M.Sc. I.T. Semester II
MODERN NETWORKING (**PSIT2P2**)

List of Practical

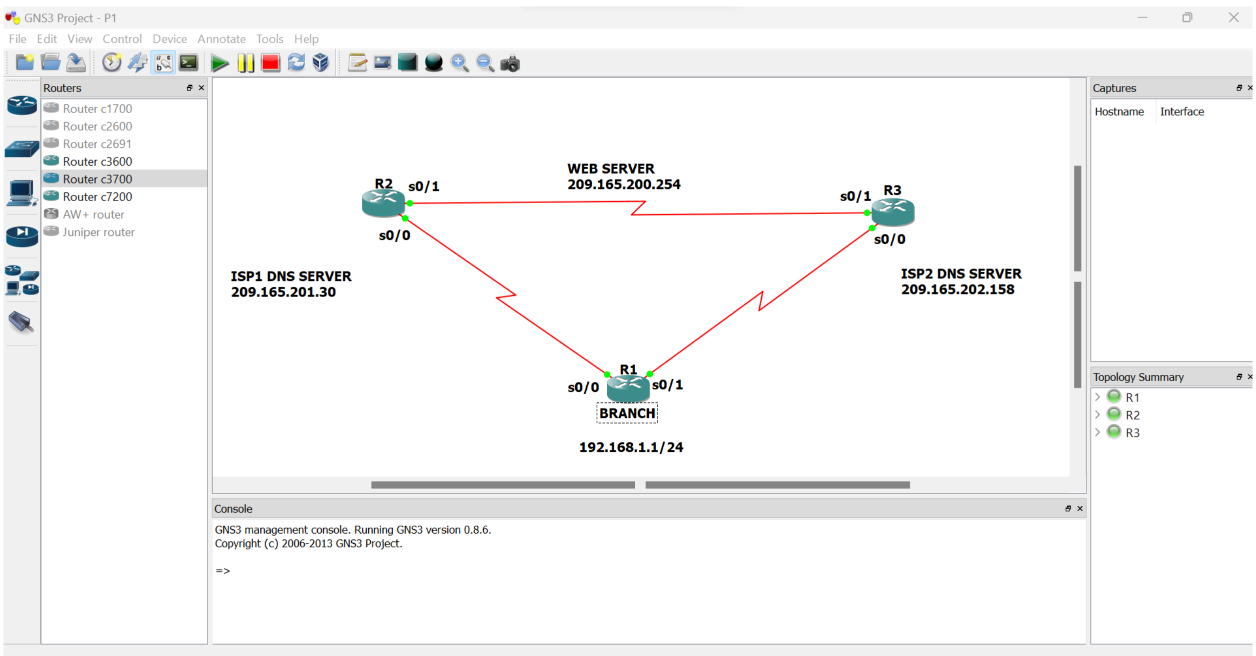
All practicals are expected to be performed on GNS3/EVE-Ng network Emulator/MININET

Programme Specific Outcome	Simulating Routing –Switching Techniques
Practical No	**Details**
1	Configure IP SLA Tracking and Path Control Topology
2	Using the AS_PATH Attribute
3	Configuring IBGP and EBGP Sessions, Local Preference, and MED
4	Secure the Management Plane
5	Configure and Verify Path Control Using PBR
6	IP Service Level Agreements and Remote SPAN in a Campus Environment
7	Inter-VLAN Routing
8	Simulating MPLS environment

PRACTICAL 1

Aim: Configure IP SLA Tracking and Path Control Topology

NETWORK TOPOLOGY



CONSOLE CODE

<u>Step 1</u>

R1 CONSOLE
Conf t
hostname R1
interface Loopback 0
description R1 LAN
ip address 192.168.1.1 255.255.255.0
interface Serial1/0
description R1 ISP1
ip address 209.165.201.2 255.255.255.252
clock rate 128000
bandwidth 128
no shutdown
interface Serial1/1
description R1 ISP2
ip address 209.165.202.130 255.255.255.252
bandwidth 128

no shutdown

Router ISP1 (R2) CONSOLE
Conf t
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 Serial1/0
description ISP1   R1
ip address 209.165.201.1 255.255.255.252
bandwidth 128
no shutdown
interface Serial1/2
description ISP1   ISP2
ip address 209.165.200.225 255.255.255.252
clock rate 128000
bandwidth 128
no shutdown

Router ISP2 (R3) CONSOLE
conf t
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 Serial1/1
description ISP2   R1
ip address 209.165.202.129 255.255.255.252
clock rate 128000
bandwidth 128
no shutdown
interface Serial1/2
description ISP2   ISP1
ip address 209.165.200.226 255.255.255.252
bandwidth 128
no shutdown

Step 2

R1 CONSOLE
end
show interfaces description | include up

```
R1#sh int description | include up
Se1/0                          up             up        R1 .. ISP1
Se1/1                          up             up        R1 .. ISP2
Lo0                            up             up        R1 LAN
R1#
```

ISP1 CONSOLE
end
show interfaces description | include up

```
ISP1#show interfaces description | include up
Se1/0                          up             up        ISP1 .. R1
Se1/2                          up             up        ISP1 .. IS
P2
Lo0                            up             up        Simulated
Internet Web Server
Lo1                            up             up        ISP1 DNS S
erver
ISP1#
```

ISP2 CONSOLE
end
show interfaces description | include up

```
ISP2#show interfaces description | include up
Se1/1                          up             up        ISP2 .. R1
Se1/2                          up             up        ISP2 .. IS
P1
Lo0                            up             up        Simulated
Internet Web Server
Lo1                            up             up        ISP2 DNS S
erver
ISP2#
```

Step 3

R1 CONSOLE
conf t
ip route 0.0.0.0 0.0.0.0 209.165.201.1

ISP1 CONSOLE
Conf t
router eigrp 1
network 209.165.200.224 0.0.0.3
network 209.165.201.0 0.0.0.31
no auto-summary
ip route 192.168.1.0 255.255.255.0 209.165.201.2

ISP2 CONSOLE
conf t
router eigrp 1
network 209.165.200.224 0.0.0.3
network 209.165.202.128 0.0.0.31
no auto-summary

ip route 192.168.1.0 255.255.255.0 209.165.202.130

Step 4

ISP1 CONSOLE
exit
conf t
ip route 192.168.1.0 255.255.255.0 209.165.201.2
end

ISP2 CONSOLE
exit
conf t
ip route 192.168.1.0 255.255.255.0 209.165.201.2
end

Step 5

R1 CONSOLE
tclsh
foreach address {
209.165.200.254
209.165.201.30
209.165.202.158
} {
ping $address source 192.168.1.1
}
exit

```
R1(tcl)#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 secon
s:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/44/60 
s
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.201.30, timeout is 2 second
:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 24/36/56 
s
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.202.158, timeout is 2 secon
s:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/72/104
ms
R1(tcl)#
```

Conf t

ip sla monitor 11
type echo protocol ipIcmpEcho 209.165.201.30
frequency 10
exit
ip sla monitor schedule 11 life forever start-time now
exit
show ip sla monitor configuration 11

```
R1(config)#exit

R1(tcl)#show ip sla monitor configuration 11
IP SLA Monitor, Infrastructure Engine-II.
Entry number: 11
Owner:
Tag:
Type of operation to perform: echo
Target address: 209.165.201.30
Request size (ARR data portion): 28
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Verify data: No
Operation frequency (seconds): 10
Next Scheduled Start Time: Start Time already passed
Group Scheduled : FALSE
Life (seconds): Forever
Entry Ageout (seconds): never
Recurring (Starting Everyday): FALSE
Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Number of statistic hours kept: 2
Number of statistic distribution buckets kept: 1
Statistic distribution interval (milliseconds): 20
Number of history Lives kept: 0
Number of history Buckets kept: 15
 --More--
*May 23 12:42:10.655: %SYS-5-CONFIG_I: Configured from console by cons
ole
History Filter Type: None
Enhanced History:


R1(tcl)#
```

show ip sla monitor statistics

```
R1(tcl)#
R1(tcl)#
R1(tcl)#sh ip sla monitor statistics
Round trip time (RTT)    Index 11
        Latest RTT: 40 ms
Latest operation start time: *12:45:40.643 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 22
Number of failures: 0
Operation time to live: Forever
```

Conf t
ip sla monitor 22
type echo protocol ipIcmpEcho 209.165.202.158
frequency 10
exit
ip sla monitor schedule 22 life forever start-time now
exit
show ip sla monitor configuration 22

```
R1(tcl)#show ip sla monitor configuration 22
IP SLA Monitor, Infrastructure Engine-II.
Entry number: 22
Owner:
Tag:
Type of operation to perform: echo
Target address: 209.165.202.158
Request size (ARR data portion): 28
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Verify data: No
Operation frequency (seconds): 10
Next Scheduled Start Time: Start Time already passed
Group Scheduled : FALSE
Life (seconds): Forever
Entry Ageout (seconds): never
Recurring (Starting Everyday): FALSE
Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Number of statistic hours kept: 2
Number of statistic distribution buckets kept: 1
Statistic distribution interval (milliseconds): 20
Number of history Lives kept: 0
Number of history Buckets kept: 15
 --More--
*May 23 12:48:06.459: %SYS-5-CONFIG_I: Configured from console by cons
ole
History Filter Type: None
Enhanced History:


R1(tcl)#
```

show ip sla monitor statistics

```
R1(tcl)#show ip sla monitor statistics
Round trip time (RTT)   Index 11
        Latest RTT: 28 ms
Latest operation start time: *12:53:00.643 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 66
Number of failures: 0
Operation time to live: Forever

Round trip time (RTT)   Index 22
        Latest RTT: 76 ms
Latest operation start time: *12:52:56.443 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 30
Number of failures: 0
Operation time to live: Forever
```

Step 6

R1 CONSOLE

Conf t
no ip route 0.0.0.0 0.0.0.0 209.165.201.1
ip route 0.0.0.0 0.0.0.0 209.165.201.1 5
exit
show ip route

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

Gateway of last resort is 209.165.201.1 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial1/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial1/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [5/0] via 209.165.201.1
R1(tcl)#
*May 23 12:54:54.515: %SYS-5-CONFIG_I: Configured from console by cons
ole
R1(tcl)#
```

Step 7

R1 CONSOLE
conf t
track 1 rtr 11 reachability
delay down 10 up 1
exit
exit
debug ip routing
conf t
ip route 0.0.0.0 0.0.0.0 209.165.201.1 2 track 1

conf t
track 2 rtr 22 reachability
delay down 10 up 1
exit
exit
debug ip routing
conf t
ip route 0.0.0.0 0.0.0.0 209.165.202.129 3 track 2
exit
show ip route

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

Gateway of last resort is 209.165.201.1 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial1/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial1/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [2/0] via 209.165.201.1
*May 23 12:56:52.475: %SYS-5-CONFIG_I: Configured from console by cons
ole
*May 23 12:56:52.591: RT: closer admin distance for 0.0.0.0, flushing
1 routes
*May 23 12:56:52.591: RT: NET-RED 0.0.0.0/0
*May 23 12:56:52.591: RT: SET_LAST_RDB for 0.0.0.0/0
  NEW rdb: via 209.165.201.1

*May 23 12:56:52.595: RT: add 0.0.0.0/0 via 209.165.201.1, static metr
```

Step 8

ISP1 CONSOLE

conf t
interface loopback 1
shutdown

R1 CONSOLE

show ip route

```
R1(tcl)#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 209.165.202.129 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial1/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial1/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [3/0] via 209.165.202.129
R1(tcl)#
```

show ip sla monitor statistics

```
R1(tcl)#show ip sla monitor statistics
Round trip time (RTT)   Index 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *13:07:20.643 UTC Tue May 23 2023
Latest operation return code: Timeout
Number of successes: 142
Number of failures: 10
Operation time to live: Forever

Round trip time (RTT)   Index 22
        Latest RTT: 44 ms
Latest operation start time: *13:07:16.443 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 116
Number of failures: 0
Operation time to live: Forever
```

trace 209.165.200.254 source 192.168.1.1

```
R1(tcl)#trace 209.165.200.254 source 192.168.1.1

Type escape sequence to abort.
Tracing the route to 209.165.200.254

  1 209.165.202.129 48 msec 68 msec 52 msec
R1(tcl)#
*May 23 13:09:25.923: RT: NET-RED 0.0.0.0/0
R1(tcl)#
```

ISP1 CONSOLE

no shutdown

R1 CONSOLE

show ip sla monitor statistics

```
R1(tcl)#sh ip sla monitor statistics
Round trip time (RTT)   Index 11
        Latest RTT: 60 ms
Latest operation start time: *13:13:00.643 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 146
Number of failures: 40
Operation time to live: Forever

Round trip time (RTT)   Index 22
        Latest RTT: 84 ms
Latest operation start time: *13:12:56.443 UTC Tue May 23 2023
Latest operation return code: OK
Number of successes: 150
Number of failures: 0
Operation time to live: Forever
```

Show ip route

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

Gateway of last resort is 209.165.201.1 to network 0.0.0.0

     209.165.201.0/30 is subnetted, 1 subnets
C       209.165.201.0 is directly connected, Serial1/0
     209.165.202.0/30 is subnetted, 1 subnets
C       209.165.202.128 is directly connected, Serial1/1
C    192.168.1.0/24 is directly connected, Loopback0
S*   0.0.0.0/0 [2/0] via 209.165.201.1
R1(tcl)#
```

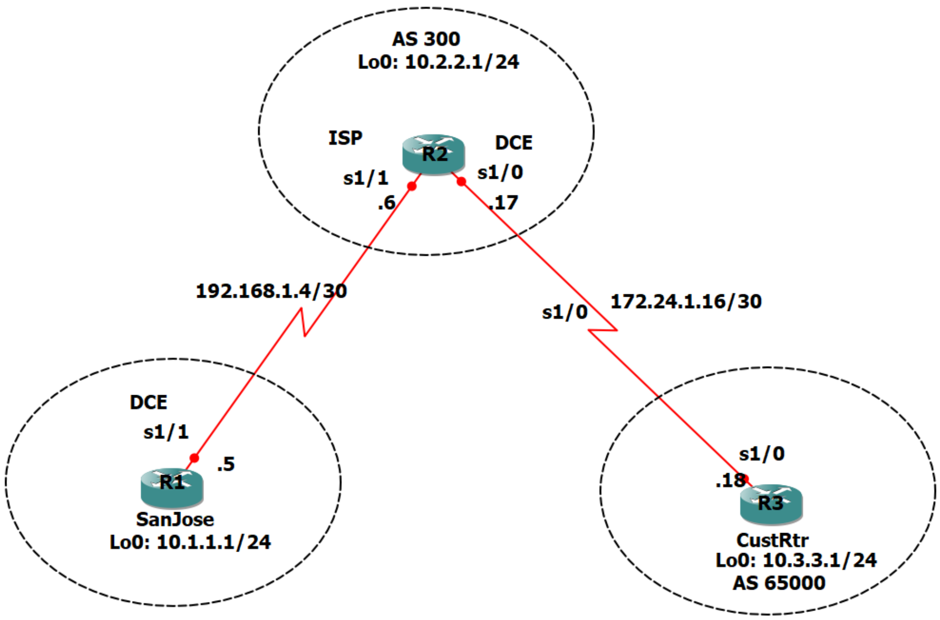
PRACTICAL 2

Introduction:

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

Aim: Using the AS_PATH Attribute.

Topology:



Objectives:

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

Background:

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

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

Required Resources

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

Step 1: Prepare the routers for the lab**.**

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

Step 2: Configure the hostname and interface addresses.

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

Router R1 (hostname SanJose)

hostname SanJose
interface Loopback0
ip address 10.1.1.1 255.255.255.0
interface Serial1/1
ip address 192.168.1.5 255.255.255.252

clock rate 128000

no shutdown

```
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 Serial1/1
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)

hostname ISP
interface Loopback0
ip address 10.2.2.1 255.255.255.0
interface Serial1/1
ip address 192.168.1.6 255.255.255.252
no shutdown
interface Serial1/0
ip address 172.24.1.17 255.255.255.252

clock rate 128000

no shutdown

```
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 Serial1/1
ISP(config-if)#ip address 192.168.1.6 255.255.255.252
ISP(config-if)#no shutdown
ISP(config-if)#interface Serial1/0
ISP(config-if)#ip address 172.24.1.17 255.255.255.252
ISP(config-if)#clock rate 128000
```

Router R3 (hostname CustRtr)

hostname CustRtr
interface Loopback0
ip address 10.3.3.1 255.255.255.0
interface Serial1/0
ip address 172.24.1.18 255.255.255.252
no shutdown

```
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 Serial1/0
CustRtr(config-if)#ip address 172.24.1.18 255.255.255.252
CustRtr(config-if)#no shutdown
```

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

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

Step 3: Configure BGP.

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

Router R1 (hostname SanJose)

router bgp 100
neighbor 192.168.1.6 remote-as 300
network 10.1.1.0 mask 255.255.255.0

```
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)#
```

Router R2 (hostname ISP)

router bgp 300
neighbor 192.168.1.5 remote-as 100
neighbor 172.24.1.18 remote-as 65000
network 10.2.2.0 mask 255.255.255.0

```
ISP(config-if)#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)#
*Jun 21 13:21:43.239: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
ISP(config-router)#network 10.2.2.0 mask 255.255.255.0
ISP(config-router)#
```

Router R3 (hostname CustRtr)

router bgp 65000
neighbor 172.24.1.17 remote-as 300
network 10.3.3.0 mask 255.255.255.0

```
CustRtr(config-if)#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)#
```

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

Router R2 (hostname ISP)
show ip bgp neighbors

R2

```
Connection is ECN Disabled, Mininum incoming TTL 0, Outgoing TTL 1
Local host: 192.168.1.6, Local port: 179
Foreign host: 192.168.1.5, Foreign port: 35468

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

Event Timers (current time is 0x1F4124):
Timer          Starts    Wakeups            Next
Retrans            11          0             0x0
TimeWait            0          0             0x0
AckHold            12          3             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0

iss: 1283501914  snduna: 1283502249  sndnxt: 1283502249     sndwnd:  16050
irs: 3703581546  rcvnxt: 3703581834  rcvwnd:      16097  delrcvwnd:    287

SRTT: 231 ms, RTTO: 769 ms, RTV: 538 ms, KRTT: 0 ms
minRTT: 32 ms, maxRTT: 300 ms, ACK hold: 200 ms
Flags: passive open, nagle, gen tcbs
IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):
Rcvd: 21 (out of order: 0), with data: 12, total data bytes: 287
Sent: 15 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion
es: 334
ISP#
```

Step 4: Remove the private AS.

a.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.

Router R1 (hostname SanJose)
show ip route

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

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 2 subnets
B       10.2.2.0 [20/0] via 192.168.1.6, 00:12:00
C       10.1.1.0 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial1/1
SanJose#
```

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

Router R1 (hostname SanJose)

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:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/64/68 ms

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

SanJose# **ping 10.3.3.1 source 10.1.1.1**

d.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.

Router R1 (hostname SanJose)

show ip bgp

```
SanJose#sh 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
Origin codes: i - IGP, e - EGP, ? - incomplete

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

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

Router R2 (hostname ISP)
router bgp 300
 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)#
```

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

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

Does SanJose still have a route to 10.3.3.0?

```
ISP#clear ip bgp *
ISP#
*Jun 21 14:05:31.947: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
```

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

Router R1 (hostname 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 seconds:
Packet sent with a source address of 10.1.1.1
.....
Success rate is 0 percent (0/5)
```

G. 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.

Router R1 (hostname SanJose)
show ip bgp

```
SanJose#sh ip bgp
BGP table version is 5, local router ID is 10.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

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

Step 5: Use the AS_PATH attribute to filter routes.

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

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

Router R2 (hostname ISP)
ip as-path access-list 1 deny ^100$
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)#
```

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

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

For more details on configuring regular expressions on Cisco routers, see:

http://www.cisco.com/en/US/docs/ios/12_2/termserv/configuration/guide/tcfaapre_ps1835_TSD_Products_Configuration_Guide_Chapter.html

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

Router R2 (hostname ISP)
router bgp 300
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)#
```

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

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

```
ISP#clear ip bgp *
ISP#
*Jun 21 14:25:40.879: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down User reset
ISP#
*Jun 21 14:25:43.247: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
```

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).

Router R2 (hostname ISP)

show ip route

```
ISP#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 rout
e
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 2 subnets
C       10.2.2.0 is directly connected, Loopback0
B       10.1.1.0 [20/0] via 192.168.1.5, 00:01:02
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial1/1
ISP#
```

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

Router R3 (hostname CustRtr)

show ip route

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

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 1 subnets
C       10.3.3.0 is directly connected, Loopback0
CustRtr#
```

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

Router R2 (hostname ISP)

show ip bgp regexp ^100$

```
ISP#sh 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
Origin codes: i - IGP, e - EGP, ? - incomplete

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

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

F. Run the following Tcl script on all routers to verify whether there is connectivity. All pings from ISP should be successful. 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.

Router R2 (hostname ISP)

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
```

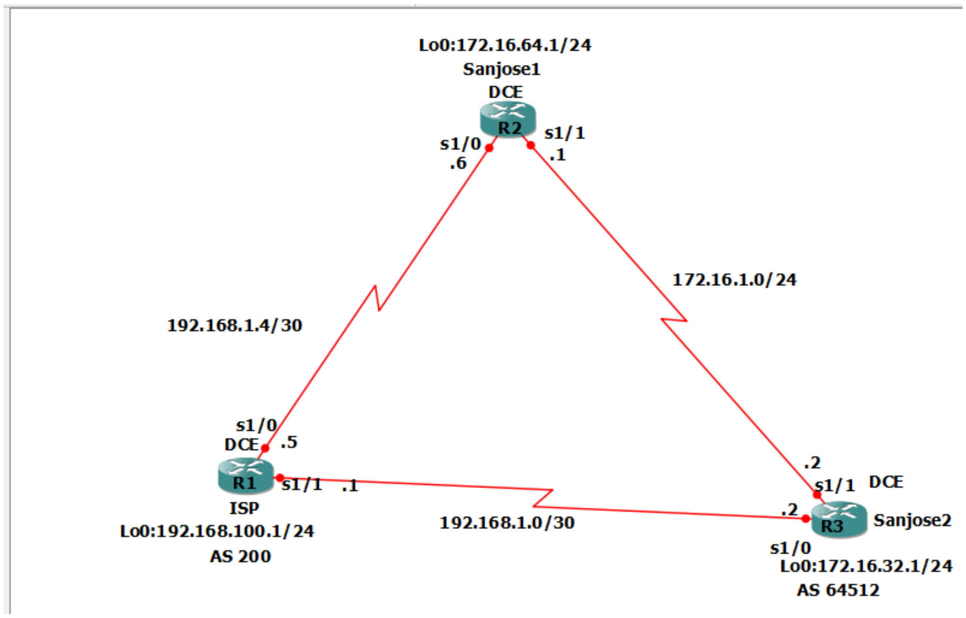
Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

PRACTICAL 3

AIM: Configuring IBGP and EBGP Sessions, Local Preference, and MED

THEORY:

Topology:



CODE:

Step 1: Configure interface addresses.

a. Using the addressing scheme in the diagram, create the loopback interfaces and apply IPv4 addresses to these and the serial interfaces on ISP (R1), SanJose1 (R2), and SanJose2 (R3). Apply the following configuration to each router along with the appropriate hostname.

R1 (hostname ISP)

conf t
hostname ISP

R2 (hostname SanJose1)

conf t
hostname SanJose1

R3(hostname SanJose2)

conf t
hostname SanJose2

Run the following in all the router consoles:

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

R1(hostname ISP)

```
conf t
hostname ISP
interface Loopback0
ip address 192.168.100.1 255.255.255.0
exit
interface S1/0
ip address 192.168.1.5 255.255.255.252
clock rate 128000
no shutdown
exit
interface S1/1
ip address 192.168.1.1 255.255.255.252
no shutdown
end
```

R2 (hostname SanJose1)

```
conf t
hostname SanJose1
interface Loopback0
ip address 192.168.100.1 255.255.255.0
exit
interface S1/0
ip address 192.168.1.5 255.255.255.252
clock rate 128000
no shutdown
exit
interface S1/1
ip address 192.168.1.1 255.255.255.252
no shutdown
End
```

Step 2: Configure EIGRP.

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

Step 3: Configure IBGP and verify BGP neighbors.

a. Configure IBGP between the SanJose1 and SanJose2 routers.

R2(hostname SanJose1)

```
router bgp 64512
neighbor 172.16.32.1 remote-as 64512
neighbor 172.16.32.1 update-source lo0
```

b. Complete the IBGP configuration on SanJose2 using the following commands.

R3(hostname SanJose2)

router bgp 64512
neighbor 172.16.64.1 remote-as 64512
neighbor 172.16.64.1 update-source lo0

c. Verify that SanJose1 and SanJose2 become BGP neighbors by issuing the show ip bgp neighbors command on SanJose1.

View the following partial output. If the BGP state is not established, troubleshoot the connection.

exit
exit
SanJose2# show ip bgp neighbors

```
SanJose1#sh ip bgp neighbors
BGP neighbor is 172.16.32.1,  remote AS 64512, internal link
  BGP version 4, remote router ID 0.0.0.0
  BGP state = Active
  Last read 00:15:17, last write 00:15:17, hold time is 180,
 keepalive interval is 60 seconds
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  0          0
    Notifications:          0          0
    Updates:                0          0
    Keepalives:             0          0
    Route Refresh:          0          0
    Total:                  0          0
  Default minimum time between advertisement runs is 0 secon
ds

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

                                   Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    Total:                               0          0
  Number of NLRIs in the update sent: max 0, min 0

  Connections established 0; dropped 0
  Last reset never
  No active TCP connection
```

Step 4: Configure EBGP and verify BGP neighbors.

a. Configure ISP to run EBGP with SanJose1 and SanJose2. Enter the following commands on ISP.

R1(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

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

R2(hostname SanJose1)

exit
SanJose1(config)# ip route 172.16.0.0 255.255.0.0 null0

c. Configure SanJose1 as an EBGP peer to ISP.

R2(hostname SanJose1)

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

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

R2(hostname SanJose1)

SanJose1# show ip bgp neighbors

```
anJose1#show ip bgp neighbors
GP neighbor is 172.16.32.1,  remote AS 64512, internal link
 BGP version 4, remote router ID 0.0.0.0
 BGP state = Active
 Last read 00:45:07, last write 00:45:07, hold time is 180, ke
e interval is 60 seconds
 Message statistics:
   InQ depth is 0
   OutQ depth is 0
                        Sent       Rcvd
   Opens:                  0          0
   Notifications:          0          0
   Updates:                0          0
   Keepalives:             0          0
   Route Refresh:          0          0
   Total:                  0          0
 Default minimum time between advertisement runs is 0 seconds

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

                                  Outbound    Inbound
 Local Policy Denied Prefixes:    --------    -------
   Total:                                0          0
 Number of NLRIs in the update sent: max 0, min 0

 Connections established 0; dropped 0
 Last reset never
 No active TCP connection
```

PRACTICAL 4

AIM: Secure the Management Plane

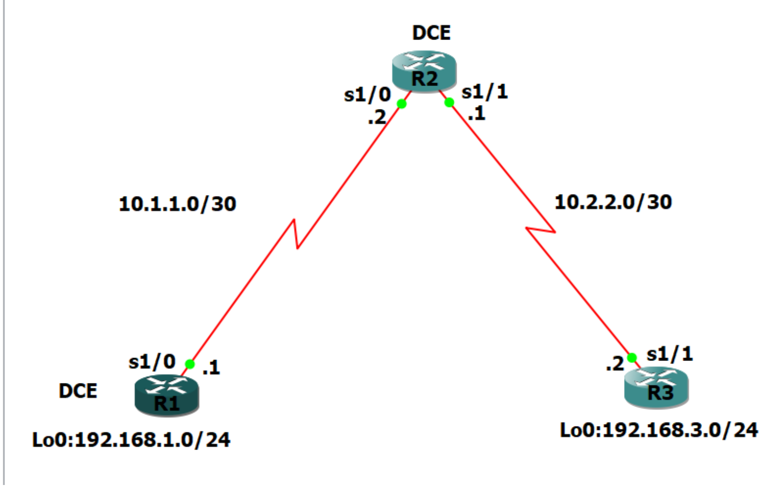
Why to secure the management plane?

The management plane of any infrastructure device should be protected as much as possible. Controlling access to routers and enabling reporting on routers are critical to network security and should be part of a comprehensive security policy.

Objectives:

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

Topology:



Step 1: Configure loopbacks and assign addresses.

R1 Console

interface Loopback 0
ip address 192.168.1.1 255.255.255.0
exit

R1 Console

conf t
interface Serial1/0
ip address 10.1.1.1 255.255.255.252
clock rate 128000
no shutdown
exit

R2 Console

interface Serial1/0
ip address 10.1.1.2 255.255.255.252
no shutdown
exit

R2 Console

conf t
interface Serial1/1
ip address 10.2.2.1 255.255.255.252
clock rate 128000
no shutdown
exit

R3 Console

interface Loopback0
ip address 192.168.3.1 255.255.255.0
exit

R3 Console

interface Serial1/1
ip address 10.2.2.2 255.255.255.252
no shutdown
exit

<u>Step 2: Configure static routes.</u>

R1 Console

ip route 0.0.0.0 0.0.0.0 10.1.1.2

R1 Console

R1#tclsh

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
+>(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 secon
ds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4
 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 = 64/71
/88 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 = 28/38
/48 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 = 28/40
/56 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.2.2.2, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.1, timeout is 2 secon
ds:
UUUUU
Success rate is 0 percent (0/5)
R1(tcl)#
```

R2 Console

ip route 192.168.1.0 255.255.255.0 10.1.1.1
ip route 192.168.3.0 255.255.255.0 10.2.2.2

```
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
```

R3 Console

ip route 0.0.0.0 0.0.0.0 10.2.2.1

<u>Step 3: Secure management access.</u>

R1 Console

security passwords min-length 10
enable secret class12345
line console 0

password ciscoconpass
exec-timeout 5 0
login
logging synchronous
exit

line vty 0 4
password ciscovtypass
exec-timeout 5 0
login
exit

line aux 0
no exec
end

service password-encryption
banner motd $Unauthorized access strictly prohibited!$
exit

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#service password-encryption
R1(config)#banner motd $Unauthorized access strickly prohibited!
$
R1(config)#exit
R1#
*May 14 12:47:10.547: %SYS-5-CONFIG_I: Configured from console b
y console
R1#
```

R3 Console

security passwords min-length 10
enable secret class12345
line console 0
password ciscoconpass
exec-timeout 5 0
login
logging synchronous
exit

line vty 0 4
password ciscovtypass
exec-timeout 5 0
login
exit

line aux 0
no exec
end

service password-encryption
banner motd $Unauthorized access strictly prohibited!$
exit

```
R3(config-line)#logging synchronous
R3(config-line)#exit
R3(config)#
R3(config)#line vty 0 4
R3(config-line)#password ciscovtypass
R3(config-line)#exec-timeout 5 0
R3(config-line)#login
R3(config-line)#exit
R3(config)#
R3(config)#line aux 0
R3(config-line)#no exec
R3(config-line)#end
R3#
*May 14 13:00:35.807: %SYS-5-CONFIG_I: Configured from console by
 console
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#service password-encryption
R3(config)#banner motd $Unauthorized-access strictly prohibited!$
R3(config)#exit
R3#
*May 14 13:02:55.295: %SYS-5-CONFIG_I: Configured from console by
 console
R3#
```

Step 4: Configure enhanced username password security.

R1 Console

username JR-ADMIN secret class12345
username ADMIN secret class54321
line console 0
login local
exit

line vty 0 4
login local
end

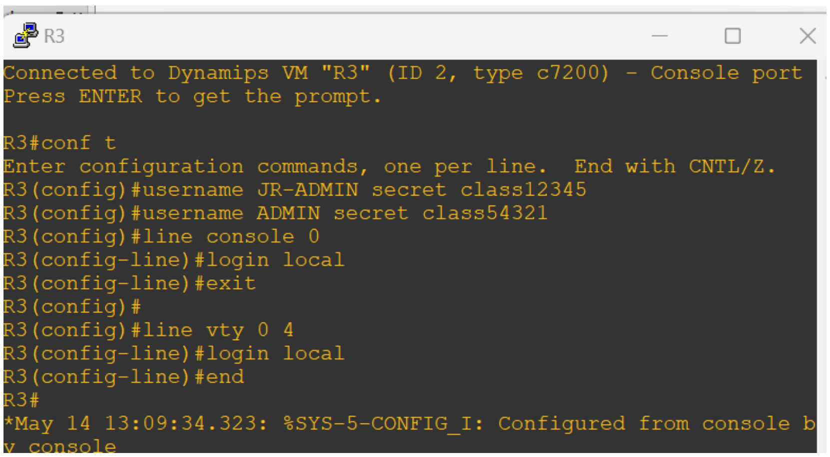
```
Connected to Dynamips VM "R1" (ID 0, type c7200) - Console port
Press ENTER to get the prompt.

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)#line console 0
R1(config-line)#login local
R1(config-line)#exit
R1(config)#
R1(config)#line vty 0 4
R1(config-line)#login local
R1(config-line)#end
R1#
*May 14 13:06:22.339: %SYS-5-CONFIG_I: Configured from console by c
onsole
R1#
```

R3 Console

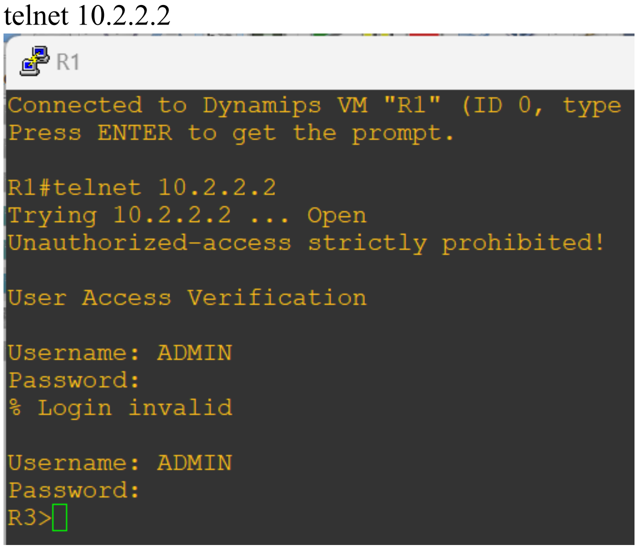
username JR-ADMIN secret class12345
username ADMIN secret class54321
line console 0
login local
exit

line vty 0 4
login local
end



R1 Console

telnet 10.2.2.2



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

R1 Console

aaa new-model

radius server RADIUS-1
address ipv4 192.168.1.101
key RADIUS-1-pa55w0rd
exit

radius server RADIUS-2
address ipv4 192.168.1.102
key RADIUS-2-pa55w0rd
exit

aaa group server radius RADIUS-GROUP
server name RADIUS-1
server name RADIUS-2
exit

aaa authentication login TELNET-LOGIN group RADIUS-GROUP local-case
line vty 0 4
login authentication TELNET-LOGIN
exit

R3 Console

aaa new-model
radius server RADIUS-1
address ipv4 192.168.1.101
key RADIUS-1-pa55w0rd
exit

radius server RADIUS-2
address ipv4 192.168.1.102
key RADIUS-2-pa55w0rd
exit

aaa group server radius RADIUS-GROUP
server name RADIUS-1
server name RADIUS-2
exit

aaa authentication login TELNET-LOGIN group RADIUS-GROUP local-case
line vty 0 4
login authentication TELNET-LOGIN
exit

R1 Console

telnet 10.2.2.2

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

User Access Verification

Username: ADMIN
Password:
R3>
```

Step 6: Enabling secure remote management using SSH.

R1 Console

ip domain-name ccnasecurity.com
crypto key generate rsa general-keys modulus 1024
ip ssh version 2
line vty 0 4
transport input ssh
end

R3 Console

ip domain-name ccnasecurity.com
crypto key generate rsa general-keys modulus 1024
ip ssh version 2
line vty 0 4
transport input ssh
end

R1 Console

ssh –l ADMIN 10.2.2.2

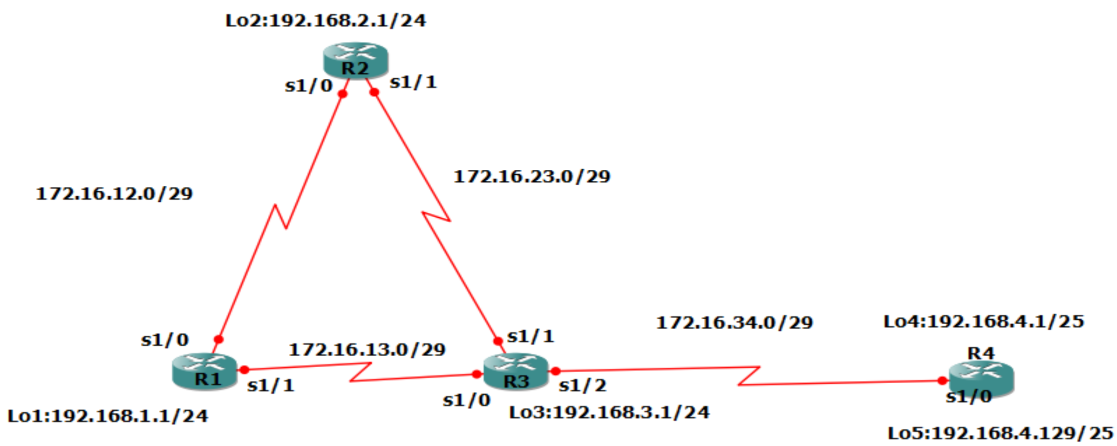
PRACTICAL 5

AIM: Configure and Verify Path Control Using PBR.

Objectives:

- Configure and verify policy-based routing.
- Select the required tools and commands to configure policy-based routing operations.
- Verify the configuration and operation by using the proper show and debug commands.

Topology:



<u>Step 1: Configure loopbacks and assign addresses.</u>

R1 Console

enable

conf t

hostname R1

interface Lo1

ip address 192.168.1.1 255.255.255.0

exit

interface s1/0

ip address 172.16.12.1 255.255.255.248

no shutdown

exit

interface s1/1

ip address 172.16.13.1 255.255.255.248

no shutdown

exit

router eigrp 100

network 192.168.1.0

network 172.16.12.0

network 172.16.13.0

no auto-summary

exit

R1#sh ip eigrp neighbors

R1#sh ip route

```
R1
R1#sh ip eigrp neighbors
IP-EIGRP neighbors for process 100
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
1   172.16.13.3             Se1/1             11 00:23:17   33   200  0  33
0   172.16.12.2             Se1/0             11 00:58:47   46   276  0  27
R1#
R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/29 is subnetted, 4 subnets
D       172.16.34.0 [90/2681856] via 172.16.13.3, 00:18:00, Serial1/1
D       172.16.23.0 [90/2681856] via 172.16.13.3, 00:23:25, Serial1/1
                    [90/2681856] via 172.16.12.2, 00:23:25, Serial1/0
C       172.16.12.0 is directly connected, Serial1/0
C       172.16.13.0 is directly connected, Serial1/1
     192.168.4.0/25 is subnetted, 2 subnets
D       192.168.4.0 [90/2809856] via 172.16.13.3, 00:16:48, Serial1/1
D       192.168.4.128 [90/2809856] via 172.16.13.3, 00:16:48, Serial1/1
C    192.168.1.0/24 is directly connected, Loopback1
D    192.168.2.0/24 [90/2297856] via 172.16.12.2, 00:23:25, Serial1/0
D    192.168.3.0/24 [90/2297856] via 172.16.13.3, 00:23:25, Serial1/1
R1#
```

R2 Console

Router>enable

Router#conf t

Router(config)#hostname R2

R2(config)#interface Lo2

R2(config-if)#ip address 192.168.2.1 255.255.255.0

R2(config-if)#exit

R2(config)#interface s1/0

R2(config-if)#ip address 172.16.12.2 255.255.255.248

R2(config-if)#no shutdown

R2(config-if)#exit

R2(config)#interface s1/1

R2(config-if)#ip address 172.16.23.2 255.255.255.248

R2(config-if)#no shutdown

R2(config-if)#exit

R2(config)#router eigrp 100

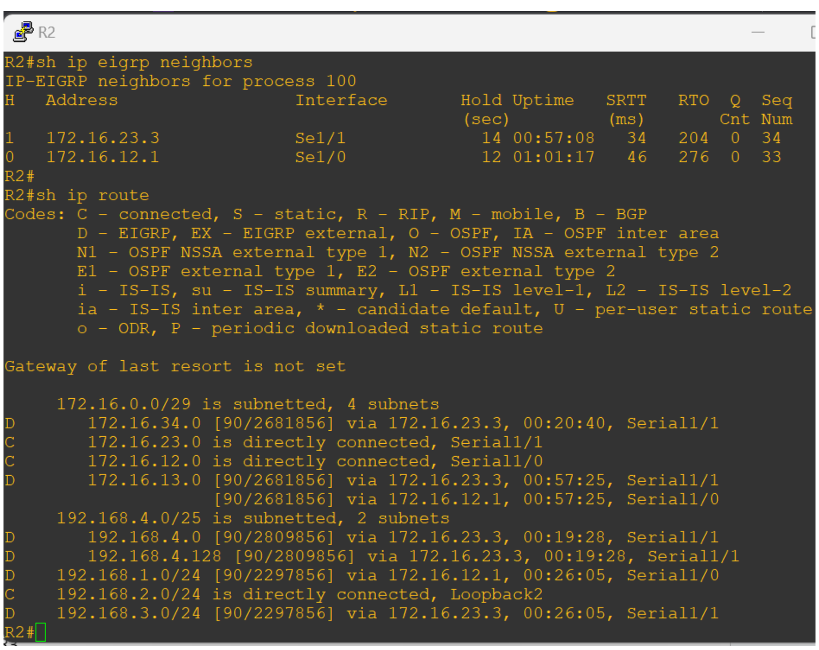
R2(config-router)#network 192.168.2.0

R2(config-router)#network 172.16.12.0

R2(config-router)#network 172.16.23.0

R2(config-router)#no auto-summary

R2#sh ip eigrp neighbors



```
R2#sh ip eigrp neighbors
IP-EIGRP neighbors for process 100
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
1   172.16.23.3             Se1/1             14 00:57:08   34   204  0  34
0   172.16.12.1             Se1/0             12 01:01:17   46   276  0  33
R2#
R2#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

     172.16.0.0/29 is subnetted, 4 subnets
D       172.16.34.0 [90/2681856] via 172.16.23.3, 00:20:40, Serial1/1
C       172.16.23.0 is directly connected, Serial1/1
C       172.16.12.0 is directly connected, Serial1/0
D       172.16.13.0 [90/2681856] via 172.16.23.3, 00:57:25, Serial1/1
                    [90/2681856] via 172.16.12.1, 00:57:25, Serial1/0
     192.168.4.0/25 is subnetted, 2 subnets
D       192.168.4.0 [90/2809856] via 172.16.23.3, 00:19:28, Serial1/1
D       192.168.4.128 [90/2809856] via 172.16.23.3, 00:19:28, Serial1/1
D    192.168.1.0/24 [90/2297856] via 172.16.12.1, 00:26:05, Serial1/0
C    192.168.2.0/24 is directly connected, Loopback2
D    192.168.3.0/24 [90/2297856] via 172.16.23.3, 00:26:05, Serial1/1
R2#
```

R3 Console

Router>enable

```
Router#conf t
Router(config)#hostname R3
R3(config)#interface Lo3
R3(config-if)#ip address 192.168.3.1 255.255.255.0
R3(config-if)#exit
R3(config)#interface s1/0
R3(config-if)#ip address 172.16.13.3 255.255.255.248
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#interface s1/1
R3(config-if)#ip address 172.16.23.3 255.255.255.248
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#interface s1/2
R3(config-if)#ip address 172.16.34.3 255.255.255.248
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#router eigrp 100
R3(config-router)#network 192.168.3.0
R3(config-router)#network 172.16.13.0
R3(config-router)#network 172.16.23.0
R3(config-router)#network 172.16.34.0
R3(config-router)#no auto-summary
R3#sh ip eigrp neighbors
```

R3

```
Connected to Dynamips VM "R3" (ID 2, type c7200) - Console port
Press ENTER to get the prompt.

R3(config)#exit
R3#
*May 15 14:42:55.407: %SYS-5-CONFIG_I: Configured from console by console
R3#sh ip eigrp neighbors
IP-EIGRP neighbors for process 100
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
2   172.16.34.4             Se1/2             12 00:21:08   59   354  0  7
1   172.16.13.1             Se1/0             11 00:27:29   45   270  0  34
0   172.16.23.2             Se1/1             13 00:58:50   55   330  0  28
R3#
```

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)#route-map R3-to-R1 permit

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)#end

R3(config)#int s1/2

R3(config-if)#ip policy route-map R3-to-R1

R3(config-if)#exit

R3#sh route-map

R3

```
R3#conf t
Enter configuration commands, one per line.  E
R3(config)#int se1/2
R3(config-if)#ip policy route-map R3-to-R1
R3(config-if)#exit
R3(config)#sh route-map
            ^
% Invalid input detected at '^' marker.

R3(config)#exit
R3#sh route
*May 15 14:08:10.415: %SYS-5-CONFIG_I: Configu
R3#sh route sh route-map
               ^
% Invalid input detected at '^' marker.

R3#sh route-map
route-map R3-to-R1, permit, sequence 10
  Match clauses:
    ip address (access-lists): PBR-ACL
  Set clauses:
    ip next-hop 172.16.13.1
  Policy routing matches: 0 packets, 0 bytes
R3#
```

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

R4 Console

Router>enable

Router#conf t

Router(config)#hostname R4

R4(config)#interface lo4

R4(config-if)#ip address 192.168.4.1 255.255.255.128

R4(config-if)#exit

R4(config)#interface lo5

R4(config-if)#ip address 192.168.4.129 255.255.255.128

R4(config-if)#exit

R4(config)#interface s1/0

R4(config-if)#ip address 172.16.34.4 255.255.255.248

R4(config-if)#no shutdown

R4(config-if)#exit

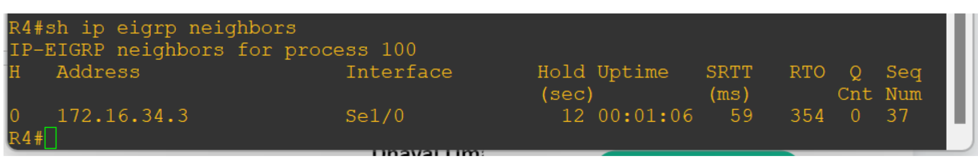
R4(config)#router eigrp 100

R4(config-router)#network 192.168.4.0

R4(config-router)#network 172.16.34.0

R4(config-router)#no auto-summary

R4#sh ip eigrp neighbors



```
R4#sh ip eigrp neighbors
IP-EIGRP neighbors for process 100
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q  Seq
                                            (sec)         (ms)       Cnt Num
0   172.16.34.3             Se1/0             12 00:01:06  59    354  0   37
R4#
```

Before Route Maps

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

  1 172.16.34.3 176 msec 164 msec 32 msec
  2 172.16.13.1 92 msec 156 msec 64 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

  1 172.16.34.3 20 msec 52 msec 24 msec
  2 172.16.13.1 72 msec 52 msec 64 msec
```

<u>After Route Maps</u>

R4#traceroute 192.168.1.1 source 192.168.4.1

R4#traceroute 192.168.1.1 source 192.168.4.129

```
R4#traceroute 192.168.1.1 source 192.168.4.1

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 40 msec 24 msec 36 msec
  2 172.16.13.1 60 msec 64 msec 68 msec
R4#
R4#traceroute 192.168.1.1 source 192.168.4.129

Type escape sequence to abort.
Tracing the route to 192.168.1.1

  1 172.16.34.3 20 msec 28 msec 32 msec
  2 172.16.13.1 64 msec 64 msec 56 msec
```

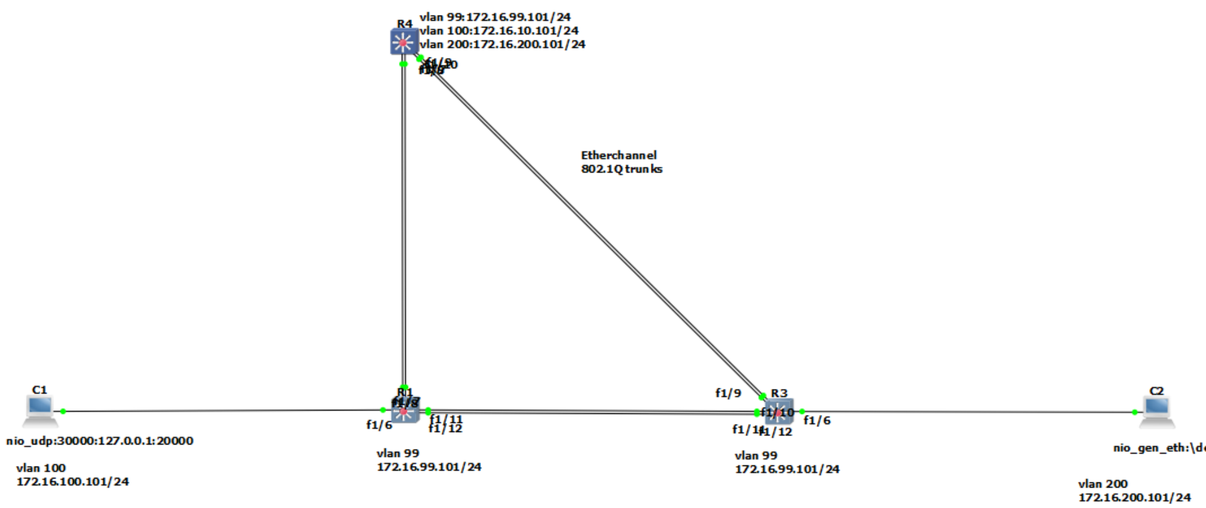
PRACTICAL 6

AIM: To Simulate IP Service Level Agreements and Remote SPAN in a Campus Environment

Objectives:

- Configure and verify policy-based routing.
- Select the required tools and commands to configure policy-based routing operations.
- Verify the configuration and operation by using the proper show and debug commands.

Topology:



<u>Step 1: Configure loopbacks and assign addresses.</u>

DLS1

DLS1# conf t

Enter configuration commands, one per line. End with CNTL/Z.

DLS1(config)# interface vlan 99

DLS1(config-if)# ip address 172.16.99.1 255.255.255.0

DLS1(config-if)# no shutdown

DLS1(config-if)# exit

DLS1(config)# enable secret class

DLS1(config)# line vty 0 15

DLS1(config-line)# no login

DLS1(config-line)# privilege level 15

```
Router>en
Router#conf t
Enter configuration commands, one per line.  End
Router(config)#hostname DLS1
DLS1(config)#int vlan 99
DLS1(config-if)#ip add 172.16.99.1 255.255.255.0
DLS1(config-if)#no shut
DLS1(config-if)#exit
DLS1(config)#enable secret class
DLS1(config)#line vty 0 15
DLS1(config-line)#no login
DLS1(config-line)#privilege level 15
DLS1(config-line)#
```

ALS1

Router>en

Router#conf t

Enter configuration commands, one per line. End with CNTL/Z.

Router(config)#hostname ALS1

ALS1(config)#interface vlan 99

ALS1(config-if)#ip add 172.16.99.1 255.255.255.0

ALS1(config-if)#no shut

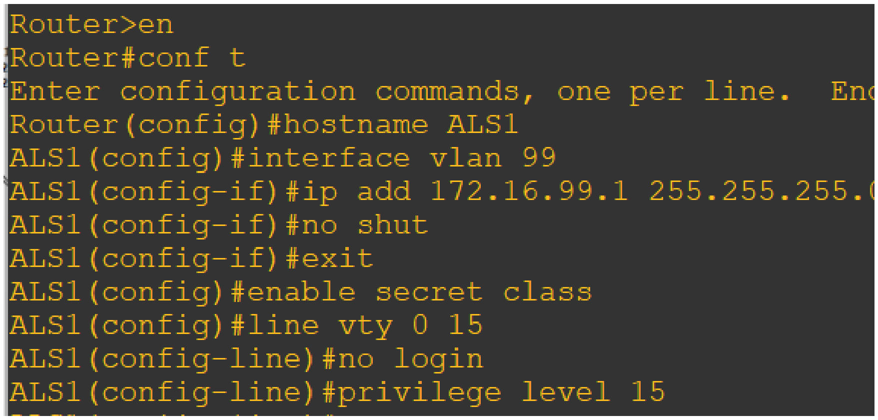
ALS1(config-if)#exit

ALS1(config)#enable secret class

ALS1(config)#line vty 0 15

ALS1(config-line)#no login

ALS1(config-line)#privilege level 15



```
Router>en
Router#conf t
Enter configuration commands, one per line.  End
Router(config)#hostname ALS1
ALS1(config)#interface vlan 99
ALS1(config-if)#ip add 172.16.99.1 255.255.255.0
ALS1(config-if)#no shut
ALS1(config-if)#exit
ALS1(config)#enable secret class
ALS1(config)#line vty 0 15
ALS1(config-line)#no login
ALS1(config-line)#privilege level 15
```

ALS2

ALS2# conf t

Enter configuration commands, one per line. End with CNTL/Z.

ALS2(config)# interface vlan 99

ALS2(config-if)# ip address 172.16.99.1 255.255.255.0

ALS2(config-if)# no shutdown

ALS2(config-if)# exit

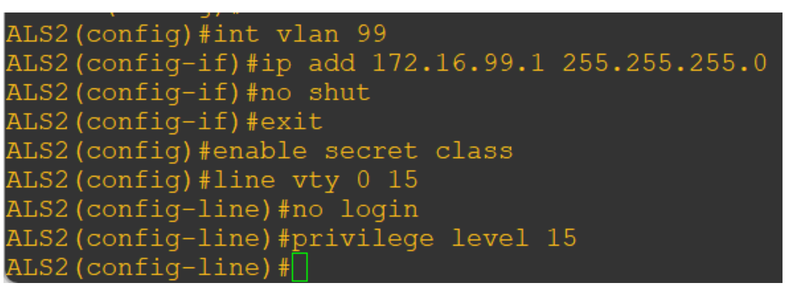
ALS2# conf t

ALS2(config)# enable secret class

ALS2(config)# line vty 0 15

ALS2(config-line)# no login

ALS2(config-line)# privilege level 15



```
ALS2(config)#int vlan 99
ALS2(config-if)#ip add 172.16.99.1 255.255.255.0
ALS2(config-if)#no shut
ALS2(config-if)#exit
ALS2(config)#enable secret class
ALS2(config)#line vty 0 15
ALS2(config-line)#no login
ALS2(config-line)#privilege level 15
ALS2(config-line)#
```

PRACTICAL 7

Aim : Inter-VLAN Routing.

Theory :

Inter-VLAN routing can be defined as a way to forward traffic between different VLAN by implementing a router in the network. As we learnt previously, VLANs logically segment the switch into different subnets, when a router is connected to the switch, an administrator can configure the router to forward the traffic between the various VLANs configured on the switch. The user nodes in the VLANs forwards traffic to the router which then forwards the traffic to the destination network regardless of the VLAN configured on the switch.

There are two ways in which Inter-VLAN routing can be accomplished.

- Traditional Inter-VLAN routing
- Router-on-a-stick

Traditional Inter-VLAN routing :

In this type of Inter-VLAN routing, a router is usually connected to the switch using multiple interfaces. One for each VLAN. The interfaces on the router are configured as the default gateways for the VLANs configured on the switch.

The ports that connect to the router from the switch are configured in access mode in their corresponding VLANs.

Introduction to Router-on-a-stick :

In the second type of Inter-VLAN routing which is Router-on-a-stick, the router is connected to the switch using a single interface. The switchport connecting to the router is configured as a trunk link. The single interface on the router is then configured with multiple IP addresses that correspond to the VLANs on the switch. This interface accepts traffic from all the VLANs and determines the destination network based on the source and destination IP in the packets. It then forwards the data to the switch with the correct VLAN information.

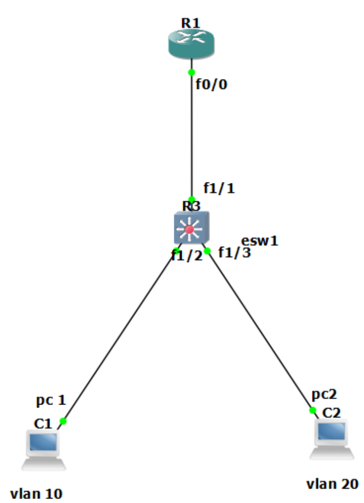
How inter VLAN works :

Inter VLAN communicate different VLANs via sub interfaces that we have create on router for each VLANs. When Host A in VLAN 10 needs to communicate with Host B in VLAN 10, it sends a packet addressed to that host. Switch A forwards the packet directly to Host B, without sending it to the router.

When Host A in VLAN 10 sends a packet to Host B in VLAN 20, Switch forwards the packet to the router, which receives the traffic on the VLAN 10 interface sub interface and forwards this to sub interface for VLAN 20.

To implement Inter-VLAN on gns3 I use the follow simple topology. In which R1 have two sub interfaces int f0/0.10 and int f0/0.20 for VLANs 10 and 20 respectively. And we use only two PC, one belong to VLAN 10 and other to 20.

NETWORK TOPLOGY :



<u>Code and Output</u> :

Configuration for Router R1:

R1#

R1#conf t

R1(config)#int f 0/0

R1(config-if)#no ip address

R1(config-if)#no shut

R1(config-if)#int f 0/0.1

R1(config-subif)#encapsulation dot1Q 10

R1(config-subif)#ip address 10.0.0.1 255.255.255.0

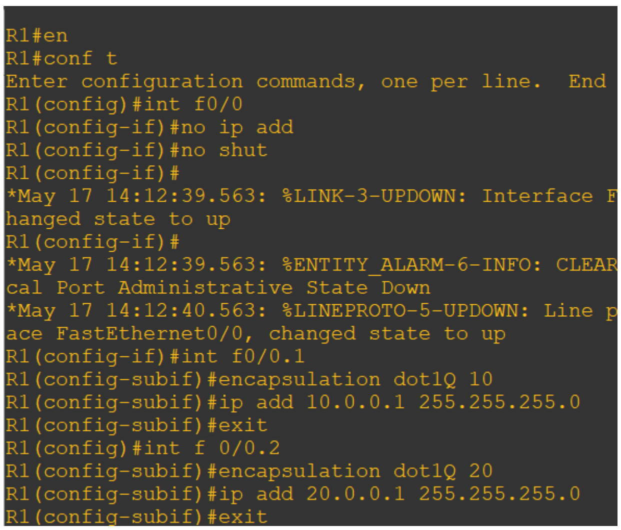
R1(config-subif)#exit

R1(config)#int f 0/0.2

R1(config-subif)#encapsulation dot1Q 20

R1(config-subif)#ip address 20.0.0.1 255.255.255.0

R1(config-subif)#exit



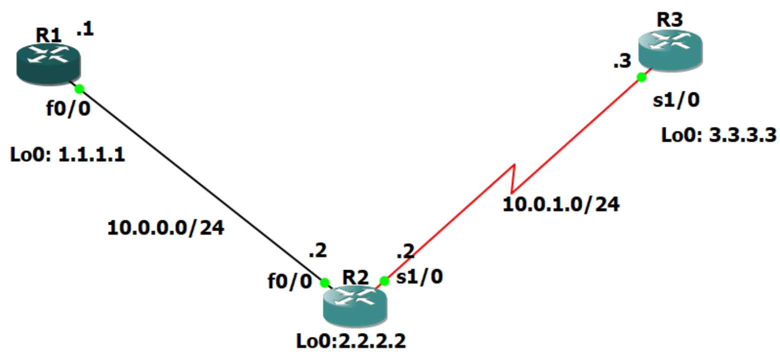
```
R1#en
R1#conf t
Enter configuration commands, one per line.  End
R1(config)#int f0/0
R1(config-if)#no ip add
R1(config-if)#no shut
R1(config-if)#
*May 17 14:12:39.563: %LINK-3-UPDOWN: Interface F
hanged state to up
R1(config-if)#
*May 17 14:12:39.563: %ENTITY_ALARM-6-INFO: CLEAR
cal Port Administrative State Down
*May 17 14:12:40.563: %LINEPROTO-5-UPDOWN: Line p
ace FastEthernet0/0, changed state to up
R1(config-if)#int f0/0.1
R1(config-subif)#encapsulation dot1Q 10
R1(config-subif)#ip add 10.0.0.1 255.255.255.0
R1(config-subif)#exit
R1(config)#int f 0/0.2
R1(config-subif)#encapsulation dot1Q 20
R1(config-subif)#ip add 20.0.0.1 255.255.255.0
R1(config-subif)#exit
```

PRACTICAL 8

Aim : Simulating MPLS environment

Theory :

NETWORK TOPLOGY :



Code and Output :

Step 1 – IP addressing of MPLS Core and OSPF

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

```
R1
Press ENTER to get the prompt.

R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#int lo0
R1(config-if)#ip add
*Jun 20 13:44:45.699: %LINEPROTO-5-UPDOWN: Line protocol on Interf
ace Loopback0, changed state to up
R1(config-if)#ip add 1.1.1.1 255.255.255.255
R1(config-if)#ip ospf 1 area 0
R1(config-if)#int f0/0
R1(config-if)#ip add 10.0.0.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#ip osp
*Jun 20 13:45:35.743: %LINK-3-UPDOWN: Interface FastEthernet0/0, c
hanged state to up
R1(config-if)#ip ospf
*Jun 20 13:45:35.743: %ENTITY_ALARM-6-INFO: CLEAR INFO Fa0/0 Physi
cal Port Administrative State Down
*Jun 20 13:45:36.743: %LINEPROTO-5-UPDOWN: Line protocol on Interf
ace FastEthernet0/0, changed state to up
R1(config-if)#ip ospf 1 area 0
R1(config-if)#
```

```
R2(config-if)#ip ospf
*Jun 20 14:06:29.299: %ENTITY_ALARM-6-INFO: CLEAR INFO Fa0/0 Physical
 Port Administrative State Down
R2(config-if)#ip ospf
*Jun 20 14:06:30.295: %LINEPROTO-5-UPDOWN: Line protocol on Interface
 FastEthernet0/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
R2(config-if)#int
*Jun 20 14:08:45.535: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastE
thernet0/0 from LOADING to FULL, Loading Done
R2(config-if)#int s1/0
R2(config-if)#ip add 10.0.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#ip osp
*Jun 20 14:13:56.775: %LINK-3-UPDOWN: Interface Serial1/0, changed st
ate to up
R2(config-if)#ip ospf a
*Jun 20 14:13:56.775: %ENTITY_ALARM-6-INFO: CLEAR INFO Se1/0 Physical
 Port Administrative State Down
R2(config-if)#ip ospf a
*Jun 20 14:13:57.779: %LINEPROTO-5-UPDOWN: Line protocol on Interface
 Serial1/0, changed state to up
R2(config-if)#ip ospf 1 area 0
R2(config-if)#
```

R3

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#int lo0
R3(config-if)#ip add
*Jun 20 14:16:05.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface
 Loopback0, changed state to up
R3(config-if)#ip add 3.3.3.3 255.255.255.255
R3(config-if)#ip ospf 1 area 0
R3(config-if)#int s1/0
R3(config-if)#ip add 10.0.1.3 255.255.255.0
R3(config-if)#no shut
R3(config-if)#ip ospf
*Jun 20 14:16:57.559: %LINK-3-UPDOWN: Interface Serial1/0, changed st
ate to up
R3(config-if)#ip ospf 1 area
*Jun 20 14:16:57.559: %ENTITY_ALARM-6-INFO: CLEAR INFO Se1/0 Physical
 Port Administrative State Down
*Jun 20 14:16:58.559: %LINEPROTO-5-UPDOWN: Line protocol on Interface
 Serial1/0, changed state to up
R3(config-if)#ip ospf 1 area 0
R3(config-if)#
*Jun 20 14:17:06.399: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on Seria
l1/0 from LOADING to FULL, Loading Done
R3(config-if)#
```

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

R1#ping 3.3.3.3 source lo0

R1

```
Connected to Dynamips VM "R1" (ID 0, type c7200) - Console port
Press ENTER to get the prompt.

R1#ping 3.3.3.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 3.3.3.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/74/88 ms
R1#
```

```
R3#ping 1.1.1.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 1.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/70/80 ms
R3#
```

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

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

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

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

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

```
R1
Connected to Dynamips VM "R1" (ID 0, type c7200) - Console port
Press ENTER to get the prompt.

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

```
R2
Connected to Dynamips VM "R2" (ID 1, type c7200) - Console port
Press ENTER to get the prompt.

R2(config-if)#router os
R2(config-if)#router ospf 1
R2(config-router)#mpls ldp autoconfig
R2(config-router)#
*Jun 20 14:33:24.719: %LDP-5-NBRCHG: LDP Neighbor 1.1.1.1:0 (1) is UP
```

```
R3
Connected to Dynamips VM "R3" (ID 2, type c7200) - Console port
Press ENTER to get the prompt.

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)#
*Jun 20 14:35:43.843: %LDP-5-NBRCHG: LDP Neighbor 2.2.2.2:0 (1) i
s UP
```

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

```
R2#sh mpls interface
Interface              IP            Tunnel   Operational
FastEthernet0/0        Yes (ldp)     No       Yes
Serial1/0              Yes (ldp)     No       Yes
R2#
```

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

```
R2#sh mpls ldp neigh
    Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
        TCP connection: 1.1.1.1.646 - 2.2.2.2.51127
        State: Oper; Msgs sent/rcvd: 15/15; Downstream
        Up time: 00:06:22
        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: 3.3.3.3.11398 - 2.2.2.2.646
        State: Oper; Msgs sent/rcvd: 12/12; Downstream
        Up time: 00:04:03
        LDP discovery sources:
          Serial1/0, Src IP addr: 10.0.1.3
        Addresses bound to peer LDP Ident:
          10.0.1.3        3.3.3.3
```

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

```
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] 64 msec 56 msec 68 msec
  2 10.0.1.3 64 msec 64 msec 72 msec
```

As you can see the trace to R2 used an MPLS Label in the path, as this is a very small MPLS core only one label was used as R3 was the final hop.

So to review we have now configured IP addresses on the MPLS core, enabled OSPF and full IP connectivity between all routers and finally enabled mpls on all the interfaces in the core and have established ldp neighbors between all routers.

The next step is to configure MP-BGP between R1 and R3

This is when you start to see the layer 3 vpn configuration come to life

Step 3 - MPLS BGP Configuration between R1 and R3

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

```
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 Lo0
R1(config-router)#no auto-summary
R1(config-router)#!
R1(config-router)#address-family vpnv4
R1(config-router-af)#neighbor 3.3.3.3 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 Lo0
R3(config-router)#no auto-summary
R3(config-router)#!
R3(config-router)#address-family vpnv4
R3(config-router-af)#neighbor 1.1.1.1
*Jun 20 14:51:08.019: %BGP-5-ADJCHANGE: neighbor 1.1.1.1 Up
```

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

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

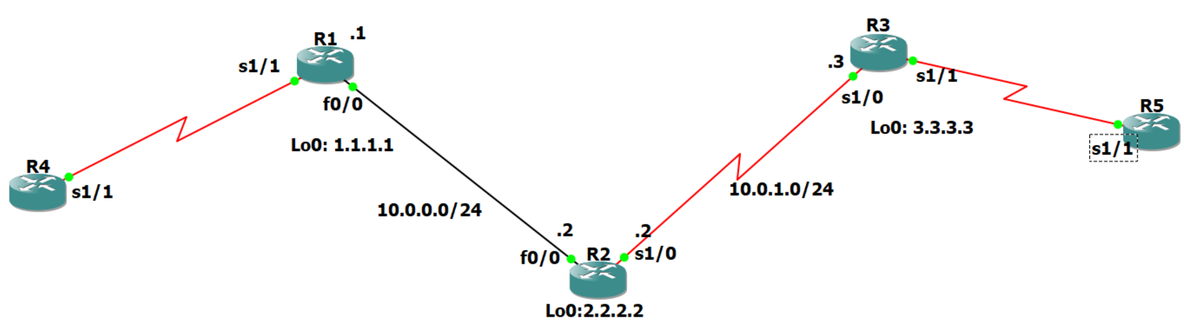
```
R1#sh bgp vpnv4 unicast all summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/
PfxRcd
3.3.3.3         4     1      13      13        1    0    0 00:07:16
 0
```

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

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
Enter configuration commands, one per line.  End with CN
R4(config)#int lo0
R4(config-if)#ip add
*Jun 20 15:28:54.971: %LINEPROTO-5-UPDOWN: Line protocol
ce Loopback0, changed state to up
R4(config-if)#ip add 4.4.4.4 255.255.255.255
R4(config-if)#ip ospf 2 area 2
R4(config-if)#int s1/1
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
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int s1/1
R1(config-if)#no shut
R1(config-if)#ip add
*Jun 20 15:32:23.115: %LINK-3-UPDOWN: Interface Serial1/1, change
d state to up
R1(config-if)#ip add
*Jun 20 15:32:23.115: %ENTITY_ALARM-6-INFO: CLEAR INFO Se1/1 Phys
ical Port Administrative State Down
R1(config-if)#ip add
*Jun 20 15:32:24.119: %LINEPROTO-5-UPDOWN: Line protocol on Inter
face Serial1/1, changed state to up
R1(config-if)#ip add 192.168.1.1 255.255.255.0
```

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

We are now going to start using VRF's

What is a VRF in networking?

Virtual routing and forwarding (VRF) is a technology included in IP (Internet Protocol) that allows multiple instances of a routing table to co-exist in a router and work together but not interfere with each other.. This increases functionality by allowing network paths to be segmented without using multiple devices.

As an example if R1 was a PE Provider Edge router of an ISP and it had two customers that were both addressed locally with the 192.168.1.0/24 address space it could accommodate both their routing tables in different VRFs - it distinguishes between the two of them using a Route Distinguisher

So back to the topology - we now need to create a VRF on R1

For this mpls I will be using VRF RED.

```
R1(config)#ip vrf RED
R1(config-vrf)#rd 4:4
R1(config-vrf)#route-target both 4:4
R1(config-vrf)#exit
R1(config)#int s1/1
R1(config-if)#ip vrf forwarding RED
% Interface Serial1/1 IP address 192.168.1.1 removed due to enabl
ing VRF RED
```

Now notice what happens when you do that - the IP address is removed which you will need to re-apply as follow.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int s1/1
R1(config-if)#ip add 192.168.1.1 255.255.255.0
R1(config-if)#
```

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

```
R1#sh run int s1/1
Building configuration...

Current configuration : 112 bytes
!
interface Serial1/1
 ip vrf forwarding RED
 ip address 192.168.1.1 255.255.255.0
 serial restart-delay 0
end
```

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

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

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

```
R1#sh ip route
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 [110/2] via 10.0.0.2, 01:26:46, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/66] via 10.0.0.2, 01:26:46, FastEthernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
O       10.0.1.0 [110/65] via 10.0.0.2, 01:26:46, FastEthernet0/0
R1#
```

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

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

NOTE: The VRF name is case sensitive!

```
R1#sh ip route vrf RED

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, Serial1/1
R1#
```

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

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int s1/1
R1(config-if)#ip ospf 2 area 2
R1(config-if)#
*Jun 20 15:47:32.423: %OSPF-5-ADJCHG: Process 2, Nbr 4.4.4.4 on Serial1/1 from LOADIN
G to FULL, Loading Done
R1(config-if)#
```

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

```
R1#sh ip route vrf RED

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/65] via 192.168.1.4, 00:00:53, Serial1/1
C    192.168.1.0/24 is directly connected, Serial1/1
R1#
```

We now need to repeat this process for R3 & R6

Router 6 will peer OSPF using process number 2 to a VRF configured on R3. It will use the local site addressing of 192.168.2.0/24.

```
R5#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R5(config)#int lo0
R5(config-if)#ip add
*Jun 20 15:59:29.159: %LINEPROTO-5-UPDOWN: Line protocol on Interface
Loopback0, changed state to up
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 s1/1
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 s1/1
R3(config-if)#no shut
R3(config-if)#ip add
*Jun 20 15:55:38.331: %LINK-3-UPDOWN: Interface Serial1/1, changed state to
 up
R3(config-if)#ip add 192
*Jun 20 15:55:38.331: %ENTITY_ALARM-6-INFO: CLEAR INFO Se1/1 Physical Port
Administrative State Down
R3(config-if)#ip add 192.16
*Jun 20 15:55:39.335: %LINEPROTO-5-UPDOWN: Line protocol on Interface Seria
l1/1, changed state to up
R3(config-if)#ip add 192.168.2.3 255.255.255.0
R3(config-if)#
```

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

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

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

```
R3(config)#int s1/1
R3(config-if)#ip vrf forwarding RED
% Interface Serial1/1 IP address 192.168.2.3 removed due to enabling VRF RE
D
```

re-apply IP Address it.

```
R3(config-if)#int s1/1
R3(config-if)#ip add 192.168.2.1 255.255.255.0
R3(config-if)#
```

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

```
R3#sh run int s1/1
Building configuration...

Current configuration : 112 bytes
!
interface Serial1/1
 ip vrf forwarding RED
 ip address 192.168.2.1 255.255.255.0
 serial restart-delay 0
end
```

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

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int s1/1
R3(config-if)#ip ospf 2 area 2
```

Check the routes in vrf RED.

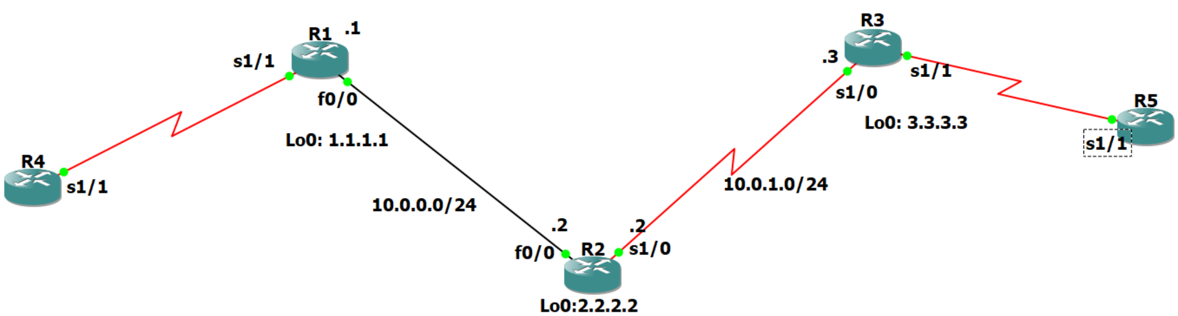
```
R3#sh ip route vrf RED

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

Gateway of last resort is not set

     6.0.0.0/32 is subnetted, 1 subnets
O       6.6.6.6 [110/65] via 192.168.2.6, 00:01:14, Serial1/1
C    192.168.2.0/24 is directly connected, Serial1/1
```

Ok so we have come a long way now let’s review the current situation. We now have this setup



R1,R2,R3 form the MPLS Core and are running OSPF with all loopbacks running a /32 address and all have full connectivity. R1 and R3 are peering with MP-BGP. LDP is enabled on all the internal interfaces. The external interfaces of the MPLS core have been placed into a VRF called RED and then a site router has been joined to that VRF on each side of the MPLS core - (These represent a small office)

The final step to get full connectivity across the MPLS core is to redistribute the routes in OSPF on R1 and R3 into MP-BGP and MP-BGP into OSPF, this is what we are going to do now.

We need to redistribute the OSPF routes from R4 into BGP in the VRF on R1, the OSPF routes from R6 into MP-BGP in the VRF on R3 and then the routes in MP-BGP in R1 and R3 back out to OSPF.

let's do some verifications

Check the routes on R4

```
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, Serial1/1
R4#
```

As expected we have the local interface and the loopback address.

When we are done we want to see 6.6.6.6 in there so we can ping across the MPLS

Check the routes on R1

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

Gateway of last resort is not set

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/2] via 10.0.0.2, 00:21:53, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/66] via 10.0.0.2, 00:21:53, 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 [110/65] via 10.0.0.2, 00:21:53, FastEthernet0/0
R1#
```

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

```
R1#sh ip route vrf RED

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

Gateway of last resort is not set

     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/65] via 192.168.1.4, 00:26:39, Serial1/1
C    192.168.1.0/24 is directly connected, Serial1/1
R1#
```

Here you can see Routing Table: RED is shown and the routes to R4 are now visible with 4.4.4.4 being in OSPF.

So we need to do the following;

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

Redistribute OSPF into MP-BGP on R1

```
R1#conf t
Enter configuration commands, one per line.
R1(config)#router bgp 1
R1(config-router)#add-family ipv4 vrf RED
                           ^
% Invalid input detected at '^' marker.

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

Redistribute OSPF into MP-BGP on R3

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

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

sh ip bgp vpnv4 vrf RED

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

   Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
*> 4.4.4.4/32       192.168.1.4             65         32768 ?
*>i6.6.6.6/32       3.3.3.3                 65    100      0 ?
*> 192.168.1.0      0.0.0.0                  0         32768 ?
*>i192.168.2.0      3.3.3.3                  0    100      0 ?
R1#
```

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

The same should be true on R3

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

   Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 4:4 (default for vrf RED)
*>i4.4.4.4/32       1.1.1.1                 65    100      0 ?
*> 6.6.6.6/32       192.168.2.6             65         32768 ?
*>i192.168.1.0      1.1.1.1                  0    100      0 ?
*> 192.168.2.0      0.0.0.0                  0         32768 ?
```

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

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

```
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
```

If all has worked we should be now able to ping 6.6.6.6 from R4

Before we do let's see what the routing table looks like on R4

```
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 [110/129] via 192.168.1.1, 00:02:32, Serial1/1
C    192.168.1.0/24 is directly connected, Serial1/1
O IA 192.168.2.0/24 [110/65] via 192.168.1.1, 00:02:32, Serial1/1
```

we have 6.6.6.6 in there

Also check the routing table on R5

```
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 [110/129] via 192.168.2.1, 00:03:04, Serial1/1
     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 [110/65] via 192.168.2.1, 00:03:04, Serial1/1
C    192.168.2.0/24 is directly connected, Serial1/1
R5#
```

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

```
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 = 132/143/168 ms
```

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

```
R4#trace 6.6.6.6

Type escape sequence to abort.
Tracing the route to 6.6.6.6

  1 192.168.1.1 44 msec 36 msec 36 msec
  2 10.0.0.2 132 msec 128 msec 168 msec
  3 192.168.2.1 96 msec 120 msec 92 msec
  4 192.168.2.6 140 msec 140 msec 128 msec
R4#
```