1.4, 00:12:27, FastEthernet0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/1
R1#
```

R1(config)#router bgp 1
R1(config-router)#address-family ipv4 vrf RED
R1(config-router-af)#redistribute ospf 2

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

R3(config)#router bgp 1
R3(config-router)#address-family ipv4 vrf RED
R3(config-router-af)#redistribute ospf 2

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

R1#sh ip bgp vpnv4 vrf RED

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

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

R3#sh ip bgp vpnv4 vrf RED

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

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

R1(config)#router ospf 2
R1(config-router)#redistribute bgp 1 subnets

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

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

```
R3#CONF T
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router ospf 2
R3(config-router)#redistribute bgp 1 subnets
```

R4#sh ip route

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
C       4.4.4.4 is directly connected, Loopback0
     6.0.0.0/32 is subnetted, 1 subnets
O IA    6.6.6.6 [110/21] via 192.168.1.1, 00:01:28, FastEthernet0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
O IA 192.168.2.0/24 [110/11] via 192.168.1.1, 00:01:28, FastEthernet0/0
R4#
```

R5#sh ip route

```
R5#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/21] via 192.168.2.1, 00:01:13, FastEthernet0/0
     6.0.0.0/32 is subnetted, 1 subnets
C       6.6.6.6 is directly connected, Loopback0
O IA 192.168.1.0/24 [110/11] via 192.168.2.1, 00:01:13, FastEthernet0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
R5#
```

R4#ping 6.6.6.6

```
R4#ping 6.6.6.6

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 6.6.6.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 124/128/140 ms
R4#
```

R4#trace 6.6.6.6

```
R4#trace 6.6.6.6

Type escape sequence to abort.
Tracing the route to 6.6.6.6

  1 192.168.1.1 32 msec 16 msec 44 msec
  2 10.0.0.2 [MPLS: Labels 17/19 Exp 0] 124 msec 128 msec 124 msec
  3 192.168.2.1 [MPLS: Label 19 Exp 0] 88 msec 96 msec 92 msec
  4 192.168.2.6 128 msec 124 msec 124 msec
R4#
```