Software Defined Networking

मुंबई विद्यापीठ
University of Mumbai
Re-accredited with A++ Grade
(CGPA 3.65) by NAAC (3rd Cycle 2021)

University of Mumbai

DEPARTMENT OF COMPUTER SCIENCE

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Software Defined Networking

Submitted by

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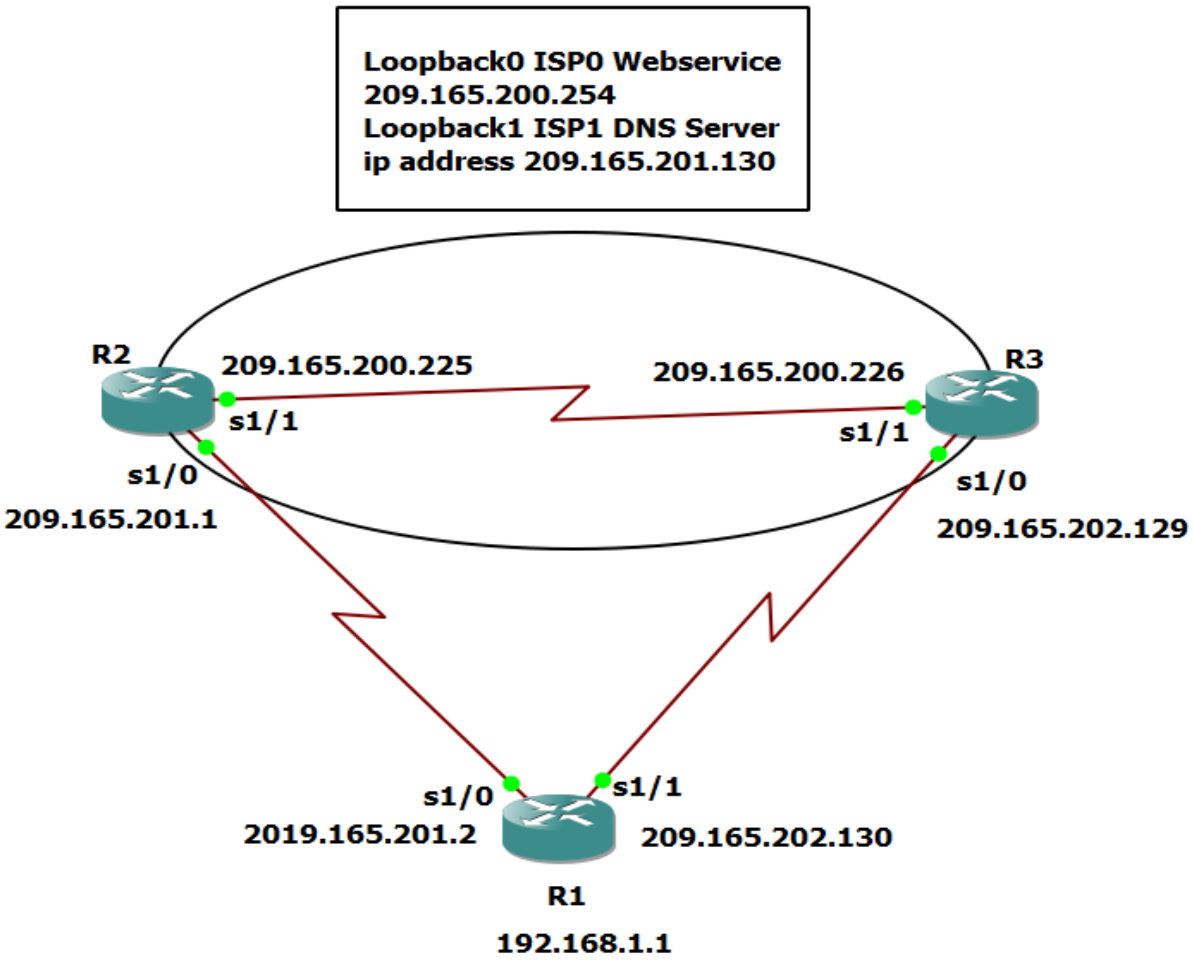
Practical no.1

Aim - Implement IP SLA (IP Service Level Agreement)

Topology:



Objectives

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

Background

You want to experiment with the Cisco IP Service Level Agreement (SLA) feature to study how it could be of value to your organization.

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

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

Note: This lab uses Cisco 1941 routers with Cisco IOS Release 15.2 with IP Base. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco IOS Release 15.2 or comparable) C7200
- Serial and Ethernet cables

Step 1: Configure loopbacks and assign addresses.

a. Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear the previous configurations. Using the addressing scheme in the diagram, create the loopback interfaces and apply IP addresses to them as well as the serial interfaces on R1, ISP1, and ISP2.

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

Router R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#interface loopback 0
R1(config-if)#
*Dec 26 11:42:42.635: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#description R1 LAN
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#interface serial 1/0
R1(config-if)#description R1 ->ISP1
R1(config-if)#ip address 209.165.201.2 255.255.255.255
Bad mask /32 for address 209.165.201.2
R1(config-if)#clock rate 128000
R1(config-if)#bandwidth 128
R1(config-if)#no shutdown
```

```
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

      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
R1#conf
*Dec 26 11:52:34.243: %SYS-5-CONFIG_I: Configured from console by console
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface serial 1/1
R1(config-if)#description R1 -> ISP2
R1(config-if)#ip address 209.165.202.130 255.255.255.252
R1(config-if)#bandwidth 128
R1(config-if)#no shutdown
```

Router ISP1 (R2):

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP1
ISP1(config)#interface loopback0
ISP1(config-if)#
*Dec 26 11:57:39.711: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
ISP1(config-if)#description simulation internet web service
ISP1(config-if)#ip address 209.165.200.254 255.255.255.255
ISP1(config-if)#interface loopback1
ISP1(config-if)#
*Dec 26 11:58:54.515: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
ISP1(config-if)#description ISP1 DNS Server
ISP1(config-if)#ip address 209.165.201.30 255.255.255.255
ISP1(config-if)#interface serial 1/0
ISP1(config-if)#description ISP1 -> R1
ISP1(config-if)#ip address 209
% Incomplete command.

ISP1(config-if)#ip address 209.165.201.1 255.255.255.252
ISP1(config-if)#bandwidth 128
ISP1(config-if)#no shutdown
ISP1(config-if)#
*Dec 26 12:01:55.823: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
ISP1(config-if)#
*Dec 26 12:01:56.831: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
ISP1(config-if)#interface serial 1/1
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):

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname ISP2
ISP2(config)#interface Loopback0
ISP2(config-if)#
*Dec 26 12:06:40.351: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
ISP2(config-if)#description Simulated Internet Web Service
ISP2(config-if)#ip address 209.165.200.254 255.255.255.255
ISP2(config-if)#interface loopback1
ISP2(config-if)#desc
*Dec 26 12:08:20.487: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
ISP2(config-if)#description ISP2 DNS Server
ISP2(config-if)#ip address 209.165.202.158 255.255.255.255
ISP2(config-if)#interface serial 1/0
ISP2(config-if)#description ISP2 -> R1
ISP2(config-if)#ip address 209.165.202.192 255.255.255.252
Bad mask /30 for address 209.165.202.192
ISP2(config-if)#ip address 209.165.202.129 255.255.255.252
ISP2(config-if)#clock rate 128000
ISP2(config-if)#bandwidth 128
ISP2(config-if)#no shutdown
```

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

```
R1#show interface description | include up
Se1/0                          up             up       R1 ->ISP1
Se1/1                          up             up       R1 -> ISP2
Lo0                            up             up       R1 LAN
```

All three interfaces should be active. Troubleshoot if necessary.

Step 2: Configure static routing.

The current routing policy in the topology is as follows:

- Router R1 establishes connectivity to the Internet through ISP1 using a default static route.
- ISP1 and ISP2 have dynamic routing enabled between them, advertising their respective public address pools.
- ISP1 and ISP2 both have static routes back to the ISP LAN.

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

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

Router R1:

```
R1#config 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)#exit
R1#
```

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)#exit
```

Router ISP2 (R3):

```
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)#exit
```

EIGRP neighbour relationship messages on ISP1 and ISP2 should be generated. Troubleshoot if necessary.

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

   Before implementing the Cisco IOS SLA feature, you must verify reachability to the Internet servers. From router R1, ping the web server, ISP1 DNS server, and ISP2 DNS server to verify connectivity. You can copy the following TCL script and paste it into R1.

```
R1(tcl)#foreach address {
+>(tcl)#209.165.200.254
+>(tcl)#209.165.201.30
+>(tcl)#209.165.200.254
+>(tcl)#} {
+>(tcl)#ping $address source 192.168.1.1
+>(tcl)#}
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.254, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 24/32/40 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.201.30, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/28/40 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.254, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/27/32 ms
R1(tcl)#
```

All pings should be successful. Troubleshoot if necessary.

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.

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

Through which ISP is traffic flowing?

Step 3: Configure IP SLA probes.

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

In this scenario, you will configure ICMP echo probes.

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

```
R1(config)#exit
R1#
*Mar  1 00:07:11.523: %SYS-5-CONFIG_I: Configured from console by console
R1#config
Configuring from terminal, memory, or network [terminal]?
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
IP SLAs, Infrastructure Engine-II.
Entry number: 11
Owner:
Tag:
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.201.30/0.0.0.0
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Vrf Name:
Request size (ARR data portion): 28
Verify data: No
Schedule:
   Operation frequency (seconds): 10  (not considered if randomly scheduled)
   Next Scheduled Start Time: Start Time already passed
   Group Scheduled : FALSE
   Randomly Scheduled : FALSE
   Life (seconds): Forever
   Entry Ageout (seconds): never
   Recurring (Starting Everyday): FALSE
   Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Distribution Statistics:
   Number of statistic hours kept: 2
   Number of statistic distribution buckets kept: 1
   Statistic distribution interval (milliseconds): 4294967295
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
Enhanced History:
```

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

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

```
R1#show ip sla statistics

Round Trip Time (RTT) for       Index 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:09:31.927 UTC Fri Mar 1 2002
Latest operation return code: Timeout
Number of successes: 0
Number of failures: 9
Operation time to live: Forever
```

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

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

```
R1#config 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
```

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

```
R1#show ip sla configuration 22
IP SLAs, Infrastructure Engine-II.
Entry number: 22
Owner:
Tag:
Type of operation to perform: icmp-echo
Target address/Source address: 209.165.202.158/0.0.0.0
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Vrf Name:
Request size (ARR data portion): 28
Verify data: No
Schedule:
   Operation frequency (seconds): 10  (not considered if randomly scheduled)
   Next Scheduled Start Time: Start Time already passed
   Group Scheduled : FALSE
   Randomly Scheduled : FALSE
   Life (seconds): Forever
   Entry Ageout (seconds): never
   Recurring (Starting Everyday): FALSE
   Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 5000
Distribution Statistics:
   Number of statistic hours kept: 2
   Number of statistic distribution buckets kept: 1
   Statistic distribution interval (milliseconds): 4294967295
History Statistics:
   Number of history Lives kept: 0
   Number of history Buckets kept: 15
   History Filter Type: None
Enhanced History:
```

```
R1#show ip sla statistics 22

Round Trip Time (RTT) for       Index 22
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: *00:17:10.775 UTC Fri Mar 1 2002
Latest operation return code: Timeout
Number of successes: 0
Number of failures: 8
Operation time to live: Forever
```

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

Step 4: Configure tracking options.

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

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

```
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
```

b. Verify the routing table.

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

S*    0.0.0.0/0 [5/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial1/0
L        209.165.201.2/32 is directly connected, Serial1/0
```

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

c. From global configuration mode on R1, use the track 1 IP sla 11 reachability command to enter the config-track sub-configuration mode.

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

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

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

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

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

f. 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#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)#
*Aug 15 20:42:32.715: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 20:42:32.719: RT: closer admin distance for 0.0.0.0, flushing 1 routes
*Aug 15 20:42:32.723: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [2/0]
*Aug 15 20:42:32.727: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 20:42:32.731: RT: rib update return code: 17
*Aug 15 20:42:32.731: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 20:42:32.735: RT: rib update return code: 17
R1(config)#
```

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

g. 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)#
```

h. Verify the routing table again.

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

S*    0.0.0.0/0 [2/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial1/0
L        209.165.201.2/32 is directly connected, Serial1/0
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)#int lo1
ISP1(config-if)#shutdwon
                ^
% Invalid input detected at '^' marker.

ISP1(config-if)#shutdown
ISP1(config-if)#
*Aug 15 20:49:39.571: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to down
*Aug 15 20:49:39.575: %LINK-5-CHANGED: Interface Loopback1, changed state to administratively down
ISP1(config-if)#
```

b. On R1, observe the debug output being generated. Recall that R1 will wait up to 10 seconds before initiating action therefore several seconds will elapse before the output is generated.

```
R1#
*Aug 15 20:49:47.787: %TRACKING-5-STATE: 1 ip sla 11 reachability Up->Down
R1#
*Aug 15 20:49:47.791: RT: del 0.0.0.0 via 209.165.201.1, static metric [2/0]
*Aug 15 20:49:47.791: RT: delete network route to 0.0.0.0/0
*Aug 15 20:49:47.795: RT: default path has been cleared
*Aug 15 20:49:47.795: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 20:49:47.799: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [5/0]
*Aug 15 20:49:47.803: RT: default path is now 0.0.0.0 via 209.165.201.1
*Aug 15 20:49:47.827: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578
```

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

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

c. On R1, verify the routing table.

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

S*    0.0.0.0/0 [5/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial1/0
L        209.165.201.2/32 is directly connected, Serial1/0
```

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

d. Verify the IP SLA statistics.

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

IPSLA operation id: 11
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: 21:11:57 UTC Fri Aug 15 2025
Latest operation return code: Timeout
Number of successes: 150
Number of failures: 138
Operation time to live: Forever



IPSLA operation id: 22
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: 21:11:52 UTC Fri Aug 15 2025
Latest operation return code: Timeout
Number of successes: 0
Number of failures: 257
Operation time to live: Forever
```

e. On R1, initiate a trace to the web server from the internal LAN IP address.

```
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 36 msec 24 msec 28 msec
R1#
```

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

f. On ISP1, re-enable the DNS address by issuing the no shutdown command on the loopback 1 interface to examine the routing behaviour when connectivity to the ISP1 DNS is restored.

```
ISP1(config-if)#no shutdown
ISP1(config-if)#
*Aug 15 21:13:31.427: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
ISP1(config-if)#
*Aug 15 21:13:31.431: %LINK-3-UPDOWN: Interface Loopback1, changed state to up
ISP1(config-if)#
```

Notice the output of the debug IP routing command on R1.

```
R1#
*Aug 15 21:13:37.807: Track: 1 Up change delayed for 5 secs
R1#
*Aug 15 21:13:42.807: Track: 1 Up change delay expired
*Aug 15 21:13:42.807: Track: 1 Change #3 ip sla 11, reachability Down->Up
*Aug 15 21:13:42.807: %TRACKING-5-STATE: 1 ip sla 11 reachability Down->Up
R1#
*Aug 15 21:13:42.807: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 21:13:42.807: RT: closer admin distance for 0.0.0.0, flushing 1 routes
*Aug 15 21:13:42.807: RT: add 0.0.0.0/0 via 209.165.201.1, static metric [2/0]
*Aug 15 21:13:42.807: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 21:13:42.807: RT: rib update return code: 17
*Aug 15 21:13:42.807: RT: updating static 0.0.0.0/0 (0x0):
    via 209.165.201.1   1048578

*Aug 15 21:13:42.807: RT: rib update return code: 17
```

g. Again examine the IP SLA statistics.

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

IPSLA operation id: 11
        Latest RTT: 20 milliseconds
Latest operation start time: 21:15:27 UTC Fri Aug 15 2025
Latest operation return code: OK
Number of successes: 162
Number of failures: 147
Operation time to live: Forever



IPSLA operation id: 22
        Latest RTT: NoConnection/Busy/Timeout
Latest operation start time: 21:15:22 UTC Fri Aug 15 2025
Latest operation return code: Timeout
Number of successes: 0
Number of failures: 278
Operation time to live: Forever
```

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

h. Verify the routing table.

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

S*    0.0.0.0/0 [2/0] via 209.165.201.1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
      209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.201.0/30 is directly connected, Serial1/0
L        209.165.201.2/32 is directly connected, Serial1/0
R1#
```

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

There are many possibilities available with object tracking and Cisco IOS IP SLAs. As shown in this lab, a probe can be based on reachability, changing routing operations, and path control based on the ability to reach an object. However, Cisco IOS IP SLAs also allow paths to be changed based on network conditions such as delay, load, and other factors.

Before deploying a Cisco IOS IP SLA solution, the impact of the additional probe traffic being generated should be considered, including how that traffic affects bandwidth utilization, and congestion levels. Tuning the configuration (for example, with the delay and frequency commands) is critical to mitigate possible issues related to excessive transitions and route changes in the presence of flapping tracked objects.

The benefits of running IP SLAs should be carefully evaluated. The IP SLA is an additional task that must be performed by the router's CPU. A large number of intensive SLAs could be a significant burden on the CPU, possibly interfering with other router functions and having detrimental impact on the overall router performance. The CPU load should be monitored after the SLAs are deployed to verify that they do not cause excessive utilization of the router CPU.

Practical no.2

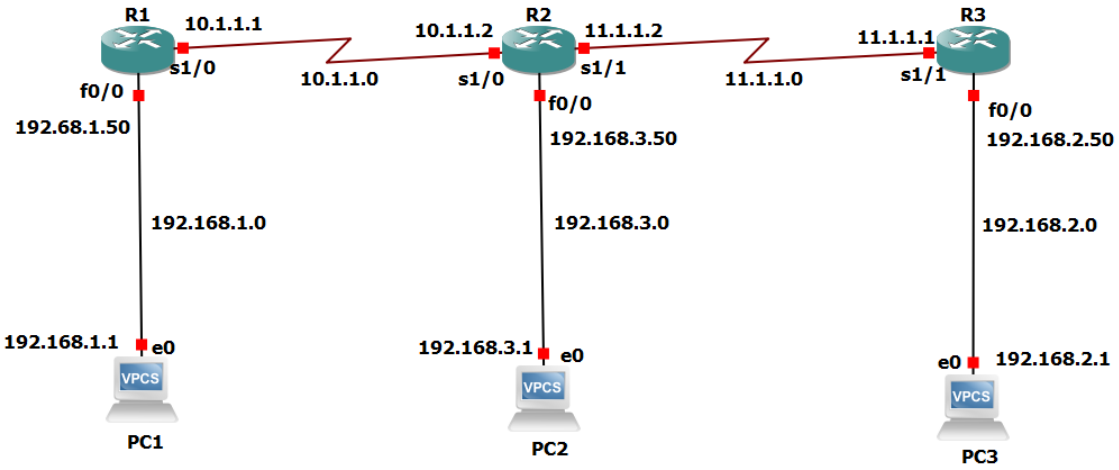
AIM: Implement IPv4 ACLs

1.Standard ACL

2.Extended ACL

Step 1: Build the network as follow

Topology:



Step 2: Explain what ACL is and how we apply it in the current system.

- Access-list (ACL) is a set of rules defined for controlling network traffic and reducing network attacks. ACLs are used to filter traffic based on the set of rules defined for the incoming or outgoing of the network.

- In a way, an ACL is like a guest list at an exclusive club.

- ACL is also called as packet filtering firewall

- There are two main different types of Access-list namely:
  1. **Standard Access-list** – These are the Access-list that are made using the source IP address only. These ACLs permit or deny the entire protocol suite. They don't distinguish between the IP traffic such as TCP, UDP, HTTPS, etc. These use range 1-99 or 1300-1999.
     Here we only give source IP Address. s

  2. **Extended Access-list** – These are the ACL that uses source IP, Destination IP, source port, and Destination port. These types of ACL, we can also mention which IP traffic should be allowed or denied. These use range 100-199 and 2000-2699. Here we give both the source and destination IP Address.

- To enable ACL on our network we use Routing protocols because via connection is not reachable so we will be applying a RIP.
- After applying RIP all the Routers and PCs are able to communicate and ping each other.

Step 3: Configure IP to all the routers and PC's

R1:

```
R1#en
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface f0/0
R1(config-if)#ip address 192.168.1.50 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Dec 26 14:40:48.327: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Dec 26 14:40:49.327: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#interface serial 1/0
R1(config-if)#ip address 10.1.1.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
```

R2:

```
R2#en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#interface f0/0
R2(config-if)#ip address 192.168.3.50 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Dec 26 14:45:32.155: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Dec 26 14:45:33.155: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#interface serial1/0
R2(config-if)#ip address 10.1.1.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Dec 26 14:46:38.243: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R2(config)#
*Dec 26 14:46:39.251: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R2(config)#interface serial1/1
R2(config-if)#ip address 11.1.1.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
```

R3:

```
R3#en
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface f0/0
R3(config-if)#ip address 192.168.2.50 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#exit
R3(config)#inter
*Dec 26 14:49:12.519: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Dec 26 14:49:13.519: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config)#interface serial 1/1
R3(config-if)#ip address 11.1.1.1 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#exit
```

PC1:

```
PC1> ip 192.168.1.1 255.255.255.0 192.168.1.50
Checking for duplicate address...
PC1 : 192.168.1.1 255.255.255.0 gateway 192.168.1.50

PC1> show ip

NAME        : PC1[1]
IP/MASK     : 192.168.1.1/24
GATEWAY     : 192.168.1.50
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 10024
RHOST:PORT  : 127.0.0.1:10025
MTU:        : 1500
```

PC2:

```
PC2> ip 192.168.3.1 255.255.255.0 192.168.3.50
Checking for duplicate address...
PC1 : 192.168.3.1 255.255.255.0 gateway 192.168.3.50

PC2> show ip

NAME        : PC2[1]
IP/MASK     : 192.168.3.1/24
GATEWAY     : 192.168.3.50
DNS         :
MAC         : 00:50:79:66:68:01
LPORT       : 10026
RHOST:PORT  : 127.0.0.1:10027
MTU:        : 1500
```

PC3:

```
PC3> ip 192.168.2.1 255.255.255.0 192.168.2.50
Checking for duplicate address...
PC1 : 192.168.2.1 255.255.255.0 gateway 192.168.2.50

PC3> show ip

NAME        : PC3[1]
IP/MASK     : 192.168.2.1/24
GATEWAY     : 192.168.2.50
DNS         :
MAC         : 00:50:79:66:68:02
LPORT       : 10028
RHOST:PORT  : 127.0.0.1:10029
MTU:        : 1500
```

Step 4: After assigning the IP Address to all the router and PC try ping the neighbour PC or router. It should work successfully.

R1:

```
R1#ping 192.168.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 8/23/36 ms
R1#ping 10.1.1.2
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 = 24/36/64 ms
```

R2:

```
R2#ping 192.168.3.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 12/18/24 ms
R2#ping 11.1.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 11.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/31/36 ms
```

R3:

```
R3#ping 192.168.2.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 8/17/28 ms
R3#ping 11.1.1.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 11.1.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/25/28 ms
```

After that try ping to indirect connection. It won't be able to ping. Because we haven't configured any routing protocols for indirect connection to work. so we will now configure RIP on all the router

Step 5: Follow below to configure RIP in routers.

R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router rip
R1(config-router)#network 192.168.1.0
R1(config-router)#network 10.1.1.0
R1(config-router)#exit
R1(config)#do wr
Building configuration...
[OK]
```

R2:

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#router rip
R2(config-router)#network 10.1.1.0
R2(config-router)#network 11.1.1.0
R2(config-router)#network 192.168.3.0
R2(config-router)#exit
R2(config)#do wr
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router rip
R3(config-router)#network 11.1.1.0
R3(config-router)#network 192.168.2.0
R3(config-router)#exit
R3(config)#do wr
```

Once RIP is configured ping indirect connection. Now ping will work as we have applied RIP protocol.

Step 6: Now we will apply ACL.

As we have discussed there are 2 types of ACL. We will apply Standard ACL now.

R1:

```
R1(config)#access-list 10 deny host 192.168.2.1
R1(config)#exit
R1#
*Dec 26 15:08:47.363: %SYS-5-CONFIG_I: Configured from console by console
R1#show access-list
Standard IP access list 10
    10 deny   192.168.2.1
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#access-list 10 permit any
R1(config)#int s1/0
R1(config-if)#ip access-group 10 in
R1(config-if)#exit
R1(config)#do wr
Building configuration...
[OK]
```

Here the scenario we are going to use is that whatever data that is being sent by PC 3 should not be received by PC 1, so based on the features of a standard ACL, we know that it needs to be place near the destination.

The number of the standard ACL should be in the range of 1-99, in our case we have chosen 10.
So, by configuring the access list to ‘deny’, we deny all communication from PC 3 to PC 3.

Here we can observe that when PC 3 tries to send data to PC 1, its access is denied.

```
PC3> ping 192.168.1.1
*10.1.1.1 icmp_seq=1 ttl=253 time=77.346 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.1 icmp_seq=2 ttl=253 time=75.751 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.1 icmp_seq=3 ttl=253 time=75.293 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.1 icmp_seq=4 ttl=253 time=75.397 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.1 icmp_seq=5 ttl=253 time=76.614 ms (ICMP type:3, code:13, Communication administratively prohibited)
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#access-list 40 deny host 192.168.3.1
R3(config)#do sh access-list
Standard IP access list 40
    10 deny   192.168.3.1
R3(config)#access-list 40 permit any
R3(config)#int s1/1
R3(config-if)#ip access-group 40 in
R3(config-if)#exit
R3(config)#exit
R3#
```

Here R3 have block PC2. So PC3 won't be receiving data from PC2.

```
PC2> ping 192.168.2.1
*11.1.1.1 icmp_seq=1 ttl=254 time=45.729 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=2 ttl=254 time=45.545 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=3 ttl=254 time=45.840 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=4 ttl=254 time=46.011 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=5 ttl=254 time=46.484 ms (ICMP type:3, code:13, Communication administratively prohibited)
```

R2:

```
R2(config)#access-list 10 deny 192.168.1.1
R2(config)#exit
R2#
*Dec 26 15:16:41.587: %SYS-5-CONFIG_I: Configured from console by console
R2#show access-list
Standard IP access list 10
    10 deny   192.168.1.1
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#access-list 10 permit any
R2(config)#int s1/0
R2(config-if)#ip access-group 10 in
R2(config-if)#exit
```

Here R2 have block PC1. So if PC1 send data PC3 it will deny.

```
PC1> ping 192.168.3.1
*10.1.1.2 icmp_seq=1 ttl=254 time=45.368 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.2 icmp_seq=2 ttl=254 time=46.954 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.2 icmp_seq=3 ttl=254 time=46.743 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.2 icmp_seq=4 ttl=254 time=45.848 ms (ICMP type:3, code:13, Communication administratively prohibited)
*10.1.1.2 icmp_seq=5 ttl=254 time=45.456 ms (ICMP type:3, code:13, Communication administratively prohibited)
```

Step 7: We will now apply Extended ACL

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#access-list 121 deny icmp host 192.168.3.1 host 192.168.2.1
R3(config)#do sh access-list 121
Extended IP access list 121
    10 deny icmp host 192.168.3.1 host 192.168.2.1
R3(config)#access-list 121 permit icmp any any
R3(config)#do sh access-list 121
Extended IP access list 121
    10 deny icmp host 192.168.3.1 host 192.168.2.1
    20 permit icmp any any
R3(config)#int s1/1
R3(config-if)#ip access-group 121 out
R3(config-if)#do sh access-list 121
Extended IP access list 121
    10 deny icmp host 192.168.3.1 host 192.168.2.1
    20 permit icmp any any
R3(config-if)#exit
R3(config)#exit
```

We will apply ACL on R3. It will deny PC2 to send data to PC3.

Here we can observe that when PC 2 tries to send data to PC 3, its access is denied.

```
PC2> ping 192.168.2.1
*11.1.1.1 icmp_seq=1 ttl=254 time=45.595 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=2 ttl=254 time=45.566 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=3 ttl=254 time=45.705 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=4 ttl=254 time=45.698 ms (ICMP type:3, code:13, Communication administratively prohibited)
*11.1.1.1 icmp_seq=5 ttl=254 time=46.673 ms (ICMP type:3, code:13, Communication administratively prohibited)
```

But if any other device ping PC 3 it will permit it

```
R2#ping 192.168.2.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 40/230/760 ms
```

Here PC3 have accept R2 but deny PC2.

We can assume that we have successfully used an extended access list.

Practical no.3

Aim:

1.Implement a GRE Tunnel

2.Implement VTP

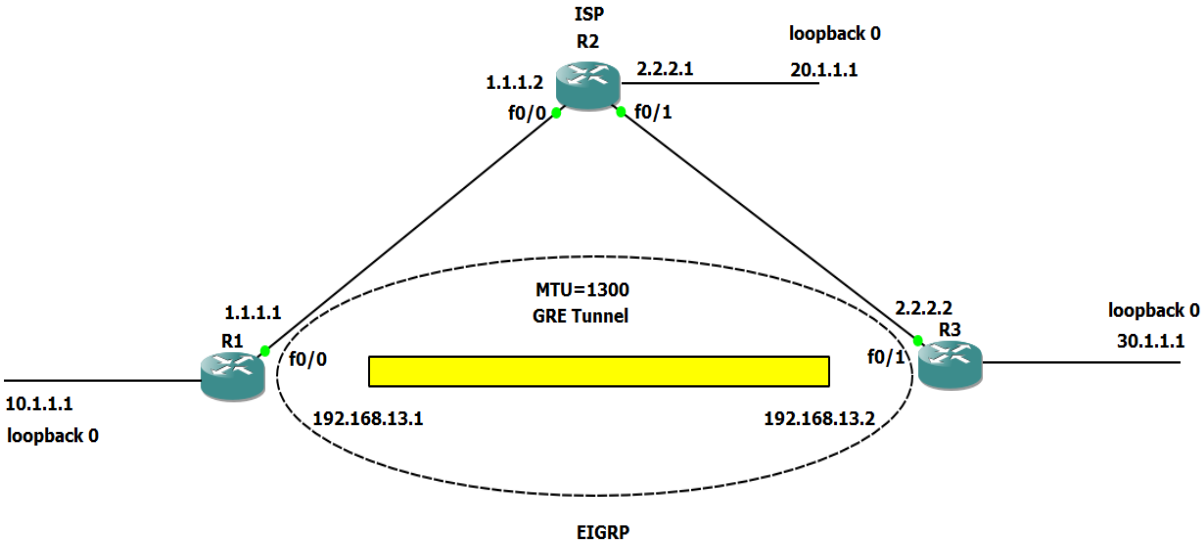
3.Implement NAT

1. Implement a GRE Tunnel:

What is GRE Tunnelling?

Generic Routing Encapsulation, or GRE, is a protocol for encapsulating data packets that use one routing protocol inside the packets of another protocol. "Encapsulating" means wrapping one data packet within another data packet, like putting a box inside another box. GRE is one way to set up a direct point-to-point connection across a network, for the purpose of simplifying connections between separate networks. It works with a variety of network layer protocols. Encapsulating packets within other packets is called "tunnelling." GRE tunnels are usually configured between two routers, with each router acting like one end of the tunnel. The routers are set up to send and receive GRE packets directly to each other. Any routers in between those two routers will not open the encapsulated packets; they only reference the headers surrounding the encapsulated packets in order to forward them.

Step 1: Design the Topology.



Step 2: Configure the System.

R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface fastEthernet 0/0
R1(config-if)#ip address 1.1.1.1 255.0.0.0
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:14:17.859: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:14:18.859: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#interface loopback 0
R1(config-if)#ip a
*Mar  1 00:14:29.203: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 10.1.1.1 255.255.255.255
R1(config-if)#no shut
R1(config-if)#end
R1#
```

R2:

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP
ISP(config)#int
ISP(config)#interface fa
ISP(config)#interface fastEthernet 0/0
ISP(config-if)#ip address 1.1.1.2 255.0.0.0
ISP(config-if)#no shut
ISP(config-if)#exit
ISP(config)#
*Mar  1 00:06:49.463: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:06:50.463: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
ISP(config)#interface fastEthernet 0/1
ISP(config-if)#ip address 2.2.2.1 255.0.0.0
ISP(config-if)#no shut
ISP(config-if)#exit
ISP(config)#
*Mar  1 00:07:19.579: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:07:20.579: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
ISP(config)#int
ISP(config)#interface loo
ISP(config)#interface loopback 0
ISP(config-if)#ip ad
*Mar  1 00:07:27.039: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
ISP(config-if)#ip address 20.1.1.1 255.255.255.255
ISP(config-if)#no shut
ISP(config-if)#end
ISP#
*Mar  1 00:07:40.927: %SYS-5-CONFIG_I: Configured from console by console
ISP#
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface fastEthernet 0/1
R3(config-if)#ip address 2.2.2.2 255.0.0.0
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:10:13.287: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:10:14.287: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R3(config)#interface loopback 0
R3(config-if)#ip adrr
*Mar  1 00:10:21.707: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip address 30.1.1.1 255.255.255
% Incomplete command.

R3(config-if)#ip address 30.1.1.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#end
R3#
```

Step 3: Check the connection between R1, ISP, R3.

```
ISP#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 80 percent (4/5), round-trip min/avg/max = 76/86/96 ms
ISP#ping 2.2.2.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.2.2, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 72/84/92 ms
ISP#
```

Step 4: Create the GRE Tunnel.

R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int tunel 1
                  ^
% Invalid input detected at '^' marker.

R1(config)#int tunnel 1
R1(config-if)#
*Aug 21 21:08:42.727: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to down
R1(config-if)#tunnel source fastEthernet 0/0
R1(config-if)#tunnel destination 2.2.2.2
R1(config-if)#ip address 192.168.13.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#end
R1#
*Aug 21 21:10:11.463: %SYS-5-CONFIG_I: Configured from console by console
R1#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        1.1.1.1         YES manual up                    up
FastEthernet1/0        unassigned      YES unset  administratively down down
Loopback0              10.1.1.1        YES manual up                    up
Tunnel1                192.168.13.1    YES manual up                    down
R1#
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#interface tunnel 1
R3(config-if)#tun
*Mar  1 00:12:58.139: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to down
R3(config-if)#tunnel source fastEthernet 0/1
R3(config-if)#tunnel destination 1.1.1.1
R3(config-if)#ip address 192.168.13.2 255.255.255.0
R3(config-if)#no shut
R3(config-if)#end
R3#
```

Step 5: Assign a Static Route for R1 & R3.

R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip route 2.0.0.0 255.0.0.0 1.1.1.2
R1(config)#end
R1#
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#ip route 1.0.0.0 255.0.0.0 2.2.2.1
R3(config)#end
R3#
*Mar  1 00:24:51.551: %SYS-5-CONFIG_I: Configured from console by console
*Mar  1 00:24:51.555: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to up
R3#
```

Step 6: Check whether the tunnel works.

```
R1#ping 192.168.13.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.13.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 116/126/160 ms
R1#
```

Step 7: Configure EIGRP for R1 & R3.

R1:

```
R1#
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router eigrp 1
R1(config-router)#network 10.0.0.0
R1(config-router)#network 192.168.13.0
R1(config-router)#no au
R1(config-router)#no auto-summary
R1(config-router)#end
R1#
```

R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router eigrp 1
R3(config-router)#network 30.0.0.0
R3(config-router)#network 192.168.13.0
R3(config-router)#
*Mar  1 00:18:26.283: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 192.168.13.1 (Tunnel1) is up: new adjacency
R3(config-router)#no au
R3(config-router)#
*Mar  1 00:18:32.579: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 192.168.13.1 (Tunnel1) is resync: summary configured
R3(config-router)#no auto-summary
R3(config-router)#end
```

Step 8: Check whether EIGRP is configured for R1 & R3.

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

C    1.0.0.0/8 is directly connected, FastEthernet0/0
C    192.168.13.0/24 is directly connected, Tunnel1
S    2.0.0.0/8 [1/0] via 1.1.1.2
     10.0.0.0/32 is subnetted, 1 subnets
C       10.1.1.1 is directly connected, Loopback0
     30.0.0.0/32 is subnetted, 1 subnets
D       30.1.1.1 [90/297372416] via 192.168.13.2, 00:00:28, Tunnel1
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface tunnel 1
R1(config-if)#ip mtu 1300
R1(config-if)#ip tcp adjust-mss 1360
R1(config-if)#end
R1#
*Mar  1 00:28:31.883: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

R2:

```
R3#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

S    1.0.0.0/8 [1/0] via 2.2.2.1
C    192.168.13.0/24 is directly connected, Tunnel1
C    2.0.0.0/8 is directly connected, FastEthernet0/1
     10.0.0.0/32 is subnetted, 1 subnets
D       10.1.1.1 [90/297372416] via 192.168.13.1, 00:01:51, Tunnel1
     30.0.0.0/32 is subnetted, 1 subnets
C       30.1.1.1 is directly connected, Loopback0
R3#
```

Step 9: To set MTU as the GRE Head.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface tunnel 1
R1(config-if)#ip mtu 1300
R1(config-if)#ip tcp adjust-mss 1360
R1(config-if)#end
R1#
*Mar  1 00:28:31.883: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

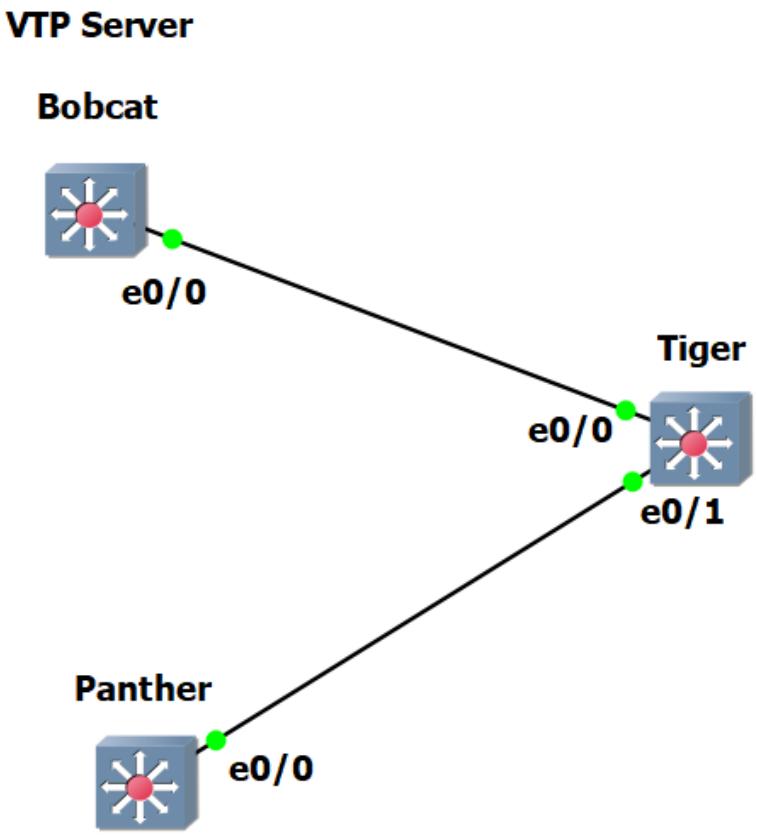
2. Implement VTP

Objective:

Create the following VLANS on switch Bobcat:

- VLAN 10: name Tigers
- VLAN 20: name Lions
- VLAN 30: name Panthers
- Configure the interfaces between the switches as trunks.
- Configure switch Bobcat to be the VTP server.
- Configure switch Panther to be a VTP client.
- Configure switch Tiger so it does not synchronise itself to the latsest VTP information, it should forward advertisements to switch Panther though.
- Change the VTP domain name to “MSCCS”.
- Use the password “MSCCS123” for VTP.
- Make sure there is no unnecessary vlan traffic flooded on the trunk links.

Topology:



- Create the following VLANS on switch Bobcat:

VLAN 10: name Tigers
VLAN 20: name Lions
VLAN 30: name Panthers

```
Bobcat#en
Bobcat# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Bobcat(config)#vlan 10
Bobcat(config-vlan)#vlan 20
Bobcat(config-vlan)#vlan 30
Bobcat(config-vlan)#exit
Bobcat(config)#exit
Bobcat#sh
*Jan  4 14:32:49.658: %SYS-5-CONFIG_I: Configured from console by console
Bobcat#show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Et0/1, Et0/2, Et0/3, Et1/0
                                                Et1/1, Et1/2, Et1/3, Et2/0
                                                Et2/1, Et2/2, Et2/3, Et3/0
                                                Et3/1, Et3/2, Et3/3, Et4/0
                                                Et4/1, Et4/2, Et4/3, Et5/0
                                                Et5/1, Et5/2, Et5/3
10   VLAN0010                         active
20   VLAN0020                         active
30   VLAN0030                         active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
1    enet  100001     1500  -      -      -        -    -        0      0
10   enet  100010     1500  -      -      -        -    -        0      0
20   enet  100020     1500  -      -      -        -    -        0      0
30   enet  100030     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    -        0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0

Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

- Configure the interfaces between the switches as trunks.

```
Bobcat#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Bobcat(config)#interface range e0/0
Bobcat(config-if-range)#switchport trunk encapsulation dot1q
Bobcat(config-if-range)#exit
```

```
Tiger#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Tiger(config)#interface range e0/1
Tiger(config-if-range)#switchport trunk encapsulation dot1q
Tiger(config-if-range)#exit
Tiger(config)#interface range e0/0
Tiger(config-if-range)#switchport trunk encapsulation dot1q
Tiger(config-if-range)#exit
```

```
Panther# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Panther(config)#interface range e0/0
Panther(config-if-range)#switchport trunk encapsulation dot1q
```

- Configure switch Bobcat to be the VTP server.

```
Bobcat(config)#interface e0/0
Bobcat(config-if)#vtp mode server
Device mode already VTP Server for VLANS.
```

- Configure switch Panther to be a VTP client.

```
Panther(config)#interface e0/0
Panther(config-if)#vtp mode client
Setting device to VTP Client mode for VLANS.
```

- Configure switch Tiger so it does not synchronise itself to the lastest VTP information, it should forward advertisements to switch Panther though.

```
Tiger(config)#inte e0/1
Tiger(config-if)#vtp mode trans
Setting device to VTP Transparent mode for VLANS.
```

- Change the VTP domain name to “MSCCS”.

```
Tiger(config)#vtp domain MSCCS
Changing VTP domain name from NULL to MSCCS
```

```
Bobcat(config)#vtp domain MSCCS
Changing VTP domain name from NULL to MSCCS
```

```
Panther(config)#vtp domain MSCCS
Domain name already set to MSCCS.
```

- Use the password “MSCCS123” for VTP.

```
Bobcat(config)#vtp password MSCCS123
Setting device VTP password to MSCCS123
```

```
Tiger(config)#vtp password MSCCS123
Setting device VTP password to MSCCS123
```

```
Panther(config)#vtp password MSCCS123
Setting device VTP password to MSCCS123
```

- Check and verify the VLANs

```
Bobcat#show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Et0/1, Et0/2, Et0/3, Et1/0
                                                Et1/1, Et1/2, Et1/3, Et2/0
                                                Et2/1, Et2/2, Et2/3, Et3/0
                                                Et3/1, Et3/2, Et3/3, Et4/0
                                                Et4/1, Et4/2, Et4/3, Et5/0
                                                Et5/1, Et5/2, Et5/3
10   VLAN0010                         active
20   VLAN0020                         active
30   VLAN0030                         active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
1    enet  100001     1500  -      -      -        -    -        0      0
10   enet  100010     1500  -      -      -        -    -        0      0
20   enet  100020     1500  -      -      -        -    -        0      0
30   enet  100030     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    -        0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0

Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

```
Tiger#show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Et0/2, Et0/3, Et1/0, Et1/1
                                                Et1/2, Et1/3, Et2/0, Et2/1
                                                Et2/2, Et2/3, Et3/0, Et3/1
                                                Et3/2, Et3/3, Et4/0, Et4/1
                                                Et4/2, Et4/3, Et5/0, Et5/1
                                                Et5/2, Et5/3
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
1    enet  100001     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    -        0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0

Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

```
Panther#show vlan

VLAN Name                              Status    Ports
---- --------------------------------- --------- -------------------------------
1    default                           active    Et0/1, Et0/2, Et0/3, Et1/0
                                                 Et1/1, Et1/2, Et1/3, Et2/0
                                                 Et2/1, Et2/2, Et2/3, Et3/0
                                                 Et3/1, Et3/2, Et3/3, Et4/0
                                                 Et4/1, Et4/2, Et4/3, Et5/0
                                                 Et5/1, Et5/2, Et5/3
10   VLAN0010                          active
20   VLAN0020                          active
30   VLAN0030                          active
1002 fddi-default                      act/unsup
1003 token-ring-default                act/unsup
1004 fddinet-default                   act/unsup
1005 trnet-default                     act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
1    enet  100001     1500  -      -      -        -    -        0      0
10   enet  100010     1500  -      -      -        -    -        0      0
20   enet  100020     1500  -      -      -        -    -        0      0
30   enet  100030     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    srb      0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0

Primary Secondary Type              Ports
------- --------- ----------------- ----------------------------------------
```

```
Panther#show vtp status
VTP Version capable             : 1 to 3
VTP version running             : 1
VTP Domain Name                 : MSCCS
VTP Pruning Mode                : Disabled
VTP Traps Generation            : Disabled
Device ID                       : aabb.cc00.0300
Configuration last modified by 0.0.0.0 at 1-4-26 14:32:38

Feature VLAN:
--------------
VTP Operating Mode                : Client
Maximum VLANs supported locally   : 1005
Number of existing VLANs          : 8
Configuration Revision            : 3
MD5 digest                        : 0xE1 0x62 0xBD 0x80 0x24 0xC3 0xFE 0x3F
                                    0x2C 0xF9 0xEE 0xA0 0x6B 0x8B 0xC2 0x15
```

- Make sure there is no unnecessary vlan traffic flooded on the trunk links.

```
Bobcat#conf
*Jan  4 15:03:01.903: %SYS-5-CONFIG_I: Configured from console by console
Bobcat#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Bobcat(config)#vtp pruning
Pruning switched on
```

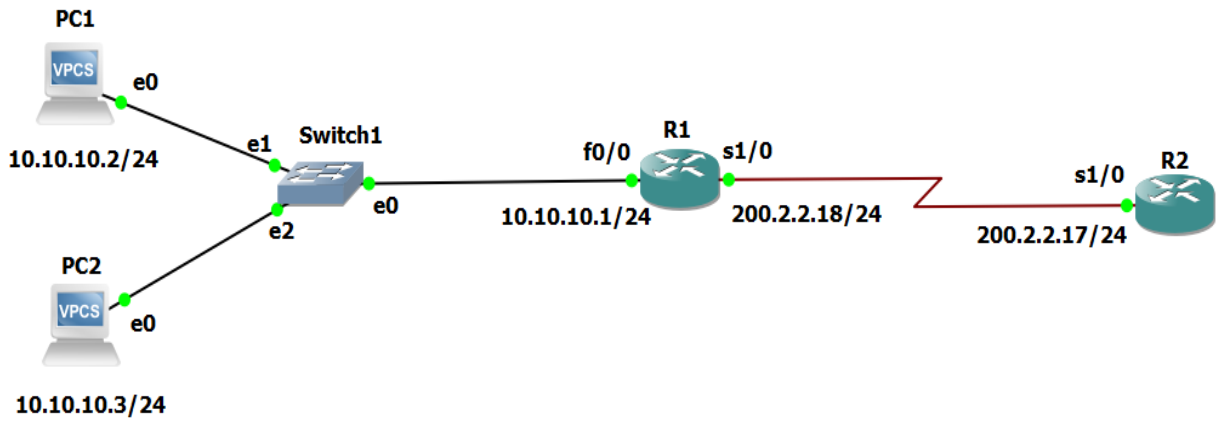
```
Panther#show vtp status
VTP Version capable             : 1 to 3
VTP version running             : 1
VTP Domain Name                 : MSCCS
VTP Pruning Mode                : Enabled
VTP Traps Generation            : Disabled
Device ID                       : aabb.cc00.0300
Configuration last modified by 0.0.0.0 at 1-4-26 15:03:13

Feature VLAN:
--------------
VTP Operating Mode                : Client
Maximum VLANs supported locally   : 1005
Number of existing VLANs          : 8
Configuration Revision            : 4
MD5 digest                        : 0x1D 0x4F 0x8B 0x72 0x1E 0xF3 0xE8 0x9B
                                    0x47 0x72 0x71 0x05 0x0D 0x77 0x18 0x60
```

3. Implement NAT:

What is NAT?

Network Address Translation (NAT) is a process in which one or more local IP address is translated into one or more Global IP address and vice versa in order to provide Internet access to the local hosts. Also, it does the translation of port numbers i.e. masks the port number of the host with another port number, in the packet that will be routed to the destination. It then makes the corresponding entries of IP address and port number in the NAT table. NAT generally operates on a router or firewall.

Step 1: Design the Topology. Use c7200 Router IOS



Step 2: Configure the network.

R1(gateway):

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname gateway
gateway(config)#interface serial1/0
gateway(config-if)#ip address 200.2.2.18 255.255.255.252
gateway(config-if)#no shut
gateway(config-if)#
*Mar  1 00:03:35.763: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
gateway(config-if)#
*Mar  1 00:03:36.767: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
gateway(config-if)#exit
gateway(config)#interface fastethernet0/0
gateway(config-if)#ip address 10.10.10.1 255.255.255.0
gateway(config-if)#n
*Mar  1 00:04:05.171: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to down
gateway(config-if)#no shut
gateway(config-if)#exit
```

R2(ISP):

```
R2#en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname ISP
ISP(config)#interface loopback 0
ISP(config-if)#ip addre
*Mar  1 00:05:34.127: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
ISP(config-if)#ip address 172.16.1.1 255.255.255.255
ISP(config-if)#no shut
ISP(config-if)#exit
ISP(config)#interface serial1/0
ISP(config-if)#ip address 200.2.2.17 255.255.255.252
ISP(config-if)#no shut
ISP(config-if)#exit
```

PC1:

```
PC1> ip 10.10.10.2 255.255.255.0 10.10.10.1
Checking for duplicate address...
PC1 : 10.10.10.2 255.255.255.0 gateway 10.10.10.1

PC1> sh ip

NAME        : PC1[1]
IP/MASK     : 10.10.10.2/24
GATEWAY     : 10.10.10.1
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 10014
RHOST:PORT  : 127.0.0.1:10015
MTU:        : 1500
```

PC2:

```
PC2> ip 10.10.10.3 255.255.255.0 10.10.10.1
Checking for duplicate address...
PC1 : 10.10.10.3 255.255.255.0 gateway 10.10.10.1

PC2> sh ip

NAME        : PC2[1]
IP/MASK     : 10.10.10.3/24
GATEWAY     : 10.10.10.1
DNS         :
MAC         : 00:50:79:66:68:01
LPORT       : 10016
RHOST:PORT  : 127.0.0.1:10017
MTU:        : 1500
```

Step 3: Create a Static Route.

```
ISP(config)#
ISP(config)#ip route 199.99.9.32 255.255.255.224 200.2.2.18
ISP(config)#end
ISP#
```

Step 4: Create a Default Route.

```
gateway#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
gateway(config)#ip route 0.0.0.0 0.0.0.0 200.2.2.17
gateway(config)#
```

Step 5: Make a pool of IP Address which can be used as Public IP Address

Run the command: ip nat pool public-access 199.99.9.32 199.99.9.35 netmask 255.255.255.252

```
gateway(config)#$cess 199.99.9.32 199.99.9.35 netmask 255.255.255.252
gateway(config)#
```

Step 6: Make an access list that will map the public IP addresses to the inside private IP addresses and define the NAT translation from inside list to outside pool.

```
gateway(config)#access-list 1 permit 10.10.10.0 0.0.0.255
```

Step 7: Now we will define which interface is inside and which one is outside.

```
gateway(config)#ip nat inside source list 1 pool public-access overload
gateway(config)#interface fastEthernet 0/0
gateway(config-if)#ip nat inside
gateway(config-if)#eixt
                   ^
% Invalid input detected at '^' marker.

gateway(config-if)#exit
gateway(config)#interface serial 1/0
gateway(config-if)#ip nat outside
gateway(config-if)#end
gateway#
```

Step 8: Now ping from the PC to the loopback of ISP.

PC1:

```
PC1> ping 172.16.1.1
84 bytes from 172.16.1.1 icmp_seq=1 ttl=254 time=129.402 ms
84 bytes from 172.16.1.1 icmp_seq=2 ttl=254 time=47.640 ms
84 bytes from 172.16.1.1 icmp_seq=3 ttl=254 time=49.156 ms
84 bytes from 172.16.1.1 icmp_seq=4 ttl=254 time=32.711 ms
84 bytes from 172.16.1.1 icmp_seq=5 ttl=254 time=48.032 ms
```

PC2:

```
PC2> ping 172.16.1.1
84 bytes from 172.16.1.1 icmp_seq=1 ttl=254 time=47.774 ms
84 bytes from 172.16.1.1 icmp_seq=2 ttl=254 time=50.774 ms
84 bytes from 172.16.1.1 icmp_seq=3 ttl=254 time=47.381 ms
84 bytes from 172.16.1.1 icmp_seq=4 ttl=254 time=45.798 ms
84 bytes from 172.16.1.1 icmp_seq=5 ttl=254 time=46.140 ms
```

Step 9: Verify NAT & PAT Translations.

```
gateway#sh ip nat translations
Pro Inside global      Inside local       Outside local      Outside global
icmp 199.99.9.33:51377 10.10.10.2:51377   172.16.1.1:51377   172.16.1.1:51377
icmp 199.99.9.33:51889 10.10.10.2:51889   172.16.1.1:51889   172.16.1.1:51889
icmp 199.99.9.33:52401 10.10.10.2:52401   172.16.1.1:52401   172.16.1.1:52401
icmp 199.99.9.33:52913 10.10.10.2:52913   172.16.1.1:52913   172.16.1.1:52913
icmp 199.99.9.33:53425 10.10.10.2:53425   172.16.1.1:53425   172.16.1.1:53425
icmp 199.99.9.33:54961 10.10.10.2:54961   172.16.1.1:54961   172.16.1.1:54961
icmp 199.99.9.33:55473 10.10.10.2:55473   172.16.1.1:55473   172.16.1.1:55473
icmp 199.99.9.33:55985 10.10.10.2:55985   172.16.1.1:55985   172.16.1.1:55985
icmp 199.99.9.33:56497 10.10.10.2:56497   172.16.1.1:56497   172.16.1.1:56497
icmp 199.99.9.33:57009 10.10.10.2:57009   172.16.1.1:57009   172.16.1.1:57009
icmp 199.99.9.33:57265 10.10.10.3:57265   172.16.1.1:57265   172.16.1.1:57265
icmp 199.99.9.33:57777 10.10.10.3:57777   172.16.1.1:57777   172.16.1.1:57777
icmp 199.99.9.33:58289 10.10.10.3:58289   172.16.1.1:58289   172.16.1.1:58289
icmp 199.99.9.33:58801 10.10.10.3:58801   172.16.1.1:58801   172.16.1.1:58801
icmp 199.99.9.33:59313 10.10.10.3:59313   172.16.1.1:59313   172.16.1.1:59313
gateway#
```

Step 10: Verify NAT & PAT Statistics.

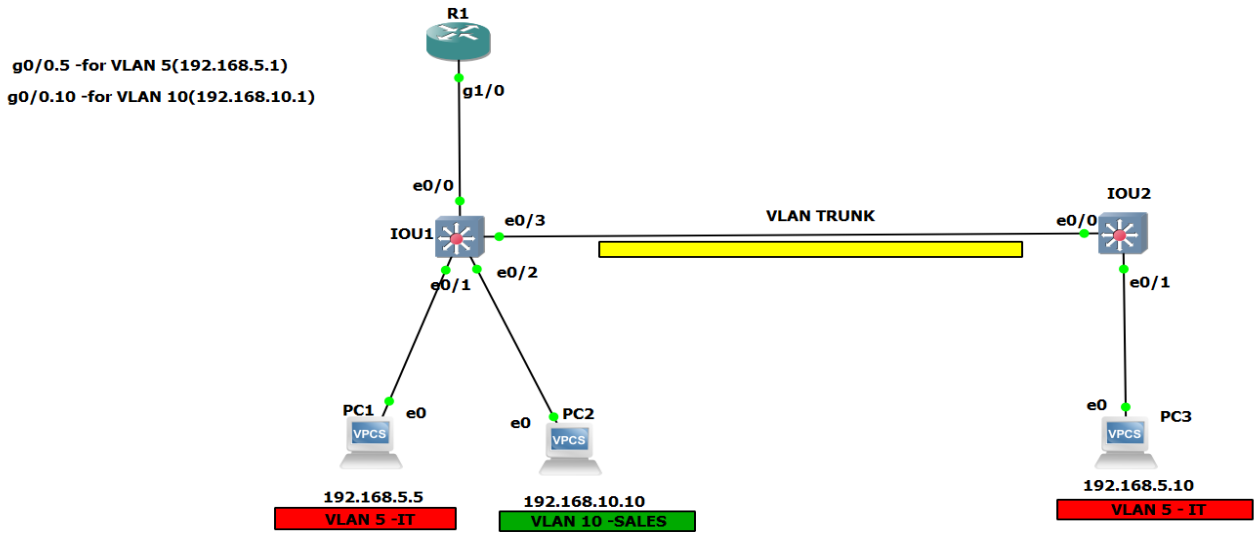
```
gateway#sh ip nat statistics
Total active translations: 0 (0 static, 0 dynamic; 0 extended)
Outside interfaces:
  Serial1/0
Inside interfaces:
  FastEthernet0/0
Hits: 20  Misses: 0
CEF Translated packets: 20, CEF Punted packets: 0
Expired translations: 10
Dynamic mappings:
-- Inside Source
[Id: 1] access-list 1 pool public-access refcount 0
 pool public-access: netmask 255.255.255.252
        start 199.99.9.32 end 199.99.9.35
        type generic, total addresses 4, allocated 0 (0%), misses 0
nat-limit statistics:
 max entry: max allowed 0, used 0, missed 0
```

Practical no.4

Aim:

Implement a GRE Tunnel Inter-VLAN Routing

Topology:



Step 1: Configuration

PC1:

```
PC1> ip 192.168.5.5/24 192.168.5.1
Checking for duplicate address...
PC1 : 192.168.5.5 255.255.255.0 gateway 192.168.5.1

PC1> sh ip

NAME          : PC1[1]
IP/MASK       : 192.168.5.5/24
GATEWAY       : 192.168.5.1
DNS           :
MAC           : 00:50:79:66:68:00
LPORT         : 20009
RHOST:PORT    : 127.0.0.1:20010
MTU           : 1500
```

PC2:

```
PC2> ip 192.168.10.10/24 192.168.10.1
Checking for duplicate address...
PC2 : 192.168.10.10 255.255.255.0 gateway 192.168.10.1

PC2> sh ip

NAME          : PC2[1]
IP/MASK       : 192.168.10.10/24
GATEWAY       : 192.168.10.1
DNS           :
MAC           : 00:50:79:66:68:01
LPORT         : 20011
RHOST:PORT    : 127.0.0.1:20012
MTU           : 1500
```

PC3:

```
PC3> ip 192.168.5.10/24 192.168.5.1
Checking for duplicate address...
PC3 : 192.168.5.10 255.255.255.0 gateway 192.168.5.1

PC3> sh ip

NAME        : PC3[1]
IP/MASK     : 192.168.5.10/24
GATEWAY     : 192.168.5.1
DNS         :
MAC         : 00:50:79:66:68:02
LPORT       : 20013
RHOST:PORT  : 127.0.0.1:20014
MTU         : 1500
```

Layer2 Switch 1:

```
IOU1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
IOU1(config)#vlan 5
IOU1(config-vlan)#name IT
IOU1(config-vlan)#exit
IOU1(config)#10
             ^
% Invalid input detected at '^' marker.

IOU1(config)#vlan 10
IOU1(config-vlan)#name SALES
IOU1(config-vlan)#exit
IOU1(config)#end
```

Layer 2 Switch 2:

```
IOU2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
IOU2(config)#vlan 5
IOU2(config-vlan)#name IT
IOU2(config-vlan)#exit
IOU2(config)#end
IOU2#
*Sep 18 11:05:37.983: %SYS-5-CONFIG_I: Configured from console by console
IOU2#wr
```

Configuring the trunk and access interface for L2 Switch 1:

```
IOU1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
IOU1(config)#interface Et 0/1
IOU1(config-if)#switchport mode access
IOU1(config-if)#switchport access vlan 5
IOU1(config-if)#exit
IOU1(config)#interface Et 0/2
IOU1(config-if)#switchport mode access
IOU1(config-if)#switch access vlan 10
IOU1(config-if)#exit
IOU1(config)#interface Et 0/3
IOU1(config-if)#switchport trunk encapsulation dot1q
IOU1(config-if)#switchport mode trunk
IOU1(config-if)#exit
IOU1(config)#interface Et 0/0
IOU1(config-if)#switchport trunk encapsulation dot1q
IOU1(config-if)#s
*Sep 18 11:12:47.428: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to down
IOU1(config-if)#swit
*Sep 18 11:12:50.428: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0, changed state to up
IOU1(config-if)#switchport mode trunk
IOU1(config-if)#exit
```

Configuring the trunk and access interface for L2 Switch 2:

```
IOU2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
IOU2(config)#interface Et 0/1
IOU2(config-if)#switchport mode access
IOU2(config-if)#switchport access vlan 5
IOU2(config-if)#exit
IOU2(config)#
IOU2(config)#interface Et 0/0
IOU2(config-if)#switchport trunk encapsulation dot1q
IOU2(config-if)#switch mode trunk
IOU2(config-if)#switchport mode trunk
IOU2(config-if)#end
```

Configuring Router R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface Gi 1/0
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Sep 18 17:05:45.855: %LINK-3-UPDOWN: Interface GigabitEthernet1/0, changed state to up
*Sep 18 17:05:46.855: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet1/0, changed state to up
R1(config)#interface Gi 1/0.5
R1(config-subif)#encapsulation
*Sep 18 17:06:18.443: %CDP-4-DUPLEX_MISMATCH: duplex mismatch discovered on GigabitEthernet1/0 (not half duplex), with IO
U1 Ethernet0/0 (half duplex).
R1(config-subif)#encapsulation dot1q 5
R1(config-subif)#ip address 192.168.5.1 255.255.255.0
R1(config-subif)#no shut
R1(config-subif)#exit
R1(config)#interface Gi 1/0.10
R1(config-subif)#enca
*Sep 18 17:07:18.479: %CDP-4-DUPLEX_MISMATCH: duplex mismatch discovered on GigabitEthernet1/0 (not half duplex), with IO
U1 Ethernet0/0 (half duplex).
R1(config-subif)#encapsulation dot1q
% Incomplete command.

R1(config-subif)#encapsulation dot1q 10
R1(config-subif)#ip address 192.168.10.1 255.255.255.0
R1(config-subif)#no shut
R1(config-subif)#exit
R1(config)#end
```

- **Testing the Network:**

1) Ping PC1 to V2 member PC2 to test the connection.

```
PC1> ping 192.168.5.1

84 bytes from 192.168.5.1 icmp_seq=1 ttl=255 time=43.297 ms
84 bytes from 192.168.5.1 icmp_seq=2 ttl=255 time=15.627 ms
84 bytes from 192.168.5.1 icmp_seq=3 ttl=255 time=15.399 ms
84 bytes from 192.168.5.1 icmp_seq=4 ttl=255 time=14.621 ms
84 bytes from 192.168.5.1 icmp_seq=5 ttl=255 time=14.479 ms

PC1> ping 192.168.10.1

84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=15.466 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=15.526 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=14.818 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=14.772 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=15.366 ms

PC1> ping 192.168.10.10

84 bytes from 192.168.10.10 icmp_seq=1 ttl=63 time=42.986 ms
84 bytes from 192.168.10.10 icmp_seq=2 ttl=63 time=28.291 ms
84 bytes from 192.168.10.10 icmp_seq=3 ttl=63 time=28.858 ms
84 bytes from 192.168.10.10 icmp_seq=4 ttl=63 time=29.882 ms
84 bytes from 192.168.10.10 icmp_seq=5 ttl=63 time=28.981 ms

PC1> ping 192.168.5.10

84 bytes from 192.168.5.10 icmp_seq=1 ttl=64 time=5.449 ms
84 bytes from 192.168.5.10 icmp_seq=2 ttl=64 time=2.646 ms
84 bytes from 192.168.5.10 icmp_seq=3 ttl=64 time=1.509 ms
84 bytes from 192.168.5.10 icmp_seq=4 ttl=64 time=1.300 ms
84 bytes from 192.168.5.10 icmp_seq=5 ttl=64 time=1.279 ms
```

2) Ping from PC2 to PCs on VLAN 5:

```
PC2> ping 192.168.10.1

84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=15.432 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=15.178 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=16.040 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=15.190 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=15.685 ms

PC2> ping 192.168.5.5

84 bytes from 192.168.5.5 icmp_seq=1 ttl=63 time=57.996 ms
84 bytes from 192.168.5.5 icmp_seq=2 ttl=63 time=31.551 ms
84 bytes from 192.168.5.5 icmp_seq=3 ttl=63 time=30.259 ms
84 bytes from 192.168.5.5 icmp_seq=4 ttl=63 time=31.582 ms
84 bytes from 192.168.5.5 icmp_seq=5 ttl=63 time=30.367 ms

PC2> ping 192.168.5.10

84 bytes from 192.168.5.10 icmp_seq=1 ttl=63 time=47.338 ms
84 bytes from 192.168.5.10 icmp_seq=2 ttl=63 time=32.269 ms
84 bytes from 192.168.5.10 icmp_seq=3 ttl=63 time=30.978 ms
84 bytes from 192.168.5.10 icmp_seq=4 ttl=63 time=31.265 ms
84 bytes from 192.168.5.10 icmp_seq=5 ttl=63 time=31.470 ms
```

3) Similarly, ping from PC3 to the other PCs on VLAN10:

```
PC3> ping 192.168.5.1

84 bytes from 192.168.5.1 icmp_seq=1 ttl=255 time=15.644 ms
84 bytes from 192.168.5.1 icmp_seq=2 ttl=255 time=16.346 ms
84 bytes from 192.168.5.1 icmp_seq=3 ttl=255 time=16.020 ms
84 bytes from 192.168.5.1 icmp_seq=4 ttl=255 time=16.120 ms
84 bytes from 192.168.5.1 icmp_seq=5 ttl=255 time=16.048 ms

PC3> ping 192.168.10.1

84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=17.039 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=16.644 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=16.868 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=15.987 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=16.988 ms

PC3> ping 192.168.10.10

84 bytes from 192.168.10.10 icmp_seq=1 ttl=63 time=61.476 ms
84 bytes from 192.168.10.10 icmp_seq=2 ttl=63 time=31.586 ms
84 bytes from 192.168.10.10 icmp_seq=3 ttl=63 time=32.099 ms
84 bytes from 192.168.10.10 icmp_seq=4 ttl=63 time=31.284 ms
84 bytes from 192.168.10.10 icmp_seq=5 ttl=63 time=30.909 ms

PC3> ping 192.168.5.10

192.168.5.10 icmp_seq=1 ttl=64 time=0.001 ms
192.168.5.10 icmp_seq=2 ttl=64 time=0.001 ms
192.168.5.10 icmp_seq=3 ttl=64 time=0.001 ms
192.168.5.10 icmp_seq=4 ttl=64 time=0.001 ms
192.168.5.10 icmp_seq=5 ttl=64 time=0.001 ms
```

- Checking if PC1 has been correctly configured:

```
PC1> sh ip

NAME        : PC1[1]
IP/MASK     : 192.168.5.5/24
GATEWAY     : 192.168.5.1
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 20009
RHOST:PORT  : 127.0.0.1:20010
MTU         : 1500
```

- Checking if PC2 has been correctly configured:

```
PC2> sh ip

NAME        : PC2[1]
IP/MASK     : 192.168.10.10/24
GATEWAY     : 192.168.10.1
DNS         :
MAC         : 00:50:79:66:68:01
LPORT       : 20011
RHOST:PORT  : 127.0.0.1:20012
MTU         : 1500
```

- Checking if PC3 has been correctly configured:

```
PC3> sh ip

NAME        : PC3[1]
IP/MASK     : 192.168.5.10/24
GATEWAY     : 192.168.5.1
DNS         :
MAC         : 00:50:79:66:68:02
LPORT       : 20013
RHOST:PORT  : 127.0.0.1:20014
MTU         : 1500
```

- Checking VLAN on Layer2 Switch 1:

```
IOU1#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Et1/1, Et1/2, Et1/3, Et2/0
                                                Et2/1, Et2/2, Et2/3, Et3/0
                                                Et3/1, Et3/2, Et3/3
5    IT                               active    Et0/1, Et1/0
10   SALES                            active    Et0/2
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

- Checking VLAN on Layer2 Switch 2:

```
IOU2#show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Et0/2, Et0/3, Et1/0, Et1/1
                                                Et1/2, Et1/3, Et2/0, Et2/1
                                                Et2/2, Et2/3, Et3/0, Et3/1
                                                Et3/2, Et3/3
5    IT                               active    Et0/1
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

- Checking the running configuration of L2 Switch 1:

```
IOU1#show running-config
Building configuration...

Current configuration : 1789 bytes
!
! Last configuration change at 11:46:31 UTC Thu Sep 18 2025
!
version 15.1
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
service compress-config
!
hostname IOU1
!
boot-start-marker
boot-end-marker
!
!
logging discriminator EXCESS severity drops 6 msg-body drops EXCESSCOLL
logging buffered 50000
logging console discriminator EXCESS
!
no aaa new-model
no ip icmp rate-limit unreachable
!
no ip cef
!
!
no ip domain-lookup
no ipv6 cef
ipv6 multicast rpf use-bgp
spanning-tree mode pvst
spanning-tree extend system-id
!
!
!
!
!
!
vlan internal allocation policy ascending
```

```
!
ip tcp synwait-time 5
!
!
!
!
interface Ethernet0/0
 switchport trunk encapsulation dot1q
 switchport mode trunk
 duplex auto
!
interface Ethernet0/1
 switchport access vlan 5
 switchport mode access
 duplex auto
!
interface Ethernet0/2
 switchport access vlan 10
 switchport mode access
 duplex auto
!
interface Ethernet0/3
 switchport trunk encapsulation dot1q
 switchport mode trunk
 duplex auto
!
interface Ethernet1/0
 switchport access vlan 5
 switchport mode access
 duplex auto
!
interface Ethernet1/1
 duplex auto
!
interface Ethernet1/2
 duplex auto
!
interface Ethernet1/3
 duplex auto
!
interface Ethernet2/0
 duplex auto
!
```

```
interface Ethernet2/1
 duplex auto
!
interface Ethernet2/2
 duplex auto
!
interface Ethernet2/3
 duplex auto
!
interface Ethernet3/0
 duplex auto
!
interface Ethernet3/1
 duplex auto
!
interface Ethernet3/2
 duplex auto
!
interface Ethernet3/3
 duplex auto
!
interface Vlan1
 no ip address
 shutdown
!
!
!
no ip http server
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
```

```
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
end
```

- Checking the running configuration of L2 Switch 2:

```
IOU2#show running-config
Building configuration...

Current configuration : 1627 bytes
!
! Last configuration change at 11:15:52 UTC Thu Sep 18 2025
!
version 15.1
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
service compress-config
!
hostname IOU2
!
boot-start-marker
boot-end-marker
!
!
logging discriminator EXCESS severity drops 6 msg-body drops EXCESSCOLL
logging buffered 50000
logging console discriminator EXCESS
!
no aaa new-model
no ip icmp rate-limit unreachable
!
no ip cef
!
!
no ip domain-lookup
no ipv6 cef
ipv6 multicast rpf use-bgp
spanning-tree mode pvst
spanning-tree extend system-id
!
!
!
!
!
!
vlan internal allocation policy ascending
!
ip tcp synwait-time 5
```

```
!
!
!
!
interface Ethernet0/0
 switchport trunk encapsulation dot1q
 switchport mode trunk
 duplex auto
!
interface Ethernet0/1
 switchport access vlan 5
 switchport mode access
 duplex auto
!
interface Ethernet0/2
 duplex auto
!
interface Ethernet0/3
 duplex auto
!
interface Ethernet1/0
 duplex auto
!
interface Ethernet1/1
 duplex auto
!
interface Ethernet1/2
 duplex auto
!
interface Ethernet1/3
 duplex auto
!
interface Ethernet2/0
 duplex auto
!
interface Ethernet2/1
 duplex auto
!
interface Ethernet2/2
 duplex auto
!
interface Ethernet2/3
 duplex auto
!
```

```
interface Ethernet3/0
 duplex auto
!
interface Ethernet3/1
 duplex auto
!
interface Ethernet3/2
 duplex auto
!
interface Ethernet3/3
 duplex auto
!
interface Vlan1
 no ip address
 shutdown
!
!
!
no ip http server
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
end
```

- The interfaces the have been set to the trunk mode in L2 Switch 1:

```
IOU1#show int trunk

Port        Mode             Encapsulation  Status        Native vlan
Et0/0       on               802.1q         trunking      1
Et0/3       on               802.1q         trunking      1

Port        Vlans allowed on trunk
Et0/0       1-4094
Et0/3       1-4094

Port        Vlans allowed and active in management domain
Et0/0       1,5,10
Et0/3       1,5,10

Port        Vlans in spanning tree forwarding state and not pruned
Et0/0       1,5,10
Et0/3       1,5,10
```

- The interfaces the have been set to the trunk mode in L2 Switch 2:

```
IOU2#show int trunk

Port        Mode             Encapsulation  Status        Native vlan
Et0/0       on               802.1q         trunking      1

Port        Vlans allowed on trunk
Et0/0       1-4094

Port        Vlans allowed and active in management domain
Et0/0       1,5

Port        Vlans in spanning tree forwarding state and not pruned
Et0/0       1,5
```

- The overall running configuration of Router 1 (R1):

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

Current configuration : 1026 bytes
!
! Last configuration change at 17:07:59 UTC Thu Sep 18 2025
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
!
hostname R1
!
boot-start-marker
boot-end-marker
!
!
!
no aaa new-model
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
!
!
no ip domain lookup
no ipv6 cef
!
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
ip tcp synwait-time 5
!
!
!
```

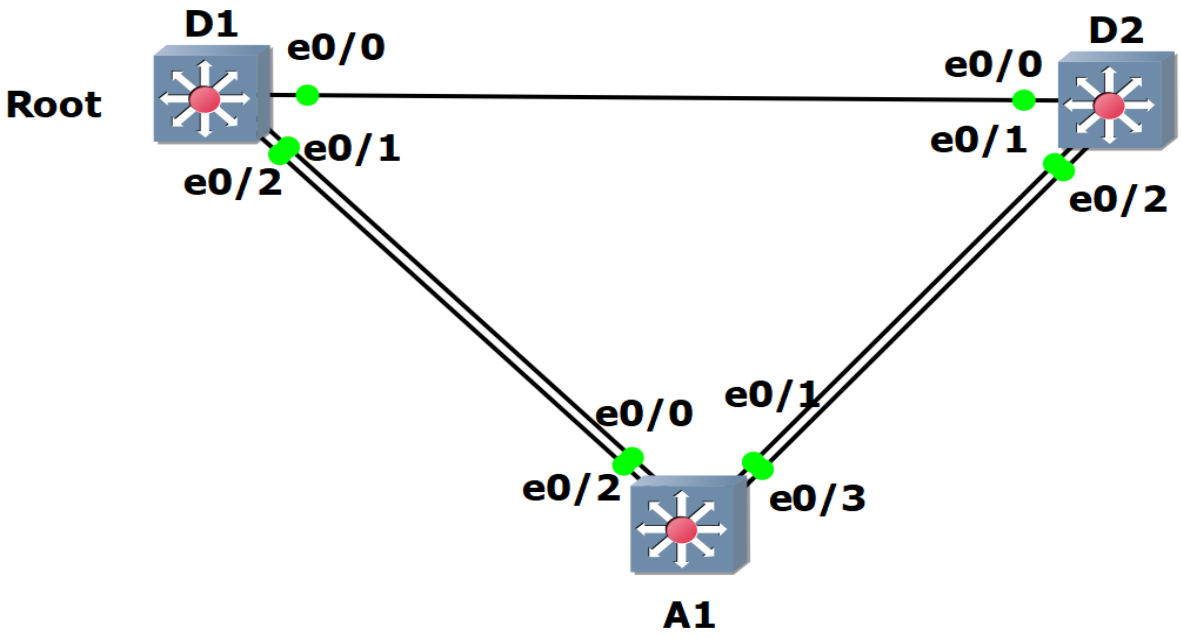
```
!
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex full
!
interface GigabitEthernet1/0
 no ip address
 negotiation auto
!
interface GigabitEthernet1/0.5
 encapsulation dot1Q 5
 ip address 192.168.5.1 255.255.255.0
!
interface GigabitEthernet1/0.10
 encapsulation dot1Q 10
 ip address 192.168.10.1 255.255.255.0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
!
!
!
control-plane
!
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
  stopbits 1
line aux 0
  exec-timeout 0 0
  privilege level 15
  logging synchronous
  stopbits 1
line vty 0 4
  login
!
!
end
```

Practical no.5

Aim:

1. **Build the Network and Configure Basic Device Settings.**
2. **Observe STP Convergence and Topology Change.**
3. **Configure and verify Rapid Spanning Tree.**

Topology:



Addressing Table

Device	Interface	IPV4 Address
D1	VLAN1	10.0.0.1/8
D2	VLAN1	10.0.0.2/8
A1	VLAN1	10.0.0.3/8

Background / Scenario

The potential effect of a loop in the Layer 2 network is significant. Layer 2 loops could impact connected hosts as well as the network equipment. Layer 2 loops can be prevented by following good design practices and careful implementation of the Spanning Tree Protocol. In this lab, you will observe the operation of spanning tree protocols to protect the Layer 2 network from loops and topology disruptions. The terms "switch" and "bridge" will be used interchangeably throughout the lab.

Switch D1:

```
D1#enable
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#line console 0
D1(config-line)#logging synchronous
D1(config-line)#exec-timeout 0 0
D1(config-line)#spanning-tree mode pvst
D1(config)#vlan 1
D1(config-vlan)#name Management
%Default VLAN 1 may not have its name changed.
D1(config-vlan)#interface Vlan1
D1(config-if)#ip address 10.0.0.1 255.0.0.0
D1(config-if)#no shutdown
D1(config-if)#interface Ethernet0/0
D1(config-if)#description to D2 e0/0
D1(config-if)#switchport
D1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D1(config-if)#no shutdown
D1(config-if)#
D1(config-if)#interface Ethernet0/1
D1(config-if)#description to A1 e0/0
D1(config-if)#switchport
D1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D1(config-if)#no shutdown
D1(config-if)#
D1(config-if)#interface Ethernet0/2
D1(config-if)#description ot A1 e0/2
D1(config-if)#switchport
D1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D1(config-if)#no shutdown
D1(config-if)#end
D1#wr
*Sep 24 17:33:30.463: %SYS-5-CONFIG_I: Configured from console by console
D1#write memory
Building configuration...
Compressed configuration from 1630 bytes to 944 bytes[OK]
D1#
D1#
```

Make D1 a deterministic root

```
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#spanning-tree vlan 1 root primary
D1(config)#end
D1#
*Sep 24 17:34:46.944: %SYS-5-CONFIG_I: Configured from console by console
D1#write memory
Building configuration...
Compressed configuration from 1630 bytes to 945 bytes[OK]
D1#
```

Switch D2:

```
D2#enable
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#line console 0
D2(config-line)#logging synchronous
D2(config-line)#exec-timeout 0 0
D2(config-line)#spanning-tree mode pvst
D2(config)#valn 1
          ^
% Invalid input detected at '^' marker.

D2(config)#vlan 1
D2(config-vlan)#name Management
%Default VLAN 1 may not have its name changed.
D2(config-vlan)#interface Vlan1
D2(config-if)#ip address 10.0.0.2 255.0.0.0
D2(config-if)#no shutdown
D2(config-if)#
D2(config-if)#interface Ethernet0/0
D2(config-if)#description to D1 e0/0
D2(config-if)#switchport
D2(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D2(config-if)#no shutdown
D2(config-if)#
D2(config-if)#interface Ethernet0/1
D2(config-if)#desription to A1 e0/1
               ^
% Invalid input detected at '^' marker.

D2(config-if)#description to A1 e0/1
D2(config-if)#switchport
D2(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D2(config-if)#no shutdown
D2(config-if)#
D2(config-if)#interface Ethernet0/2
D2(config-if)#
D2(config-if)#description to A1 e0/3
D2(config-if)#switchport
D2(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
D2(config-if)#no shutdown
D2(config-if)#switchport
D2(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
```

```
D2(config-if)#no shutdown
D2(config-if)#end
D2#writ
*Sep 24 17:40:03.597: %SYS-5-CONFIG_I: Configured from console by console
D2#write memeory
           ^
% Invalid input detected at '^' marker.

D2#write memory
Building configuration...
Compressed configuration from 1592 bytes to 923 bytes[OK]
```

Switch A1:

```
A1#enable
A1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
A1(config)#no ip domain-lookup
A1(config)#service password-encryption
A1(config)#banner motd
% Incomplete command.

A1(config)#banner motd # STP/RSTP Lab -A1 #
A1(config)#line console 0
A1(config-line)#logging synchronous
A1(config-line)#exec-timeout 0 0
A1(config-line)#spanning-tree mode pvst
A1(config)#vlan 1
A1(config-vlan)#name Management
%Default VLAN 1 may not have its name changed.
A1(config-vlan)#interface Vlan1
A1(config-if)#ip address 10.0.0.3 255.0.0.0
A1(config-if)#no shutdown
A1(config-if)#intrface Ethernet0/0
               ^
% Invalid input detected at '^' marker.

A1(config-if)#interface Ethernet0/0
A1(config-if)#description to D1 e0/1
A1(config-if)#switchport
A1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
A1(config-if)#no  shutdown
A1(config-if)#interface Ethernet0/1
A1(config-if)#description to D2 e0/1
A1(config-if)#switchport
A1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
A1(config-if)#no shutdown
A1(config-if)#
A1(config-if)#interface Ethernet0/2
A1(config-if)#description to D1 e0/2
A1(config-if)#switchport
A1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
A1(config-if)#no shutdown
A1(config-if)#interface Ethernet0/3
A1(config-if)#description to D2 e0/2
A1(config-if)#switchport
A1(config-if)#switchport mode trunk
Command rejected: An interface whose trunk encapsulation is "Auto" can not be configured to "trunk" mode.
A1(config-if)#no shutdown
A1(config-if)#end
A1#write
*Sep 24 17:51:02.771: %SYS-5-CONFIG_I: Configured from console by console
A1#write memory
Building configuration...
Compressed configuration from 1646 bytes to 964 bytes[OK]
A1#
```

4) Sanity Checks (what/why/how)

```
D1#show interfaces trunk

Port        Mode             Encapsulation  Status        Native vlan
Et0/0       desirable        n-isl          trunking      1
Et0/1       desirable        n-isl          trunking      1
Et0/2       desirable        n-isl          trunking      1

Port        Vlans allowed on trunk
Et0/0       1-4094
Et0/1       1-4094
Et0/2       1-4094

Port        Vlans allowed and active in management domain
Et0/0       1
Et0/1       1
Et0/2       1

Port        Vlans in spanning tree forwarding state and not pruned
Et0/0       1
Et0/1       1
Et0/2       1
```

```
D2#show interfaces trunk

Port        Mode             Encapsulation  Status        Native vlan
Et0/0       desirable        n-isl          trunking      1
Et0/1       desirable        n-isl          trunking      1
Et0/2       desirable        n-isl          trunking      1

Port        Vlans allowed on trunk
Et0/0       1-4094
Et0/1       1-4094
Et0/2       1-4094

Port        Vlans allowed and active in management domain
Et0/0       1
Et0/1       1
Et0/2       1

Port        Vlans in spanning tree forwarding state and not pruned
Et0/0       1
Et0/1       1
Et0/2       1
```

```
A1#show interfaces trunk

Port        Mode             Encapsulation  Status        Native vlan
Et0/0       desirable        n-isl          trunking      1
Et0/1       desirable        n-isl          trunking      1
Et0/2       desirable        n-isl          trunking      1
Et0/3       desirable        n-isl          trunking      1

Port        Vlans allowed on trunk
Et0/0       1-4094
Et0/1       1-4094
Et0/2       1-4094
Et0/3       1-4094

Port        Vlans allowed and active in management domain
Et0/0       1
Et0/1       1
Et0/2       1
Et0/3       1

Port        Vlans in spanning tree forwarding state and not pruned
Et0/0       1
Et0/1       none
Et0/2       none
Et0/3       none
```

```
D1#show spanning-tree summary
Switch is in pvst mode
Root bridge for: VLAN0001
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                      0         0        0         16         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                        0         0        0         16         16
```

```
D2#show spanning-tree summary
Switch is in pvst mode
Root bridge for: none
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                      0         0        0         16         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                        0         0        0         16         16
```

```
A1#show spanning-tree summary
Switch is in pvst mode
Root bridge for: none
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                      3         0        0         13         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                        3         0        0         13         16
```

(From D1 for example PING):

```
D1#ping 10.0.0.2 source vlan1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
Packet sent with a source address of 10.0.0.1
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 1/3/5 ms
D1#ping 10.0.0.3 source vlan1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.3, timeout is 2 seconds:
Packet sent with a source address of 10.0.0.1
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 1/1/1 ms
```

5) Part 2 — Discover the Default Spanning Tree (PVST+) (Per-VLAN Spanning Tree Plus)

A) Identify the Root Bridge

```
D1#show spanning-tree root

                                        Root    Hello Max Fwd
Vlan                 Root ID            Cost    Time  Age Dly  Root Port
---------------- -------------------- --------- ----- --- ---  ------------
VLAN0001         24577 aabb.cc00.0100         0    2   20  15
```

Record: Bridge ID of the root, Root Port (local), and Root Path Cost. If you set root primary on D1, D1 should be the root.

B) Inspect Port Roles/States

- **Root Bridge (likely D1):** all participating ports should be **Designated Forwarding**.
- **Non-root (A1, D2):** each has exactly **one Root** port; redundant paths become **Alternate (Blocking/Discarding)**. Which one blocks depends on **root path cost** and tie-breakers (bridge/port IDs).

```
D1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     aabb.cc00.0100
              This bridge is the root
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    24577  (priority 24576 sys-id-ext 1)
              Address     aabb.cc00.0100
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Desg FWD 100       128.1    Shr
Et0/1               Desg FWD 100       128.2    Shr
Et0/2               Desg FWD 100       128.3    Shr
Et0/3               Desg FWD 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

```
D2#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     aabb.cc00.0100
              Cost        100
              Port        1 (Ethernet0/0)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     aabb.cc00.0200
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Root FWD 100       128.1    Shr
Et0/1               Desg FWD 100       128.2    Shr
Et0/2               Desg FWD 100       128.3    Shr
Et0/3               Desg FWD 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

```
A1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     aabb.cc00.0100
              Cost        100
              Port        1 (Ethernet0/0)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     aabb.cc00.0300
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Root FWD 100       128.1    Shr
Et0/1               Altn BLK 100       128.2    Shr
Et0/2               Altn BLK 100       128.3    Shr
Et0/3               Altn BLK 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

6) Show It Adjusts — Simulate a Failure (PVST+) Turn on event logs (D2) and fail a link (shut D2 ↔ A1 on D2 e0/1):

```
D2#debug spanning-tree events
Spanning Tree event debugging is on
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#interface e0/1
D2(config-if)#shutdown
D2(config-if)#end
*Sep 24 18:18:05.952: STP: VLAN0001 sent Topology Change Notice on Et0/0
*Sep 24 18:18:05.952: STP[1]: Generating TC trap for port Ethernet0/1
D2(config-if)#end
D2#
*Sep 24 18:18:07.957: %LINK-5-CHANGED: Interface Ethernet0/1, changed state to administratively down
*Sep 24 18:18:08.222: %SYS-5-CONFIG_I: Configured from console by console
*Sep 24 18:18:08.957: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/1, changed state to down
```

Observe:

- STP re-computes; a previously Alternate link should unblock to maintain a single loop-free path.
- PVST+ takes several seconds (listening/learning) before forwarding resumes.

Restore link & stop logs:

```
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#interface e0/1
D2(config-if)#no shutdown
D2(config-if)#end
D2#
*Sep 24 18:19:42.289: %SYS-5-CONFIG_I: Configured from console by console
D2#
*Sep 24 18:19:43.186: %LINK-3-UPDOWN: Interface Ethernet0/1, changed state to up
*Sep 24 18:19:44.190: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/1, changed state to up
*Sep 24 18:19:44.199: set portid: VLAN0001 Et0/1: new port id 8002
*Sep 24 18:19:44.199: STP: VLAN0001 Et0/1 -> listening
D2#undebug all
All possible debugging has been turned off
```

Re-check roles:

```
D2#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     aabb.cc00.0100
              Cost        100
              Port        1 (Ethernet0/0)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     aabb.cc00.0200
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Root FWD 100       128.1    Shr
Et0/1               Desg FWD 100       128.2    Shr
Et0/2               Desg FWD 100       128.3    Shr
Et0/3               Desg FWD 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

7) Migrate to RSTP (Rapid-PVST) and Compare

Enable on all switches:

```
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#spanning-tree mode rapid-pvst
D1(config)#end
D1#memor
*Sep 24 18:22:04.266: %SYS-5-CONFIG_I: Configured from console by console
D1#write memory
Building configuration...
Compressed configuration from 1636 bytes to 952 bytes[OK]
```

```
D1#show spanning-tree summary
Switch is in rapid-pvst mode
Root bridge for: VLAN0001
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                     0         0        0         16         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                       0         0        0         16         16
```

```
D1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID    Priority    24577
             Address     aabb.cc00.0100
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    24577  (priority 24576 sys-id-ext 1)
             Address     aabb.cc00.0100
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Desg FWD 100       128.1    Shr Peer(STP)
Et0/1               Desg FWD 100       128.2    Shr Peer(STP)
Et0/2               Desg FWD 100       128.3    Shr Peer(STP)
Et0/3               Desg FWD 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

```
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#spanning-tree mode rapid-pvst
D2(config)#end
D2#
*Sep 24 18:24:50.226: %SYS-5-CONFIG_I: Configured from console by console
D2#write memory
Building configuration...
Compressed configuration from 1600 bytes to 924 bytes[OK]
```

```
D2#show spanning-tree summary
Switch is in rapid-pvst mode
Root bridge for: none
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                    0         0        0         16         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                      0         0        0         16         16
```

```
D2#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID    Priority    24577
             Address     aabb.cc00.0100
             Cost        100
             Port        1 (Ethernet0/0)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     aabb.cc00.0200
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Root FWD 100       128.1    Shr
Et0/1               Desg FWD 100       128.2    Shr Peer(STP)
Et0/2               Desg FWD 100       128.3    Shr Peer(STP)
Et0/3               Desg FWD 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

```
A1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
A1(config)#spanning-tree mode rapid-pvst
A1(config)#end
A1#write
*Sep 24 18:28:21.473: %SYS-5-CONFIG_I: Configured from console by console
A1#write memory
Building configuration...
Compressed configuration from 1654 bytes to 971 bytes[OK]
```

```
A1#show spanning-tree summary
Switch is in rapid-pvst mode
Root bridge for: none
EtherChannel misconfig guard is enabled
Extended system ID           is enabled
Portfast Default             is disabled
PortFast BPDU Guard Default  is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default            is disabled
UplinkFast                   is disabled
BackboneFast                 is disabled
Configured Pathcost method used is short

Name                   Blocking Listening Learning Forwarding STP Active
---------------------- -------- --------- -------- ---------- ----------
VLAN0001                      3         0        0         13         16
---------------------- -------- --------- -------- ---------- ----------
1 vlan                        3         0        0         13         16
```

```
A1#show spanning-tree vlan 1

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID     Priority    24577
              Address     aabb.cc00.0100
              Cost        100
              Port        1 (Ethernet0/0)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     aabb.cc00.0300
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  300 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Et0/0               Root FWD 100       128.1    Shr
Et0/1               Altn BLK 100       128.2    Shr
Et0/2               Altn BLK 100       128.3    Shr
Et0/3               Altn BLK 100       128.4    Shr
Et1/0               Desg FWD 100       128.5    Shr
Et1/1               Desg FWD 100       128.6    Shr
Et1/2               Desg FWD 100       128.7    Shr
Et1/3               Desg FWD 100       128.8    Shr
Et2/0               Desg FWD 100       128.9    Shr
Et2/1               Desg FWD 100       128.10   Shr
Et2/2               Desg FWD 100       128.11   Shr
Et2/3               Desg FWD 100       128.12   Shr
Et3/0               Desg FWD 100       128.13   Shr
Et3/1               Desg FWD 100       128.14   Shr
Et3/2               Desg FWD 100       128.15   Shr
Et3/3               Desg FWD 100       128.16   Shr
```

Repeat the same failure test (again D2 e0/1):

```
D2#debug spanning-tree events
Spanning Tree event debugging is on
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#interface e0/1
D2(config-if)#shutdown
D2(config-if)#end
D2#
*Sep 24 18:31:37.983: %SYS-5-CONFIG_I: Configured from console by console
D2#
*Sep 24 18:31:39.243: %LINK-5-CHANGED: Interface Ethernet0/1, changed state to administratively down
*Sep 24 18:31:40.244: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/1, changed state to down
```

Expected: Noticeably **faster** reconvergence (often sub-second to a couple of seconds on point-to-point links), thanks to RSTP's proposal/agreement and sync processes.

```
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#interface e0/1
D2(config-if)#no shutdown
D2(config-if)#end
D2#
*Sep 24 18:33:12.762: %SYS-5-CONFIG_I: Configured from console by console
D2#unde
*Sep 24 18:33:13.833: %LINK-3-UPDOWN: Interface Ethernet0/1, changed state to up
*Sep 24 18:33:14.834: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/1, changed state to up
*Sep 24 18:33:14.843: RSTP(1): initializing port Et0/1
*Sep 24 18:33:14.843: RSTP(1): Et0/1 is now designated
*Sep 24 18:33:14.844: RSTP(1): transmitting a proposal on Et0/1
D2#undebug
*Sep 24 18:33:14.971: RSTP(1): transmitting a proposal on Et0/1
D2#undebug all
All possible debugging has been turned off
D2#
*Sep 24 18:33:16.981: RSTP(1): transmitting a proposal on Et0/1
```

Results Checked

PVST+ took approx. 16 microseconds

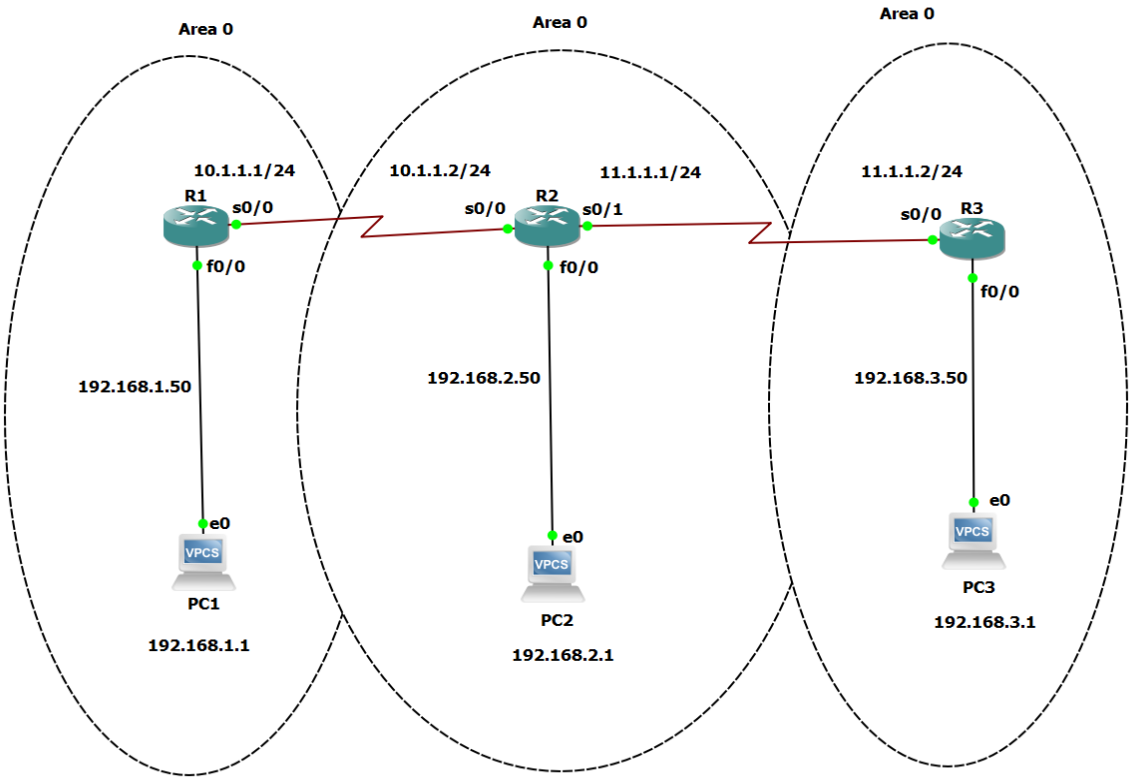
RSTP took approx. 7 microseconds

Practical no.6

Aim: OSPF Implementation

1. Implement Single-Area OSPFv2

Step 1: To create a network take 3 routers and 3 PC's



Step 2: Configure PC:

PC1:

```
PC1> ip 192.168.1.1 255.255.255.0 gateway 192.168.1.50
Checking for duplicate address...
PC1 : 192.168.1.1 255.255.255.0 gateway 192.168.1.50

PC1> sh ip

NAME        : PC1[1]
IP/MASK     : 192.168.1.1/24
GATEWAY     : 192.168.1.50
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 10028
RHOST:PORT  : 127.0.0.1:10029
MTU:        : 1500
```

PC2:

```
PC2> ip 192.168.2.1 255.255.255.0 gateway 192.168.2.50
Checking for duplicate address...
PC1 : 192.168.2.1 255.255.255.0 gateway 192.168.2.50

PC2> sh ip

NAME        : PC2[1]
IP/MASK     : 192.168.2.1/24
GATEWAY     : 192.168.2.50
DNS         :
MAC         : 00:50:79:66:68:01
LPORT       : 10026
RHOST:PORT  : 127.0.0.1:10027
MTU:        : 1500
```

PC3:

```
PC3> ip 192.168.3.1 255.255.255.0 gateway 192.168.3.50
Checking for duplicate address...
PC1 : 192.168.3.1 255.255.255.0 gateway 192.168.3.50

PC3> sh ip

NAME        : PC3[1]
IP/MASK     : 192.168.3.1/24
GATEWAY     : 192.168.3.50
DNS         :
MAC         : 00:50:79:66:68:02
LPORT       : 10024
RHOST:PORT  : 127.0.0.1:10025
MTU:        : 1500
```

Step 3: Configure IP Address in Router

R1:

```
R1#en
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f0/0
R1(config-if)#ip address 192.168.1.50 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit
*Mar  1 00:09:08.895: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:09:09.895: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config-if)#exit
R1(config)#int s0/0
R1(config-if)#ip address 10.1.1.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit
```

R2:

```
R2#en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int f0/0
R2(config-if)#ip address 192.168.2.50 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:10:39.495: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:10:40.495: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#int s0/0
R2(config-if)#ip address 10.1.1.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:11:16.707: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R2(config)#
*Mar  1 00:11:17.711: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R2(config)#int s0/1
R2(config-if)#ip address 11.1.1.1 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:11:50.363: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
R2(config)#
*Mar  1 00:11:51.367: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R2(config)#do write
Building configuration...
[OK]
```

R3:

```
R3#en
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/0
R3(config-if)#ip address 192.168.3.50 255.255.255.0
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:11:51.083: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:11:52.083: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config)#int s0/0
R3(config-if)#ip address 11.1.1.2 255.255.255.0
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:12:18.883: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R3(config)#do w
*Mar  1 00:12:19.887: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R3(config)#do write
Building configuration...
[OK]
```

Step 4: Check whether the IP Address assigned is correct or not by using ‘do sh ip int br’

R1:

```
R1(config)#do sh ip int br
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            192.168.1.50    YES manual up                    up
Serial0/0                  10.1.1.1        YES manual up                    up
FastEthernet0/1            unassigned      YES unset  administratively down down
Serial0/1                  unassigned      YES unset  administratively down down
Serial0/2                  unassigned      YES unset  administratively down down
```

R2:

```
R2(config)#do sh ip int br
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            192.168.2.50    YES manual up                    up
Serial0/0                  10.1.1.2        YES manual up                    up
FastEthernet0/1            unassigned      YES unset  administratively down down
Serial0/1                  11.1.1.1        YES manual up                    up
Serial0/2                  unassigned      YES unset  administratively down down
```

R3:

```
R3(config)#do sh ip int br
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            192.168.3.50    YES manual up                    up
Serial0/0                  11.1.1.2        YES manual up                    up
FastEthernet0/1            unassigned      YES unset  administratively down down
Serial0/1                  unassigned      YES unset  administratively down down
Serial0/2                  unassigned      YES unset  administratively down down
```

Step 5: Check whether direct connection ping is working in all the routers and PCs.

PC1:

```
PC1> ping 192.168.1.50
84 bytes from 192.168.1.50 icmp_seq=1 ttl=255 time=30.787 ms
84 bytes from 192.168.1.50 icmp_seq=2 ttl=255 time=15.726 ms
84 bytes from 192.168.1.50 icmp_seq=3 ttl=255 time=15.820 ms
84 bytes from 192.168.1.50 icmp_seq=4 ttl=255 time=15.651 ms
84 bytes from 192.168.1.50 icmp_seq=5 ttl=255 time=15.785 ms
```

PC2:

```
PC2> ping 192.168.2.50
84 bytes from 192.168.2.50 icmp_seq=1 ttl=255 time=31.253 ms
84 bytes from 192.168.2.50 icmp_seq=2 ttl=255 time=31.522 ms
84 bytes from 192.168.2.50 icmp_seq=3 ttl=255 time=15.605 ms
84 bytes from 192.168.2.50 icmp_seq=4 ttl=255 time=15.165 ms
84 bytes from 192.168.2.50 icmp_seq=5 ttl=255 time=15.630 ms
```

PC3:

```
PC3> ping 192.168.3.50
84 bytes from 192.168.3.50 icmp_seq=1 ttl=255 time=60.488 ms
84 bytes from 192.168.3.50 icmp_seq=2 ttl=255 time=15.461 ms
84 bytes from 192.168.3.50 icmp_seq=3 ttl=255 time=16.332 ms
84 bytes from 192.168.3.50 icmp_seq=4 ttl=255 time=15.938 ms
84 bytes from 192.168.3.50 icmp_seq=5 ttl=255 time=15.589 ms
```

R1:

```
R1(config)#do ping 10.1.1.2

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 = 20/24/36 ms
```

R2:

```
R2(config)#do ping 10.1.1.1

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 = 12/28/40 ms
R2(config)#do ping 11.1.1.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 11.1.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/32/44 ms
```

R3:

```
R3(config)#do ping 11.1.1.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 11.1.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/54/116 ms
```

Direct Connection ping is working successfully. But indirect won't work because we haven't done any protocol. So, we will do OSPF in single area.

Step 6: Configure OSPF protocol in all the routers.

```
R1(config)#router ospf 1
R1(config-router)#network 192.168.1.0 0.0.0.255 area 0
R1(config-router)#network 10.1.1.0 0.0.0.255 area 0
R1(config-router)#exit
R1(config)#do write
Building configuration...
[OK]
```

R2:

```
R2(config)#router ospf 1
R2(config-router)#network 192.168.2.0 0.0.0.255 area 0
R2(config-router)#network 10.1.1.0 0.0.0.255 area 0
R2(config-router)#
*Mar  1 00:25:53.203: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.50 on Serial0/0 from LOADING to FULL, Loading Done
R2(config-router)#network 11.1.1.0 0.0.0.255 area 0
R2(config-router)#exit
R2(config)#do write
Building configuration...
[OK]
```

R3:

```
R3(config)#router ospf 1
R3(config-router)#network 192.168.3.0 0.0.0.255 area 0
R3(config-router)#network 11.1.1.0 0.0.0.255 area 0
R3(config-router)#exit
R3(config)#
*Mar  1 00:26:07.819: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.2.50 on Serial0/0 from LOADING to FULL, Loading Done
R3(config)#do write
Building configuration...
[OK]
```

Step 7: Once OSPF is done enter command ‘sh ip route’ in all router to check whether OSPF is done properly.

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

     10.0.0.0/24 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Serial0/0
     11.0.0.0/24 is subnetted, 1 subnets
O       11.1.1.0 [110/128] via 10.1.1.2, 00:03:38, Serial0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
O    192.168.2.0/24 [110/74] via 10.1.1.2, 00:03:53, Serial0/0
O    192.168.3.0/24 [110/138] via 10.1.1.2, 00:01:18, Serial0/0
```

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

     10.0.0.0/24 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Serial0/0
     11.0.0.0/24 is subnetted, 1 subnets
C       11.1.1.0 is directly connected, Serial0/1
O    192.168.1.0/24 [110/74] via 10.1.1.1, 00:04:36, Serial0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
O    192.168.3.0/24 [110/74] via 11.1.1.2, 00:02:12, Serial0/1
```

R3:

```
R3#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
O       10.1.1.0 [110/128] via 11.1.1.1, 00:03:55, Serial0/0
     11.0.0.0/24 is subnetted, 1 subnets
C       11.1.1.0 is directly connected, Serial0/0
O    192.168.1.0/24 [110/138] via 11.1.1.1, 00:03:55, Serial0/0
O    192.168.2.0/24 [110/74] via 11.1.1.1, 00:03:55, Serial0/0
C    192.168.3.0/24 is directly connected, FastEthernet0/0
```

Step 8: Enter command ‘sh ip protocols’ to check which all protocols are applied in our network

R1:

```
R1#sh ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.1.50
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.1.1.0 0.0.0.255 area 0
    192.168.1.0 0.0.0.255 area 0
 Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.50         110      00:07:40
    192.168.3.50         110      00:05:21
    192.168.1.50         110      00:09:17
  Distance: (default is 110)
```

R2:

```
R2#sh ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.2.50
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.1.1.0 0.0.0.255 area 0
    11.1.1.0 0.0.0.255 area 0
    192.168.2.0 0.0.0.255 area 0
 Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.50         110      00:08:26
    192.168.3.50         110      00:06:17
    192.168.1.50         110      00:08:42
  Distance: (default is 110)
```

R3:

```
R3#sh ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.3.50
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    11.1.1.0 0.0.0.255 area 0
    192.168.3.0 0.0.0.255 area 0
 Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.50         110      00:06:56
    192.168.3.50         110      00:06:56
    192.168.1.50         110      00:06:56
  Distance: (default is 110)
```

Step 9: Enter command ‘sh ip ospf neigbor’ to check OSPF Neigbor

R1:

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.2.50      0   FULL/  -        00:00:34    10.1.1.2        Serial0/0
R1#
```

R2:

```
R2#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.3.50      0   FULL/  -        00:00:38    11.1.1.2        Serial0/1
192.168.1.50      0   FULL/  -        00:00:32    10.1.1.1        Serial0/0
R2#
```

R3:

```
R3#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.2.50      0   FULL/  -        00:00:38    11.1.1.1        Serial0/0
R3#
```

Step 10: Now you can ping any indirect connection because we have done OSPF on the router

PC1:

```
PC1> ping 192.168.2.1
84 bytes from 192.168.2.1 icmp_seq=1 ttl=62 time=30.625 ms
84 bytes from 192.168.2.1 icmp_seq=2 ttl=62 time=31.673 ms
84 bytes from 192.168.2.1 icmp_seq=3 ttl=62 time=31.086 ms
84 bytes from 192.168.2.1 icmp_seq=4 ttl=62 time=32.033 ms
84 bytes from 192.168.2.1 icmp_seq=5 ttl=62 time=30.866 ms

PC1> ping 192.168.3.1
84 bytes from 192.168.3.1 icmp_seq=1 ttl=61 time=30.383 ms
84 bytes from 192.168.3.1 icmp_seq=2 ttl=61 time=31.169 ms
84 bytes from 192.168.3.1 icmp_seq=3 ttl=61 time=31.627 ms
84 bytes from 192.168.3.1 icmp_seq=4 ttl=61 time=32.294 ms
84 bytes from 192.168.3.1 icmp_seq=5 ttl=61 time=30.392 ms
```

PC2:

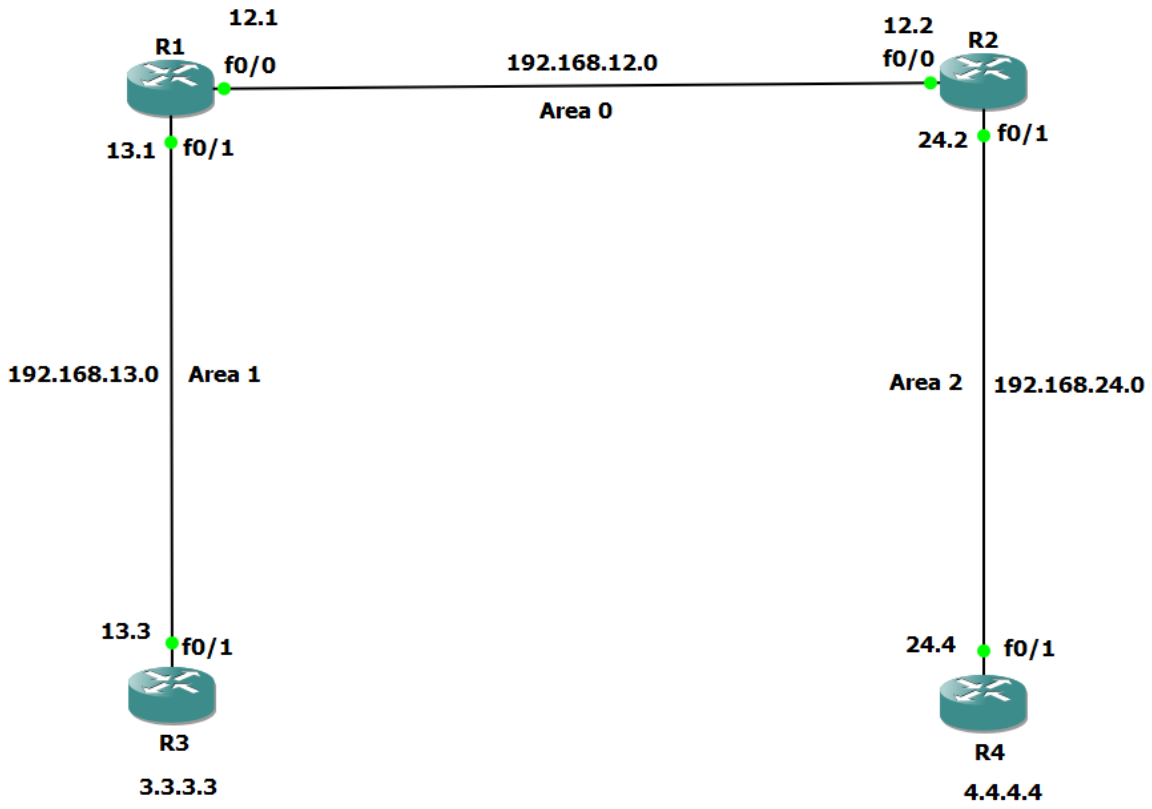
```
PC2> ping 192.168.1.1
84 bytes from 192.168.1.1 icmp_seq=1 ttl=62 time=33.201 ms
84 bytes from 192.168.1.1 icmp_seq=2 ttl=62 time=31.573 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=62 time=31.593 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=62 time=31.112 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=62 time=31.375 ms

PC2> ping 192.168.3.1
84 bytes from 192.168.3.1 icmp_seq=1 ttl=62 time=30.396 ms
84 bytes from 192.168.3.1 icmp_seq=2 ttl=62 time=31.642 ms
84 bytes from 192.168.3.1 icmp_seq=3 ttl=62 time=30.955 ms
84 bytes from 192.168.3.1 icmp_seq=4 ttl=62 time=30.748 ms
84 bytes from 192.168.3.1 icmp_seq=5 ttl=62 time=31.719 ms
```

PC3:

```
PC3> ping 192.168.1.1
84 bytes from 192.168.1.1 icmp_seq=1 ttl=61 time=32.139 ms
84 bytes from 192.168.1.1 icmp_seq=2 ttl=61 time=31.737 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=61 time=31.181 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=61 time=31.833 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=61 time=31.057 ms

PC3> ping 192.168.2.1
84 bytes from 192.168.2.1 icmp_seq=1 ttl=62 time=31.885 ms
84 bytes from 192.168.2.1 icmp_seq=2 ttl=62 time=31.086 ms
84 bytes from 192.168.2.1 icmp_seq=3 ttl=62 time=31.047 ms
84 bytes from 192.168.2.1 icmp_seq=4 ttl=62 time=31.247 ms
84 bytes from 192.168.2.1 icmp_seq=5 ttl=62 time=31.365 ms
```

2. Implement Multi-Area OSPFv2

Step 1: Take 4 router and make a network as below.



Step 2: Configure all the network as below

R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int f0/0
R1(config-if)#ip address 192.168.12.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:02:59.131: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:00.131: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#int f0/1
R1(config-if)#ip address 192.168.13.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:03:41.523: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:03:42.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#do write
Building configuration...
[OK]
```

R2:

```
R2#en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int f0/0
R2(config-if)#ip address 192.168.12.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:03:57.747: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:58.747: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#int f0/1
R2(config-if)#ip address 192.168.24.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
*Mar  1 00:05:02.327: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:05:03.327: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config-if)#exit
R2(config)#do write
Building configuration...
[OK]
```

R3:

```
R3#en
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int f0/1
R3(config-if)#ip address 192.168.13.3 255.255.255.0
R3(config-if)# no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:05:24.451: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:05:25.451: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R3(config)# int loopback 0
R3(config-if)#ip address
*Mar  1 00:05:35.667: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip address 3.3.3.3 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#do write
Building configuration...
[OK]
```

R4:

```
R4#en
R4#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#int f0/1
R4(config-if)#ip address 192.168.24.4 255.255.255.0
R4(config-if)#no shut
R4(config-if)#exit
R4(config)#int
*Mar  1 00:09:53.183: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:09:54.183: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R4(config)#int loopback 0
R4(config-if)#ip addr
*Mar  1 00:10:16.207: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R4(config-if)#ip address 4.4.4.4 255.255.255.255
R4(config-if)#no shut
R4(config-if)#exit
R4(config)#do write
Building configuration...
[OK]
```

Step 3: Now try to ping any router. It won't work because there is no Protocol applied.

So now we will apply Multi – Area OSPFv2(Area 0, 1, 2). Configure the system for Multi – Area OSPFv2 as below:

R1:

```
R1(config)#router ospf 1
R1(config-router)#network 192.168.12.0 0.0.0.255 area 0
R1(config-router)#network 192.168.13.0 0.0.0.255 area 1
R1(config-router)#exit
R1(config)#do write
Building configuration...
[OK]
```

R2:

```
R2(config)#router ospf 1
R2(config-router)#network 192.168.12.0 0.0.0.255 area 0
R2(config-router)#
*Mar  1 00:12:53.215: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.13.1 on FastEthernet0/0 from LOADING to FULL, Loadin
g Done
R2(config-router)#network 192.168.24.0 0.0.0.255 area 2
R2(config-router)#exit
R2(config)#do write
Building configuration...
[OK]
```

R3:

```
R3(config)#router ospf 1
R3(config-router)#network 192.168.13.0 0.0.0.255 area 1
R3(config-router)#network
*Mar  1 00:13:08.091: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.13.1 on FastEthernet0/1 from LOADING to FULL, Loading Done
R3(config-router)#network 3.3.3.3 0.0.0.0 area 1
R3(config-router)#exit
R3(config)#do write
Building configuration...
[OK]
```

R4:

```
R4(config)#router ospf 1
R4(config-router)#network 192.168.24.0 0.0.0.255 area 2
R4(config-router)#
*Mar  1 00:16:59.167: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.24.2 on FastEthernet0/1 from LOADING to FULL, Loading Done
R4(config-router)#network 4.4.4.4 0.0.0.0 area 2
R4(config-router)#exit
R4(config)#do write
Building configuration...
[OK]
```

Step 4: Enter the command 'show ip route ospf' to check whether OSPF is successfully configured.

R1:

```
R1#show ip route ospf
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/11] via 192.168.13.3, 00:03:07, FastEthernet0/1
     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/21] via 192.168.12.2, 00:01:40, FastEthernet0/0
O IA 192.168.24.0/24 [110/20] via 192.168.12.2, 00:04:59, FastEthernet0/0
```

R2:

```
R2#show ip route ospf
O IA 192.168.13.0/24 [110/20] via 192.168.12.1, 00:06:03, FastEthernet0/0
     3.0.0.0/32 is subnetted, 1 subnets
O IA    3.3.3.3 [110/21] via 192.168.12.1, 00:04:05, FastEthernet0/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.24.4, 00:02:37, FastEthernet0/1
```

R3:

```
R3#show ip route ospf
O IA 192.168.12.0/24 [110/20] via 192.168.13.1, 00:05:02, FastEthernet0/1
     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/31] via 192.168.13.1, 00:03:11, FastEthernet0/1
O IA 192.168.24.0/24 [110/30] via 192.168.13.1, 00:05:02, FastEthernet0/1
```

R4:

```
R4#show ip route ospf
O IA 192.168.12.0/24 [110/20] via 192.168.24.2, 00:03:55, FastEthernet0/1
O IA 192.168.13.0/24 [110/30] via 192.168.24.2, 00:03:55, FastEthernet0/1
     3.0.0.0/32 is subnetted, 1 subnets
O IA    3.3.3.3 [110/31] via 192.168.24.2, 00:03:55, FastEthernet0/1
```

Step 5: To check the neighbor enter ‘show ip ospf neighbor’ and check the neighbor

R1:

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.24.2      1   FULL/BDR        00:00:36    192.168.12.2    FastEthernet0/0
3.3.3.3           1   FULL/BDR        00:00:32    192.168.13.3    FastEthernet0/1
```

R2:

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.13.1      1   FULL/DR         00:00:37    192.168.12.1    FastEthernet0/0
4.4.4.4           1   FULL/BDR        00:00:32    192.168.24.4    FastEthernet0/1
```

R3:

```
R3#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.13.1      1   FULL/DR         00:00:29    192.168.13.1    FastEthernet0/1
```

R4:

```
R4#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.24.2      1   FULL/DR         00:00:37    192.168.24.2    FastEthernet0/1
```

As now we have successfully configured and checked that OSPF multi-Area is there in our network. Try pinging any router or loopback from any router.

Step 6:

R1:

```
R1#ping 192.168.13.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.13.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/30/32 ms
R1#ping 192.168.24.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.24.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/60/80 ms
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 = 28/35/52 ms
R1#ping 4.4.4.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 4.4.4.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/58/64 ms
```

R2:

```
R2#ping 192.168.13.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.13.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/56/64 ms
R2#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 = 40/58/72 ms
R2#ping 4.4.4.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 4.4.4.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/30/32 ms
```

R3:

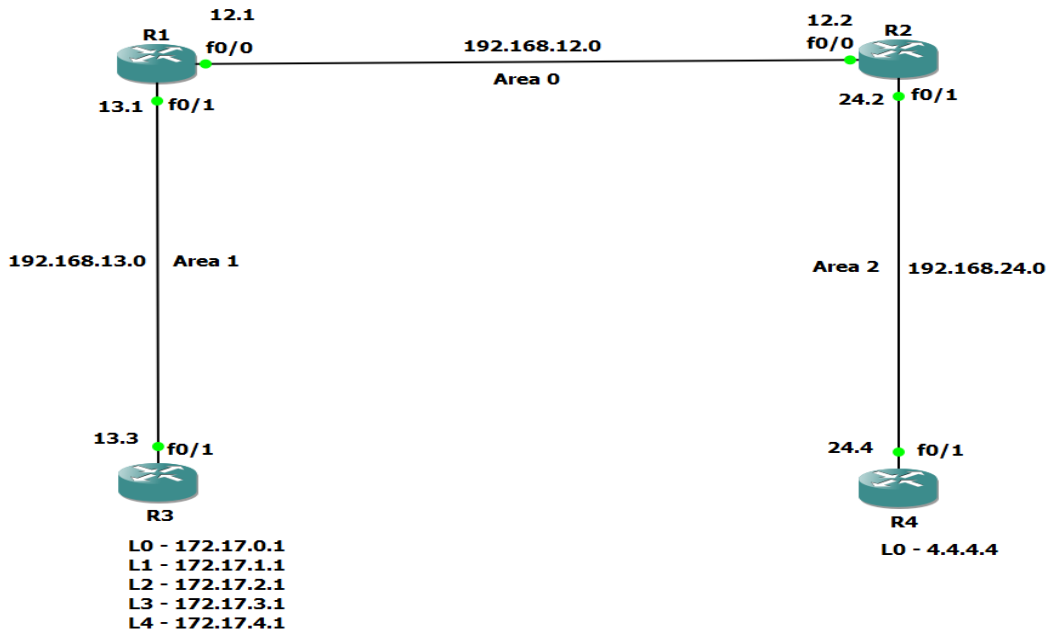
```
R3#ping 192.168.12.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/56/64 ms
R3#ping 192.168.24.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.24.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 72/92/108 ms
R3#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 = 1/1/1 ms
R3#ping 4.4.4.4

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 4.4.4.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 76/88/96 ms
```

R4:

```
R4#ping 192.168.13.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.13.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/56/64 ms
R4#ping 192.168.12.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/60/68 ms
R4#ping 192.168.13.3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.13.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/93/112 ms
R4#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 = 80/88/92 ms
```

3. OSPFv2 Route Summarization and Filtering

Step 1: Follow the same Topology as the Multi – Area OSPFv2.



Step 2: Add more loopbacks to Router 3 and configure the OSPF accordingly.

```
R3#en
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int loopback 0
R3(config-if)#ip address 172.17.0.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int loopback 1
R3(config-if)#
*Mar  1 00:36:38.787: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R3(config-if)#ip address 172.17.1.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int loopback 2
R3(config-if)#
*Mar  1 00:37:13.779: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
R3(config-if)#ip address 172.17.2.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int loopback 3
R3(config-if)#
*Mar  1 00:37:53.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed state to up
R3(config-if)#ip address 172.17.3.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int loopback 4
R3(config-if)#
*Mar  1 00:38:23.919: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback4, changed state to up
R3(config-if)#ip address 172.17.4.1 255.255.255.255
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#exit
```

Step 3: Enter 'show ip route' on R2 and you will see all the loopback of R3. Because till now we haven't performed any summarization on R1.

```
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

C    192.168.12.0/24 is directly connected, FastEthernet0/1
C    192.168.13.0/24 is directly connected, FastEthernet0/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.13.1, 01:05:18, FastEthernet0/0
     172.17.0.0/32 is subnetted, 5 subnets
O IA    172.17.4.1 [110/21] via 192.168.12.1, 00:01:39, FastEthernet0/1
O IA    172.17.0.1 [110/21] via 192.168.12.1, 00:12:42, FastEthernet0/1
O IA    172.17.1.1 [110/21] via 192.168.12.1, 00:12:32, FastEthernet0/1
O IA    172.17.2.1 [110/21] via 192.168.12.1, 00:12:33, FastEthernet0/1
O IA    172.17.3.1 [110/21] via 192.168.12.1, 00:12:17, FastEthernet0/1
O IA 192.168.11.0/24 [110/20] via 192.168.12.1, 01:08:31, FastEthernet0/1
```

Step 4: So now we will perform summarization on R1

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#area 1 range 172.17.0.0 255.255.252.0
R1(config-router)#end
R1#
*Mar  1 02:01:03.271: %SYS-5-CONFIG_I: Configured from console by console
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.12.0/24 is directly connected, FastEthernet0/1
O IA 192.168.13.0/24 [110/20] via 192.168.12.2, 00:00:20, FastEthernet0/1
     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/21] via 192.168.12.2, 00:00:20, FastEthernet0/1
     172.17.0.0/16 is variably subnetted, 7 subnets, 3 masks
O       172.17.4.1/32 [110/11] via 192.168.11.1, 00:00:20, FastEthernet0/0
O       172.17.0.1/32 [110/11] via 192.168.11.1, 00:00:20, FastEthernet0/0
O       172.17.1.1/32 [110/11] via 192.168.11.1, 00:00:22, FastEthernet0/0
O       172.17.0.0/24 is a summary, 00:00:22, Null0
O       172.17.0.0/22 is a summary, 00:00:22, Null0
O       172.17.2.1/32 [110/11] via 192.168.11.1, 00:00:22, FastEthernet0/0
O       172.17.3.1/32 [110/11] via 192.168.11.1, 00:00:22, FastEthernet0/0
C    192.168.11.0/24 is directly connected, FastEthernet0/0
```

Step 5: Once again we will go to R2 and enter the command ‘show ip route’. Now we have done

summarization on R1 so we will see only 2 loopbacks of R3.

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.12.0/24 is directly connected, FastEthernet0/1
C    192.168.13.0/24 is directly connected, FastEthernet0/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.13.1, 01:12:12, FastEthernet0/0
     172.17.0.0/16 is variably subnetted, 3 subnets, 3 masks
O IA    172.17.4.1/32 [110/21] via 192.168.12.1, 00:08:33, FastEthernet0/1
O IA    172.17.0.0/24 [110/21] via 192.168.12.1, 00:00:54, FastEthernet0/1
O IA    172.17.0.0/22 [110/21] via 192.168.12.1, 00:00:54, FastEthernet0/1
O IA 192.168.11.0/24 [110/20] via 192.168.12.1, 01:15:25, FastEthernet0/1
```

That’s how we do summarization.

Step 6: And now you can ping any loopback of R3 from any router. Just to confirm I have pinged the loopback of R3 via R4.

```
R4#ping 172.17.3.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/63/68 ms
R4#ping 172.17.4.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.4.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/64/72 ms
R4#ping 172.17.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/44/68 ms
```

I have pinged the loopback of R3 via R1.

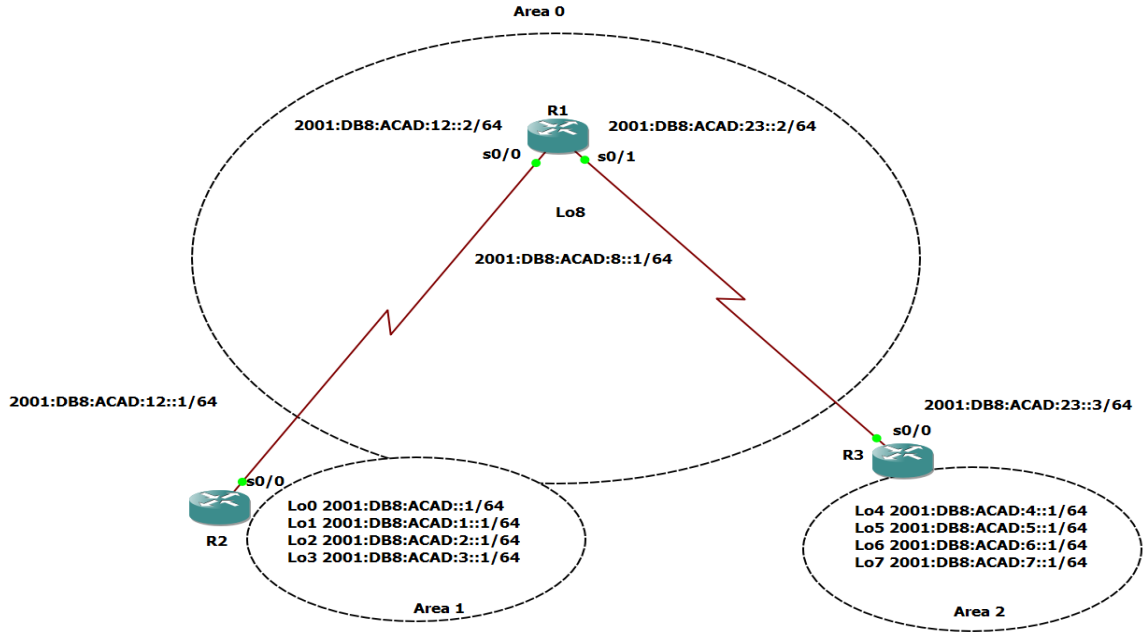
```
R1#ping 172.17.2.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/40/64 ms
R1#ping 172.17.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/25/36 ms
R1#ping 172.17.3.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/27/40 ms
R1#ping 172.17.4.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.4.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/27/32 ms
```

I have pinged the loopback of R3 via R2.

```
R2#ping 172.17.2.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/61/72 ms
R2#ping 172.17.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/60/72 ms
R2#ping 172.17.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/60/64 ms
R2#ping 172.17.3.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/59/60 ms
R2#ping 172.17.4.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.17.4.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/59/72 ms
```

4. Implement Multiarea OSPFv3

Step 1: Build the topology



Step 2: Configure IP's address and Loopback in all the router according to the topology

We will use IPv6 for OSPF version 3 ,There's a different command for IPv6 configuration. Follow as below.

R1:

```
R1#
*Mar  1 00:13:56.795: %SYS-5-CONFIG_I: Configured from console by console
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#int s0/0
R1(config-if)#no shut
R1(config-if)#ipv6 address 2001:DB8:ACAD:12::1/64
R1(config-if)#no shut
R1(config-if)#int L0
R1(config-if)#ipv6 address 2001:DB8:ACAD::1/64
R1(config-if)#no shut
R1(config-if)#int L1
R1(config-if)#ipv6 address 2001:DB8:ACAD:1::1/64
R1(config-if)#no shut
R1(config-if)#int L2
R1(config-if)#no shut
R1(config-if)#
*Mar  1 00:18:50.559: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
R1(config-if)#ipv6 address 2001:DB8:ACAD:2::1/64
R1(config-if)#no shut
R1(config-if)#int L3
R1(config-if)#no shut'
*Mar  1 00:19:33.259: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed state to up
R1(config-if)#no shut
R1(config-if)#ipv6 address 2001:DB8:ACAD:3::1/64
R1(config-if)#no shut
R1(config-if)#do wr
Building configuration...
[OK]
```

R2:

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int s0/0
R2(config-if)#no shut
R2(config-if)#
*Mar  1 00:13:13.903: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar  1 00:13:14.903: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R2(config-if)#ipv6 address 2001:DB8:ACAD:12::2/64
R2(config-if)#no shut
R2(config-if)#int s0/1
R2(config-if)#no shut
R2(config-if)#
*Mar  1 00:14:36.619: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
R2(config-if)#
*Mar  1 00:14:37.623: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R2(config-if)#ipv6 address 2001:DB8:ACAD:23::2/64
*Mar  1 00:15:03.203: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to down
R2(config-if)#ipv6 address 2001:DB8:ACAD:23::2/64
R2(config-if)#no shut
R2(config-if)#int L8
R2(config-if)#
*Mar  1 00:16:49.347: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback8, changed state to up
R2(config-if)#ipv6 address 2001:DB8:ACAD:8::1/64
R2(config-if)#no shut
R2(config-if)#do wr
Building configuration...
[OK]
R2(config-if)#
```

R3:

```
R3#en
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int s0/1
R3(config-if)#no shut
R3(config-if)#ipv6 add
*Mar  1 01:11:29.955: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
*Mar  1 01:11:30.955: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R3(config-if)#ipv6 address 2001:DB8:ACAD:23::3/64
R3(config-if)#no shut
R3(config-if)#int L4
R3(config-if)#no shut
*Mar  1 01:11:59.163: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback4, changed state to up
R3(config-if)#no shut
R3(config-if)#ipv6 add
R3(config-if)#ipv6 address 2001:DB8:ACAD:4::1/64
R3(config-if)#no shut
R3(config-if)#int L5
R3(config-if)#no shut
R3(config-if)#
*Mar  1 01:12:26.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback5, changed state to up
R3(config-if)#ipv6 add
R3(config-if)#ipv6 address 2001:DB8:ACAD:5::1/64
R3(config-if)#no shut
R3(config-if)#int L6
R3(config-if)#no shut
*Mar  1 01:12:57.535: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback6, changed state to up
R3(config-if)#no shut
R3(config-if)#ipv6 ad
R3(config-if)#ipv6 address 2001:DB8:ACAD:6::1/64
R3(config-if)#no shut
R3(config-if)#int L7
R3(config-if)#no
*Mar  1 01:13:26.687: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback7, changed state to up
R3(config-if)#no shut
R3(config-if)#ipv6 add
R3(config-if)#ipv6 address 2001:DB8:ACAD:7::1/64
R3(config-if)#no shut
R3(config-if)#do wr
Building configuration...
[OK]
R3(config-if)#ex
```

Step 3: Once IP is assigned to all. We have to do IPv6 unicast. And we have to assign router ID to the routers.

R1:

```
*Mar  1 00:22:53.199: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R1(config)#ipv6 unicast-routing
R1(config)#do wr
Building configuration...
[OK]
R1(config)#ipv6 router ospf 1
R1(config-rtr)#
*Mar  1 00:45:26.915: %OSPFv3-4-NORTRID: OSPFv3 process 1 could not pick a router-id,
please configure manually
R1(config-rtr)#router-id 1.1.1.1
R1(config-rtr)#do sh ipv6 ospf
 Routing Process "ospfv3 1" with ID 1.1.1.1
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 0. 0 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps

R1(config-rtr)#
```

R2:

```
R2(config-if)#
*Mar  1 00:28:53.835: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R2(config-if)#exit
R2(config)#ipv6 unicast-routing
R2(config)#do wr
Building configuration...
[OK]
R2(config)#ipv6 router ospf 1
R2(config-rtr)#
*Mar  1 00:38:34.715: %OSPFv3-4-NORTRID: OSPFv3 process 1 could not pick a router-id,
please configure manually
R2(config-rtr)#router-id 2.2.2.2
R2(config-rtr)#do sh ipv6 ospf
 Routing Process "ospfv3 1" with ID 2.2.2.2
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 0. 0 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps

R2(config-rtr)#
```

R3:

```
R3(config)#ipv6 unicast-routing
R3(config)#do wr
Building configuration...
[OK]
R3(config)#ipv6 router ospf 1
R3(config-rtr)#
*Mar  1 00:33:05.611: %OSPFv3-4-NORTRID: OSPFv3 process 1 could not pick a router-id,
please configure manually
R3(config-rtr)#router-id 3.3.3.3
R3(config-rtr)#do sh ipv6 ospf
 Routing Process "ospfv3 1" with ID 3.3.3.3
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 0. 0 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps

R3(config-rtr)#
```

Step 4: Now we will configure multi-area OSPFv3 in all the router.

R1:

```
R1(config-rtr)#exit
R1(config)#int L0
R1(config-if)#ipv6 ospf 1 area 1
R1(config-if)#ipv6 ospf network point-to-point
R1(config-if)#int L1
R1(config-if)#ipv6 ospf 1 area 1
R1(config-if)#ipv6 ospf network point-to-point
R1(config-if)#int L2
R1(config-if)#ipv6 ospf 1 area 1
R1(config-if)#ipv6 ospf network point-to-point
R1(config-if)#int L3
R1(config-if)#ipv6 ospf 1 area 1
R1(config-if)#ipv6 ospf network point-to-point
R1(config-if)#int s0/0
R1(config-if)#ipv6 ospf 1 area 0
R1(config-if)#do wr
Building configuration...
[OK]
R1(config-if)#exit
R1(config)#
```

R2:

```
R2(config-rtr)#exit
R2(config)#int s0/0\
                 ^
% Invalid input detected at '^' marker.

R2(config)#int s0/0
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#
*Mar  1 00:51:02.843: %OSPFv3-5-ADJCHG: Process 1, Nbr 1.1.1.1 on Serial0/0 from LOADING to FULL, Loading Done
R2(config-if)#int s0/1
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#int L8
R2(config-if)#ipv6 ospf 1 area 0
R2(config-if)#ipv6 ospf network point-to-point
R2(config-if)#do wr
Building configuration...
[OK]
R2(config-if)#
```

R3:

```
R3(config)#
R3(config)#int L4
R3(config-if)#ipv6 ospf 1 area 2
R3(config-if)#ipv6 ospf network point-to-point
R3(config-if)#int L5
R3(config-if)#ipv6 ospf 1 area 2
R3(config-if)#ipv6 ospf network point-to-point
R3(config-if)#int L6
R3(config-if)#ipv6 ospf 1 area 2
R3(config-if)#ipv6 ospf network point-to-point
R3(config-if)#int L7
R3(config-if)#ipv6 ospf 1 area 2
R3(config-if)#ipv6 ospf network point-to-point
R3(config-if)#int s0/1
R3(config-if)#ipv6 ospf 1 area 0
R3(config-if)#
*Mar  1 00:52:01.027: %OSPFv3-5-ADJCHG: Process 1, Nbr 2.2.2.2 on Serial0/1 from LOADING to FULL, Loading Done
R3(config-if)#do wr
Building configuration...
[OK]
R3(config-if)#
```

Step 5: Use the show ipv6 protocols command to verify multi-area OSPFv3 status.

R1:

```
R1(config)#do sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Interfaces (Area 0):
    Serial0/0
  Interfaces (Area 1):
    Loopback3
    Loopback2
    Loopback1
    Loopback0
  Redistribution:
    None
R1(config)#
```

R2:

```
R2(config-if)#exit
R2(config)#do sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Interfaces (Area 0):
    Loopback8
    Serial0/1
    Serial0/0
  Redistribution:
    None
R2(config)#
```

R3:

```
R3(config)#do sh ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "static"
IPv6 Routing Protocol is "ospf 1"
  Interfaces (Area 0):
    Serial0/1
  Interfaces (Area 2):
    Loopback7
    Loopback6
    Loopback5
    Loopback4
  Redistribution:
    None
R3(config)#
```

Step 6: Use the 'show ipv6 ospf' command to verify configurations.

R1:

```
R1#show ipv6 ospf
 Routing Process "ospfv3 1" with ID 1.1.1.1
 It is an area border router
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 2. 2 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps
    Area BACKBONE(0)
        Number of interfaces in this area is 1
        SPF algorithm executed 4 times
        Number of LSA 16. Checksum Sum 0x096D03
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
    Area 1
        Number of interfaces in this area is 4
        SPF algorithm executed 8 times
        Number of LSA 14. Checksum Sum 0x06D8BB
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0

R1#
```

R2:

```
R2#show ipv6 ospf
 Routing Process "ospfv3 1" with ID 2.2.2.2
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps
    Area BACKBONE(0)
        Number of interfaces in this area is 3
        SPF algorithm executed 2 times
        Number of LSA 19. Checksum Sum 0x0AADC7
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
```

R3:

```
R3(config)#exit
R3#
*Mar  1 00:58:44.667: %SYS-5-CONFIG_I: Configured from console by console
R3#show ipv6 ospf
 Routing Process "ospfv3 1" with ID 3.3.3.3
 It is an area border router
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of areas in this router is 2. 2 normal 0 stub 0 nssa
 Reference bandwidth unit is 100 mbps
    Area BACKBONE(0)
        Number of interfaces in this area is 1
        SPF algorithm executed 2 times
        Number of LSA 16. Checksum Sum 0x09AFEC
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
    Area 2
        Number of interfaces in this area is 4
        SPF algorithm executed 7 times
        Number of LSA 14. Checksum Sum 0x04BBAA
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0

R3#
```

Step 7: Verify OSPFv3 neighbors and routing information.

R1:

```
R1#sh ipv6 ospf neighbor

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
2.2.2.2           1   FULL/  -        00:00:38    6               Serial0/0
R1#
```

R2:

```
R2#sh ipv6 ospf neighbor

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
3.3.3.3           1   FULL/  -        00:00:33    7               Serial0/1
1.1.1.1           1   FULL/  -        00:00:36    6               Serial0/0
R2#
```

R3:

```
R3#sh ipv6 ospf neighbor

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
2.2.2.2           1   FULL/  -        00:00:31    7               Serial0/1
R3#
```

Step 8: Check 'show ipv6 route ospf ' to see the OSPF configuration

R1:

```
R1#show ipv6 route ospf
IPv6 Routing Table - 19 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
OI  2001:DB8:ACAD:4::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/0
OI  2001:DB8:ACAD:5::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/0
OI  2001:DB8:ACAD:6::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/0
OI  2001:DB8:ACAD:7::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/0
O   2001:DB8:ACAD:8::/64 [110/65]
     via FE80::C002:12FF:FEE8:0, Serial0/0
O   2001:DB8:ACAD:23::/64 [110/128]
     via FE80::C002:12FF:FEE8:0, Serial0/0
R1#
```

R2:

```
R2#sh ipv6 route ospf
IPv6 Routing Table - 16 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
OI  2001:DB8:ACAD::/64 [110/65]
     via FE80::C001:4BFF:FE90:0, Serial0/0
OI  2001:DB8:ACAD:1::/64 [110/65]
     via FE80::C001:4BFF:FE90:0, Serial0/0
OI  2001:DB8:ACAD:2::/64 [110/65]
     via FE80::C001:4BFF:FE90:0, Serial0/0
OI  2001:DB8:ACAD:3::/64 [110/65]
     via FE80::C001:4BFF:FE90:0, Serial0/0
OI  2001:DB8:ACAD:4::/64 [110/65]
     via FE80::C003:48FF:FEDC:0, Serial0/1
OI  2001:DB8:ACAD:5::/64 [110/65]
     via FE80::C003:48FF:FEDC:0, Serial0/1
OI  2001:DB8:ACAD:6::/64 [110/65]
     via FE80::C003:48FF:FEDC:0, Serial0/1
OI  2001:DB8:ACAD:7::/64 [110/65]
     via FE80::C003:48FF:FEDC:0, Serial0/1
O   2001:DBB:ACAD:12::/64 [110/128]
     via FE80::C001:4BFF:FE90:0, Serial0/0
R2#
```

R3:

```
R3#sh ipv6 route ospf
IPv6 Routing Table - 18 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
OI  2001:DB8:ACAD::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/1
OI  2001:DB8:ACAD:1::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/1
OI  2001:DB8:ACAD:2::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/1
OI  2001:DB8:ACAD:3::/64 [110/129]
     via FE80::C002:12FF:FEE8:0, Serial0/1
O   2001:DB8:ACAD:8::/64 [110/65]
     via FE80::C002:12FF:FEE8:0, Serial0/1
O   2001:DB8:ACAD:12::/64 [110/128]
     via FE80::C002:12FF:FEE8:0, Serial0/1
O   2001:DBB:ACAD:12::/64 [110/192]
     via FE80::C002:12FF:FEE8:0, Serial0/1
R3#
```

Step 9: Issue the 'show ipv6 ospf database' command on all routers to check the IPv6 OSPF Database.

R1:

```
R1#sh ipv6 ospf database

            OSPFv3 Router with ID (1.1.1.1) (Process ID 1)

                Router Link States (Area 0)

ADV Router      Age         Seq#       Fragment ID  Link count  Bits
1.1.1.1         1183        0x80000002 0            1           B
2.2.2.2         685         0x80000005 0            2           None
3.3.3.3         686         0x80000001 0            1           B

                Inter Area Prefix Link States (Area 0)

ADV Router      Age         Seq#       Prefix
1.1.1.1         1632        0x80000001 2001:DB8:ACAD:3::/64
1.1.1.1         1632        0x80000001 2001:DB8:ACAD:2::/64
1.1.1.1         1632        0x80000001 2001:DB8:ACAD:1::/64
1.1.1.1         1632        0x80000001 2001:DB8:ACAD::/64
3.3.3.3         687         0x80000001 2001:DB8:ACAD:7::/64
3.3.3.3         687         0x80000001 2001:DB8:ACAD:6::/64
3.3.3.3         687         0x80000001 2001:DB8:ACAD:5::/64
3.3.3.3         687         0x80000001 2001:DB8:ACAD:4::/64

                Link (Type-8) Link States (Area 0)

ADV Router      Age         Seq#       Link ID    Interface
1.1.1.1         1635        0x80000001 6          Se0/0
2.2.2.2         1188        0x80000001 6          Se0/0

                Intra Area Prefix Link States (Area 0)

ADV Router      Age         Seq#       Link ID    Ref-lstype  Ref-LSID
1.1.1.1         1636        0x80000001 0          0x2001      0
2.2.2.2         1091        0x80000004 0          0x2001      0
3.3.3.3         693         0x80000001 0          0x2001      0

                Router Link States (Area 1)

ADV Router      Age         Seq#       Fragment ID  Link count  Bits
1.1.1.1         1639        0x80000009 0            0           B

                Inter Area Prefix Link States (Area 1)

ADV Router      Age         Seq#       Prefix
1.1.1.1         1631        0x80000001 2001:DB8:ACAD:12::/64
1.1.1.1         1632        0x80000001 2001:DBB:ACAD:12::/64
1.1.1.1         1134        0x80000001 2001:DB8:ACAD:23::/64
1.1.1.1         1088        0x80000001 2001:DB8:ACAD:8::/64
1.1.1.1         690         0x80000001 2001:DB8:ACAD:4::/64
1.1.1.1         690         0x80000001 2001:DB8:ACAD:5::/64
1.1.1.1         690         0x80000001 2001:DB8:ACAD:6::/64
1.1.1.1         691         0x80000001 2001:DB8:ACAD:7::/64

                Link (Type-8) Link States (Area 1)

ADV Router      Age         Seq#       Link ID    Interface
1.1.1.1         1665        0x80000001 33         Lo3
1.1.1.1         1678        0x80000001 32         Lo2
1.1.1.1         1687        0x80000001 31         Lo1
1.1.1.1         1699        0x80000001 30         Lo0

                Intra Area Prefix Link States (Area 1)

ADV Router      Age         Seq#       Link ID    Ref-lstype  Ref-LSID
1.1.1.1         1663        0x80000008 0          0x2001      0
```

R2:

```
R2#sh ipv6 ospf database

            OSPFv3 Router with ID (2.2.2.2) (Process ID 1)

                Router Link States (Area 0)

ADV Router      Age         Seq#        Fragment ID  Link count  Bits
1.1.1.1         1335        0x80000002  0            1           B
2.2.2.2         836         0x80000005  0            2           None
3.3.3.3         837         0x80000001  0            1           B

                Inter Area Prefix Link States (Area 0)

ADV Router      Age         Seq#        Prefix
1.1.1.1         1784        0x80000001  2001:DB8:ACAD:3::/64
1.1.1.1         1784        0x80000001  2001:DB8:ACAD:2::/64
1.1.1.1         1784        0x80000001  2001:DB8:ACAD:1::/64
1.1.1.1         1784        0x80000001  2001:DB8:ACAD::/64
3.3.3.3         837         0x80000001  2001:DB8:ACAD:7::/64
3.3.3.3         837         0x80000001  2001:DB8:ACAD:6::/64
3.3.3.3         837         0x80000001  2001:DB8:ACAD:5::/64
3.3.3.3         837         0x80000001  2001:DB8:ACAD:4::/64

                Link (Type-8) Link States (Area 0)

ADV Router      Age         Seq#        Link ID    Interface
2.2.2.2         1237        0x80000001  30         Lo8
2.2.2.2         1283        0x80000001  7          Se0/1
3.3.3.3         840         0x80000001  7          Se0/1
1.1.1.1         1787        0x80000001  6          Se0/0
2.2.2.2         1337        0x80000001  6          Se0/0

                Intra Area Prefix Link States (Area 0)

ADV Router      Age         Seq#        Link ID    Ref-lstype  Ref-LSID
1.1.1.1         1787        0x80000001  0          0x2001      0
2.2.2.2         1239        0x80000004  0          0x2001      0
3.3.3.3         842         0x80000001  0          0x2001      0
```

R3:

```
R3#sh ipv6 ospf database

            OSPFv3 Router with ID (3.3.3.3) (Process ID 1)

                Router Link States (Area 0)

ADV Router      Age         Seq#        Fragment ID  Link count  Bits
1.1.1.1         1386        0x80000002  0            1           B
2.2.2.2         887         0x80000005  0            2           None
3.3.3.3         886         0x80000001  0            1           B

                Inter Area Prefix Link States (Area 0)

ADV Router      Age         Seq#        Prefix
1.1.1.1         15          0x80000002  2001:DB8:ACAD:3::/64
1.1.1.1         15          0x80000002  2001:DB8:ACAD:2::/64
1.1.1.1         15          0x80000002  2001:DB8:ACAD:1::/64
1.1.1.1         15          0x80000002  2001:DB8:ACAD::/64
3.3.3.3         887         0x80000001  2001:DB8:ACAD:7::/64
3.3.3.3         887         0x80000001  2001:DB8:ACAD:6::/64
3.3.3.3         887         0x80000001  2001:DB8:ACAD:5::/64
3.3.3.3         887         0x80000001  2001:DB8:ACAD:4::/64

                Link (Type-8) Link States (Area 0)

ADV Router      Age         Seq#        Link ID    Interface
2.2.2.2         1335        0x80000001  7          Se0/1
3.3.3.3         891         0x80000001  7          Se0/1

                Intra Area Prefix Link States (Area 0)

ADV Router      Age         Seq#        Link ID    Ref-lstype  Ref-LSID
1.1.1.1         20          0x80000002  0          0x2001      0
2.2.2.2         1291        0x80000004  0          0x2001      0
3.3.3.3         892         0x80000001  0          0x2001      0

                Router Link States (Area 2)

ADV Router      Age         Seq#        Fragment ID  Link count  Bits
3.3.3.3         892         0x80000009  0            0           B

                Inter Area Prefix Link States (Area 2)

ADV Router      Age         Seq#        Prefix
3.3.3.3         884         0x80000001  2001:DB8:ACAD:12::/64
3.3.3.3         885         0x80000001  2001:DB8:ACAD:8::/64
3.3.3.3         885         0x80000001  2001:DB8:ACAD:23::/64
3.3.3.3         886         0x80000001  2001:DB8:ACAD::/64
3.3.3.3         886         0x80000001  2001:DB8:ACAD:1::/64
3.3.3.3         886         0x80000001  2001:DB8:ACAD:2::/64
3.3.3.3         886         0x80000001  2001:DB8:ACAD:3::/64

                Link (Type-8) Link States (Area 2)

ADV Router      Age         Seq#        Link ID    Interface
3.3.3.3         927         0x80000001  33         Lo7
3.3.3.3         941         0x80000001  32         Lo6
3.3.3.3         950         0x80000001  31         Lo5
3.3.3.3         964         0x80000001  30         Lo4

                Intra Area Prefix Link States (Area 2)

ADV Router      Age         Seq#        Link ID    Ref-lstype  Ref-LSID
3.3.3.3         924         0x80000007  0          0x2001      0
```

Now you have successfully configured multi-area OSPF v3 using IPv6

Practical no.7

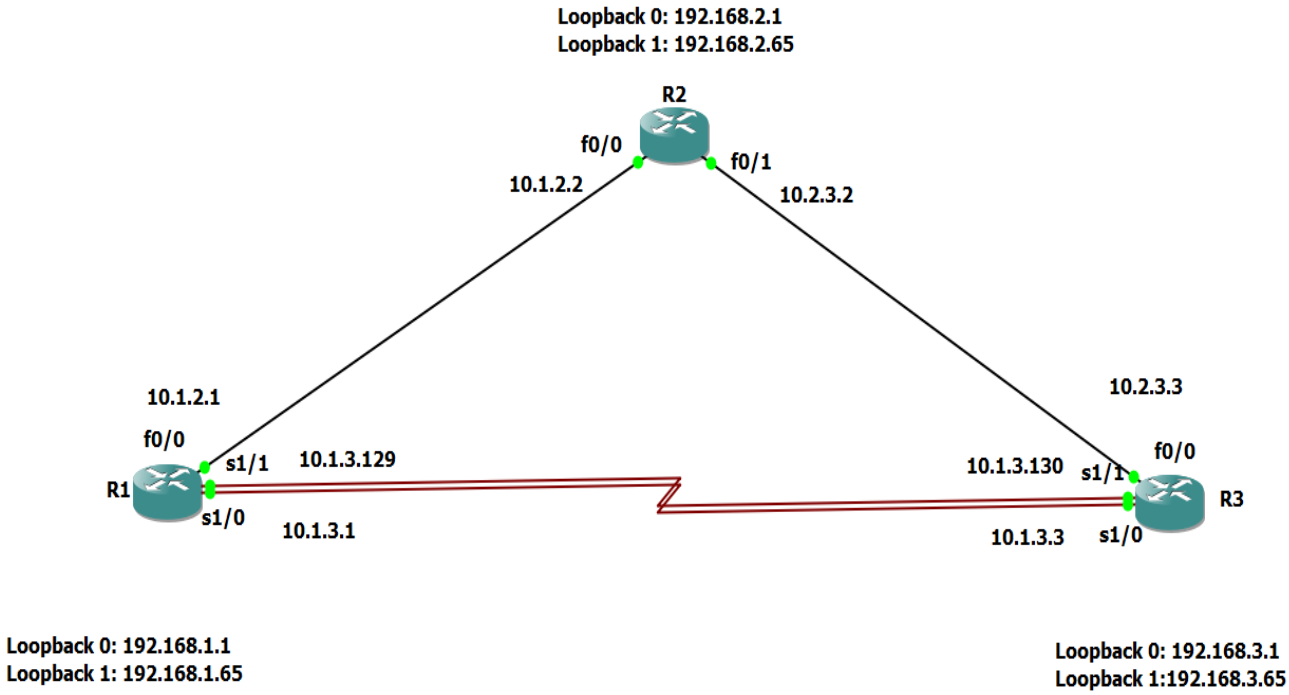
Aim: Implement BGP Communities

1. **Implement eBGP for Ipv4.**
2. **Implement MP (Multi-protocol) -BGP**
3. **Implement BGP path Manipulation**

1. Implement eBGP for Ipv4.

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Step 1: Design the Topology



Step 2: Configure all 3 Routers.

Router R1:

```
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)#exit
R1(config)#Interface loopback 0
R1(config-if)#
*Mar  1 00:15:27.511: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 192.168.1.1 255.255.255.224
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#Interface loopback 1
R1(config-if)#
*Mar  1 00:16:15.115: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R1(config-if)#ip address 192.168.1.65 255.255.255.0
% 192.168.1.0 overlaps with Loopback0
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#Interafce fastethernet 0/0
               ^
% Invalid input detected at '^' marker.

R1(config)#Interface fastethernet 0/0
R1(config-if)#ip address 10.1.2.1 255.255.255.0
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:18:31.619: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:18:32.619: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#interface serial 1/0
R1(config-if)#ip address 10.1.3.1 255.255.255.128
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:19:22.491: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R1(config)#in
*Mar  1 00:19:23.495: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R1(config)#interface serial 1/1
R1(config-if)#ip address 10.1.3.129 255.255.255.128
R1(config-if)#no sh
*Mar  1 00:19:52.887: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to down
R1(config-if)#no shut
R1(config-if)#exit
```

Router R2:

```
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 sync
R2(config-line)#exec-timeout 0 0
R2(config-line)#interface loopback 0
R2(config-if)#ip addre
*Mar  1 00:16:59.211: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip address 192.168.2.1 255.255.255.224
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#interface loopback 1
R2(config-if)#ip ad
*Mar  1 00:17:37.299: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R2(config-if)#ip address 192.168.2.65 225.255.255.192
Bad mask 0xE1FFFFC0 for address 192.168.2.65
R2(config-if)#ip address 192.168.2.65 255.255.255.192
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#interface fastethernet 0/0
R2(config-if)#ip address 10.1.2.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#interface fastethernet 0/1
R2(config-if)#ip address 10.2.3.2 255.255.255.0
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:22:17.323: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:22:18.323: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
```

Router R3:

```
*Mar  1 00:18:25.403: %SYS-5-CONFIG_I: Configured from console by console
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)#exit
R3(config)#int loopback0
R3(config-if)#ip address 192.168.3.1 255.255.255.224
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int loopback1
R3(config-if)#ip address 192.168.3.65 255.255.255.192
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#int fa0/0
R3(config-if)#ip address 10.2.3.3 255.255.255.0
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:21:37.279: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:21:38.279: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config)#int s1/0
R3(config-if)#ip address 10.1.3.3 255.255.255.128
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:22:55.899: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R3(config)#
*Mar  1 00:22:56.903: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R3(config)#int s1/1
R3(config-if)#ip address 10.1.3.130 255.255.255.128
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:23:25.291: %LINK-3-UPDOWN: Interface Serial1/1, changed state to up
R3(config)#
*Mar  1 00:23:26.295: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to up
R3(config)#
```

Part 2: Configure and verify eBGP for IPv4 on all Routers

Step 1: Implement BGP and neighbour relationship on R1

```
R1(config)#router bgp 1000
R1(config-router)#bgp router-id 1.1.1.1
R1(config-router)#neighbor 10.1.2.2 remote-as 500
R1(config-router)#neighbor 10.1.3.3 remote-as 300
R1(config-router)#neighbor 10.1.3.130 remote-as 300
R1(config-router)#network 192.168.1.0 mask 255.255.255.224
R1(config-router)#network 192.168.1.64 mask 255.255.255.192
R1(config-router)#
```

Step 2: Implement BGP and neighbor relationships on R2.

```
R2(config)#router bgp 500
R2(config-router)#bgp router-id 2.2.2.2
R2(config-router)#neighbor 10.1.2.1 remote-as 1000
R2(config-router)#neighbor 10.2.3.3 remote-as 300
*Mar  1 00:37:43.807: %BGP-5-ADJCHANGE: neighbor 10.1.2.1 Up
R2(config-router)#neighbor 10.2.3.3 remote-as 300
R2(config-router)#network 192.168.2.0 mask 255.255.255.224
R2(config-router)#network 192.168.2.64 mask 255.255.255.192
R2(config-router)#
```

Step 3: Implement BGP and neighbor relationships on R3.

```
R3(config)#router bgp 300
R3(config-router)#bgp router-id 3.3.3.3
R3(config-router)#no bgp default ipv4-unicast
R3(config-router)#neighbor 10.2.3.2 remote-as 500
R3(config-router)#neighbor 10.1.3.1 remote-as 1000
R3(config-router)#neighbor 10.1.3.129 remote-as 1000
R3(config-router)#
```

Step 4: Verifying BGP neighbor relationships.

```
R1#show ip route bgp
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.2.64/26 [20/0] via 10.1.2.2, 00:05:37
B       192.168.2.0/27 [20/0] via 10.1.2.2, 00:06:07
R1#
```

```
R2#show ip route bgp
     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.1.64/26 [20/0] via 10.1.2.1, 00:08:16
B       192.168.1.0/27 [20/0] via 10.1.2.1, 00:08:16
R2#
```

```
R2#sh ip bgp neighbors
BGP neighbor is 10.1.2.1,  remote AS 1000, external link
  BGP version 4, remote router ID 1.1.1.1
  BGP state = Established, up for 00:08:58
  Last read 00:00:57, last write 00:00:57, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                2          3
    Keepalives:            11         11
    Route Refresh:          0          0
    Total:                 14         15
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 5, neighbor version 5/0
  Output queue size: 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                               Sent       Rcvd
  Prefix activity:             ----       ----
    Prefixes Current:             2          2 (Consumes 104 bytes)
    Prefixes Total:               2          2
    Implicit Withdraw:            0          0
    Explicit Withdraw:            0          0
    Used as bestpath:           n/a          2
    Used as multipath:          n/a          0

                                  Outbound    Inbound
  Local Policy Denied Prefixes:   --------    -------
    AS_PATH loop:                      n/a          2
    Bestpath from this peer:             2        n/a
    Total:                               2          2
  Number of NLRIs in the update sent: max 1, min 1

  Connections established 1; dropped 0
  Last reset never
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled, Mininum incoming TTL 0, Outgoing TTL 1
Local host: 10.1.2.2, Local port: 179
```

```
Foreign host: 10.1.2.1, Foreign port: 40782
Connection tableid (VRF): 0

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

Event Timers (current time is 0x2B2000):
Timer          Starts    Wakeups            Next
Retrans            15          0             0x0
TimeWait            0          0             0x0
AckHold            14          3             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0
ProcessQ            0          0             0x0

iss: 4009861579  snduna: 4009861959  sndnxt: 4009861959     sndwnd:  16005
irs: 3423027460  rcvnxt: 3423027888  rcvwnd:      15957  delrcvwnd:    427

SRTT: 259 ms, RTTO: 579 ms, RTV: 320 ms, KRTT: 0 ms
minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: passive open, gen tcbs
Option Flags: nagle
IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):
Rcvd: 28 (out of order: 0), with data: 16, total data bytes: 427
Sent: 19 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 15, total data bytes: 379
 Packets received in fast path: 0, fast processed: 0, slow path: 0
 Packets send in fast path: 0
 fast lock acquisition failures: 0, slow path: 0

BGP neighbor is 10.2.3.3,  remote AS 300, external link
  BGP version 4, remote router ID 0.0.0.0
  BGP state = Active
  Last read 00:08:53, last write 00:08:53, 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 30 seconds

 For address family: IPv4 Unicast
  BGP table version 5, neighbor version 0/0
  Output queue size: 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                              Sent       Rcvd
  Prefix activity:            ----       ----
    Prefixes Current:            2          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
R2#
```

• The interfaces on R3 need to be activated in IPv4 AF configuration mode.

```
R3(config-router)#address-family ipv4
R3(config-router-af)#neighbor 10.1.3.1 activate
R3(config-router-af)#neighbor 10.1.3.1 activate
*Mar  1 00:43:35.035: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Up
R3(config-router-af)#neighbor 10.1.3.129 activate
R3(config-router-af)#neighbor 10.2.3.2 activate
*Mar  1 00:44:18.411: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Up
R3(config-router-af)#neighbor 10.2.3.2 activate
R3(config-router-af)#network
*Mar  1 00:44:33.743: %BGP-5-ADJCHANGE: neighbor 10.2.3.2 Up
R3(config-router-af)#network 192.168.3.0 mask 255.255.255.224
R3(config-router-af)#network 192.168.3.64 mask 255.255.255.192
R3(config-router-af)#
```

• Verify that the BGP state between R2 and R3 has now been established.

```
R2#sh ip bgp neighbors | begin BGP neighbor is 10.2.3.3
BGP neighbor is 10.2.3.3,  remote AS 300, external link
  BGP version 4, remote router ID 3.3.3.3
  BGP state = Established, up for 00:01:51
  Last read 00:00:50, last write 00:00:50, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                3          3
    Keepalives:             4          4
    Route Refresh:          0          0
    Total:                  8          8
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 7, neighbor version 7/0
  Output queue size: 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                              Sent       Rcvd
  Prefix activity:            ----       ----
    Prefixes Current:            6          4 (Consumes 208 bytes)
    Prefixes Total:              6          4
    Implicit Withdraw:           2          0
    Explicit Withdraw:           0          0
    Used as bestpath:          n/a          2
    Used as multipath:         n/a          0

                                Outbound    Inbound
  Local Policy Denied Prefixes:    --------    -------
    AS_PATH loop:                      n/a          2
    Total:                               0          2
  Number of NLRIs in the update sent: max 2, min 2

  Connections established 1; dropped 0
  Last reset never
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled, Mininum incoming TTL 0, Outgoing TTL 1
Local host: 10.2.3.2, Local port: 15873
Foreign host: 10.2.3.3, Foreign port: 179
```

```
Connection tableid (VRF): 0

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

Event Timers (current time is 0x300D88):
Timer          Starts    Wakeups            Next
Retrans             6          0             0x0
TimeWait            0          0             0x0
AckHold             7          4             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0
ProcessQ            0          0             0x0

iss: 4112549065  snduna: 4112549370  sndnxt: 4112549370     sndwnd:  16080
irs: 1685250064  rcvnxt: 1685250369  rcvwnd:      16080  delrcvwnd:    304

SRTT: 165 ms, RTTO: 1172 ms, RTV: 1007 ms, KRTT: 0 ms
minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: active open
Option Flags: nagle
IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):
Rcvd: 12 (out of order: 0), with data: 9, total data bytes: 304
Sent: 14 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 8, total data bytes: 304
 Packets received in fast path: 0, fast processed: 0, slow path: 0
 Packets send in fast path: 0
 fast lock acquisition failures: 0, slow path: 0
R2#
```

Step 5: Examining the running-configs.

```
R1#sh running-config | section bgp
router bgp 1000
 no synchronization
 bgp router-id 1.1.1.1
 bgp log-neighbor-changes
 network 192.168.1.0 mask 255.255.255.224
 network 192.168.1.64 mask 255.255.255.192
 neighbor 10.1.2.2 remote-as 500
 neighbor 10.1.3.3 remote-as 300
 neighbor 10.1.3.130 remote-as 300
 no auto-summary
R1#
```

```
R2#sh running-config | section bgp
router bgp 500
 no synchronization
 bgp router-id 2.2.2.2
 bgp log-neighbor-changes
 network 192.168.2.0 mask 255.255.255.224
 network 192.168.2.64 mask 255.255.255.192
 neighbor 10.1.2.1 remote-as 1000
 neighbor 10.2.3.3 remote-as 300
 no auto-summary
R2#
```

```
R3#sh running-config | section bgp
router bgp 300
 bgp router-id 3.3.3.3
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 10.1.3.1 remote-as 1000
 neighbor 10.1.3.129 remote-as 1000
 neighbor 10.2.3.2 remote-as 500
 !
 address-family ipv4
  neighbor 10.1.3.1 activate
  neighbor 10.1.3.129 activate
  neighbor 10.2.3.2 activate
  no auto-summary
  no synchronization
  network 192.168.3.0 mask 255.255.255.224
  network 192.168.3.64 mask 255.255.255.192
 exit-address-family
R3#
```

Step 6: Verifying BGP operations.

```
R1#sh ip bgp
BGP table version is 7, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 192.168.1.0/27   0.0.0.0                  0         32768 i
*> 192.168.1.64/26  0.0.0.0                  0         32768 i
*  192.168.2.0/27   10.1.3.130                            0 300 500 i
*                   10.1.3.3                              0 300 500 i
*>                  10.1.2.2                 0            0 500 i
*  192.168.2.64/26  10.1.3.130                            0 300 500 i
*                   10.1.3.3                              0 300 500 i
*>                  10.1.2.2                 0            0 500 i
*  192.168.3.0/27   10.1.2.2                              0 500 300 i
*                   10.1.3.130               0            0 300 i
*>                  10.1.3.3                 0            0 300 i
*  192.168.3.64/26  10.1.2.2                              0 500 300 i
*                   10.1.3.130               0            0 300 i
*>                  10.1.3.3                 0            0 300 i
R1#
```

```
R2#sh ip bgp 192.168.1.0
BGP routing table entry for 192.168.1.0/27, version 2
Paths: (2 available, best #2, table Default-IP-Routing-Table)
  Advertised to update-groups:
        1
  300 1000
    10.2.3.3 from 10.2.3.3 (3.3.3.3)
      Origin IGP, localpref 100, valid, external
  1000
    10.1.2.1 from 10.1.2.1 (1.1.1.1)
      Origin IGP, metric 0, localpref 100, valid, external, best
R2#
```

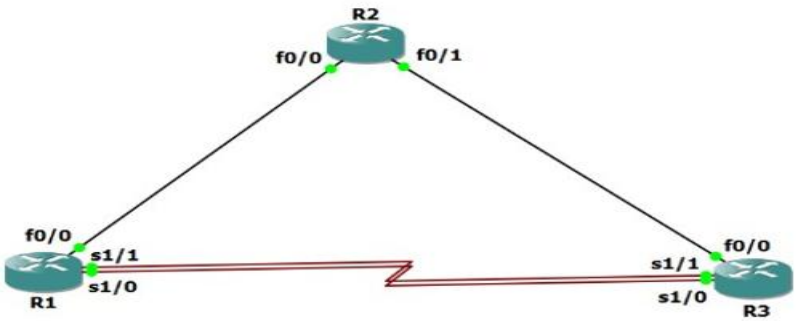
```
R2#sh ip bgp neighbors
BGP neighbor is 10.1.2.1,  remote AS 1000, external link
  BGP version 4, remote router ID 1.1.1.1
  BGP state = Established, up for 00:20:12
  Last read 00:00:11, last write 00:00:11, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                3          4
    Keepalives:            23         23
    Route Refresh:          0          0
    Total:                 27         28
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 7, neighbor version 7/0
  Output queue size: 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                               Sent       Rcvd
  Prefix activity:             ----       ----
    Prefixes Current:             6          4 (Consumes 208 bytes)
    Prefixes Total:               4          4
    Implicit Withdraw:            0          0
    Explicit Withdraw:            0          0
    Used as bestpath:           n/a          2
    Used as multipath:          n/a          0

                                  Outbound    Inbound
  Local Policy Denied Prefixes:   --------    -------
    AS_PATH loop:                      n/a          2
    Bestpath from this peer:             2        n/a
    Total:                               2          2
  Number of NLRIs in the update sent: max 2, min 1

  Connections established 1; dropped 0
  Last reset never
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled, Mininum incoming TTL 0, Outgoing TTL 1
Local host: 10.1.2.2, Local port: 179
```

```
Foreign host: 10.1.2.1, Foreign port: 40782
Connection tableid (VRF): 0

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

Event Timers (current time is 0x3522C8):
Timer          Starts    Wakeups            Next
Retrans            27          0             0x0
TimeWait            0          0             0x0
AckHold            26          4             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0
Linger              0          0             0x0
ProcessQ            0          0             0x0

iss: 4009861579  snduna: 4009862221  sndnxt: 4009862221     sndwnd:  15743
irs: 3423027460  rcvnxt: 3423028150  rcvwnd:      15695  delrcvwnd:    689

SRTT: 292 ms, RTTO: 359 ms, RTV: 67 ms, KRTT: 0 ms
minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: passive open, gen tcbs
Option Flags: nagle
IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):
Rcvd: 52 (out of order: 0), with data: 28, total data bytes: 689
Sent: 32 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 27, total data bytes: 641
 Packets received in fast path: 0, fast processed: 0, slow path: 0
 Packets send in fast path: 0
 fast lock acquisition failures: 0, slow path: 0

BGP neighbor is 10.2.3.3,  remote AS 300, external link
  BGP version 4, remote router ID 3.3.3.3
  BGP state = Established, up for 00:07:43
  Last read 00:00:43, last write 00:00:43, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  1          1
    Opens:                  1          1
    Notifications:          0          0
    Updates:                3          3
    Keepalives:            10         10
    Route Refresh:          0          0
    Total:                 14         14
  Default minimum time between advertisement runs is 30 seconds

 For address family: IPv4 Unicast
  BGP table version 7, neighbor version 7/0
  Output queue size: 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                               Sent       Rcvd
  Prefix activity:             ----       ----
    Prefixes Current:             6          4 (Consumes 208 bytes)
    Prefixes Total:               6          4
    Implicit Withdraw:            2          0
    Explicit Withdraw:            0          0
    Used as bestpath:           n/a          2
    Used as multipath:          n/a          0

                                 Outbound    Inbound
  Local Policy Denied Prefixes:  --------    -------
    AS_PATH loop:                     n/a          2
    Total:                              0          2
  Number of NLRIs in the update sent: max 2, min 2

  Connections established 1; dropped 0
  Last reset never
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Connection is ECN Disabled, Mininum incoming TTL 0, Outgoing TTL 1
Local host: 10.2.3.2, Local port: 15873
Foreign host: 10.2.3.3, Foreign port: 179
Connection tableid (VRF): 0

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

Event Timers (current time is 0x355A7C):
Timer          Starts    Wakeups            Next
Retrans            11          0             0x0
TimeWait            0          0             0x0
AckHold            12          9             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
Linger              0          0             0x0
ProcessQ            0          0             0x0

iss: 4112549065  snduna: 4112549465  sndnxt: 4112549465     sndwnd:  15985
irs: 1685250064  rcvnxt: 1685250464  rcvwnd:      15985  delrcvwnd:    399

SRTT: 231 ms, RTTO: 769 ms, RTV: 538 ms, KRTT: 0 ms
minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms
Status Flags: active open
Option Flags: nagle
IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):
Rcvd: 17 (out of order: 0), with data: 14, total data bytes: 399
Sent: 24 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 13, total data bytes: 399
 Packets received in fast path: 0, fast processed: 0, slow path: 0
 Packets send in fast path: 0
 fast lock acquisition failures: 0, slow path: 0
R2#
```

2. Implement MP (Multi-protocol) -BGP

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Step 1: Design the Topology



Step 2: Configure basic settings for each router.

Router R1:

```
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)#exec-timeout 0 0
R1(config-line)#logging synchronous
R1(config-line)#exit
R1(config)#banner motd # This is R1, BGP Manipulation Lab #
R1(config)#ipv6 unicast-routing
R1(config)#int f0/0
R1(config-if)#ip address 10.1.2.1 255.255.255.0
R1(config-if)#ipv6 address fe80::1:1 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1012::/64
%FastEthernet0/0: Warning: 2001:DB8:ACAD:1012::/64 is a Subnet Router Anycast
R1(config-if)#no sh
%FastEthernet0/0: Warning: 2001:DB8:ACAD:1012::/64 is a Subnet Router Anycast
R1(config-if)#exit
*Mar  1 00:06:58.827: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:06:59.827: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config-if)#exit
R1(config)#int s1/0
R1(config-if)#ip address 10.1.3.1 255.255.255.128
R1(config-if)#ipv6 address fe80::1:2 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1013::1/80
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
*Mar  1 00:08:49.815: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R1(config)#
*Mar  1 00:08:50.827: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R1(config)#
*Mar  1 00:09:13.271: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to down
R1(config)#int s1/1
R1(config-if)#ip address 10.1.3.1 255.255.255.128
R1(config-if)#ipv6 address fe80::1:3 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1014::1/80
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
*Mar  1 00:11:05.299: %LINK-3-UPDOWN: Interface Serial1/1, changed state to up
R1(config)#
*Mar  1 00:11:06.311: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to up
R1(config)#int loopback0
*Mar  1 00:11:33.303: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to down
R1(config)#int loopback0
R1(config-if)#
```

```
*Mar  1 00:11:35.883: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 192.168.1.1 255.255.255.224
R1(config-if)#ipv6 address fe80::1:4 link-local
R1(config-if)#ipv6 address 2001:db8acad:1000::1/64
% Incomplete command.

R1(config-if)#no sh
R1(config-if)#exit
R1(config)#ipv6 address 2001:db8:acad:1000::1/64
               ^
% Invalid input detected at '^' marker.

R1(config)#int loopback0
R1(config-if)#ipv6 address 2001:db8:acad:1000::1/64
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#int loopback1
R1(config-if)#ip addres
*Mar  1 00:15:24.051: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#ipv6 adsdress fe80::1:5 link-local
                   ^
% Invalid input detected at '^' marker.

R1(config-if)#ipv6 address fe80::1:5 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1001::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#exit
R1#
```

Router R2:

```
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)#exec-timeout 0 0
R2(config-line)#logging synchronous
R2(config-line)#exit
R2(config)#banner motd # This is R2, BGP Path Manipulation Lab #
R2(config)#ipv6 unicast-routing
R2(config)#int f0/0
R2(config-if)#ip address 10.1.2.2 255.255.255.0
R2(config-if)#ipv6 address fe80::2:1 link-local
R2(config-if)#ipv6 address 2001:db8:acad:1021::2/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
*Mar  1 00:14:31.659: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:14:32.659: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#int f0/1
R2(config-if)#ip address 10.2.3.2 255.255.255.0
R2(config-if)#ipv6 address fe80::2:2 link-local
R2(config-if)#ipv6 address 2001:db8:acad:1023::/2?
WORD  X:X:X:X::X/<0-128>

R2(config-if)#ipv6 address 2001:db8:acad:1023::2/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
*Mar  1 00:16:28.103: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:16:29.103: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config)#int loopback0
R2(config-if)#
*Mar  1 00:16:57.079: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip address 192.168.2.1 255.255.255.224
R2(config-if)#ipv6 address fe80::2:3 link-local
R2(config-if)#ipv6 address 2001:db8:acad:2000::2/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int loopback1
R2(config-if)#
*Mar  1 00:18:27.371: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R2(config-if)#ip address 192.168.2.65 255.255.255.192
R2(config-if)#ipv6 address fe80::2:4 link-local
R2(config-if)#ipv6 address 2001:db8:acad:2001::2/64
R2(config-if)#no sh
R2(config-if)#exit
```

Router R3:

```
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)#exec-timeout 0 0
R3(config-line)#logging synchronous
R3(config-line)#exit
R3(config)#banner motd # This is R3, BGP Path Manipulation Lab 3
Enter TEXT message.  End with the character '#'.

#
R3(config)#banner motd # This is R3, BGP Path Manipulation Lab 3 #
R3(config)#ipv6 unicast-routing
R3(config)#int f0/0
R3(config-if)#ip address 10.2.3.3 255.255.255.0
R3(config-if)#ipv6 address fe80::3:1 link-local
R3(config-if)#ipv6 address 2001:db8:acad:1023::3/64
R3(config-if)#no sh
R3(config-if)#exit
```

```
R3(config)#int s1/0
R3(config-if)#ip address 10.1.3.3 255.255.255.128
R3(config-if)#ipv6 address fe80::3:2 link-local
R3(config-if)#ipv6 address 2001:db8:acad:1013::3/80
R3(config-if)#no sh
R3(config-if)#ip
% Incomplete command.

R3(config-if)#
*Mar  1 00:20:52.315: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R3(config-if)#exit
*Mar  1 00:20:53.327: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R3(config-if)#exit
R3(config)#int s1/1
R3(config-if)#ip address 10.1.3.130 255.255.255.128
R3(config-if)#ipv6 address fe80::3:3 link-local
R3(config-if)#ipv6 address 2001:db8:acad:1014::3/80
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
*Mar  1 00:22:38.903: %LINK-3-UPDOWN: Interface Serial1/1, changed state to up
R3(config)#
*Mar  1 00:22:39.915: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to up
R3(config)#int loopback0
R3(config-if)#
*Mar  1 00:22:53.903: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip address 192.168.3.1 255.255.255.224
R3(config-if)#ipv6 address fe80::3:4 link-local
R3(config-if)#ipv6 address 2001:db8:acad:3000::1/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int loopback1
R3(config-if)#
*Mar  1 00:24:14.415: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R3(config-if)#ip address 192.168.3.65 255.255.255.192
R3(config-if)#ipv6 address fe80::3:5 link-local
R3(config-if)#ipv6 address 2001:db8:acad:3001::1/64
R3(config-if)#no sh
R3(config-if)#exit
```

Part 2: Configure and Verify Multi-Protocol BGP on all Routers

Step 1: On R1, create the core BGP configuration

```
R1(config)#router bgp 6500
R1(config-router)#bgp router-id 1.1.1.1
R1(config-router)#no bgp default ipv4-unicast
R1(config-router)#neighbor 10.1.2.2 remote-as 500
R1(config-router)#neighbor 10.1.3.3 remote-as 300
R1(config-router)#neighbor 10.1.3.130 remote-as 300
R1(config-router)#neighbor 2001:db8:acad:1013::3 remote 500
R1(config-router)#no neighbor 2001:db8:acad:1013::3 remote 500
R1(config-router)#neighbor 2001:db8:acad:1012::2 remote-as 500
R1(config-router)#neighbor 2001:db8:acad:1013::3 remote-as 300
R1(config-router)#neighbor 2001:db8:acad:1014::3 remote-as 300
R1(config-router)#
```

Step 2: On R1, configure the IPv4 unicast address family.

```
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#network 192.168.1.0 mask 255.255.255.224
R1(config-router-af)#network 192.168.1.64 mask 255.255.255.192
R1(config-router-af)#no neighbor 2001:db8:acad:1012::2 activate
R1(config-router-af)#no neighbor 2001:db8:acad:1013::3 activate
R1(config-router-af)#no neighbor 2001:db8:acad:1014::3 activate
R1(config-router-af)#neighbor 10.1.2.2 activate
R1(config-router-af)#neighbor 10.1.3.3 activate
R1(config-router-af)#neighbor 10.1.3.130 activate
R1(config-router-af)#
```

Step 3: On R1, configure the IPv6 unicast address family.

```
R1(config-router-af)#exit
R1(config-router)#address-family ipv6 unicast
R1(config-router-af)#network 2001:db8:acad:1000::/64
R1(config-router-af)#network 2001:db8:acad:1001::/64
R1(config-router-af)#neighbor 2001:db8:acad:1012::2 activate
R1(config-router-af)#neighbor 2001:db8:acad:1013::3 activate
R1(config-router-af)#neighbor 2001:db8:acad:1014::3 activate
R1(config-router-af)#
```

Step 4: Verify that MP-BGP is operational.

```
R1#sh bgp ipv6 unicast summary
BGP router identifier 1.1.1.1, local AS number 6500
BGP table version is 3, main routing table version 3
2 network entries using 304 bytes of memory
2 path entries using 152 bytes of memory
2/1 BGP path/bestpath attribute entries using 248 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 704 total bytes of memory
BGP activity 8/4 prefixes, 8/4 paths, scan interval 60 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:ACAD:1012::2
                4   500       0       0        0    0    0 never    Active
2001:DB8:ACAD:1013::3
                4   300       0       0        0    0    0 never    Active
2001:DB8:ACAD:1014::3
                4   300       0       0        0    0    0 never    Active
% NOTE: This command is deprecated. Please use 'show bgp ipv6 unicast'
R1#
```

- **Use the show bgp ipv4 unicast and show bgp ipv6 unicast commands to view the specified BGP tables.**

```
R1#sh bgp ipv4 unicast
BGP table version is 3, 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
*> 192.168.1.0/27   0.0.0.0                  0         32768 i
*> 192.168.1.64/26  0.0.0.0                  0         32768 i
R1#
```

```
R1#sh bgp ipv6 unicast
BGP table version is 3, 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
*> 2001:DB8:ACAD:1000::/64
                    ::                       0         32768 i
*> 2001:DB8:ACAD:1001::/64
                    ::                       0         32768 i
% NOTE: This command is deprecated. Please use 'show bgp ipv6 unicast'
R1#
```

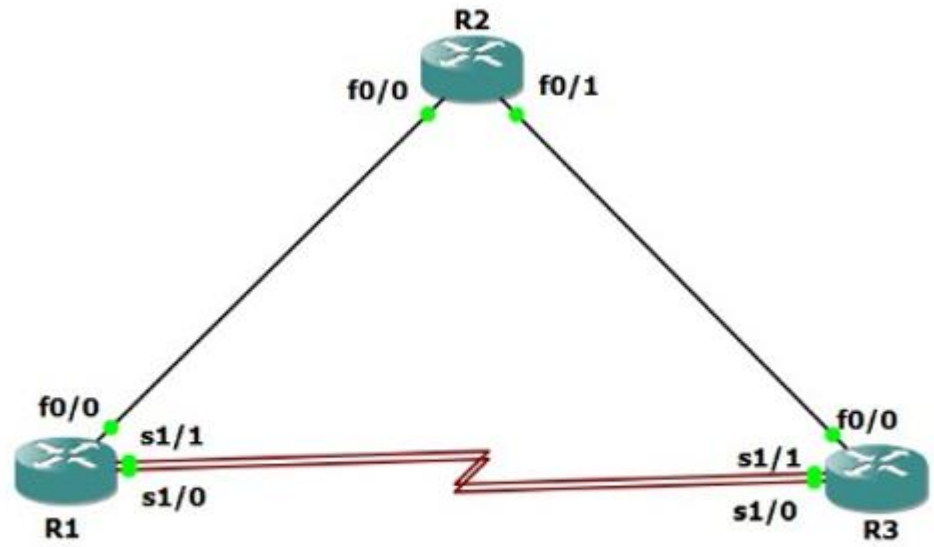
- Viewing Routing tables.

```
R1#sh ipv6 route bgp
IPv6 Routing Table - 11 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
R1#
```

3. Implement BGP path Manipulation

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Step 1: Topology



Step 2: Configure basic settings for each router.

Router R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#line con 0
R1(config-line)#exec-timeout 0 0
R1(config-line)#logging synchronous
R1(config-line)#banner motd # This is R1, BGP Path Manipulation Lab #
R1(config)#ipv6 unicast-routing
R1(config)#int f0/0
R1(config-if)#ip address 10.1.2.1 255.255.255.0
R1(config-if)#ipv6 address fe80::1:1 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1012::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
*Mar  1 00:03:29.151: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:30.151: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#int s1/0
R1(config-if)#ip address 10.1.3.1 255.255.255.128
R1(config-if)#ipv6 address fe80::1:2 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1013::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
*Mar  1 00:05:34.083: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R1(config)#
*Mar  1 00:05:35.095: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
```

```
R1(config)#int s1/1
R1(config-if)#ip address 10.1.3.
*Mar  1 00:06:03.979: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to down
R1(config-if)#ip address 10.1.3.129 255.255.255.128
R1(config-if)#ipv6 address fe80::1:3 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1014::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
*Mar  1 00:07:08.543: %LINK-3-UPDOWN: Interface Serial1/1, changed state to up
R1(config)#
*Mar  1 00:07:09.555: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to up
R1(config)#int loopback 0
R1(config-if)#
*Mar  1 00:07:24.015: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R1(config-if)#ip address 192.168.1.1 2
*Mar  1 00:07:34.115: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to down
R1(config-if)#ip address 192.168.1.1 255.255.255.224
R1(config-if)#ipv6 address fe80::1:4 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1000::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int loopback 1
R1(config-if)#
*Mar  1 00:08:32.959: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#ipv6 address fe80::1:5 link-local
R1(config-if)#ipv6 address 2001:db8:acad:1001::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
```

Router R2:

```
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)#exec-timeout 0 0
R2(config-line)#logging synchronous
R2(config-line)#banner motd # This is R2, BGP Path Manipulation Lab #
R2(config)#ipv6 unicast-routing
R2(config)#int f0/0
R2(config-if)#ip address 10.1.2.2 255.255.255.0
R2(config-if)#ipv6 address fe80::2:1 link-local
R2(config-if)#ipv6 address 2001:db8:acad:1012::2/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
*Mar  1 00:08:31.615: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:08:32.615: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#int f0/1
R2(config-if)#ip address 10.2.3.2 255.255.255.0
R2(config-if)#ipv6 address fe80::2:2 link-local
R2(config-if)#ipv6 address 2001:fe8:acad:1023::2/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
*Mar  1 00:09:59.283: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:10:00.283: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config)#int loopback 0
R2(config-if)#
*Mar  1 00:10:39.895: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip address 192.168.2.1 255.255.255.224
R2(config-if)#ipv6 address fe80::2:3 link-local
R2(config-if)#ipv6 address 2001:db8:acad:2000::1/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int llopback 1
                ^
% Invalid input detected at '^' marker.

R2(config)#int loopback 1
R2(config-if)#
*Mar  1 00:12:07.415: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R2(config-if)#ip address 192.168.2.65 255.255.225.192
Bad mask 0xFFFFE1C0 for address 192.168.2.65
R2(config-if)#ip address 192.168.2.65 255.255.255.192
R2(config-if)#ipv6 address fe80::2:4 link-local
R2(config-if)#ipv6 address 2001:db8:acad:2001::1/64
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
```

Router R3:

```
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)#exec-timeout 0 0
R3(config-line)#logging synchronous
R3(config-line)#banner motd # This is R3, BGP Path Manipulation Lab #
R3(config)#ipv6 unicast-routing
R3(config)#int f0/0
R3(config-if)#ip address 10.2.3.3 255.255.255.0
R3(config-if)#ipv6 address fe80::3:1 link-local
R3(config-if)#ipv6 address 2001:db8:acad:1023::3/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
*Mar  1 00:14:05.191: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:14:06.191: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config)#int s1/0
R3(config-if)#ip address 10.1.3.3 255.255.255.128
R3(config-if)#ipv6 address fe80::3:2 link-local
R3(config-if)#ipv6 aadress 2001:db8:acad:1013::3/64
                 ^
% Invalid input detected at '^' marker.

R3(config-if)#ipv6 address 2001:db8:acad:1013::3/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
*Mar  1 00:15:36.203: %LINK-3-UPDOWN: Interface Serial1/0, changed state to up
R3(config)#
*Mar  1 00:15:37.215: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to up
R3(config)#int s1/1
R3(config-if)#ip address 10.1.3.130 255.255.255.128
R3(config-if)#ipv6 address fe80::3:3 link-local
R3(config-if)#ipv6 address 2001:db8:acad:1014::3/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
*Mar  1 00:16:53.579: %LINK-3-UPDOWN: Interface Serial1/1, changed state to up
*Mar  1 00:16:54.579: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/1, changed state to up
R3(config)#int loopback 0
R3(config-if)#ip
*Mar  1 00:17:39.559: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R3(config-if)#ip address 192.168.3.1 255.255.255.224
R3(config-if)#ipv6 address fe80::3:4 link-local
R3(config-if)#ipv6 address 2001:db8:acad:3000::1/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int loopback 1
R3(config-if)#
*Mar  1 00:18:57.499: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
R3(config-if)#ip address 192.168.3.65 255.255.255.192
R3(config-if)#ipv6 address 2001:db8:acad:3001::1/64
R3(config-if)#ipv6 fe80::3:5 link-local
                 ^
% Invalid input detected at '^' marker.

R3(config-if)#ipv6 address fe80::3:5 link-local
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
```

Part 2: Configure and Verify Multi-Protocol BGP on all Routers

Step 1: On R1, create the core BGP Configuration

```
R1(config)#router bgp 6500
R1(config-router)#bgp router-id 1.1.1.1
R1(config-router)#no bgp default ipv4-unicast
R1(config-router)#neighbor 10.1.2.2 remote-as 500
R1(config-router)#neighbor 10.1.3.3 remote-as 300
R1(config-router)#neighbor 10.1.3.130 remote-as 300
R1(config-router)#neighbor 2001:db8:acad:1012::2 remote-as 500
R1(config-router)#neighbor 2001:db8:acad:1013::3 remote-as 300
R1(config-router)#neighbor 2001:db8:acad:1014::3 remote-as 300
R1(config-router)#
```

Step 2: On R1, configure the IPV4 unicast address family

```
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#network 192.168.1.0 mask 255.255.255.224
R1(config-router-af)#network 192.168.1.64 mask 255.255.255.192
R1(config-router-af)#no neighbor 2001:db8:acad:1012::2 activate
R1(config-router-af)#no neighbor 2001:db8:acad:1013::3 activate
R1(config-router-af)#no neighbor 2001:db8:acad:1014::3 activate
R1(config-router-af)#neighbor 10.1.2.2 activate
R1(config-router-af)#neighbor 10.1.3.3 activate
R1(config-router-af)#neighbor 10.1.3.130 activate
```

Step 3: On R1, configure the IPv6 unicast address family.

```
R1(config-router-af)#address-family ipv6 unicast
R1(config-router-af)#network 2001:db8:acad:1000::/64
R1(config-router-af)#network 2001:db8:acad:1001::/64
R1(config-router-af)#neighbor 2001:db8:acad:1012::2 activate
R1(config-router-af)#neighbor 2001:db8:acad:1013::3 activate
R1(config-router-af)#neighbor 2001:db8:acad:1014::3 activate
```

Step 4: Configure MP-BGP on R2 and R3 as you did in the previous step.

```
R2(config)#router bgp 500
R2(config-router)#bgp router-id 2.2.2.2
R2(config-router)#no bgp default ipv4-unicast
R2(config-router)#neighbor 10.1.2.1 remote-as 6500
R2(config-router)#neighbor 10.2.3.3 remote-as 300
R2(config-router)#neighbor 2001:db8:acad:1012::1 remote-as 6500
R2(config-router)#neighbor 2001:db8:acad:1023::3 remote-as 300
R2(config-router)#address-family ipv4
R2(config-router-af)#network 192.168.2.0 mask 255.255.255.224
R2(config-router-af)#network 192.168.2.64 mask 255.255.255.192
R2(config-router-af)#neighbor 10.1.2.1 activate
R2(config-router-af)#neighbor 10.2.3.3 activate
R2(config-router-af)#no neighbor 2001:db8:acad:10
*Mar  1 00:39:33.515: %BGP-5-ADJCHANGE: neighbor 10.1.2.1 Up
R2(config-router-af)#no neighbor 2001:db8:acad:1012::1 activate
R2(config-router-af)#no neighbor 2001:db8:acad:1023::3 activate
R2(config-router-af)#exit-address-family
R2(config-router)#address-family ipv6
R2(config-router-af)#network 2001:db8:acad:2000::/64
R2(config-router-af)#network 2001:db8:acad:2001::/64
R2(config-router-af)#neighbor 2001:db8:acad:1012::1 activate
R2(config-router-af)#neighbor 2001:db8:acad:1023::3 activate
R2(config-router-af)#exit-addres
*Mar  1 00:42:05.911: %BGP-5-ADJCHANGE: neighbor 2001:DB8:ACAD:1012::1 Up
R2(config-router-af)#exit-address-family
R2(config-router)#
```

```
R3(config)#router bgp 300
R3(config-router)#bgp router-id 3.3.3.3
R3(config-router)#no bgp default ipv4-unicast
R3(config-router)#neighbor 10.1.3.1 remote-as 6500
R3(config-router)#neighbor 10.1.3.129 remote-as 6500
R3(config-router)#neighbor 10.2.3.2 remote-as 500
R3(config-router)#neighbor 2001:db8:acad:1013::1 remote-as 6500
R3(config-router)#neighbor 2001:db8:acad:1014::1 remote-as 6500
R3(config-router)#neighbor 2001:db8:acad:1023::2 remote-as 500
R3(config-router)#address-family ipv4
R3(config-router-af)#network 192.168.3.0 mask 255.255.255.224
R3(config-router-af)#network 192.168.3.64 mask 255.255.255.192
R3(config-router-af)#neighbor 10.1.3.1 activate
R3(config-router-af)#neighbor 10.1.3.129 activate
R3(config-router-af)#
*Mar  1 00:44:18.055: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Up
R3(config-router-af)#
*Mar  1 00:44:28.563: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Up
R3(config-router-af)#no neighbor 2001
R3(config-router-af)#no neighbor 2001:db8:acad:1013::1 activate
R3(config-router-af)#no neighbor 2001:db8:acad:1014::1 activate
R3(config-router-af)#no neighbor 2001:db8:acad:1023::2 activate
R3(config-router-af)#exit-address-family
R3(config-router)#address-family ipv6
R3(config-router-af)#network 2001:db8:acad:3000::/64
R3(config-router-af)#network 2001:db8:acad:3001::/64
R3(config-router-af)#neighbor 2001:db8:acad:1013::1 activate
R3(config-router-af)#neighbor 2001:db8:acad:1014::1 activate
*Mar  1 00:47:24.119: %BGP-5-ADJCHANGE: neighbor 2001:DB8:ACAD:1013::1 Up
R3(config-router-af)#neighbor 2001:db8:acad:1014::1 activate
R3(config-router-af)#neighbor 2001:db8:acad:1023::2 activate
*Mar  1 00:47:46.583: %BGP-5-ADJCHANGE: neighbor 2001:DB8:ACAD:1014::1 Up
R3(config-router-af)#neighbor 2001:db8:acad:1023::2 activate
R3(config-router-af)#exit-address-family
R3(config-router)#
```

Step 5: Verify that MP-BGP is operational.

```
R1#sh bgp ipv4 unicast summary
BGP router identifier 1.1.1.1, local AS number 6500
BGP table version is 7, main routing table version 7
6 network entries using 720 bytes of memory
8 path entries using 416 bytes of memory
4/3 BGP path/bestpath attribute entries using 496 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory
BGP using 1712 total bytes of memory
BGP activity 12/0 prefixes, 16/0 paths, scan interval 60 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.1.2.2        4   500      23      23        7    0    0 00:16:00        2
10.1.3.3        4   300      13      13        7    0    0 00:06:16        2
10.1.3.130      4   300      13      13        7    0    0 00:06:05        2
R1#
```

```
R1#sh bgp ipv6 unicast summary
BGP router identifier 1.1.1.1, local AS number 6500
BGP table version is 7, main routing table version 7
6 network entries using 912 bytes of memory
8 path entries using 608 bytes of memory
4/3 BGP path/bestpath attribute entries using 496 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory
BGP using 2096 total bytes of memory
BGP activity 12/0 prefixes, 16/0 paths, scan interval 60 secs

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:ACAD:1012::2
                4   500      21      21        7    0    0 00:14:17        2
2001:DB8:ACAD:1013::3
                4   300       8      10        7    0    0 00:03:58        2
2001:DB8:ACAD:1014::3
                4   300      10      10        7    0    0 00:03:36        2
% NOTE: This command is deprecated. Please use 'show bgp ipv6 unicast'
R1#
```

```
R1#show bgp ipv4 unicast | begin Network
   Network          Next Hop            Metric LocPrf Weight Path
*> 192.168.1.0/27   0.0.0.0                  0         32768 i
*> 192.168.1.64/26  0.0.0.0                  0         32768 i
*> 192.168.2.0/27   10.1.2.2                 0             0 500 i
*> 192.168.2.64/26  10.1.2.2                 0             0 500 i
*  192.168.3.0/27   10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
*  192.168.3.64/26  10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
R1#
```

```
R1#show bgp ipv6 unicast | begin Network
   Network          Next Hop            Metric LocPrf Weight Path
*> 2001:DB8:ACAD:1000::/64
                    ::                       0         32768 i
*> 2001:DB8:ACAD:1001::/64
                    ::                       0         32768 i
*> 2001:DB8:ACAD:2000::/64
                    2001:DB8:ACAD:1012::2
                                             0             0 500 i
*> 2001:DB8:ACAD:2001::/64
                    2001:DB8:ACAD:1012::2
                                             0             0 500 i
*  2001:DB8:ACAD:3000::/64
                    2001:DB8:ACAD:1014::3
                                             0             0 300 i
*>                  2001:DB8:ACAD:1013::3
                                             0             0 300 i
*  2001:DB8:ACAD:3001::/64
                    2001:DB8:ACAD:1014::3
                                             0             0 300 i
*>                  2001:DB8:ACAD:1013::3
                                             0             0 300 i
R1#
```

• **View Routing Tables:**

```
R1#show ipv6 route bgp
IPv6 Routing Table - 15 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
B   2001:DB8:ACAD:2000::/64 [20/0]
     via FE80::2:1, FastEthernet0/0
B   2001:DB8:ACAD:2001::/64 [20/0]
     via FE80::2:1, FastEthernet0/0
B   2001:DB8:ACAD:3000::/64 [20/0]
     via FE80::3:2, Serial1/0
B   2001:DB8:ACAD:3001::/64 [20/0]
     via FE80::3:2, Serial1/0
R1#
```

Part 3: Configure and Verify BGP Path Manipulation

Settings on all Routers

Step 1: Configure ACL-based route filtering.

• On R1, issue the command show bgp ipv4 unicast | i 300 to see what prefixes ASN300 is sharing via BGP.

• Take note of those prefixes that do not originate in ASN300.

```
R1#show bgp ipv4 unicast | i 300
*  192.168.3.0/27   10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
*  192.168.3.64/26  10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
R1#show bgp ipv4 unicast | begin 192.168.3
*  192.168.3.0/27   10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
*  192.168.3.64/26  10.1.3.130              0             0 300 i
*>                  10.1.3.3                 0             0 300 i
R1#
```

• On R3, configure an access list designed to match the source address and mask of the networks belonging to ASN300:

```
R3(config)#ip access-list extended ALLOWED_TO_R!
R3(config-ext-nacl)#permit ip 192.168.3.0 0.0.0.0 255.255.255.224 0.0.0.0
R3(config-ext-nacl)#permit ip 192.168.3.64 0.0.0.0 255.255.255.192 0.0.0.0
R3(config-ext-nacl)#exit
R3(config)#
```

• On R3, apply the ALLOWED_TO_R1 ACL as a distribute list to the IPv4 neighbor adjacencies with R1.

```
R3(config)#router bgp 300
R3(config-router)#address-family ipv4 unicast
R3(config-router-af)#neighbor 10.1.3.1 distribute-list ALLOWED_TO_R1 out
R3(config-router-af)#neighbor 10.1.3.129 distribute-list ALLOWED_TO_R1 out
R3(config-router-af)#end
R3#
*Mar  1 01:07:27.307: %SYS-5-CONFIG_I: Configured from console by console
R3#
```

• Perform a reset of the IPv4 adjacency with R1 for the outbound traffic without tearing down the session.

```
R3#clear bgp ipv4 unicast 6500 out
R3#
```

• On R1, issue the command show bgp ipv4 unicast | i 300 to see what prefixes routes ASN300 is now sharing via BGP. All of the prefixes should now originate in ASN300:

```
R1#show bgp ipv4 unicast | i 300
*  192.168.3.0/27   10.1.3.130              0             0 300 i
*>                  10.1.3.3                0             0 300 i
*  192.168.3.64/26  10.1.3.130              0             0 300 i
*>                  10.1.3.3                0             0 300 i
R1#
```

Step 2: Configure prefix-list-based route filtering.

• On R1, issue the command show bgp ipv4 unicast | begin 192.168.3 to see what prefixes ASN500 is sharing via BGP. Take note of those prefixes that do not originate in ASN500.

```
R1#show bgp ipv4 unicast | begin 192.168.3
*  192.168.3.0/27   10.1.3.130              0             0 300 i
*>                  10.1.3.3                0             0 300 i
*  192.168.3.64/26  10.1.3.130              0             0 300 i
*>                  10.1.3.3                0             0 300 i
R1#
```

• On R1, configure a prefix list designed to match the source address and mask of networks belonging to ASN500.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip prefix-list ALLOWED_FROM_R2 seq 5 permit 192.168.2.0/24 le 27
R1(config)#
```

• Apply the ALLOWED_FROM_R2 prefix list to the IPv4 neighbor adjacencies for R2.

```
R1(config)#router bgp 6500
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#neighbor 10.1.2.2 prefix-list ALLOWED_FROM_R2 in
R1(config-router-af)#end
R1#
*Mar  1 01:22:12.035: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

• Perform a reset of the IPv4 adjacency with R2 for the inbound traffic without tearing down the session

```
R1#clear bgp ipv4 unicast 500 in
R1#
```

• On R1, issue the command show bgp ipv4 unicast | i 500 to see what prefixes routes ASN500 is now sharing via BGP. All of the prefixes should now originate in ASN500.

```
R1#show bgp ipv4 unicast | i 500
*> 192.168.2.0/27   10.1.2.2                0             0 500 i
*> 192.168.2.64/26  10.1.2.2                0             0 500 i
R1#
```

Step 3: Configure an AS-PATH ACL to filter routes being advertised.

• On R2, issue the command show bgp ipv4 unicast | begin Network to see what prefixes ASN6500 is sharing via BGP.

```
R2#show bgp ipv4 unicast | begin Network
   Network          Next Hop            Metric LocPrf Weight Path
*> 192.168.1.0/27   10.1.2.1                 0             0 6500 i
*> 192.168.1.64/26  10.1.2.1                 0             0 6500 i
*> 192.168.2.0/27   0.0.0.0                  0         32768 i
*> 192.168.2.64/26  0.0.0.0                  0         32768 i
*> 192.168.3.0/27   10.1.2.1                               0 6500 300 i
*> 192.168.3.64/26  10.1.2.1                               0 6500 300 i
R2#
```

• On R1, configure AS-PATH ACL to match the routes from the local ASN.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#ip as-path access-list 1 permit ^$
R1(config)#
```

• On R1, apply the AS-PATH ACL as a filter-list on the adjacency configured with R2.

```
R1(config)#router bgp 6500
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#neighbor 10.1.2.2 filter-list 1 out
R1(config-router-af)#end
R1#
*Mar  1 01:26:06.247: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

• On R1, perform a reset of the IPv4 adjacency with R2 for the outbound traffic without tearing down the session

```
R1#clear bgp ipv4 unicast 500 out
R1#
```

• On R2, issue the command show bgp ipv4 unicast | i 6500 to see what prefixes routes ASN6500 is now sharing via BGP. All of the prefixes should now originate in ASN6500.

```
R2#show bgp ipv4 unicast | i 6500
*> 192.168.1.0/27   10.1.2.1               0             0 6500 i
*> 192.168.1.64/26  10.1.2.1               0             0 6500 i
R2#
```

Step 4: Configure IPv6 prefix-list-based route filtering.

• On R1, issue the command show bgp ipv6 unicast neighbors 2001:db8:acad:1012::2 routes to see what IPv6 prefixes ASN500 is sharing via BGP.

```
R1#show bgp ipv6 unicast neighbors 2001:db8:acad:1012::2 routes
BGP table version is 7, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 2001:DB8:ACAD:2000::/64
                    2001:DB8:ACAD:1012::2
                                         0             0 500 i
*> 2001:DB8:ACAD:2001::/64
                    2001:DB8:ACAD:1012::2
                                         0             0 500 i

Total number of prefixes 2
R1#
```

• On R1, configure an IPv6 prefix list designed to match the source address and mask of networks belonging to ASN500.

```
R1(config)#$-list IPV6_ALLOWED_FROM_R2 seq 5 permit 2001:db8:acad:2000::/64
R1(config)#$-list IPV6_ALLOWED_FROM_R2 seq 10 permit 2001:db8:acad:2001::/64
R1(config)#
```

• Apply the IPV6_ALLOWED_FROM_R2 prefix list to the IPv6 neighbour adjacencies for R2

```
R1(config)#router bgp 6500
R1(config-router)#address-family ipv6 unicast
R1(config-router-af)#$01:db8:acad:1012::2 prefix-list IPV6_ALLOWED_FROM_R2 in
R1(config-router-af)#end
R1#
*Mar  1 02:05:49.031: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

• Perform a reset of the IPv6 adjacency with R2 for the inbound traffic without tearing down the session.

```
R1#clear bgp ipv6 unicast 500 in
R1#
```

• On R1, issue the command show bgp ipv6 unicast neighbors 2001:db8:acad:1012::2 routes to see what IPv6 prefixes routes ASN500 is now sharing via BGP. All of the IPv6 prefixes should now originate in ASN500.

```
R1#show bgp ipv6 unicast neighbors 2001:db8:acad:1012::2 routes
BGP table version is 7, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 2001:DB8:ACAD:2000::/64
                    2001:DB8:ACAD:1012::2
                                         0             0 500 i
*> 2001:DB8:ACAD:2001::/64
                    2001:DB8:ACAD:1012::2
                                         0             0 500 i

Total number of prefixes 2
R1#
```

Step 5: Configure BGP path attribute manipulation to effect routing

```
R1#show bgp ipv4 unicast 192.168.3.0
BGP routing table entry for 192.168.3.0/27, version 7
Paths: (2 available, best #2, table Default-IP-Routing-Table)
  Not advertised to any peer
  300
    10.1.3.130 from 10.1.3.130 (3.3.3.3)
      Origin IGP, metric 0, localpref 100, valid, external
  300
    10.1.3.3 from 10.1.3.3 (3.3.3.3)
      Origin IGP, metric 0, localpref 100, valid, external, best
R1#
```

• On R1, configure a prefix list designed to match the source address and mask of networks belonging to ASN300.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#$ist PREFERRED_IPV4_PATH seq 5 permit 192.168.3.0/24 le 27
R1(config)#
```

• Create a route-map named USE_THIS_PATH_FOR_IPV4 that matches on the prefix list you just created and sets the local preference to 250.

```
R1(config)#route-map USE_THIS_PATH_FOR_IPV4 permit 10
R1(config-route-map)#match ip address prefix-list PREFERRED_IPV4_PATH
R1(config-route-map)#set local_preference 250
                      ^
% Invalid input detected at '^' marker.

R1(config-route-map)#set local-preference 250
R1(config-route-map)#exit
R1(config)#
```

• Next, apply this route map to the BGP neighbor 10.1.3.130.

```
R1(config)#router bgp 6500
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#neighbor 10.1.3.130 route-map USE_THIS_PATH_FOR_IPV4 in
R1(config-router-af)#end
R1#
*Mar  1 02:16:10.807: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

• Perform a reset of the IPv4 adjacency with R3 for the inbound traffic without tearing down the session.

```
R1#clear bgp ipv4 unicast 300 in
R1#
```

• On R1, issue the command show ip route bgp and take note of the next hop addresses for the 192.168.3.0/27 and 192.168.3.64/26 networks; it should be 10.1.3.130 for both. Issue the command show bgp ipv4 unicast and you should see the local preference value in the appropriate column.

```
R1#show ip route bgp
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.2.64/26 [20/0] via 10.1.2.2, 01:32:25
B       192.168.2.0/27 [20/0] via 10.1.2.2, 01:32:25
     192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.3.64/26 [20/0] via 10.1.3.130, 00:00:33
B       192.168.3.0/27 [20/0] via 10.1.3.130, 00:00:33
R1#
*> 192.168.1.0/27   0.0.0.0                  0         32768 i
*> 192.168.1.64/26  0.0.0.0                  0         32768 i
*> 192.168.2.0/27   10.1.2.2                 0             0 500 i
*> 192.168.2.64/26  10.1.2.2                 0             0 500 i
*> 192.168.3.0/27   10.1.3.130               0    250      0 300 i
*                   10.1.3.3                 0             0 300 i
*> 192.168.3.64/26  10.1.3.130               0    250      0 300 i
*                   10.1.3.3                 0             0 300 i
R1#
```

• Final Config R1:

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

Current configuration : 3975 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ipv6 unicast-routing
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
```

```
!
!
no ip domain lookup
ipv6 unicast-routing
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
archive
 log config
  hidekeys
!
!
!
!
ip tcp synwait-time 5
!
!
!
!
interface Loopback0
 ip address 192.168.1.1 255.255.255.224
 ipv6 address FE80::1:4 link-local
 ipv6 address 2001:DB8:ACAD:1000::1/64
!
interface Loopback1
 ip address 192.168.1.65 255.255.255.192
 ipv6 address FE80::1:5 link-local
 ipv6 address 2001:DB8:ACAD:1001::1/64
!
interface FastEthernet0/0
 ip address 10.1.2.1 255.255.255.0
 duplex auto
 speed auto
 ipv6 address FE80::1:1 link-local
 ipv6 address 2001:DB8:ACAD:1012::1/64
!
interface Serial0/0
 no ip address
 shutdown
 clock rate 2000000
!
interface FastEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface Serial0/1
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/2
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/3
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/4
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/5
 no ip address
 shutdown
 clock rate 2000000
!
```

```
interface Serial1/0
 ip address 10.1.3.1 255.255.255.128
 ipv6 address FE80::1:2 link-local
 ipv6 address 2001:DB8:ACAD:1013::1/64
 serial restart-delay 0
!
interface Serial1/1
 ip address 10.1.3.129 255.255.255.128
 ipv6 address FE80::1:3 link-local
 ipv6 address 2001:DB8:ACAD:1014::1/64
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
!
router bgp 6500
 bgp router-id 1.1.1.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 10.1.2.2 remote-as 500
 neighbor 10.1.3.3 remote-as 300
 neighbor 10.1.3.130 remote-as 300
 neighbor 2001:DB8:ACAD:1012::2 remote-as 500
 neighbor 2001:DB8:ACAD:1013::3 remote-as 300
 neighbor 2001:DB8:ACAD:1014::3 remote-as 300
 !
 address-family ipv4
  neighbor 10.1.2.2 activate
  neighbor 10.1.2.2 prefix-list ALLOWED_FROM_R2 in
  neighbor 10.1.2.2 filter-list 1 out
  neighbor 10.1.3.3 activate
  neighbor 10.1.3.130 activate
  neighbor 10.1.3.130 route-map USE_THIS_PATH_FOR_IPV4 in
  no auto-summary
  no synchronization
  network 192.168.1.0 mask 255.255.255.224
  network 192.168.1.64 mask 255.255.255.192
 exit-address-family
 !
 address-family ipv6
  neighbor 2001:DB8:ACAD:1012::2 activate
  neighbor 2001:DB8:ACAD:1012::2 prefix-list IPV6_ALLOWED_FROM_R2 in
  neighbor 2001:DB8:ACAD:1013::3 activate
  neighbor 2001:DB8:ACAD:1014::3 activate
  network 2001:DB8:ACAD:1000::/64
  network 2001:DB8:ACAD:1001::/64
 exit-address-family
!
ip forward-protocol nd
!
ip as-path access-list 1 permit ^$
!
no ip http server
no ip http secure-server
!
!
ip prefix-list ALLOWED_FROM_R2 seq 5 permit 192.168.2.0/24 le 27
!
ip prefix-list PREFERRED_IPV4_PATH seq 5 permit 192.168.3.0/24 le 27
no cdp log mismatch duplex
!
!
ipv6 prefix-list IPV6_ALLOWED_FROM_R2 seq 5 permit 2001:DB8:ACAD:2000::/64
ipv6 prefix-list IPV6_ALLOWED_FROM_R2 seq 10 permit 2001:DB8:ACAD:2001::/64
```

```
!
!
route-map USE_THIS_PATH_FOR_IPV4 permit 10
 match ip address prefix-list PREFERRED_IPV4_PATH
 set local-preference 250
!
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner motd ^C This is R1, BGP Path Manipulation Lab ^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end

R1#
```

- Final Config R2:

```
R2#show run
Building configuration...

Current configuration : 3069 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ipv6 unicast-routing
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
```

```
!
!
!
archive
 log config
  hidekeys
!
!
!
!
ip tcp synwait-time 5
!
!
!
!
interface Loopback0
 ip address 192.168.2.1 255.255.255.224
 ipv6 address FE80::2:3 link-local
 ipv6 address 2001:DB8:ACAD:2000::1/64
!
interface Loopback1
 ip address 192.168.2.65 255.255.255.192
 ipv6 address FE80::2:4 link-local
 ipv6 address 2001:DB8:ACAD:2001::1/64
!
interface FastEthernet0/0
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
 ipv6 address FE80::2:1 link-local
 ipv6 address 2001:DB8:ACAD:1012::2/64
!
interface Serial0/0
 no ip address
 shutdown
 clock rate 2000000
!
interface FastEthernet0/1
 ip address 10.2.3.2 255.255.255.0
 duplex auto
 speed auto
 ipv6 address FE80::2:2 link-local
 ipv6 address 2001:FE8:ACAD:1023::2/64
!
interface Serial0/1
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/2
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/3
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/4
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/5
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial1/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
```

```
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
!
router bgp 500
 bgp router-id 2.2.2.2
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 10.1.2.1 remote-as 6500
 neighbor 10.2.3.3 remote-as 300
 neighbor 2001:DB8:ACAD:1012::1 remote-as 6500
 neighbor 2001:DB8:ACAD:1023::3 remote-as 300
 !
 address-family ipv4
  neighbor 10.1.2.1 activate
  neighbor 10.2.3.3 activate
  no auto-summary
  no synchronization
  network 192.168.2.0 mask 255.255.255.224
  network 192.168.2.64 mask 255.255.255.192
 exit-address-family
 !
 address-family ipv6
  neighbor 2001:DB8:ACAD:1012::1 activate
  neighbor 2001:DB8:ACAD:1023::3 activate
  network 2001:DB8:ACAD:2000::/64
  network 2001:DB8:ACAD:2001::/64
 exit-address-family
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner motd ^C This is R2, BGP Path Manipulation Lab ^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end

R2#
```

- Final Config R3:

```
R3#show run
Building configuration...

Current configuration : 3535 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R3
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ipv6 unicast-routing
!
multilink bundle-name authenticated
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
archive
 log config
  hidekeys
!
!
!
!
ip tcp synwait-time 5
!
!
!
!
interface Loopback0
 ip address 192.168.3.1 255.255.255.224
 ipv6 address FE80::3:4 link-local
 ipv6 address 2001:DB8:ACAD:3000::1/64
!
interface Loopback1
 ip address 192.168.3.65 255.255.255.192
 ipv6 address FE80::3:5 link-local
 ipv6 address 2001:DB8:ACAD:3001::1/64
!
interface FastEthernet0/0
 ip address 10.2.3.3 255.255.255.0
 duplex auto
 speed auto
 ipv6 address FE80::3:1 link-local
 ipv6 address 2001:DB8:ACAD:1023::3/64
!
interface Serial0/0
 no ip address
 shutdown
 clock rate 2000000
!
interface FastEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface Serial0/1
 no ip address
 shutdown
```

```
 clock rate 2000000
!
interface Serial0/2
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/3
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/4
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/5
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial1/0
 ip address 10.1.3.3 255.255.255.128
 ipv6 address FE80::3:2 link-local
 ipv6 address 2001:DB8:ACAD:1013::3/64
 serial restart-delay 0
!
interface Serial1/1
 ip address 10.1.3.130 255.255.255.128
 ipv6 address FE80::3:3 link-local
 ipv6 address 2001:DB8:ACAD:1014::3/64
 serial restart-delay 0
!
interface Serial1/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial1/3
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/0
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/1
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/2
 no ip address
 shutdown
 serial restart-delay 0
!
interface Serial2/3
 no ip address
 shutdown
 serial restart-delay 0
!
router bgp 300
 bgp router-id 3.3.3.3
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 10.1.3.1 remote-as 6500
 neighbor 10.1.3.129 remote-as 6500
 neighbor 10.2.3.2 remote-as 500
 neighbor 2001:DB8:ACAD:1013::1 remote-as 6500
 neighbor 2001:DB8:ACAD:1014::1 remote-as 6500
 neighbor 2001:DB8:ACAD:1023::2 remote-as 500
 !
 address-family ipv4
  neighbor 10.1.3.1 activate
  neighbor 10.1.3.1 distribute-list ALLOWED_TO_R1 out
  neighbor 10.1.3.129 activate
  neighbor 10.1.3.129 distribute-list ALLOWED_TO_R1 out
  no auto-summary
  no synchronization
  network 192.168.3.0 mask 255.255.255.224
  network 192.168.3.64 mask 255.255.255.192
 exit-address-family
 !
 address-family ipv6
  neighbor 2001:DB8:ACAD:1013::1 activate
  neighbor 2001:DB8:ACAD:1014::1 activate
  neighbor 2001:DB8:ACAD:1023::2 activate
```

```
 exit-address-family
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
ip access-list extended ALLOWED_TO_R!
 permit ip host 192.168.3.0 host 255.255.255.224
 permit ip host 192.168.3.64 host 255.255.255.192
!
no cdp log mismatch duplex
!
!
!
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner motd ^C This is R3, BGP Path Manipulation Lab ^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end

R3#
```

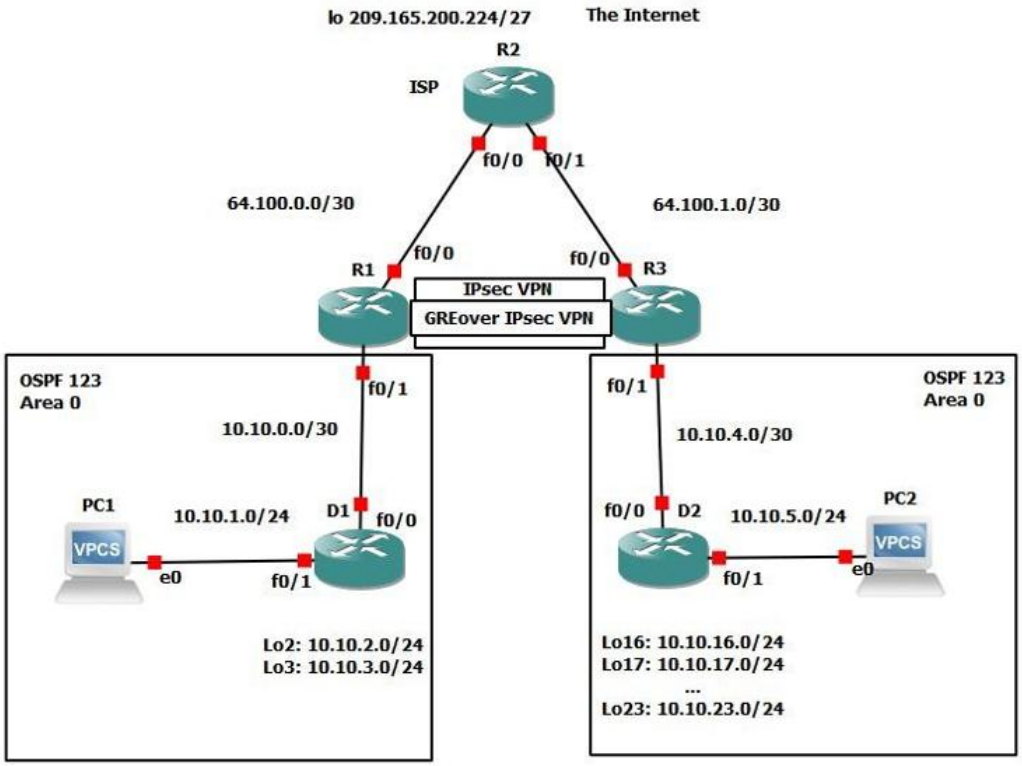
Practical no.8

Aim: Implement IP Sec Site -to -Site VPNs

What is IP Sec VPN?

- IP sec is a set of protocols that work together to establish encrypted connections between devices. It contributes to the security of data sent over public networks. IPsec is a popular VPN protocol that works by encrypting IP packets and authenticating the source of the packets.
- Users can connect to an IPsec VPN by launching a VPN client application. This usually necessitates the user having the application installed on their device.
- VPN logins are usually password-based. While data sent over a VPN is encrypted, if user passwords are compromised, attackers can log into the VPN and steal this encrypted data. Using two-factor authentication (2FA) can strengthen IPsec VPN security, since stealing a password alone will no longer give an attacker access.

Step 1: Design the network topology.



Step 2: Configure the network.

Router 1(R1):

```
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-time 0 0
R1(config-line)#exit
R1(config)#$ $This is id R1, Implement GRE overr IPsec Site-to-Site VPN$
R1(config)#int fa0/0
R1(config-if)#description Connection to R2
R1(config-if)#ip address 64.100.0.2 255.255.255.252
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:03:28.403: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:29.403: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#int fa0/1
R1(config-if)#description Connection to D1
R1(config-if)#ip address 10.10.0.1 255.255.255.252
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
*Mar  1 00:04:38.991: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:04:39.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#router ospf 123
R1(config-router)#router-id 1.1.1.1
R1(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
R1(config-router)#network 10.10.0.0 0.0.0.3 area 0
R1(config-router)#default-information originate
R1(config-router)#exit
R1(config)#ip route 0.0.0.0 0.0.0.0 64.100.0.1
R1(config)#end
R1#
*Mar  1 00:06:51.567: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

Router 2(R2):

```
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-time 0 0
R2(config-line)#exit
R2(config)#$ $This is id R2, Implement GRE over IPsec Site-to-Site VPN$
R2(config)#int fa0/0
R2(config-if)#description Connection to R1
R2(config-if)#ip address 64.100.0.1 255.255.255.252
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:02:38.495: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:02:39.495: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#int fa0/1
R2(config-if)#description Connection to R3
R2(config-if)#ip address 64.100.1.1 255.255.255.252
R2(config-if)#no shut
R2(config-if)#exit
R2(config)#
*Mar  1 00:03:39.063: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:03:40.063: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config)#int loopback 0
R2(config-if)#
*Mar  1 00:04:05.695: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#description internet simulated address
R2(config-if)#ip address 209.165.200.225 255.255.255.224
R2(config-if)#exit
R2(config)#ip route 0.0.0.0 0.0.0.0 loopback0
R2(config)#ip route 10.10.0.0 255.255.252.0 64.100.0.2
R2(config)#ip route 10.10.4.0 255.255.252.0 64.100.1.2
R2(config)#ip route 10.10.16.0 255.255.248.0 64.100.1.2
R2(config)#end
R2#
*Mar  1 00:09:21.627: %SYS-5-CONFIG_I: Configured from console by console
R2#
```

Router 3(R3):

```
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 sync
R3(config-line)#exec-time 0 0
R3(config-line)#exit
R3(config)#$ $This is id R3, Implement GRE over IPsec Site-to-Site VPN$
R3(config)#int f0/0
R3(config-if)#description Connection to R2
R3(config-if)#ip address 64.100.1.2 255.255.255.252
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:29:50.291: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:29:51.291: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config)#int fa0/1
R3(config-if)#description Connection to D2
R3(config-if)#ip address 10.10.4.1 255.255.255.252
R3(config-if)#no shut
R3(config-if)#exit
R3(config)#
*Mar  1 00:32:58.835: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:32:59.835: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R3(config)#ip route 0.0.0.0 0.0.0.0 64.100.1.1
R3(config)#router ospf 123
R3(config-router)#router-id 3.3.3.1
R3(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
R3(config-router)#network 10.10.4.0 0.0.0.3 area 0
R3(config-router)#default-information originate
R3(config-router)#exit
R3(config)#exit
R3#
*Mar  1 00:35:11.803: %SYS-5-CONFIG_I: Configured from console by console
R3#
```

Router 4(D1):

```
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#no ip domain lookup
D1(config)#line con 0
D1(config-line)#logging sync
D1(config-line)#exec-time 0 0
D1(config-line)#exit
D1(config)#$ $This is id D1, Implement GRE over IPsec Site-to-Site VPN$
D1(config)#int fa0/0
D1(config-if)#description Connection to R1
D1(config-if)#ip address 10.10.0.2 255.255.255.252
D1(config-if)#no shut
D1(config-if)#exit
D1(config)#
*Mar  1 00:33:30.803: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:33:31.803: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
D1(config)#int fa0/1
D1(config-if)#description Connection to PC1
D1(config-if)#ip address 10.10.1.1 255.255.255.0
D1(config-if)#no shut
D1(config-if)#exit
D1(config)#
*Mar  1 00:34:18.435: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:34:19.435: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
D1(config)#int loopback 2
D1(config-if)#
*Mar  1 00:34:37.831: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed state to up
D1(config-if)#description Loopback to simulate an OSPF network
D1(config-if)#ip address 10.10.2.1 255.255.255.0
D1(config-if)#ip ospf network point-to-point
D1(config-if)#exit
D1(config)#int loopback 3
D1(config-if)#
*Mar  1 00:36:28.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed state to up
D1(config-if)#description Loopback to simulate an OSPF network
D1(config-if)#ip address 10.10.3.1 255.255.255.0
D1(config-if)#ip ospf network point-to-point
D1(config-if)#exit
D1(config)#
D1(config)#router ospf 123
D1(config-router)#router-id 1.1.1.2
D1(config-router)#auto-cost reference-bandwidth 100
D1(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
D1(config-router)#network 10.10.0.0 0.0.3.255 area 0
D1(config-router)#exit
D1(config)#exit
D1#
*Mar  1 00:39:39.323: %SYS-5-CONFIG_I: Configured from console by console
D1#
*Mar  1 00:39:40.527: %OSPF-5-ADJCHG: Process 123, Nbr 1.1.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
D1#
```

- Router 5(D2):

```
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#no ip domain lookup
D2(config)#line con 0
D2(config-line)#logging sync
D2(config-line)#exec-time 0 0
D2(config-line)#exit
D2(config)#$ $This is id D2, Implement GRE over IPsec Site-to-Site VPN$
D2(config)#int fa0/0
D2(config-if)#description Connection to R3
D2(config-if)#ip address 10.10.4.2 255.255.255.252
D2(config-if)#no shut
D2(config-if)#e
*Mar  1 00:39:48.483: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:39:49.483: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
D2(config-if)#exit
D2(config)#int fa0/1
D2(config-if)#description Connection to PC2
D2(config-if)#ip address 10.10.5.1 255.255.255.0
D2(config-if)#no shut
D2(config-if)#exit
D2(config)#
*Mar  1 00:40:52.923: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:40:53.951: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
D2(config)#int loopback 16
D2(config-if)#
*Mar  1 00:41:18.107: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback16, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.16.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 17
D2(config-if)#
*Mar  1 00:42:32.175: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback17, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.17.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 18
D2(config-if)#
*Mar  1 00:44:21.099: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback18, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.18.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 19
*Mar  1 00:46:29.435: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback19, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.19.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 20
D2(config-if)#
*Mar  1 00:47:57.887: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback20, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.20.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 21
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#
*Mar  1 00:49:21.047: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback21, changed state to up
D2(config-if)#ip address 10.10.21.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 22
D2(config-if)#
*Mar  1 00:50:35.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback22, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.22.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#int loopback 23
D2(config-if)#
*Mar  1 00:51:30.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback23, changed state to up
D2(config-if)#description loopback to simulate an OSPF network
D2(config-if)#ip address 10.10.23.1 255.255.255.0
D2(config-if)#ip ospf network point-to-point
D2(config-if)#exit
D2(config)#router ospf 123
D2(config-router)#router-id 3.3.3.2
D2(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
D2(config-router)#network 10.10.4.0 0.0.1.255 area 0
D2(config-router)#network 10.10.16.0 0.0.7.255 area 0
D2(config-router)#e
*Mar  1 00:53:49.555: %OSPF-5-ADJCHG: Process 123, Nbr 3.3.3.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
D2(config-router)#exit
D2(config)#end
D2#
```

- PC1:

```
PC1> ip 10.10.1.10/24 10.10.1.1
Checking for duplicate address...
PC1 : 10.10.1.10 255.255.255.0 gateway 10.10.1.1

PC1> sh ip

NAME        : PC1[1]
IP/MASK     : 10.10.1.10/24
GATEWAY     : 10.10.1.1
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 10032
RHOST:PORT  : 127.0.0.1:10033
MTU:        : 1500

PC1>
```

- PC2:

```
PC2> ip 10.10.5.10/24 10.10.5.1
Checking for duplicate address...
PC1 : 10.10.5.10 255.255.255.0 gateway 10.10.5.1

PC2> sh ip

NAME        : PC2[1]
IP/MASK     : 10.10.5.10/24
GATEWAY     : 10.10.5.1
DNS         :
MAC         : 00:50:79:66:68:01
LPORT       : 10034
RHOST:PORT  : 127.0.0.1:10035
MTU:        : 1500

PC2>
```

Step 3: On PC1, verify end-to-end connectivity.

From PC1, ping the first loopback on D3 (10.10.16.1)

```
PC1> ping 10.10.16.1
84 bytes from 10.10.16.1 icmp_seq=1 ttl=251 time=46.510 ms
84 bytes from 10.10.16.1 icmp_seq=2 ttl=251 time=42.610 ms
84 bytes from 10.10.16.1 icmp_seq=3 ttl=251 time=58.851 ms
84 bytes from 10.10.16.1 icmp_seq=4 ttl=251 time=74.688 ms
84 bytes from 10.10.16.1 icmp_seq=5 ttl=251 time=43.387 ms

PC1>
```

Finally, from PC1, ping the default gateway loopback on R2 (209.165.200.225)

```
PC1> ping 209.165.200.225
84 bytes from 209.165.200.225 icmp_seq=1 ttl=253 time=51.180 ms
84 bytes from 209.165.200.225 icmp_seq=2 ttl=253 time=48.635 ms
84 bytes from 209.165.200.225 icmp_seq=3 ttl=253 time=48.582 ms
84 bytes from 209.165.200.225 icmp_seq=4 ttl=253 time=48.084 ms
84 bytes from 209.165.200.225 icmp_seq=5 ttl=253 time=49.034 ms

PC1>
```

Step 4: Verify the routing table of R1 and R3.

Verify the OSPF routing table of R1

```
R1#sh ip route ospf
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O       10.10.1.0/24 [110/200] via 10.10.0.2, 00:24:42, FastEthernet0/1
O       10.10.2.0/24 [110/101] via 10.10.0.2, 00:24:42, FastEthernet0/1
O       10.10.3.0/24 [110/101] via 10.10.0.2, 00:24:42, FastEthernet0/1
R1#
```

Verify the routing table of R3.

```
R3#sh ip route ospf
     10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
O       10.10.5.0/24 [110/200] via 10.10.4.2, 00:05:24, FastEthernet0/1
O       10.10.16.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.17.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.18.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.19.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.20.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.21.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.22.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
O       10.10.23.0/24 [110/101] via 10.10.4.2, 00:05:14, FastEthernet0/1
R3#
```

Step 5: Configure GRE over IPsec using a Crypto Map on R1.

- **On R1, configure the ISAKMP policy and pre-shared key.**

  Like site-to-site VPNs using crypto maps, GRE over IPsec also requires an ISAKMP policy configuration and pre-shared key configured.

  In this lab, we will use the following parameters for the ISAKMP policy 10 on R1:

  o Encryption: aes 256 o Hash: sha256
  o Authentication method: pre-share
  key o Diffie-Hellman group: 14 o
  Lifetime: 3600 seconds (60 minutes / 1
  hour)

Configure ISAKMP policy 10 on R1:

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#crypto isakmp policy 10
R1(config-isakmp)#encryption aes 256
R1(config-isakmp)#has sha
R1(config-isakmp)#authentication pre-share
R1(config-isakmp)#group 1
R1(config-isakmp)#lifetime 36000
R1(config-isakmp)#exit
R1(config)#
```

Configure the pre-shared key of cisco123 on R1. This command points to the remote peer R3 G0/0/0 IP address.

```
R1(config)#
R1(config)#crypto isakmp key cisco123 address 64.100.1.2
R1(config)#
```

- On R1, configure the transform set and VPN ACL.

  Create a transform set called GRE-VPN using AES 256 cipher with ESP and the SHA 256 hash function.

```
R1(config)#crypto ipsec transform-set GRE-VPN esp-aes 256 esp-sha-hmac
R1(cfg-crypto-trans)#
```

Unlike a site-to-site IPsec VPN, the transform must use transport mode. The mode command is used to identify the type of tunnel that will be established. The default is mode tunnel mode. However, GRE over IPsec should be configured using the mode transport command.

```
R1(cfg-crypto-trans)#mode transport
R1(cfg-crypto-trans)#exit
R1(config)#
```

- On R1, configure the crypto map and apply it to the interface.

  Create a crypto map called GRE-CMAP that associates the new GRE-VPN-ACL, transform set, and peer.

```
R1(config)#crypto map GRE-CMAP 10 ipsec-isakmp
% NOTE: This new crypto map will remain disabled until a peer
        and a valid access list have been configured.
R1(config-crypto-map)#match address GRE-VPN-ACL
R1(config-crypto-map)#set transform-set GRE-VPN
R1(config-crypto-map)#set peer 64.100.1.2
R1(config-crypto-map)#exit
R1(config)#
```

  Finally, assign a crypto map called GRE-MAP on G0/0/0

```
R1(config)#int fa0/0
R1(config-if)#crypto map GRE-CMAP
R1(config-if)#
*Mar  1 01:11:42.563: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R1(config-if)#exit
R1(config)#
```

- On R1, configure the GRE tunnel interface.

  Configure a GRE tunnel interface as shown. To enable GRE on the tunnel interface, the tunnel mode gre ipv4 command is required. However, this command is enabled by default and will therefore not be configured in our example.

```
R1(config)#int tunnel 1
R1(config-if)#
*Mar  1 01:12:23.783: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to down
R1(config-if)#bandwidth 4000
R1(config-if)#ip address 172.16.1.1 255.255.255.252
R1(config-if)#ip mtu 1400
R1(config-if)#tunnel source 64.100.0.2
R1(config-if)#tunnel destination 64.100.1.2
R1(config-if)#e
*Mar  1 01:13:51.835: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to up
R1(config-if)#end
R1#
*Mar  1 01:13:57.935: %SYS-5-CONFIG_I: Configured from console by console
R1#
```

Step 6: Configure GRE over IPsec using a Tunnel IPsec Profile on R3.

In this part, we will configure GRE over IPsec using tunnel IPsec profiles on R3.

- On R3, configure the ISAKMP policy, pre-shared key, and transform set.

  In this step, we will configure the same parameters for the ISAKMP policy 10 that we configured on R1.

  Configure ISAKMP policy 10 on R3:

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#crypto isakmp policy 10
R3(config-isakmp)#encryption aes 256
R3(config-isakmp)#hash sh
R3(config-isakmp)#authentication pre-share
R3(config-isakmp)#group 1
R3(config-isakmp)#lifetime 3600
R3(config-isakmp)#exit
R3(config)#
```

Configure the pre-shared key of cisco123 on R1. This command points to the remote peer R3 G0/0/0 IP address.

```
R3(config)#
R3(config)#crypto isakmp key cisco123 address 64.100.0.2
R3(config)#
```

Create a new transform set called GRE-VPN using the same security parameters and transport mode that we configured on R1. Also configure the mode transport command.

```
R3(config)#crypto ipsec transform-set GRE-VPN esp-aes 256 esp-sha-hmac
R3(cfg-crypto-trans)#mode transport
R3(cfg-crypto-trans)#exit
R3(config)#
```

- On R3, configure the IPsec profile.
  Instead of a crypto map, we will configure an IPsec profile called GRE-PROFILE using the crypto ipsec profile ipsec-profile-name global configuration command.

```
R3(config)#crypto ipsec profile GRE-profile
R3(ipsec-profile)#
```

In IPsec profile configuration mode, specify the transform set to be negotiated using the set transform-set transform-set-name command. Multiple transform sets can be specified in order of priority. The fist transform-set-name specified is the highest priority.

```
R3(ipsec-profile)#set transform-set GRE-VPN
R3(ipsec-profile)#exit
R3(config)#
```

- On R3, configure the tunnel interface.
  On R3, configure a GRE tunnel interface.

```
R3(config)#int tunnel 1
R3(config-if)#
*Mar  1 01:27:53.523: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to down
R3(config-if)#bandwidth 4000
R3(config-if)#ip address 172.16.1.2 255.255.255.252
R3(config-if)#ip mtu 1400
R3(config-if)#tunnel source 64.1000.1.2
                            ^
% Invalid input detected at '^' marker.

R3(config-if)#tunnel source 64.100.1.2
R3(config-if)#tunnel destination 64.100.0.2
R3(config-if)#
*Mar  1 01:29:32.723: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel1, changed state to up
R3(config-if)#
```

Apply the IPsec profile GRE-PROFILE to the Tunnel 1 interface using the tunnel protection ipsec profile profile-name command.

```
R3(config-if)#tunnel protection ipsec profile GRE-profile
R3(config-if)#
*Mar  1 01:30:14.675: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R3(config-if)#end
R3#
*Mar  1 01:30:19.575: %SYS-5-CONFIG_I: Configured from console by console
R3#
```

- On R1 and R3, enable OSPF routing on the tunnel interface.

Verify that the GRE over IPsec VPN is operational.

On R1, perform an extended ping to the R3 10.10.16.1 interface.

```
R1#ping 10.10.16.1 source 10.10.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.16.1, timeout is 2 seconds:
Packet sent with a source address of 10.10.0.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/32/44 ms
R1#
```

The pings are successful, and it appears that the VPN is operational. On R1, verify the IPsec SA encrypted and decrypted statistics.

```
R1#sh crypto ipsec sa | include encrypt | decrypt
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
R1#
```

From D1, trace the path taken to the R3 10.10.16.1 interface.

```
D1#trace 10.10.16.1

Type escape sequence to abort.
Tracing the route to 10.10.16.1

  1 10.10.0.1 12 msec 20 msec 24 msec
  2 64.100.0.1 32 msec 28 msec 32 msec
  3 64.100.1.2 40 msec 64 msec 32 msec
  4 10.10.4.2 80 msec 76 msec 64 msec
D1#
```

On R1, configure OSPF to advertise the tunnel interfaces.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router ospf 123
R1(config-router)#network 172.16.1.0 0.0.0.3 area 0
R1(config-router)#
```

On R3, configure OSPF to advertise the tunnel interfaces.

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#router ospf 123
R3(config-router)#network 172.16.1.0 0.0.0.3 area 0
R3(config-router)#
*Mar  1 01:34:16.631: %OSPF-5-ADJCHG: Process 123, Nbr 1.1.1.1 on Tunnel1 from LOADING to FULL, Loading Done
R3(config-router)#
```

Step 7: Verify the GRE over IPsec Tunnel on R1 and R3.

Now that the GRE over IPsec has been configured, we must verify that the tunnel interfaces are correctly enabled, that the crypto session is active, and then generate traffic to confirm it is traversing securely over the IPsec tunnel.

```
R1(config-router)#end
R1#
*Mar  1 01:27:58.955: %SYS-5-CONFIG_I: Configured from console by console
R1#sh int tunnel 1
Tunnel1 is up, line protocol is up
  Hardware is Tunnel
  Internet address is 172.16.1.1/30
  MTU 1514 bytes, BW 4000 Kbit/sec, DLY 500000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation TUNNEL, loopback not set
  Keepalive not set
  Tunnel source 64.100.0.2, destination 64.100.1.2
  Tunnel protocol/transport GRE/IP
    Key disabled, sequencing disabled
    Checksumming of packets disabled
  Tunnel TTL 255
  Fast tunneling enabled
  Tunnel transmit bandwidth 8000 (kbps)
  Tunnel receive bandwidth 8000 (kbps)
  Last input 00:00:08, output 00:00:05, 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: fifo
  Output queue: 0/0 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     12 packets input, 1596 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     20 packets output, 2332 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 output buffer failures, 0 output buffers swapped out
R1#
```

On R3, use the show interfaces tunnel 1 command to verify the interface settings.

```
R3(config-router)#end
R3#
*Mar  1 01:35:52.623: %SYS-5-CONFIG_I: Configured from console by console
R3#sh int tunnel 1 | include is up | Internet address | Enc | Tunnel proto$
Tunnel1 is up, line protocol is up
  Internet address is 172.16.1.2/30
R3#
```

➢ Remember that when u type “sh int tunnel 1 | include is up | Internet address | Enc | Tunnel proto$” it will automatically change to “$el 1 | include is up | Internet address | Enc | Tunnel protocol$”

```
R3#$el 1 | include is up | Internet address | Enc | Tunnel protocol$
Tunnel1 is up, line protocol is up
  Internet address is 172.16.1.2/30
R3#
```

- On R1 and R3, verify the crypto settings.

On R1, use the show crypto session command to verify the operation of the VPN tunnel.

```
R1#sh crypto session
Crypto session current status

Interface: FastEthernet0/0
Session status: UP-ACTIVE
Peer: 64.100.1.2 port 500
  IKE SA: local 64.100.0.2/500 remote 64.100.1.2/500 Active
  IPSEC FLOW: permit 47 host 64.100.0.2 host 64.100.1.2
        Active SAs: 2, origin: crypto map

R1#
```

On R3, use the show crypto session command to verify the operation of the VPN tunnel.

```
R3#sh crypto session
Crypto session current status

Interface: Tunnel1
Session status: UP-ACTIVE
Peer: 64.100.0.2 port 500
  IKE SA: local 64.100.1.2/500 remote 64.100.0.2/500 Active
  IPSEC FLOW: permit 47 host 64.100.1.2 host 64.100.0.2
        Active SAs: 2, origin: crypto map

R3#
```

On R1 and R3, verify OSPF routing.

On R1and R3, verify which interfaces are configured for OSPF using the show ip ospf interface brief command.

```
R1#sh ip ospf int bri
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Tu1          123   0               172.16.1.1/30      250   P2P   1/1
Fa0/1        123   0               10.10.0.1/30       100   DR    1/1
R1#
```

```
R3#sh ip ospf int bri
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Tu1          123   0               172.16.1.2/30      250   P2P   1/1
Fa0/1        123   0               10.10.4.1/30       100   DR    1/1
R3#
```

On R1and R3, verify the OSPF neighbours using the show ip ospf interface brief command.

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
3.3.3.1           0   FULL/  -        00:00:32    172.16.1.2      Tunnel1
1.1.1.2           1   FULL/BDR        00:00:31    10.10.0.2       FastEthernet0/1
R1#
3.3.3.2           1   FULL/BDR        00:00:37    10.10.4.2       FastEthernet0/1
R3#
```

Verify the R1 routing table for OSPF routes.

```
R1#sh ip route ospf
     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
O       10.10.1.0/24 [110/200] via 10.10.0.2, 01:06:40, FastEthernet0/1
O       10.10.2.0/24 [110/101] via 10.10.0.2, 01:06:40, FastEthernet0/1
O       10.10.3.0/24 [110/101] via 10.10.0.2, 01:06:40, FastEthernet0/1
O       10.10.4.0/30 [110/350] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.5.0/24 [110/450] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.16.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.17.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.18.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.19.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.20.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.21.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.22.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
O       10.10.23.0/24 [110/351] via 172.16.1.2, 00:16:54, Tunnel1
R1#
```

Verify the R3 routing table for OSPF routes.

```
R3#sh ip route ospf
     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
O       10.10.0.0/30 [110/350] via 172.16.1.1, 00:17:19, Tunnel1
O       10.10.1.0/24 [110/450] via 172.16.1.1, 00:17:19, Tunnel1
O       10.10.2.0/24 [110/351] via 172.16.1.1, 00:17:19, Tunnel1
O       10.10.3.0/24 [110/351] via 172.16.1.1, 00:17:19, Tunnel1
O       10.10.5.0/24 [110/200] via 10.10.4.2, 00:47:26, FastEthernet0/1
O       10.10.16.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.17.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.18.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.19.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.20.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.21.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.22.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
O       10.10.23.0/24 [110/101] via 10.10.4.2, 00:47:16, FastEthernet0/1
R3#
```

Verify that there is an operational logical point-to-point link between R1 and R3 using the GRE tunnel interface.

```
R1#sh ip route 172.16.0.0
Routing entry for 172.16.0.0/30, 1 known subnets
  Attached (1 connections)

C       172.16.1.0 is directly connected, Tunnel1
R1#
```

```
R3#sh ip route 172.16.0.0
Routing entry for 172.16.0.0/30, 1 known subnets
  Attached (1 connections)

C       172.16.1.0 is directly connected, Tunnel1
R3#
```

• Test the GRE over IPsec VPN tunnel.

From D1, trace the path taken to the R3 10.10.16.1 interface.

```
D1#trace 10.10.16.1

Type escape sequence to abort.
Tracing the route to 10.10.16.1

  1 10.10.0.1 24 msec 24 msec 20 msec
  2 172.16.1.2 36 msec 40 msec 44 msec
  3 10.10.4.2 56 msec 40 msec 84 msec
D1#
```

On R1, verify the IPsec SA encrypted and decrypted statistics.

```
R1#sh crypto ipsec sa | include encrypt | decrypt
    #pkts decaps: 140, #pkts decrypt: 140, #pkts verify: 140
R1#
```

The output verifies that the GRE over IPsec VPN tunnel is properly encrypting traffic between both sites. The packets encrypted include the trace packets along with OSPF packet.