

Roll No: - CS22006

Software Defined Networking

Name: Avinash Kauran

Class: MSc Computer Science

Roll No: CS22006

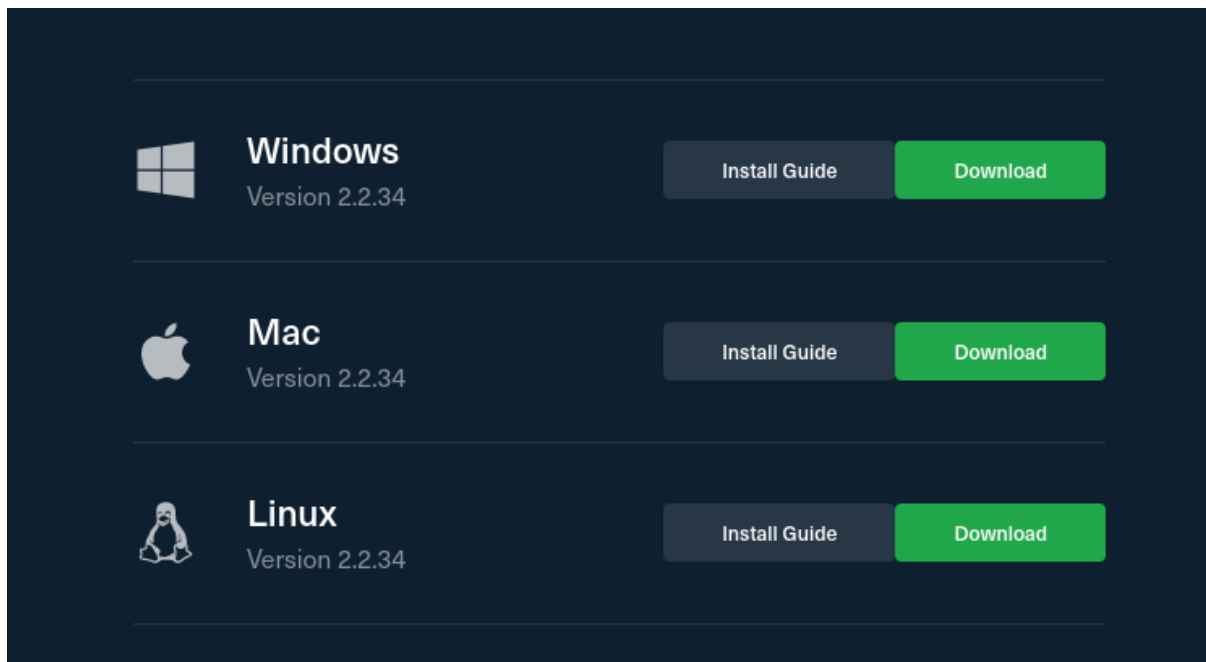
INDEX

Index No	Practical	Date
0	Setup of GNS3	14-09-2022
1	IP SLA	23-09-2022
2	Implement IPv4 ACLs 1. Standard 2. Extended	24-09-2022
3	1. Implement a GRE Tunnel 2. Implement VTP 3. Implement NAT	29-10-2022
4	Implement Inter-VLAN Routing	30-09-2022
5	Observe STP Topology Changes and Implement RSTP	20-10-2022
6	1. Implement EtherChannel 2. Tune and Optimize EtherChannel Operations	29-10-2022
7	1. Implement Single-Area OSPFv2 2. Implement Multi-Area OSPFv2 3. OSPFv2 Route Summarization and Filtering 4. Implement Multiarea OSPFv3	15-09-2022
8	Implement BGP Communities 1. Implement eBGP for Ipv4(only perform part 1 and part 2 from doc) 2.Implement MP(Multi-protocol) -BGP (meaning it supports multiple protocol eg: IPv6,ospf etc)-part 1& 2 3. Implement BGP path Manipulation	8-11-2022
9	Implement IP Sec Site -to -Site VPNs	11-11-2022

Practical 0

Step 1: Visit the [link](#) and download for your respective OS

Mine is Linux



Step 2: I am using the packet manager to install gns3 from AUR
command:

```
yay -S gns3-gui gns3-server
:: Checking for conflicts...
:: Checking for inner conflicts...
[Repo:17] python-attrs-22.1.0-1 python-pyrsistent-0.19.0-1 python-jsonschema-4.16.0-1 busybox-1.3
1.0-1 python-multidict-6.0.2-1 python-async-timeout-4.0.2-1 python-yarl-1.8.1-1 python-charset-no
iosignal-1.2.0-3 python-frozenset-1.3.1-1 python-aiohttp-3.8.1-4 python-aiohttp-cors-0.7.0-7 pyt
python-wcwidth-0.2.5-6 python-prompt_toolkit-3.0.31-1 python-py-cpuinfo-8.0.0-3
[Repo:3] python-build-0.8.0-2 python-installer-0.5.1-1 python-wheel-0.37.1-1
[Aur:3] python-sentry_sdk-1.9.8-1 gns3-gui-2.2.34-1 gns3-server-2.2.34-1

:: Remove make dependencies after install? [y/N]
:: (1/3) Downloaded PKGBUILD: gns3-gui
:: (2/3) Downloaded PKGBUILD: gns3-server
:: (3/3) Downloaded PKGBUILD: python-sentry_sdk
 3 python-sentry_sdk          (Build Files Exist)
 2 gns3-gui                  (Build Files Exist)
 1 gns3-server                (Build Files Exist)
==> Diffs to show?
==> [N]one [A]ll [Ab]ort [I]nstalled [No]tInstalled or (1 2 3, 1-3, ^4)
==> 
```

Roll No: - CS22006

```
~ : yay - Konsole

:: (3/3) Parsing SRCINFO: gns3-server
resolving dependencies...
looking for conflicting packages...

Package (20)                                New Version  Net Change  Download Size
community/busybox                          1.34.1-1     1.42 MiB   0.72 MiB
community/python-aiofiles                  22.1.0-1     0.07 MiB   0.02 MiB
community/python-aiohttp                   3.8.1-4      4.16 MiB   0.53 MiB
community/python-aiohttp-cors              0.7.0-7      0.11 MiB   0.03 MiB
community/python-aiosignal                 1.2.0-3      0.02 MiB   0.01 MiB
community/python-async-timeout              4.0.2-1      0.02 MiB   0.01 MiB
community/python-async_generator            1.10-7       0.16 MiB   0.04 MiB
extra/python-attrs                         22.1.0-1     0.43 MiB   0.08 MiB
community/python-build                     0.8.0-2      1.04 MiB   0.22 MiB
community/python-charset-normalizer         2.1.1-1      0.31 MiB   0.07 MiB
community/python-frozenset                 1.3.1-1      0.11 MiB   0.03 MiB
community/python-installer                 0.5.1-1      1.16 MiB   0.22 MiB
community/python-josnschema                4.16.0-1     0.94 MiB   0.13 MiB
community/python-multidict                 6.0.2-1      0.14 MiB   0.03 MiB
community/python-prompt_toolkit            3.0.31-1     3.50 MiB   0.55 MiB
community/python-py-cpuinfo                8.0.0-3      0.20 MiB   0.04 MiB
community/python-pyrsistent                0.19.0-1     0.49 MiB   0.09 MiB
community/python-wcwidth                   0.2.5-6      0.47 MiB   0.03 MiB
community/python-wheel                     0.37.1-1     0.16 MiB   0.04 MiB
community/python-yarl                      1.8.1-1      0.22 MiB   0.07 MiB

Total Download Size: 2.97 MiB
Total Installed Size: 15.14 MiB

:: Proceed with installation? [Y/n]
```

Installation is done

```
~ : zsh - Konsole

Package (1)  New Version  Net Change
gns3-server  2.2.34-1     29.53 MiB

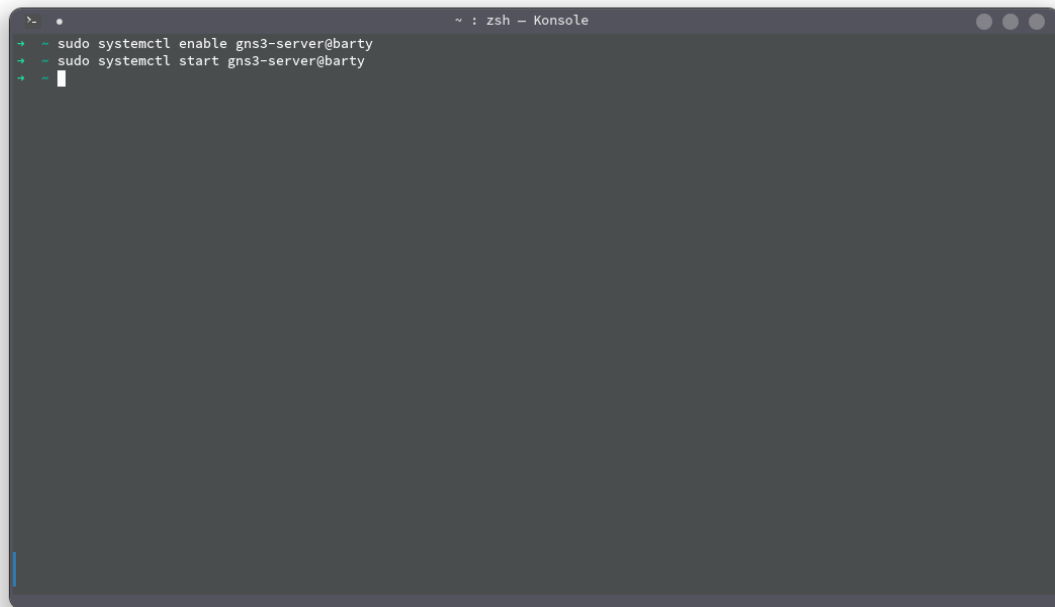
Total Installed Size: 29.53 MiB

:: Proceed with installation? [Y/n]
(1/1) checking keys in keyring [-----] 100%
(1/1) checking package integrity [-----] 100%
(1/1) loading package files [-----] 100%
(1/1) checking for file conflicts [-----] 100%
:: Processing package changes...
(1/1) installing gns3-server [-----] 100%
    To enable and start gns3-server execute the following,
    replacing 'USER' with your username:

        systemctl enable gns3-server@USER
        systemctl start gns3-server@USER
Optional dependencies for gns3-server
dynamips: Cisco router emulator
gns3-gui: graphical user interface for GNS3 server [installed]
qemu: Used by GNS3 to run Cisco ASA, PIX and IDS [installed]
libvirt: needed for the NAT cloud [installed]
vpcs: Simple PC emulation for basic network operations
ubridge: Bridge for UDP tunnels, Ethernet, TAP and VMnet interfaces
:: Running post-transaction hooks...
(1/2) Reloading system manager configuration...
(2/2) Arming ConditionNeedsUpdate...
→
```

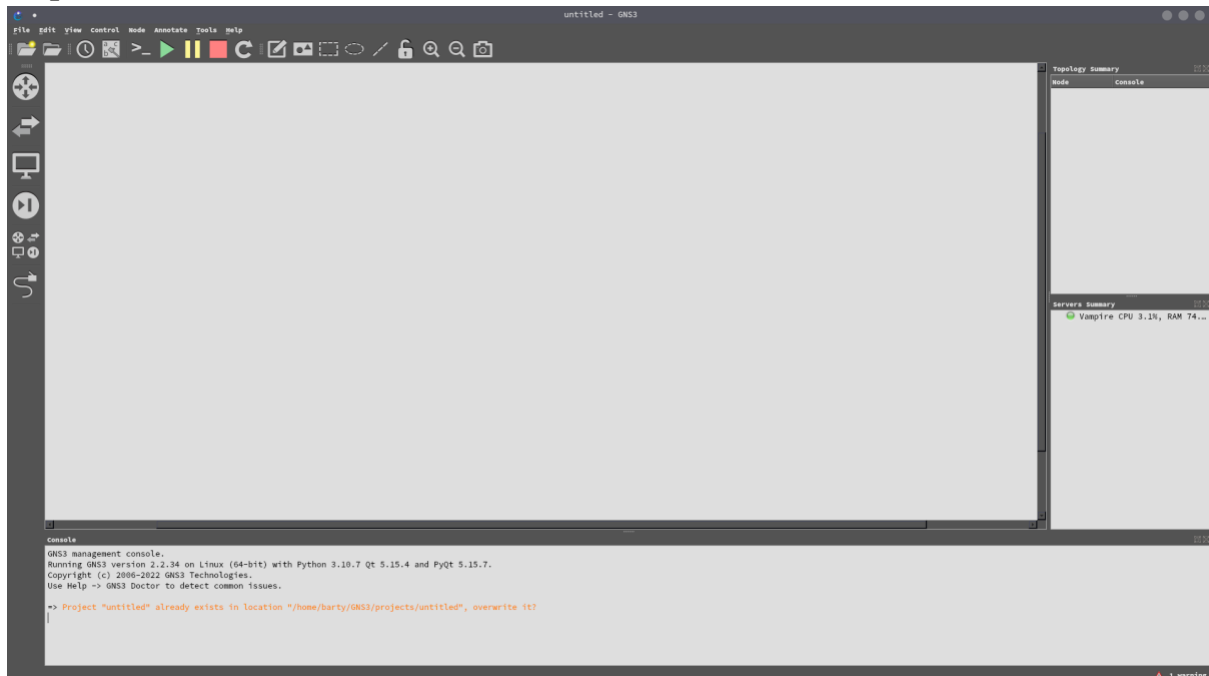
Step 3: Enable and start the gns3 service for your current user

Command: `sudo systemctl enable gns3-server@<username>`
`sudo systemctl start gns3-server@<username>`



```
~ : zsh - Konsole
+ ~ sudo systemctl enable gns3-server@barty
+ ~ sudo systemctl start gns3-server@barty
+ ~
```

Step 4: Launch GNS3



SDN Practical 1

Step 1 : Build the topology and start all routers



Step 2: What is IP SLA

- 1) IP SLA is an active computer network measurement technology that was initially developed by Cisco Systems.
- 2) IP SLA was previously known as Service Assurance Agent or Response Time Reporter.
- 3) IP SLA is used to track network performance like latency, ping response, and jitter, it also helps us to provide service quality

Step 3: Configure the routers

● Setting up Router 1's IP address

```

Adnan0(config)#int serial 0/0
Adnan0(config-if)#ip add 192.168.0.1 255.255.255.0
Adnan0(config-if)#no sh
Adnan0(config-if)#
*Mar  1 00:01:14.975: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar  1 00:01:15.975: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
Adnan0(config-if)#exit
  
```

● Adding loopback to router 2

```

Adnan1(config)#int loopback 1
Adnan1(config-if)#ip addr
*Mar  1 00:03:09.151: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed state to up
Adnan1(config-if)#ip add 4.4.4.4 255.255.255.0
Adnan1(config-if)#exit
Adnan1(config)#
  
```

● Setting up Router 2's IP address

```

Adnan1(config)#int serial 0/0
Adnan1(config-if)#ip add 192.168.0.2 255.255.255.0
Adnan1(config-if)#no sh
Adnan1(config-if)#
*Mar  1 00:02:45.539: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar  1 00:02:46.539: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
Adnan1(config-if)#exit
  
```

Step 4: Save your work on both routers

```
Adnan0#wr
Building configuration...
[OK]
Adnan0#copy run start
Destination filename [startup-config]?
Building configuration...
[OK]
Adnan0#
```

```
[OK]
Adnan1#copy run
Adnan1#copy run st
Adnan1#copy run startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
Adnan1#
```

Step 5: Setting up routing

```
Adnan0(config)#ip route 0.0.0.0 0.0.0.0 192.168.0.2
Adnan0(config)#exit
```

Step 6: Setting up SLA

- type echo protocol ipIcmpEcho 4.4.4.4 source-ip 192.168.0.1

```
Adnan0(config)#ip sla monitor 1
Adnan0(config-sla-monitor)#echo protocol ip
Adnan0(config-sla-monitor)#echo protocol ip
Adnan0(config-sla-monitor)#echo protocol ipE
Adnan0(config-sla-monitor)#echo protocol ipE
Adnan0(config-sla-monitor)#echo protocol ipE
Adnan0(config-sla-monitor)#echo protocol ipI
Adnan0(config-sla-monitor)#echo protocol ipIcm
Adnan0(config-sla-monitor)#echo protocol ipIcm
Adnan0(config-sla-monitor)#echo protocol ipIcm
Adnan0(config-sla-monitor)#echo protocol ipIcmp
Adnan0(config-sla-monitor)#$ol ipIcmpEcho 4.4.4.4 source-ip 192.168.0.1
echo protocol ipIcmpEcho 4.4.4.4 source-ip 192.168.0.1
^
% Invalid input detected at '^' marker.

Adnan0(config-sla-monitor)#type echo protocol ipIcmpEcho 4.4.4.4 source-ip 192$
Adnan0(config-sla-monitor-echo)#frequency 10
Adnan0(config-sla-monitor-echo)#threshold 200
Adnan0(config-sla-monitor-echo)#exit
Adnan0(config)#ip sla
Adnan0(config)#ip sla mo
Adnan0(config)#ip sla monitor sche
Adnan0(config)#ip sla monitor schedule 1 life forever
Adnan0(config)#ip sla monitor schedule 1 life fore
Adnan0(config)#ip sla monitor schedule 1 life forever start
Adnan0(config)#ip sla monitor schedule 1 life forever start-time now
Adnan0(config)#
```

Step 7: Output

- **ip sla monitor collection-statistics**

```
Adnan0#show ip sla monitor collection-statistics
Entry number: 1
Start Time Index: *00:11:08.307 UTC Fri Mar 1 2002
Number of successful operations: 7
Number of operations over threshold: 0
Number of failed operations due to a Disconnect: 0
Number of failed operations due to a Timeout: 26
Number of failed operations due to a Busy: 0
Number of failed operations due to a No Connection: 0
Number of failed operations due to an Internal Error: 0
Number of failed operations due to a Sequence Error: 0
Number of failed operations due to a Verify Error: 0
RTT Values:
RTTAvg: 26      RTTMin: 7      RTTMax: 43
NumOfRTT: 7    RTTSum: 186    RTTSum2: 5870
```

- **ip sla monitor distribution-statistics**

```
Adnan0#show ip sla moni
Adnan0#show ip sla monitor dis
Adnan0#show ip sla monitor distribution-statistics
Captured Statistics
Entry      = Entry number
StartT     = Start time of entry (hundredths of seconds)
Pth        = Path index
Hop        = Hop in path index
Dst        = Time distribution index
Comps      = Operations completed
OvrTh      = Operations completed over thresholds
SumCmp     = Sum of RTT (milliseconds)
SumCmp2L   = Sum of RTT squared low 32 bits (milliseconds)
SumCmp2H   = Sum of RTT squared high 32 bits (milliseconds)
TMax       = RTT maximum (milliseconds)
TMin       = RTT minimum (milliseconds)

Entry StartT   Pth Hop Dst Comps   OvrTh   SumCmp   SumCmp2L   SumCmp2H   TMax   TMin
1      66830   1  1  1  16      0      321      8727      0      43    3

Adnan0#
```

- **ip sla monitor operational-state**

```
Adnan0#show ip sla moni
Adnan0#show ip sla monitor ope
Adnan0#show ip sla monitor operational-state
Entry number: 1
Modification time: *00:11:03.307 UTC Fri Mar 1 2002
Number of Octets Used by this Entry: 2272
Number of operations attempted: 45
Number of operations skipped: 0
Current seconds left in Life: Forever
Operational state of entry: Active
Last time this entry was reset: Never
Connection loss occurred: FALSE
Timeout occurred: FALSE
Over thresholds occurred: FALSE
Latest RTT (milliseconds): 23
Latest operation start time: *00:18:23.307 UTC Fri Mar 1 2002
Latest operation return code: OK
RTT Values:
RTTAvg: 23      RTTMin: 23      RTTMax: 23
NumOfRTT: 1    RTTSum: 23      RTTSum2: 529

Adnan0#
```

- **ip sla monitor configuration**

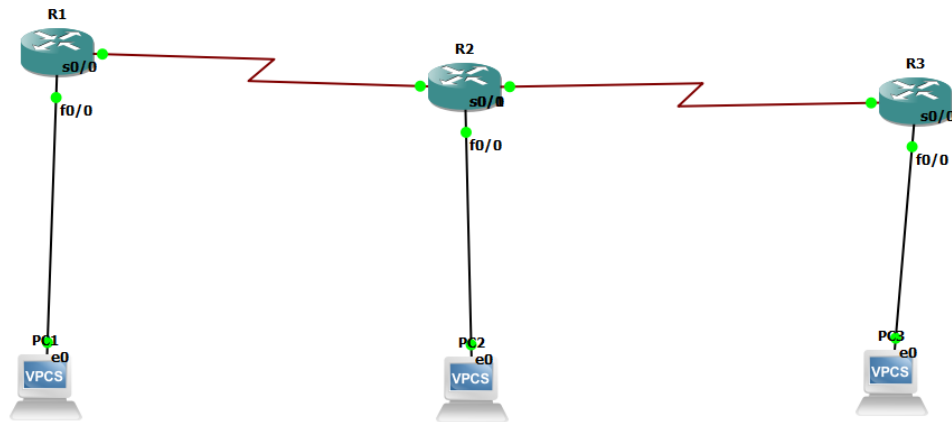

```
Adnan0#show ip sla monitor con
Adnan0#show ip sla monitor configuration
SA Agent, Infrastructure Engine-II
Entry number: 1
Owner:
Tag:
Type of operation to perform: echo
Target address: 4.4.4.4
Source address: 192.168.0.1
Request size (ARR data portion): 28
Operation timeout (milliseconds): 5000
Type Of Service parameters: 0x0
Verify data: No
Operation frequency (seconds): 10
Next Scheduled Start Time: Start Time already passed
Group Scheduled : FALSE
Life (seconds): Forever
Entry Ageout (seconds): never
Recurring (Starting Everyday): FALSE
Status of entry (SNMP RowStatus): Active
Threshold (milliseconds): 200
Number of statistic hours kept: 2
Number of statistic distribution buckets kept: 1
Statistic distribution interval (milliseconds): 20
Number of history Lives kept: 0
Number of history Buckets kept: 15
History Filter Type: None
Enhanced History:
```

- ip sla monitor statistics

```
Adnan0#show ip sla moni
Adnan0#show ip sla monitor stat
Adnan0#show ip sla monitor statistics
Round trip time (RTT)   Index 1
    Latest RTT: 7 ms
Latest operation start time: *00:20:03.307 UTC Fri Mar 1 2002
Latest operation return code: OK
Number of successes: 29
Number of failures: 26
Operation time to live: Forever
```

SDN Practical 2

Step 1: Topology



Step 2: Setup Routers

• Setting up router 1

```
R1(config)#int fastEthernet 0/0
R1(config)#ip add 192.168.0.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#int s0/0
*Mar 1 00:04:03.047: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:04:04.047: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config-if)#ip add 10.0.0.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#
*Mar 1 00:04:22.871: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar 1 00:04:23.871: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
```

• Checking direct connection from pc 1 to router 1

```
PC1> ip 192.168.0.100 255.255.255.0 192.168.0.1
Checking for duplicate address...
PC1 : 192.168.0.100 255.255.255.0 gateway 192.168.0.1

PC1> ping 192.168.0.1
84 bytes from 192.168.0.1 icmp_seq=1 ttl=255 time=15.636 ms
84 bytes from 192.168.0.1 icmp_seq=2 ttl=255 time=15.851 ms
84 bytes from 192.168.0.1 icmp_seq=3 ttl=255 time=15.382 ms
84 bytes from 192.168.0.1 icmp_seq=4 ttl=255 time=15.135 ms
84 bytes from 192.168.0.1 icmp_seq=5 ttl=255 time=15.341 ms

PC1>
```

- Setting up router 2

```
R2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#int fas
R2(config)#int fastEthernet 0/0
R2(config-if)#ip add 192.168.1.1 255.255.255.0
R2(config-if)#no sh
R2(config-if)#
*Mar 1 00:02:15.767: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:02:16.767: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config-if)#int serial 0/0
R2(config-if)#ip add 10.0.0.2 255.255.255.0
R2(config-if)#no sh
R2(config-if)#
*Mar 1 00:02:36.159: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar 1 00:02:37.159: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R2(config-if)#int serial 0/1
R2(config-if)#ip add 11.0.0.1 255.255.2
*Mar 1 00:03:02.111: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to down
R2(config-if)#ip add 11.0.0.1 255.255.255.0
R2(config-if)#no sh
R2(config-if)#
*Mar 1 00:03:10.563: %LINK-3-UPDOWN: Interface Serial0/1, changed state to up
*Mar 1 00:03:11.563: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/1, changed state to up
R2(config-if)#
```

- Checking direct connection from pc 3 to router 3

```
PC2> ip 192.168.1.100 255.255.255.0 192.168.1.1
Checking for duplicate address...
PC1 : 192.168.1.100 255.255.255.0 gateway 192.168.1.1

PC2> ping 192.168.1.1
192.168.1.1 icmp_seq=1 timeout
84 bytes from 192.168.1.1 icmp_seq=2 ttl=255 time=15.006 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=255 time=15.522 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=255 time=15.823 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=255 time=14.850 ms

PC2> █
```

- Setting up router 3

```
R3(config)#int fast
R3(config)#int fastEthernet 0/0
R3(config-if)#ip add 192.168.2.1 255.255.255.0
R3(config-if)#no sh
R3(config-if)#
*Mar 1 00:00:56.419: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:57.419: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R3(config-if)#exit
R3(config)#int serial 0/0
R3(config-if)#ip add 11.0.0.2 255.255.255.0
R3(config-if)#no sh
R3(config-if)#
*Mar 1 00:01:19.047: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar 1 00:01:20.047: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R3(config-if)# █
```

- Checking direct connection from pc 3 to router 3

```
PC3> ip 192.168.2.100 255.255.255.0 192.168.2.1
Checking for duplicate address...
PC1 : 192.168.2.100 255.255.255.0 gateway 192.168.2.1
```

```
PC3> ping 192.168.2.1
84 bytes from 192.168.2.1 icmp_seq=1 ttl=255 time=15.248 ms
84 bytes from 192.168.2.1 icmp_seq=2 ttl=255 time=15.584 ms
84 bytes from 192.168.2.1 icmp_seq=3 ttl=255 time=15.432 ms
84 bytes from 192.168.2.1 icmp_seq=4 ttl=255 time=15.165 ms
84 bytes from 192.168.2.1 icmp_seq=5 ttl=255 time=15.213 ms

PC3> █
```

Step 3: Adding rip protocol in all routers

- Router 1

```
R1(config)#router rip
R1(config-router)#network 192.168.0.0
R1(config-router)#network 10.0.0.0
R1(config-router)#exit
R1(config)#█
```

- Router 2

```
R2(config)#router rip
R2(config-router)#network 192.168.1.0
R2(config-router)#network 10.0.0.0
R2(config-router)#network 11.0.0.0
R2(config-router)#exit
R2(config)#█
```

- Router 3

```
R3(config)#router rip
R3(config-router)#network 192.168.2.0
R3(config-router)#network 11.0.0.0
R3(config-router)#exit
R3(config)#█
```

Step 4: Checking for via connections

- PC 3 to router 1 & 2 and pc 1

```
PC3> ping 192.168.0.1
84 bytes from 192.168.0.1 icmp_seq=1 ttl=253 time=15.363 ms
84 bytes from 192.168.0.1 icmp_seq=2 ttl=253 time=15.455 ms
84 bytes from 192.168.0.1 icmp_seq=3 ttl=253 time=15.520 ms
84 bytes from 192.168.0.1 icmp_seq=4 ttl=253 time=15.755 ms
84 bytes from 192.168.0.1 icmp_seq=5 ttl=253 time=15.120 ms

PC3> ping 192.168.1.1
84 bytes from 192.168.1.1 icmp_seq=1 ttl=254 time=16.192 ms
84 bytes from 192.168.1.1 icmp_seq=2 ttl=254 time=15.527 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=254 time=15.055 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=254 time=15.471 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=254 time=15.037 ms

PC3> ping 192.168.1.100
84 bytes from 192.168.1.100 icmp_seq=1 ttl=62 time=30.741 ms
84 bytes from 192.168.1.100 icmp_seq=2 ttl=62 time=31.424 ms
84 bytes from 192.168.1.100 icmp_seq=3 ttl=62 time=31.642 ms
84 bytes from 192.168.1.100 icmp_seq=4 ttl=62 time=30.572 ms
84 bytes from 192.168.1.100 icmp_seq=5 ttl=62 time=31.635 ms
```

Step 5: Adding standard ACL

```
R3(config)#access-l
R3(config)#access-list 10 deny host 192.168.1.0
R3(config)#access-li
R3(config)#access-list 10 permit any
R3(config)#int serial 0/0
R3(config-if)#ip access
R3(config-if)#ip access-group 10 in
R3(config-if)#exit
R3(config)#exit
R3#
*Mar  1 00:22:14.271: %SYS-5-CONFIG_I: Configured from console by console
R3#show acces
R3#show access-li
R3#show access-lists
Standard IP access list 10
 10 deny 192.168.1.0
 20 permit any (3 matches)
```

Step 6: Adding extended ACL

```
R3(config)#access
R3(config)#access-list 141 deny icmp host 192.168.1.1 host 192.168.2.1
R3(config)#do show acces
R3(config)#do show access-list
Standard IP access list 10
  10 deny 192.168.1.0
  20 permit any (22 matches)
Extended IP access list 141
  10 deny icmp host 192.168.1.1 host 192.168.2.1
R3(config)#access
R3(config)#access-list 141 permit icmp any any
R3(config)#do show access-list
Standard IP access list 10
  10 deny 192.168.1.0
  20 permit any (25 matches)
Extended IP access list 141
  10 deny icmp host 192.168.1.1 host 192.168.2.1
  20 permit icmp any any
R3(config)#int serial 0/0
R3(config-if)#ip access-group 141 out
R3(config-if)#ip access-group 141 in
R3(config-if)#do show acces
R3(config-if)#do show access-list
Standard IP access list 10
  10 deny 192.168.1.0
  20 permit any (28 matches)
Extended IP access list 141
  10 deny icmp host 192.168.1.1 host 192.168.2.1
  20 permit icmp any any
R3(config-if)#
```

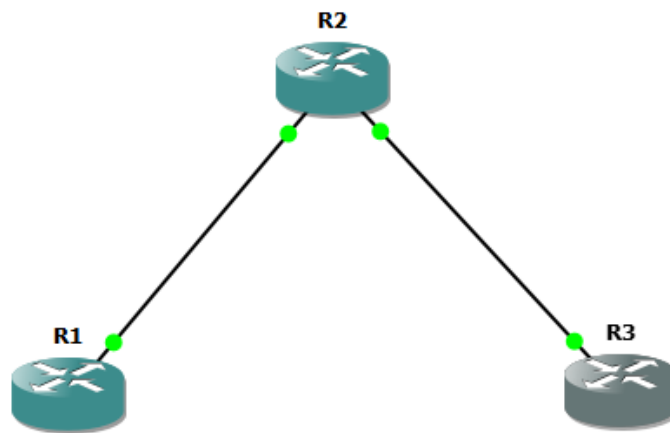
SDN Practical 3

Aim: -

1. Implement a GRE Tunnel
2. Implement VTP
3. Implement NAT

1. Implement a GRE Tunnel

Step 1: Topology



Step 2: Configure the routers

R1

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#hostname R1
R1(config)#banner motd #R1, Implement GRE tunnel#
R1(config)#line con 0
R1(config-line)#exec-timeout 0 0
R1(config-line)#logging synchronous
R1(config-line)#exit
R1(config)#int f0/0
R1(config-if)#ip add 192.168.0.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
R1(config)#int loopback 0
R1(config-if)#ip add 10.0.0.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
R1(config)#int loopback 1
R1(config-if)#ip add 172.16.0.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
R1(config)#router ospf 1
R1(config-router)#network 192.168.0.0 0.0.0.255 area 0
R1(config-router)#network 10.0.0.0 0.0.0.255 area 0
R1(config-router)#exit
R1(config)#exit
```

R2

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#banner motd #R2, Implement GRE tunnel#
R2(config)#line con 0
R2(config-line)#exec-timeout 0 0
R2(config-line)#logging synchronous
R2(config-line)#exit
R2(config)#int f0/0
R2(config-if)#ip add 192.168.0.2 255.255.255.0
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
R2(config)#int f0/1
R2(config-if)#ip add 192.168.1.1 255.255.255.0
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#
R2(config)#router ospf 1
R2(config-router)#network 192.168.0.0 0.0.0.255 area 0
R2(config-router)#network 192.168.1.0 0.0.0.255 area 0
R2(config-router)#exit
R2(config)#exit
```

R3

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
R3(config)#banner motd #R3, Implement GRE tunnel#
R3(config)#line con 0
R3(config-line)#exec-timeout 0 0
R3(config-line)#logging synchronous
R3(config-line)#exit
R3(config)#int f0/0
R3(config-if)#ip add 192.168.1.2 255.255.255.0
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
R3(config)#int loopback 0
R3(config-if)#ip add 10.0.1.1 255.255.255.0
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
R3(config)#int loopback 1
R3(config-if)#ip add 172.16.1.1 255.255.255.0
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
R3(config)#router ospf 1
R3(config-router)#network 192.168.1.0 0.0.0.255 area 0
R3(config-router)#network 10.0.1.0 0.0.0.255 area 0
R3(config-router)#exit
R3(config)#exit
```


Step 3: Verify reachability between R1 and R3.

R3 -> R1

```
R3#ping 192.168.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.0.1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 24/44/84 ms
R3#ping 10.0.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/49/84 ms
R3#
```

R1 -> R3

```
R1#ping 192.168.1.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.2, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/64/96 ms
R1#ping 10.0.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.1.1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/51/68 ms
R1#
```

Step 4: Create an GRE tunnel between R1 and R3.

R1

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#int tunnel 0
R1(config-if)#ip add 100.100.100.1 255.255.255.252
R1(config-if)#tunnel source loopback 0
R1(config-if)#tunnel destination 10.0.1.1
R1(config-if)#exit
R1(config)#
R1(config)#ip route 172.16.1.0 255.255.255.0 tunnel 0
*Mar 1 00:15:29.371: %SYS-5-CONFIG_I: Configured from console
R1(config)#ip route 172.16.1.0 255.255.255.0 tunnel 0
*Mar 1 00:15:32.043: %LINEPROTO-5-UPDOWN: Line protocol on Int
R1(config)#ip route 172.16.1.0 255.255.255.0 tunnel 0
R1(config)#
```

R3

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#int tunnel 0
R3(config-if)#ip add 100.100.100.2 255.255.255.252
R3(config-if)#tunnel source loopback 0
R3(config-if)#tunnel destination 10.0.0.1
R3(config-if)#exit
R3(config)#
R3(config)#ip route 172.16.0.0 255.255.255.0 tunnel 0
R3(config)#
R3(config)#
*Mar  1 00:15:36.335: %LINEPROTO-5-UPDOWN: Line protocol on In
R3(config)#
```

```
R1#show int tunnel 0
Tunnel0 is up, line protocol is up
  Hardware is Tunnel
  Internet address is 100.100.100.1/30
  MTU 1514 bytes, BW 9 Kbit, DLY 5000000 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation TUNNEL, loopback not set
  Keepalive not set
  Tunnel source 10.0.0.1 (Loopback0), destination 10.0.1.1
  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 00:02:05, output 00:02:05, 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
    5 packets input, 620 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
    5 packets output, 620 bytes, 0 underruns
      0 output errors, 0 collisions, 0 interface resets
    0 output buffer failures, 0 output buffers swapped out
R1#
```

Step 5: verify ping between R1 and R3

R1 -> R3

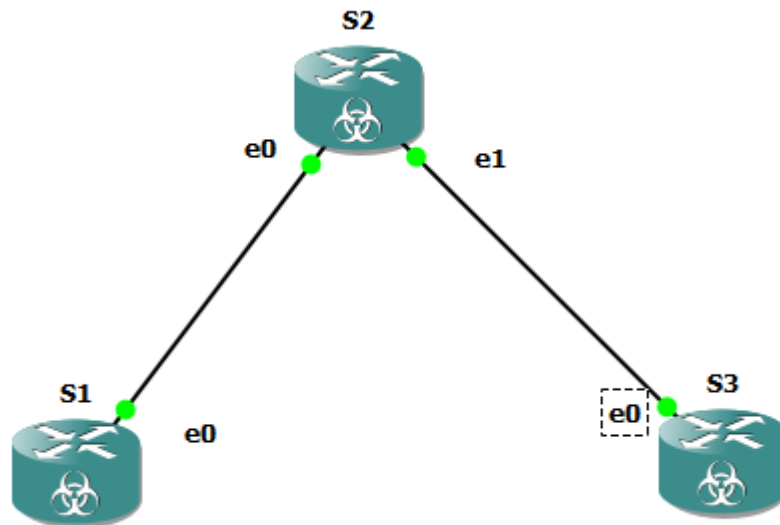
```
R1#ping 172.16.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/44/60 ms
R1#
```

R3 -> R1

```
R3#ping 172.16.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.0.1, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/44/60 ms
R3#
```

2. Implement VTP

Step 1: Topology



Step 2: Add VLAN on S1

```

vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#vlan 10
vIOS-L2-01(config-vlan)#name ket
vIOS-L2-01(config-vlan)#
vIOS-L2-01(config-vlan)#vlan 20
vIOS-L2-01(config-vlan)#name cat
vIOS-L2-01(config-vlan)#
vIOS-L2-01(config-vlan)#vlan 30
vIOS-L2-01(config-vlan)#name snake
vIOS-L2-01(config-vlan)#
vIOS-L2-01(config-vlan)#exit
vIOS-L2-01(config)#exit
vIOS-L2-01(config)#exit
  
```

```
vIOS-L2-01#show vlan
```

VLAN	Name	Status	Ports
1	default	active	Gi0/1, Gi0/2, Gi0/3, Gi1/0 Gi1/1
10	ket	active	
20	cat	active	
30	snake	active	
100	VLAN100	active	
200	VLAN0200	active	
300	VLAN0300	active	
1002	fddi-default	act/unsup	
1003	trcrf-default	act/unsup	
1004	fddinet-default	act/unsup	
1005	trbrf-default	act/unsup	

Step 3: Configure the switches

S1

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with Ctrl-Z.
vIOS-L2-01(config)#int g0/0
vIOS-L2-01(config-if)#sw trunk enc dot1q
vIOS-L2-01(config-if)#sw mode trunk
*Nov 27 12:09:21.281: %SYS-5-CONFIG_I: Configured from console
vIOS-L2-01(config-if)#sw mode trunk
vIOS-L2-01(config-if)#
```

S2

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with Ctrl-Z.
vIOS-L2-01(config)#int range g0/0-1
vIOS-L2-01(config-if-range)#sw trunk enc dot1q
vIOS-L2-01(config-if-range)#sw mode trunk
vIOS-L2-01(config-if-range)#
```

S3

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with Ctrl-Z.
vIOS-L2-01(config)#int g0/0
vIOS-L2-01(config-if)#sw trunk enc dot1q
vIOS-L2-01(config-if)#sw mode trunk
vIOS-L2-01(config-if)#
```

Step 4: Implement VTP

S1

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with Ctrl-Z.
vIOS-L2-01(config)#vtp mode server
Setting device to VTP Server mode for VLANs.
vIOS-L2-01(config)#vtp domain KET
Changing VTP domain name from CISCO-vIOS to KET
vIOS-L2-01(config)#vtp password KET
*Nov 27 12:13:12.539: %SW_VLAN-6-VTP_DOMAIN_NAME_CHG:
vIOS-L2-01(config)#vtp password KET
Setting device VTP password to KET
vIOS-L2-01(config)#
```

S2

```
vIOS-L2-01(config)#vtp mode trans
Device mode already VTP Transparent for VLANs.
vIOS-L2-01(config)#vtp domain KET
Changing VTP domain name from CISCO-vIOS to KET
vIOS-L2-01(config)#vtp password KET
Setting device VTP password to KET
vIOS-L2-01(config)#
*Nov 27 12:13:08.369: %SW_VLAN-6-VTP_DOMAIN_NAME_CHG:
vIOS-L2-01(config)#
```

S3

```
vIOS-L2-01(config)#vtp mode client
Setting device to VTP Client mode for VLANs.
vIOS-L2-01(config)#vtp domain KET
Changing VTP domain name from CISCO-vIOS to KET
vIOS-L2-01(config)#vtp password KET
*Nov 27 12:14:09.977: %SW_VLAN-6-VTP_DOMAIN_NAME_CHG:
vIOS-L2-01(config)#vtp password KET
Setting device VTP password to KET
vIOS-L2-01(config)#
```

Step 5: Check VTP Status

S1

```
vIOS-L2-01#show vtp status
VTP Version capable      : 1 to 3
VTP version running      : 2
VTP Domain Name          : KET
VTP Pruning Mode         : Disabled
VTP Traps Generation     : Disabled
Device ID                : 0c5a.af76.0000
Configuration last modified by 0.0.0.0 at 0-0-00 00:00:00
Local updater ID is 0.0.0.0 (no valid interface found)

Feature VLAN:
-----
VTP Operating Mode       : Server
Maximum VLANs supported locally : 1005
Number of existing VLANs : 11
Configuration Revision    : 0
MD5 digest               : 0x36 0x91 0x5B 0x51 0xBF 0x15 0x55 0x08
                        : 0x38 0xB1 0x20 0x29 0x87 0x13 0x48 0xF4
vIOS-L2-01#
```

S2

```
vIOS-L2-01#show vtp status
VTP Version capable      : 1 to 3
VTP version running      : 2
VTP Domain Name          : KET
VTP Pruning Mode         : Disabled
VTP Traps Generation     : Disabled
Device ID                : 0ce1.8bcc.0000
Configuration last modified by 0.0.0.0 at 0-0-00 00:00:00

Feature VLAN:
-----
VTP Operating Mode       : Transparent
Maximum VLANs supported locally : 1005
Number of existing VLANs : 8
Configuration Revision    : 0
MD5 digest               : 0x90 0xC2 0xDF 0xD2 0xE7 0xC9 0x20 0xE3
                        : 0x91 0x79 0x20 0x5D 0x5E 0x84 0x4D 0x88
vIOS-L2-01#
```

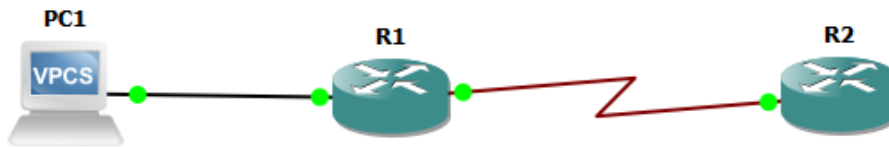
S3

```
vIOS-L2-01#show vtp status
VTP Version capable      : 1 to 3
VTP version running      : 2
VTP Domain Name          : KET
VTP Pruning Mode         : Disabled
VTP Traps Generation     : Disabled
Device ID                : 0c4e.feaf.0000
Configuration last modified by 0.0.0.0 at 0-0-00 00:00:00

Feature VLAN:
-----
VTP Operating Mode       : Client
Maximum VLANs supported locally : 1005
Number of existing VLANs : 8
Configuration Revision    : 0
MD5 digest               : 0x90 0xC2 0xDF 0xD2 0xE7 0xC9 0x20 0xE3
                        : 0x91 0x79 0x20 0x5D 0x5E 0x84 0x4D 0x88
vIOS-L2-01#
```

3. Implement NAT

Step 1: Topology



Step 2: Configure ISP (Router 2)

```
R2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#hostname ISP
ISP(config)#enable password cisco
ISP(config)#enable secret class
ISP(config)#line console 0
ISP(config-line)#password cisco
ISP(config-line)#login
ISP(config-line)#exit
ISP(config)#line vty 0 4
ISP(config-line)#password cisco
ISP(config-line)#login
ISP(config-line)#exit
ISP(config)#int loopback 0
ISP(config-if)#ip add 172.16.1.1 255.255.255.255
ISP(config-if)#no sh
ISP(config-if)#exit
ISP(config)#int serial 0/0
ISP(config-if)#ip add 200.2.2.17 255.255.255.252
ISP(config-if)#no sh
ISP(config-if)#clockrate 64000
ISP(config-if)#
```

Step 3: Configure Gateway

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#hostname Gateway
Gateway(config)#enable password cisco
Gateway(config)#enable secret class
Gateway(config)#line console 0
Gateway(config-line)#password cisco
Gateway(config-line)#login
Gateway(config-line)#exit
Gateway(config)#line vty 0 4
Gateway(config-line)#password cisco
Gateway(config-line)#login
Gateway(config-line)#exit
Gateway(config)#int f0/0
Gateway(config-if)#ip add 10.10.10.1 255.255.255.0
Gateway(config-if)#no sh
Gateway(config-if)#exit
Gateway(config)#
Gateway(config)#int serial 0/0
Gateway(config-if)#ip add 200.2.2.18 255.255.255.252
Gateway(config-if)#no sh
Gateway(config-if)#exit
```

Step 4: Configure PC

```
PC1> ip 10.10.10.100/24 10.10.10.1
Checking for duplicate address...
PC1 : 10.10.10.100 255.255.255.0 gateway 10.10.10.1
```

Step 5: Check connectivity from pc to gateway

```
PC1> ping 200.2.2.18

84 bytes from 200.2.2.18 icmp_seq=1 ttl=255 time=10.963 ms
84 bytes from 200.2.2.18 icmp_seq=2 ttl=255 time=0.879 ms
84 bytes from 200.2.2.18 icmp_seq=3 ttl=255 time=10.229 ms
84 bytes from 200.2.2.18 icmp_seq=4 ttl=255 time=4.151 ms
84 bytes from 200.2.2.18 icmp_seq=5 ttl=255 time=1.095 ms

PC1> █
```

Step 6: Create a static route from the ISP to the Gateway router.

```
ISP#conf t
Enter configuration commands, one per line. End with CNTL/Z.
ISP(config)#ip route 199.99.9.32 255.255.255.224 200.2.2.18
ISP(config)# █
```

Step 7: Add a default route from the Gateway router to the ISP router.

```
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 8: Define the pool of usable public IP addresses

```
ip nat pool public-access 199.99.9.40 199.99.9.62 netmask 255.255.255.224
```

```
Gateway(config)#ip nat pool public-access ?
A.B.C.D      Start IP address
netmask      Specify the network mask
prefix-length Specify the prefix length

Gateway(config)#$cess 199.99.9.40 199.99.9.62 netmask 255.255.255.224
Gateway(config)# █
```

Step 9: Define an access list that will match the inside private IP addresses

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

Step 10: Define the NAT translation from inside list to outside pool

```
Gateway(config)#ip nat inside source list 1 pool public-access
Gateway(config)# █
```


Step 11: Specify the interfaces

```
Gateway(config)#int f 0/0
Gateway(config-if)#ip nat inside
Gateway(config-if)#exit
Gateway(config)#int serial 0/0
Gateway(config-if)#ip nat outside
Gateway(config-if)#exit
```

Step 12: Testing the configuration

From the PC, ping 200.2.2.17

```
PC1> ping 200.2.2.17

84 bytes from 200.2.2.17 icmp_seq=1 ttl=254 time=10.060 ms
84 bytes from 200.2.2.17 icmp_seq=2 ttl=254 time=9.578 ms
84 bytes from 200.2.2.17 icmp_seq=3 ttl=254 time=9.521 ms
84 bytes from 200.2.2.17 icmp_seq=4 ttl=254 time=3.792 ms
84 bytes from 200.2.2.17 icmp_seq=5 ttl=254 time=10.327 ms

PC1> 200.2.2.17
```

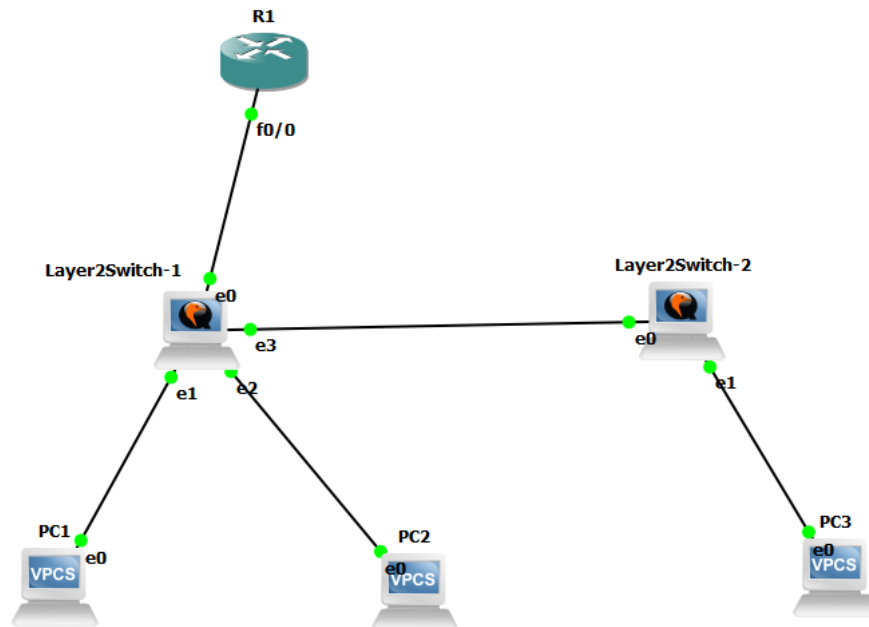
Check the NAT translation on the Gateway router,

```
Gateway#show ip nat translations
Pro Inside global      Inside local      Outside local      Outside global
--- 199.99.9.40         10.10.10.100      ---               ---
Gateway#
```

SDN Practical 4 (VLAN Routing)

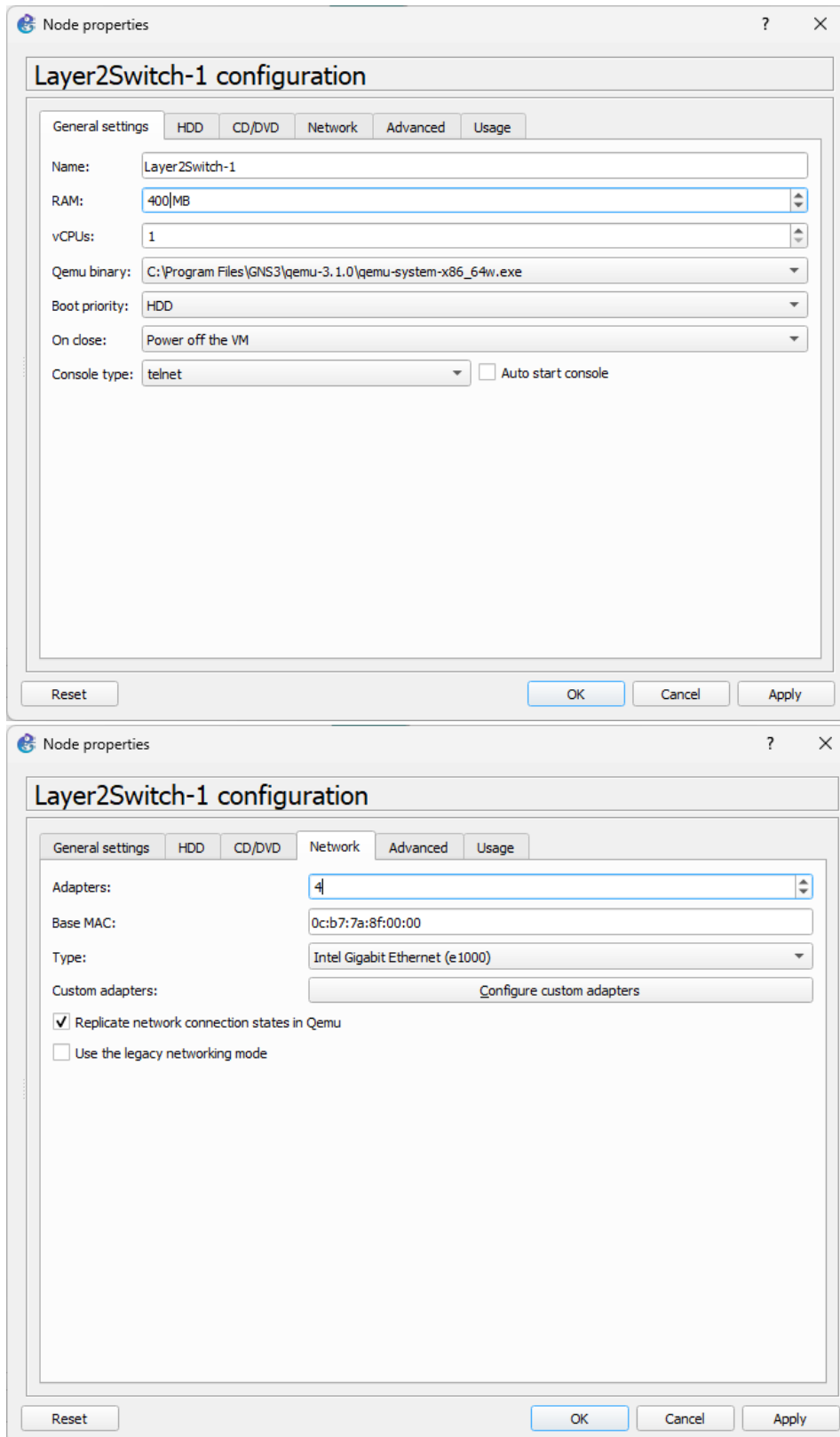
Step 1: Install Layer 2 Switch from [here](#)

Step 2: Design the topology



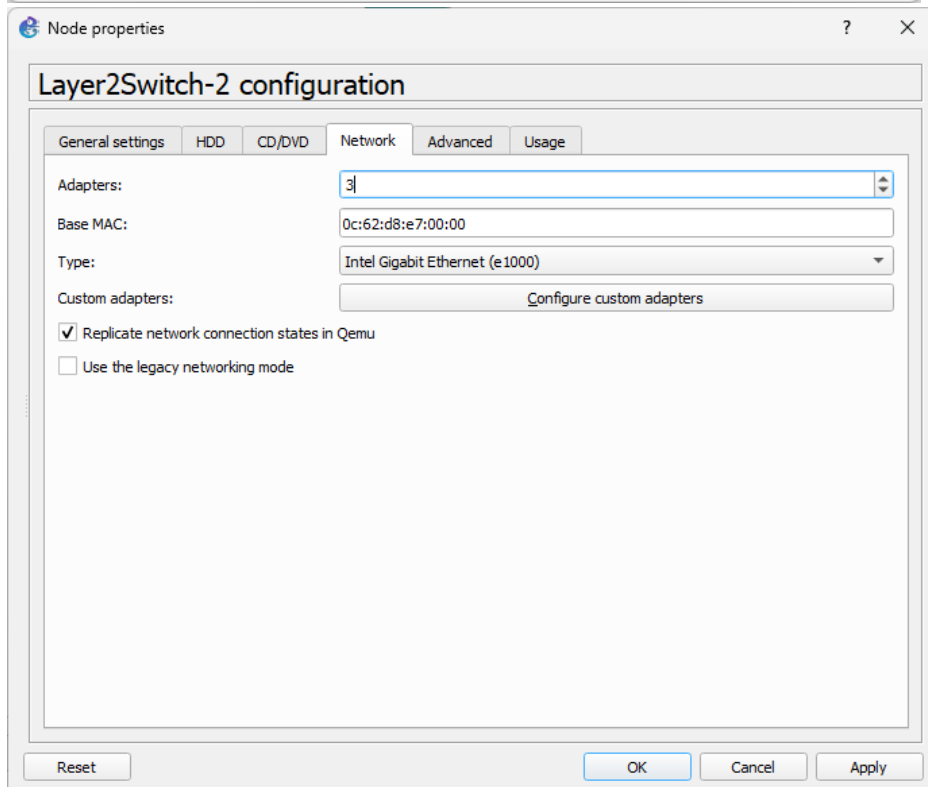
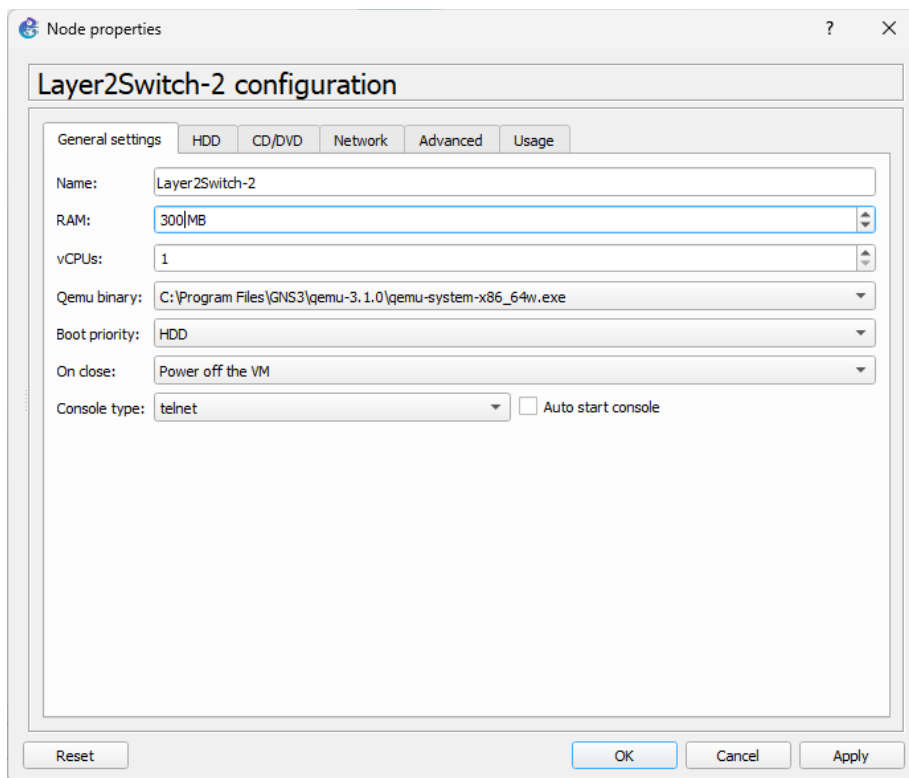
Step 3: Configure the Layer 2 Switch-1.

- Switch RAM to 400 MB in the general tab
- Change number of adapter to 4 in network tab



Step 4: Configure the Layer 2 Switch-2.

- Switch RAM to 300 MB in the general tab
- Change number of adapter to 2 in network tab



Step 5: Configuring the PC's

- PC 1

```
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> show 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      : 10014
RHOST:PORT : 127.0.0.1:10015
MTU        : 1500
```

- PC 2

```
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> show 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      : 10012
RHOST:PORT : 127.0.0.1:10013
MTU        : 1500
```

- PC 3

```
PC3> ip 192.168.5.10/24 192.168.5.1
Checking for duplicate address...
shPC1 : 192.168.5.10 255.255.255.0 gateway 192.168.5.1

PC3> show 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      : 10016
RHOST:PORT : 127.0.0.1:10017
MTU        : 1500
```

Step 6: Configuring Switches:

- Switch 1

```
vIOS-L2-01>enable
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#vlan 5
vIOS-L2-01(config-vlan)#name cat
vIOS-L2-01(config-vlan)#exit
vIOS-L2-01(config)#vlan 10
vIOS-L2-01(config-vlan)#name snake
```

- Switch 2

```
vIOS-L2-01>enable
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#vlan 5
vIOS-L2-01(config-vlan)#name cat
```

Step 7: Configuring trunk and access interfaces for Switches

• Switch 1

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#int gigabit
vIOS-L2-01(config)#int gigabitEthernet 0/1
vIOS-L2-01(config-if)#switchpo
vIOS-L2-01(config-if)#switchport mode acc
vIOS-L2-01(config-if)#switchport mode access
vIOS-L2-01(config-if)#swit
vIOS-L2-01(config-if)#switchport acc
vIOS-L2-01(config-if)#switchport access vlan 5
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#int gigabitEthernet 0/2
vIOS-L2-01(config-if)#switchport mode access
vIOS-L2-01(config-if)#switchport access vlan 10
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#int gigabitEthernet 0/3
vIOS-L2-01(config-if)#switchport trunk enc
vIOS-L2-01(config-if)#switchport trunk encapsulation do
vIOS-L2-01(config-if)#switchport trunk encapsulation dot1q
vIOS-L2-01(config-if)#switchport mode trunk
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#int gigabitEthernet 0/0
vIOS-L2-01(config-if)#switchport trunk encapsulation dot1q
vIOS-L2-01(config-if)#switchport mode trunk
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#exit
vIOS-L2-01#wr
```

• Switch 2

```
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#int gig
vIOS-L2-01(config)#int gigabitEthernet 0/1
vIOS-L2-01(config-if)#switc
vIOS-L2-01(config-if)#switchport mod
vIOS-L2-01(config-if)#switchport mode access
vIOS-L2-01(config-if)#switchport access vlan 5
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#int gigabitEthernet 0/0
vIOS-L2-01(config-if)#swit
vIOS-L2-01(config-if)#switchport trunk enc
vIOS-L2-01(config-if)#switchport trunk encapsulation do
vIOS-L2-01(config-if)#switchport trunk encapsulation dot1q
vIOS-L2-01(config-if)#swit
vIOS-L2-01(config-if)#swit
vIOS-L2-01(config-if)#switchport mode trunk
vIOS-L2-01(config-if)#exit
vIOS-L2-01(config)#exit
vIOS-L2-01#wr
```

Step 8: Configuring router 1

```
R1(config)#int fastEthernet 0/0
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int fas
R1(config)#int fastEthernet 0/0.5
R1(config-subif)#enc
R1(config-subif)#encapsulation do
R1(config-subif)#encapsulation dot1q 5
R1(config-subif)#ip add 192.
R1(config-subif)#ip add 192.168.5.1 255.255.255.0
R1(config-subif)#no sh
R1(config-subif)#exit
R1(config)#int fas
R1(config)#int fastEthernet 0/0.10
R1(config-subif)#enca
R1(config-subif)#encapsulation do
R1(config-subif)#encapsulation dot1q 10
R1(config-subif)#ip add 192.168.10.1 255.255.255.0
R1(config-subif)#no sh
R1(config-subif)#exit
```

Step 8: Testing the network

- Pinging all PC's from PC 1 to check VLAN connection

```
PC1> ping 192.168.5.1
192.168.5.1 icmp_seq=1 timeout
84 bytes from 192.168.5.1 icmp_seq=2 ttl=255 time=18.098 ms
84 bytes from 192.168.5.1 icmp_seq=3 ttl=255 time=17.443 ms
84 bytes from 192.168.5.1 icmp_seq=4 ttl=255 time=16.614 ms
84 bytes from 192.168.5.1 icmp_seq=5 ttl=255 time=16.136 ms

PC1> ping 192.168.10.1
84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=19.577 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=16.622 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=18.100 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=16.307 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=17.271 ms

PC1> ping 192.168.5.10
84 bytes from 192.168.5.10 icmp_seq=1 ttl=64 time=6.160 ms
84 bytes from 192.168.5.10 icmp_seq=2 ttl=64 time=7.538 ms
84 bytes from 192.168.5.10 icmp_seq=3 ttl=64 time=10.345 ms
84 bytes from 192.168.5.10 icmp_seq=4 ttl=64 time=6.288 ms
84 bytes from 192.168.5.10 icmp_seq=5 ttl=64 time=14.769 ms

PC1> ping 192.168.10.10
192.168.10.10 icmp_seq=1 timeout
84 bytes from 192.168.10.10 icmp_seq=2 ttl=63 time=35.603 ms
84 bytes from 192.168.10.10 icmp_seq=3 ttl=63 time=38.294 ms
84 bytes from 192.168.10.10 icmp_seq=4 ttl=63 time=31.880 ms
84 bytes from 192.168.10.10 icmp_seq=5 ttl=63 time=31.286 ms

PC1> ping 192.168.10.10
192.168.10.10 icmp_seq=1 timeout
192.168.10.10 icmp_seq=2 timeout
84 bytes from 192.168.10.10 icmp_seq=3 ttl=63 time=34.879 ms
84 bytes from 192.168.10.10 icmp_seq=4 ttl=63 time=48.089 ms
84 bytes from 192.168.10.10 icmp_seq=5 ttl=63 time=31.889 ms
```

- Pinging all PC's from PC 2 to check VLAN connection

```
PC2> ping 192.168.10.1
84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=15.777 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=19.464 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=20.642 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=18.554 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=16.328 ms

PC2> ping 192.168.5.5
84 bytes from 192.168.5.5 icmp_seq=1 ttl=63 time=31.586 ms
84 bytes from 192.168.5.5 icmp_seq=2 ttl=63 time=33.870 ms
84 bytes from 192.168.5.5 icmp_seq=3 ttl=63 time=31.871 ms
84 bytes from 192.168.5.5 icmp_seq=4 ttl=63 time=35.496 ms
84 bytes from 192.168.5.5 icmp_seq=5 ttl=63 time=35.823 ms

PC2> ping 192.168.5.10
192.168.5.10 icmp_seq=1 timeout
84 bytes from 192.168.5.10 icmp_seq=2 ttl=63 time=31.624 ms
84 bytes from 192.168.5.10 icmp_seq=3 ttl=63 time=31.552 ms
84 bytes from 192.168.5.10 icmp_seq=4 ttl=63 time=47.024 ms
84 bytes from 192.168.5.10 icmp_seq=5 ttl=63 time=36.837 ms
```

- Pinging all PC's from PC 3 to check VLAN connection

```
PC3> ping 192.168.5.1
84 bytes from 192.168.5.1 icmp_seq=1 ttl=255 time=16.461 ms
84 bytes from 192.168.5.1 icmp_seq=2 ttl=255 time=19.033 ms
84 bytes from 192.168.5.1 icmp_seq=3 ttl=255 time=20.267 ms
84 bytes from 192.168.5.1 icmp_seq=4 ttl=255 time=25.025 ms
84 bytes from 192.168.5.1 icmp_seq=5 ttl=255 time=17.914 ms

PC3> ping 192.168.10.1
84 bytes from 192.168.10.1 icmp_seq=1 ttl=255 time=18.840 ms
84 bytes from 192.168.10.1 icmp_seq=2 ttl=255 time=18.037 ms
84 bytes from 192.168.10.1 icmp_seq=3 ttl=255 time=18.943 ms
84 bytes from 192.168.10.1 icmp_seq=4 ttl=255 time=17.536 ms
84 bytes from 192.168.10.1 icmp_seq=5 ttl=255 time=17.881 ms

PC3> ping 192.168.5.5
84 bytes from 192.168.5.5 icmp_seq=1 ttl=64 time=5.265 ms
84 bytes from 192.168.5.5 icmp_seq=2 ttl=64 time=8.602 ms
84 bytes from 192.168.5.5 icmp_seq=3 ttl=64 time=7.850 ms
84 bytes from 192.168.5.5 icmp_seq=4 ttl=64 time=7.647 ms
84 bytes from 192.168.5.5 icmp_seq=5 ttl=64 time=10.465 ms
```


Step 9: Checking network briefs

- Switch 1

```
vIOS-L2-01#show vlan br
```

VLAN	Name	Status	Ports
1	default	active	
5	cat	active	Gi0/1
10	snake	active	Gi0/2
100	VLAN100	active	
200	VLAN0200	active	
300	VLAN0300	active	
1002	fddi-default	act/unsup	
1003	trcrf-default	act/unsup	
1004	fddinet-default	act/unsup	
1005	trbrf-default	act/unsup	

```
vIOS-L2-01#
```

- Switch 2

```
vIOS-L2-01#show vlan br
```

VLAN	Name	Status	Ports
1	default	active	Gi0/2
5	cat	active	Gi0/1
100	VLAN100	active	
200	VLAN0200	active	
300	VLAN0300	active	
1002	fddi-default	act/unsup	
1003	trcrf-default	act/unsup	
1004	fddinet-default	act/unsup	
1005	trbrf-default	act/unsup	

```
vIOS-L2-01#
```

Step 10: Checking running configuration of switches

- Switch 1

```
vIOS-L2-01#show run
vIOS-L2-01#show running-config
Building configuration...

Current configuration : 5125 bytes
!
! Last configuration change at 17:54:01 UTC Thu Oct 6 2022
!
version 15.0
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
service compress-config
!
hostname vIOS-L2-01
!
boot-start-marker
boot-end-marker
!
!
!
no aaa new-model
!
!
!
!
vtp domain CISCO-VIOS
vtp mode transparent
!
!
!
ip cef
no ipv6 cef
!
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
vlan 5
    name cat
!
vlan 10
    name snake
!
vlan 100
    name VLAN100
!
vlan 200,300
!
!
!
!
!
!
!
!
!
!
```

```
!  
interface GigabitEthernet0/0  
  switchport trunk encapsulation dot1q  
  switchport mode trunk  
  media-type rj45  
  negotiation auto  
!  
interface GigabitEthernet0/1  
  switchport access vlan 5  
  media-type rj45  
  negotiation auto  
!  
interface GigabitEthernet0/2  
  switchport access vlan 10  
  media-type rj45  
  negotiation auto  
!  
interface GigabitEthernet0/3  
  switchport trunk encapsulation dot1q  
  switchport mode trunk  
  media-type rj45  
  negotiation auto  
!  
ip forward-protocol nd  
!  
no ip http server  
no ip http secure-server  
!  
!  
!  
!  
!  
control-plane  
!  
banner exec ^C
```

- Switch 2

```
vIOS-L2-01#show run
vIOS-L2-01#show running-config
Building configuration...

Current configuration : 4949 bytes
!
! Last configuration change at 17:59:05 UTC Thu Oct 6 2022
!
version 15.0
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
service compress-config
!
hostname vIOS-L2-01
!
boot-start-marker
boot-end-marker
!
!
!
no aaa new-model
!
!
!
!
!
vtp domain CISCO-vIOS
vtp mode transparent
!
!
!
ip cef
no ipv6 cef
!
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
vlan 5
 name cat
!
vlan 100
 name VLAN100
!
vlan 200,300
!
!
!
!
!
!
!
!
!
!
```

```
!
interface GigabitEthernet0/0
 switchport trunk encapsulation dot1q
 switchport mode trunk
 media-type rj45
 negotiation auto
!
interface GigabitEthernet0/1
 switchport access vlan 5
 media-type rj45
 negotiation auto
!
interface GigabitEthernet0/2
 media-type rj45
 negotiation auto
!
ip forward-protocol nd
!
no ip http server
no ip http secure-server
!
!
!
!
!
control-plane
!
banner exec ^C
```

Step 11: Checking trunk interface of switches

- Switch 1

```
vIOS-L2-01#show int trunk

Port      Mode      Encapsulation  Status      Native vlan
Gi0/0     on        802.1q         trunking    1
Gi0/3     on        802.1q         trunking    1

Port      Vlans allowed on trunk
Gi0/0     1-4094
Gi0/3     1-4094

Port      Vlans allowed and active in management domain
Gi0/0     1,5,10,100,200,300
Gi0/3     1,5,10,100,200,300

Port      Vlans in spanning tree forwarding state and not pruned
Gi0/0     1,5,10,100,200,300
Gi0/3     1,5,10,100,200,300
vIOS-L2-01#
```

- Switch 2

```
vIOS-L2-01#show int trunk

Port      Mode      Encapsulation  Status      Native vlan
Gi0/0     on        802.1q         trunking    1

Port      Vlans allowed on trunk
Gi0/0     1-4094

Port      Vlans allowed and active in management domain
Gi0/0     1,5,100,200,300

Port      Vlans in spanning tree forwarding state and not pruned
Gi0/0     1,5,100,200,300
vIOS-L2-01#
```

Step 12: Checking running configuration of router

Roll No: - CS22006

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

Current configuration : 1939 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
ip tcp synwait-time 5
!
!
!
!
no ip domain lookup
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
interface FastEthernet0/0
 no ip address
 duplex auto
 speed auto
!
interface FastEthernet0/0.5
 encapsulation dot1Q 5
 ip address 192.168.5.1 255.255.255.0
!
interface FastEthernet0/0.10
 encapsulation dot1Q 10
 ip address 192.168.10.1 255.255.255.0
!
interface Serial0/0
 no ip address
```

```
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
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
```

Roll No: - CS22006

```
interface Serial2/2
  no ip address
  shutdown
  serial restart-delay 0
!
interface Serial2/3
  no ip address
  shutdown
  serial restart-delay 0
!
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
!
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
```

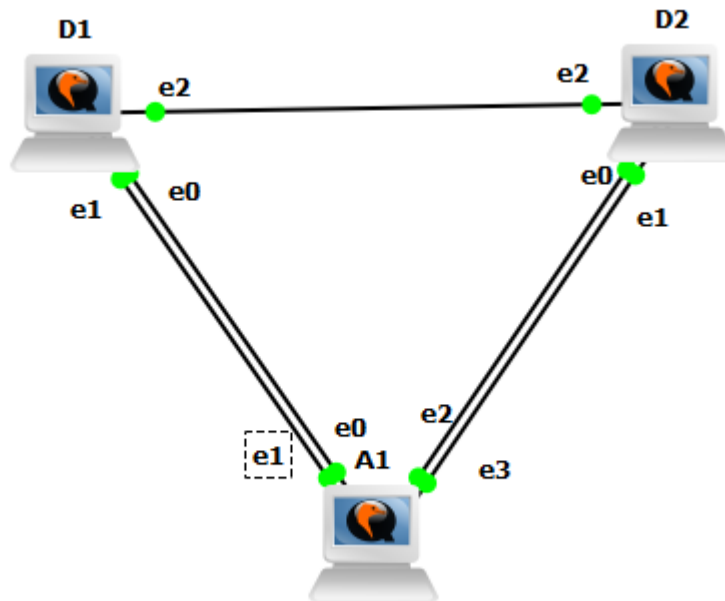

SDN Practical 5

1. Implement Advanced STP Modifications and Mechanisms
2. Implement MST

1. Implement Advanced STP Modifications and Mechanisms

Step 1: Install Layer 2 Switch from [here](#)

Step 2: Design the topology



Step3: Configure Switches

- D1

```

vIOS-L2-01>
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname D1
D1(config)#spanning-tree mode pvst
D1(config)#banner motd #D1, STP topology Changes and RSTP Lab#
D1(config)#line con 0
D1(config-line)#exec-timeout 0 0
D1(config-line)#logging synchronous
D1(config-line)#exit
D1(config)#int range g0/0-2
D1(config-if-range)#switchport trunk encapsulation dot1q
D1(config-if-range)#switchport mode trunk
D1(config-if-range)#no sh
D1(config-if-range)#exit
D1(config)#vlan 69
D1(config-vlan)#name CAT_VLAN
D1(config-vlan)#int vlan 1
D1(config-if)#ip add
*Nov 6 15:50:29.686: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to down
D1(config-if)#ip add 10.0.0.1 255.255.255.0
D1(config-if)#no sh
D1(config-if)#exit
D1(config)#
*Nov 6 15:50:44.138: %LINK-3-UPDOWN: Interface Vlan1, changed state to up
*Nov 6 15:50:45.138: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to up
D1(config)#
  
```

- D2

```
vIOS-L2-01>
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname D2
D2(config)#banner motd #D2, STP Topology Chaneg and RSTP Lab#
D2(config)#spanning-tree mode pvst
D2(config)#line con 0
D2(config-line)#exec-timeout 0 0
D2(config-line)#logging synchronous
D2(config-line)#exit
D2(config)#int range g0/0-2
D2(config-if-range)#switchport trunk encapsulation dot1q
D2(config-if-range)#switchport mode trunk
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#vlan 69
D2(config-vlan)#name CAT_VLAN
D2(config-vlan)#int vlan 1
D2(config-if)#ip add 10
*Nov 6 15:52:33.387: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to down
D2(config-if)#ip add 10.0.0.2 255.0.0.0
D2(config-if)#no sh
D2(config-if)#exit
D2(config)#
*Nov 6 15:52:45.952: %LINK-3-UPDOWN: Interface Vlan1, changed state to up
*Nov 6 15:52:46.952: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to up
D2(config)#
```

- A1

```
vIOS-L2-01>
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname A1
A1(config)#banner motd #A1, STP Topology Change and RSTP Lab#
A1(config)#spanning-tree mode pvst
A1(config)#line con 0
A1(config-line)#exec-timeout 0 0
A1(config-line)#logging synchronous
A1(config-line)#exit
A1(config)#int range g0/0-3
A1(config-if-range)#switchport trunk encapsulation dot1q
A1(config-if-range)#switchport mode trunk
A1(config-if-range)#no sh
A1(config-if-range)#exit
A1(config)#vlan 69
A1(config-vlan)#name CAT_VLAN
A1(config-vlan)#int vlan 1
A1(config-if)#ip
*Nov 6 15:54:34.669: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to down
A1(config-if)#ip add 10.0.0.3 255.0.0.0
A1(config-if)#no sh
A1(config-if)#exit
A1(config)#
*Nov 6 15:54:51.215: %LINK-3-UPDOWN: Interface Vlan1, changed state to up
*Nov 6 15:54:52.215: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan1, changed state to up
A1(config)#
```

Step 4: Discover the Default Spanning Tree.

D1#show spanning-tree root

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32769 0c17.2a98.0000	0	2	20	15	
VLAN0069	32837 0c17.2a98.0000	0	2	20	15	
VLAN0100	32868 0c17.2a98.0000	0	2	20	15	
VLAN0200	32968 0c17.2a98.0000	0	2	20	15	
VLAN0300	33068 0c17.2a98.0000	0	2	20	15	

D1#

D2#show spanning-tree root

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32769 0c17.2a98.0000	4	2	20	15	Gi0/2
VLAN0069	32837 0c17.2a98.0000	4	2	20	15	Gi0/2
VLAN0100	32868 0c17.2a98.0000	4	2	20	15	Gi0/2
VLAN0200	32968 0c17.2a98.0000	4	2	20	15	Gi0/2
VLAN0300	33068 0c17.2a98.0000	4	2	20	15	Gi0/2

D2#

D2#

A1#show spanning-tree root

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32769 0c17.2a98.0000	4	2	20	15	Gi0/0
VLAN0069	32837 0c17.2a98.0000	4	2	20	15	Gi0/0
VLAN0100	32868 0c17.2a98.0000	4	2	20	15	Gi0/0
VLAN0200	32968 0c17.2a98.0000	4	2	20	15	Gi0/0
VLAN0300	33068 0c17.2a98.0000	4	2	20	15	Gi0/0

A1#

A1#show spanning-tree

VLAN0001

Spanning tree enabled protocol ieee

Root ID Priority 32769
 Address 0c17.2a98.0000
 Cost 4
 Port 1 (GigabitEthernet0/0)
 Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID Priority 32769 (priority 32768 sys-id-ext 1)
 Address 0c8d.c990.0000
 Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
 Aging Time 300 sec

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	4	128.1	Shr
Gi0/1	Altn	BLK	4	128.2	Shr
Gi0/2	Altn	BLK	4	128.3	Shr
Gi0/3	Altn	BLK	4	128.4	Shr
Gi1/0	Desg	FWD	4	128.5	Shr
Gi1/1	Desg	FWD	4	128.6	Shr

--More--

```

D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#int g0/2
D1(config-if)#sh
D1(config-if)#exit
D1(config)#

```

```

D2#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0c17.2a98.0000
             Cost        4
             Port        3 (GigabitEthernet0/2)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
             Address     0c7f.6d21.0000
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time   300 sec

Interface                Role Sts Cost      Prio.Nbr Type
-----
Gi0/0                    Desg FWD 4         128.1   Shr
Gi0/1                    Desg FWD 4         128.2   Shr
Gi0/2                    Root FWD 4         128.3   Shr
Gi0/3                    Desg FWD 4         128.4   Shr
Gi1/0                    Desg FWD 4         128.5   Shr
Gi1/1                    Desg FWD 4         128.6   Shr

```

```

D1(config)#int g0/2
D1(config-if)#no sh
D1(config-if)#

```

```

D2#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0c17.2a98.0000
             Cost        4
             Port        3 (GigabitEthernet0/2)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
             Address     0c7f.6d21.0000
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time   15 sec

Interface                Role Sts Cost      Prio.Nbr Type
-----
Gi0/0                    Desg FWD 4         128.1   Shr
Gi0/1                    Desg FWD 4         128.2   Shr
Gi0/2                    Root FWD 4         128.3   Shr
Gi0/3                    Desg FWD 4         128.4   Shr
Gi1/0                    Desg FWD 4         128.5   Shr
Gi1/1                    Desg FWD 4         128.6   Shr

```

```
A1#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0c17.2a98.0000
             Cost        4
             Port        1 (GigabitEthernet0/0)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
             Address     0c8d.c990.0000
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time  300 sec

Interface                Role Sts Cost      Prio.Nbr Type
-----
Gi0/0                    Root FWD 4         128.1   Shr
Gi0/1                    Altn BLK 4         128.2   Shr
Gi0/2                    Altn BLK 4         128.3   Shr
Gi0/3                    Altn BLK 4         128.4   Shr
Gi1/0                    Desg FWD 4         128.5   Shr
Gi1/1                    Desg FWD 4         128.6   Shr
```

Step 5: Implement and Observe Rapid Spanning Tree Protocol.

```
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)#int g0/2
D2(config-if)#sh
D2(config-if)#
*Nov 6 16:03:53.135: %LINK-5-CHANGED: Interface GigabitEthernet0/2, changed state to administratively down
*Nov 6 16:03:54.135: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/2, changed state to down
D2(config-if)#
*Nov 6 16:04:09.168: STP: VLAN0069 heard root 32837-0c17.2a98.0000 on Gi0/0
*Nov 6 16:04:09.168:      supersedes 32837-0c7f.6d21.0000
*Nov 6 16:04:09.168: STP: VLAN0069 new root is 32837, 0c17.2a98.0000 on port Gi0/0, cost 8
*Nov 6 16:04:09.168: STP: VLAN0069 sent Topology Change Notice on Gi0/0
*Nov 6 16:04:09.177: STP[69]: Generating TC trap for port GigabitEthernet0/1
*Nov 6 16:04:09.177: STP: VLAN0069 Gi0/1 -> blocking
D2(config-if)#
*Nov 6 16:04:10.913: STP: VLAN0001 heard root 32769-0c17.2a98.0000 on Gi0/0
*Nov 6 16:04:10.913:      supersedes 32769-0c7f.6d21.0000
*Nov 6 16:04:10.913: STP: VLAN0001 new root is 32769, 0c17.2a98.0000 on port Gi0/0, cost 8
*Nov 6 16:04:10.913: STP: VLAN0001 sent Topology Change Notice on Gi0/0
*Nov 6 16:04:10.913: STP[1]: Generating TC trap for port GigabitEthernet0/1
*Nov 6 16:04:10.913: STP: VLAN0001 Gi0/1 -> blocking
*Nov 6 16:04:10.914: STP: VLAN0100 heard root 32868-0c17.2a98.0000 on Gi0/1
*Nov 6 16:04:10.914:      supersedes 32868-0c7f.6d21.0000
*Nov 6 16:04:10.914: STP: VLAN0100 new root is 32868, 0c17.2a98.0000 on port Gi0/1, cost 8
*Nov 6 16:04:10.914: STP: VLAN0100 sent Topology Change Notice on Gi0/1
*Nov 6 16:04:10.914: STP: VLAN0200 heard root 32968-0c17.2a98.0000 on Gi0/1
*Nov 6 16:04:10.914:      supersedes 32968-0c7f.6d21.0000
*Nov 6 16:04:10.914: STP: VLAN0200 new root is 32968, 0c17.2a98.0000 on port Gi0/1, cost 8
*Nov 6 16:04:10.915: STP: VLAN0200 sent Topology Change Notice on Gi0/1
*Nov 6 16:04:10.915: STP: VLAN0300 heard root 33068-0c17.2a98.0000 on Gi0/1
*Nov 6 16:04:10.915:      supersedes 33068-0c7f.6d21.0000
*Nov 6 16:04:10.915: STP: VLAN0300 new root is 33068, 0c17.2a98.0000 on port Gi0/1, cost 8
*Nov 6 16:04:10.915: STP: VLAN0300 sent Topology Change Notice on Gi0/1
D2(config-if)#
*Nov 6 16:04:10.915: STP: VLAN0100 new root port Gi0/0, cost 8
*Nov 6 16:04:10.915: STP[100]: Generating TC trap for port GigabitEthernet0/1
*Nov 6 16:04:10.915: STP: VLAN0100 Gi0/1 -> blocking
*Nov 6 16:04:10.915: STP: VLAN0200 new root port Gi0/0, cost 8
*Nov 6 16:04:10.915: STP[200]: Generating TC trap for port GigabitEthernet0/1
*Nov 6 16:04:10.915: STP: VLAN0200 Gi0/1 -> blocking
*Nov 6 16:04:10.915: STP: VLAN0300 new root port Gi0/0, cost 8
*Nov 6 16:04:10.915: STP[300]: Generating TC trap for port GigabitEthernet0/1
*Nov 6 16:04:10.915: STP: VLAN0300 Gi0/1 -> blocking
D2(config-if)#
*Nov 6 16:04:12.915: STP: VLAN0100 sent Topology Change Notice on Gi0/0
*Nov 6 16:04:12.915: STP: VLAN0200 sent Topology Change Notice on Gi0/0
*Nov 6 16:04:12.915: STP: VLAN0300 sent Topology Change Notice on Gi0/0
D2(config-if)#
```

```

D1(config)#spanning-tree mode rapid-pvst
D1(config)#exit
D1#show sp
*Nov 6 16:04:48.454: %SYS-5-CONFIG_I: Configured from console by console
D1#show spanning-tree

```

```

/!LAN0001
Spanning tree enabled protocol rstp
Root ID    Priority    32769
           Address    0c17.2a98.0000
           This bridge is the root
           Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
           Address    0c17.2a98.0000
           Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
           Aging Time  300 sec

```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	BLK	4	128.1	Shr
Gi0/1	Desg	BLK	4	128.2	Shr
Gi0/2	Desg	BLK	4	128.3	Shr
Gi0/3	Desg	BLK	4	128.4	Shr
Gi1/0	Desg	BLK	4	128.5	Shr
Gi1/1	Desg	BLK	4	128.6	Shr

```

D2(config)#spanning-tree mode rapid-pvst
D2(config)#
*Nov 6 16:07:01.279: setting bridge id (which=3) prio 32769 prio cfg 32768 sysid 1 (on) id 8001.0c7f.6d21.0000
*Nov 6 16:07:01.279: RSTP(1): initializing port Gi0/0
*Nov 6 16:07:01.279: RSTP(1): Gi0/0 is now designated
*Nov 6 16:07:01.279: RSTP(1): initializing port Gi0/1
*Nov 6 16:07:01.279: RSTP(1): Gi0/1 is now designated
*Nov 6 16:07:01.279: RSTP(1): initializing port Gi0/3
*Nov 6 16:07:01.279: RSTP(1): Gi0/3 is now designated
*Nov 6 16:07:01.279: RSTP(1): initializing port Gi1/0
*Nov 6 16:07:01.279: RSTP(1): Gi1/0 is now designated
*Nov 6 16:07:01.279: RSTP(1): initializing port Gi1/1
*Nov 6 16:07:01.279: RSTP(1): Gi1/1 is now designated
*Nov 6 16:07:01.279: setting bridge id (which=3) prio 32837 prio cfg 32768 sysid 69 (on) id 8045.0c7f.6d21.0000
*Nov 6 16:07:01.279: RSTP(69): initializing port Gi0/0
*Nov 6 16:07:01.279: RSTP(69): Gi0/0 is now designated
*Nov 6 16:07:01.279: RSTP(69): initializing port Gi0/1
*Nov 6 16:07:01.279: RSTP(69): Gi0/1 is now designated
*Nov 6 16:07:01.279: setting bridge id (which=3) prio 32868 prio cfg 32768 sysid 100 (on) id 8064.0c7f.6d21.0000
*Nov 6 16:07:01.279: RSTP(100): initializing port Gi0/0
*Nov 6 16:07:01.279: RSTP(100): Gi0/0 is now designated
*Nov 6 16:07:01.279: RSTP(100): initializing port Gi0/1
*Nov 6 16:07:01.279: RSTP(100): Gi0/1 is now designated
*Nov 6 16:07:01.279: setting bridge id (which=3) prio 32968 prio cfg 32768 sysid 200 (on) id 80C8.0c7f.6d21.0000
*Nov 6 16:07:01.279: RSTP(200): initializing port Gi0/0
*Nov 6 16:07:01.279: RSTP(200): Gi0/0 is now designated
*Nov 6 16:07:01.279: RSTP(200): initializing port Gi0/1
*Nov 6 16:07:01.279: RSTP(200): Gi0/1 is now designated

```

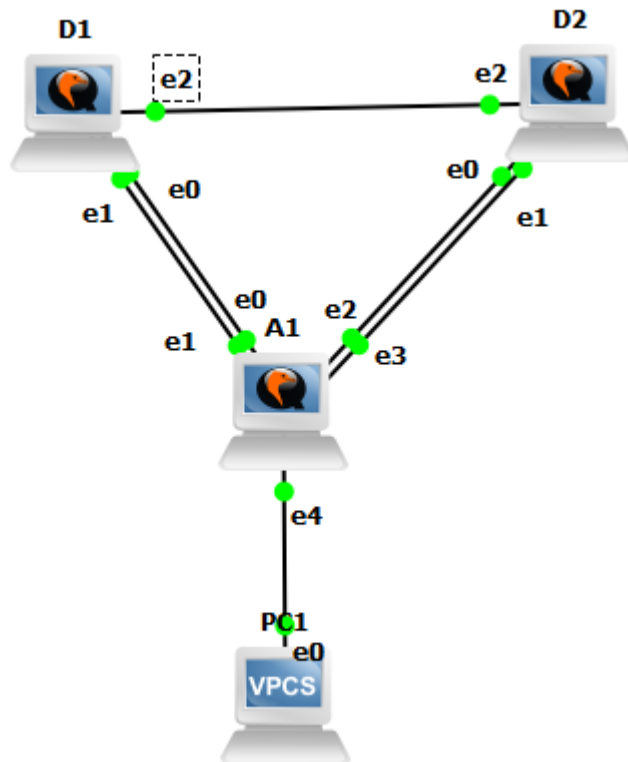
```

A1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
A1(config)#spanning-tree mode rapid-pvst
A1(config)#

```

2. Implement MST

Step 1: Design the topology



Step 2: Configure the Switches

- D1

```

vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
vIOS-L2-01(config)#hostname D1
D1(config)#banner motd #D1 MSTP#
D1(config)#spanning-tree mode rapid-pvst
D1(config)#line con 0
D1(config-line)#exec-timeout 0 0
D1(config-line)#logging synchronous
D1(config-line)#exit
D1(config)#int range
*Nov  6 16:16:41.778: %PLATFORM-5-SIGNATURE_VERIFIED: Image 'flash0:/vios_l2-adventerprisek9
tion
D1(config)#int range g0/0-2
D1(config-if-range)#switchport trunk encapsulation dot1q
D1(config-if-range)#switchport mode trunk
D1(config-if-range)#no sh
D1(config-if-range)#exit
D1(config)#vlan 2
D1(config-vlan)#name CAT2_VLAN
D1(config-vlan)#exit
D1(config)#vlan 3
D1(config-vlan)#name CAT3_VLAN
D1(config-vlan)#exit
D1(config)#vlan 4
D1(config-vlan)#name CAT4_VLAN
D1(config-vlan)#exi
D1(config)#vlan 5
D1(config-vlan)#name CAT5_VLAN
D1(config-vlan)#exit
D1(config)#
D1(config)#

```

- D2

```
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
vIOS-L2-01(config)#hostname D2
D2(config)#banner motd #D2 MSTP#
D2(config)#spanning-tree mode rapid-pvst
D2(config)#line con 0
D2(config-line)#exec-timeout 0 0
D2(config-line)#logging synchronous
D2(config-line)#exit
D2(config)#int range g0/0-2
D2(config-if-range)#switchport trunk encapsulation dot1q
D2(config-if-range)#switchport mode trunk
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#vlan 2
D2(config-vlan)#name CAT2_VLAN
D2(config-vlan)#vlan 3
D2(config-vlan)#name CAT3_VLAN
D2(config-vlan)#vlan 4
D2(config-vlan)#name CAT4_VLAN
D2(config-vlan)#vlan 5
D2(config-vlan)#name CAT5_VLAN
D2(config-vlan)#exit
D2(config)#
```

- A1

```
vIOS-L2-01>
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
vIOS-L2-01(config)#hostname A1
A1(config)#banner motd #A1 MSTP#
A1(config)#spanning-tree mode rapid-pvst
A1(config)#line con 0
A1(config-line)#exec-timeout 0 0
A1(config-line)#logging synchronous
A1(config-line)#exit
A1(config)#int range g0/0-3
A1(config-if-range)#switchport trunk encapsulation dot1q
A1(config-if-range)#switchport mode trunk
A1(config-if-range)#no sh
A1(config-if-range)#exit
A1(config)#int range g1/0
A1(config-if-range)#no sh
A1(config-if-range)#exit
A1(config)#vlan 2
A1(config-vlan)#name CAT2_VLAN
A1(config-vlan)#vlan 3
A1(config-vlan)#name CAT3_VLAN
A1(config-vlan)#vlan 4
A1(config-vlan)#name CAT4_VLAN
A1(config-vlan)#vlan 5
A1(config-vlan)#name CAT5_VLAN
A1(config-vlan)#exit
A1(config)#
```


Step 3: Implement and Observe MST.

```
D1(config)#spanning-tree mode mst
D1(config)#
```

```
D2(config)#spanning-tree mode mst
D2(config)#
```

```
D1#show spanning-tree
```

```
MST0
Spanning tree enabled protocol mstp
Root ID    Priority    32768
           Address    0c32.bb8c.0000
           This bridge is the root
           Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec

Bridge ID   Priority    32768 (priority 32768 sys-id-ext 0)
           Address    0c32.bb8c.0000
           Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	FWD	20000	128.1	Shr Bound(PVST)
Gi0/1	Desg	FWD	20000	128.2	Shr Bound(PVST)
Gi0/2	Desg	FWD	20000	128.3	Shr
Gi0/3	Desg	FWD	20000	128.4	Shr
Gi1/0	Desg	FWD	20000	128.5	Shr
Gi1/1	Desg	FWD	20000	128.6	Shr

```
D1#show spanning-tree mst
```

```
##### MST0    vlans mapped: 1-4094
Bridge         address 0c32.bb8c.0000 priority 32768 (32768 sysid 0)
Root           this switch for the CIST
Operational    hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured     hello time 2 , forward delay 15, max age 20, max hops 20
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	FWD	20000	128.1	Shr Bound(PVST)
Gi0/1	Desg	FWD	20000	128.2	Shr Bound(PVST)
Gi0/2	Desg	FWD	20000	128.3	Shr
Gi0/3	Desg	FWD	20000	128.4	Shr
Gi1/0	Desg	FWD	20000	128.5	Shr
Gi1/1	Desg	FWD	20000	128.6	Shr

```
D1#
```

```
A1#show spanning-tree root
```

Vlan	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
VLAN0001	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0002	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0003	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0004	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0005	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0100	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0200	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0
VLAN0300	32768 0c32.bb8c.0000	4	2	20	15	Gi0/0

```
A1#
```

```
D2#show spanning-tree root
```

MST Instance	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
MST0	32768 0c32.bb8c.0000	0	2	20	15	Gi0/2

```
D2#
```

```
A1#conf t
```

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

```
A1(config)#spanning-tree mode mst
```

```
A1(config)#
```

```
D1#conf t
```

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

```
D1(config)#spanning-tree mst config
```

```
D1(config-mst)#name CAT_MST
```

```
D1(config-mst)#revision 1
```

```
D1(config-mst)#instance 1 vlan 2
```

```
D1(config-mst)#instance 2 vlan 4
```

```
D1(config-mst)#exit
```

```
D1(config)#exit
```

```
D1#
```

```
D1#show spanning-tree mst
```

```
##### MST0      vlans mapped:  1,3,5-4094
Bridge          address 0c32.bb8c.0000  priority      32768 (32768 sysid 0)
Root            this switch for the CIST
Operational     hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured      hello time 2 , forward delay 15, max age 20, max hops   20
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	LRN	20000	128.1	Shr
Gi0/1	Desg	LRN	20000	128.2	Shr
Gi0/2	Desg	LRN	20000	128.3	Shr
Gi0/3	Desg	LRN	20000	128.4	Shr
Gi1/0	Desg	LRN	20000	128.5	Shr
Gi1/1	Desg	LRN	20000	128.6	Shr

```
##### MST1      vlans mapped:  2
Bridge          address 0c32.bb8c.0000  priority      32769 (32768 sysid 1)
Root            this switch for MST1
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	LRN	20000	128.1	Shr
Gi0/1	Desg	LRN	20000	128.2	Shr
Gi0/2	Desg	LRN	20000	128.3	Shr

```
##### MST2      vlans mapped:  4
Bridge          address 0c32.bb8c.0000  priority      32770 (32768 sysid 2)
Root            this switch for MST2
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Desg	LRN	20000	128.1	Shr
Gi0/1	Desg	LRN	20000	128.2	Shr
Gi0/2	Desg	LRN	20000	128.3	Shr

```
D1#
```

```
A1#show spanning-tree mst
```

```
##### MST0    vlans mapped:    1-4094
Bridge        address 0ce8.79ea.0000  priority    32768 (32768 sysid 0)
Root          address 0c32.bb8c.0000  priority    32768 (32768 sysid 0)
              port    Gi0/2          path cost   20000
Regional Root address 0c74.459c.0000  priority    32768 (32768 sysid 0)
              internal cost 20000      rem hops 19
Operational   hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured    hello time 2 , forward delay 15, max age 20, max hops    20
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Altn	BLK	20000	128.1	Shr Bound(RSTP)
Gi0/1	Altn	BLK	20000	128.2	Shr Bound(RSTP)
Gi0/2	Root	FWD	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr
Gi1/0	Desg	FWD	20000	128.5	Shr
Gi1/1	Desg	FWD	20000	128.6	Shr

```
A1#
```

```
A1#show spanning-tree mst config digest
```

```
Name      []
Revision  0      Instances configured 1
Digest     0xAC36177F50283CD4883821D8AB26DE62
Pre-std Digest 0xBB3B6C15EF8D0898B855ED10D24DF44DE
A1#
```

```
D1#show spanning-tree mst config digest
```

```
Name      [CAT_MST]
Revision  1      Instances configured 3
Digest     0x746D865FEAD726D8F401F9396B8B62DA
Pre-std Digest 0xDE5D7C8B79A99142EBC0A1C265ED7B05
D1#
```

```
D1#conf t
```

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

```
D1(config)#spanning-tree mst conf
```

```
D1(config-mst)#show cur
```

```
Current MST configuration
```

```
Name      [CAT_MST]
```

```
Revision  1      Instances configured 3
```

```
Instance  Vlans mapped
```

0	1,3,5-4094
1	2
2	4

```
D1(config-mst)#revision 2
```

```
D1(config-mst)#instance 1 vlan 3
```

```
D1(config-mst)#instance 2 vlan 5
```

```
D1(config-mst)#show pending
```

```
Pending MST configuration
```

```
Name      [CAT_MST]
```

```
Revision  2      Instances configured 3
```

```
Instance  Vlans mapped
```

0	1,6-4094
1	2-3
2	4-5

```
D1(config-mst)#exit
```

```
D1(config)#exit
```

```
D1#
```

```

D2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D2(config)#spanning-tree mst conf
D2(config-mst)#name CAT_MST
D2(config-mst)#revision 2
D2(config-mst)#instance 1 vlan 2
D2(config-mst)#instance 2 vlan 4
D2(config-mst)#instance 1 vlan 3
D2(config-mst)#instance 2 vlan 5
D2(config-mst)#exit
D2(config)#exit
D2#

```

```

A1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
A1(config)#spanning-tree mst conf
A1(config-mst)#name CAT_MST
A1(config-mst)#revision 2
A1(config-mst)#instance 1 vlan 2
A1(config-mst)#instance 2 vlan 4
A1(config-mst)#instance 1 vlan 3
A1(config-mst)#instance 2 vlan 5
A1(config-mst)#exit
A1(config)#exit
A1#

```

```
A1#show spanning-tree mst
```

```

##### MST0      vlans mapped: 1,6-4094
Bridge          address 0ce8.79ea.0000 priority 32768 (32768 sysid 0)
Root            address 0c32.bb8c.0000 priority 32768 (32768 sysid 0)
                port    Gi0/0      path cost 0
Regional Root   address 0c32.bb8c.0000 priority 32768 (32768 sysid 0)
                internal cost 20000 rem hops 19
Operational     hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured      hello time 2 , forward delay 15, max age 20, max hops 20

```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr
Gi1/0	Desg	FWD	20000	128.5	Shr
Gi1/1	Desg	FWD	20000	128.6	Shr

```

##### MST1      vlans mapped: 2-3
Bridge          address 0ce8.79ea.0000 priority 32769 (32768 sysid 1)
Root            address 0c32.bb8c.0000 priority 32769 (32768 sysid 1)
                port    Gi0/0      cost 20000 rem hops 19

```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr

```

##### MST2      vlans mapped: 4-5
Bridge          address 0ce8.79ea.0000 priority 32770 (32768 sysid 2)
Root            address 0c32.bb8c.0000 priority 32770 (32768 sysid 2)
                port    Gi0/0      cost 20000 rem hops 19

```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr

```
A1#
```

Step 4: Controlling the Root Bridge.

```
D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#spanning-tree mst 2 root secondary
D1(config)#
```

```
A1#show spanning-tree root
```

MST Instance	Root ID	Root Cost	Hello Time	Max Age	Fwd Dly	Root Port
MST0	32768 0c32.bb8c.0000	0	2	20	15	Gi0/0
MST1	32769 0c32.bb8c.0000	20000	2	20	15	Gi0/0
MST2	28674 0c32.bb8c.0000	20000	2	20	15	Gi0/0

```
A1#
```

```
A1#show spanning-tree mst 1
```

```
##### MST1      vlans mapped: 2-3
Bridge          address 0ce8.79ea.0000 priority 32769 (32768 sysid 1)
Root            address 0c32.bb8c.0000 priority 32769 (32768 sysid 1)
                port    Gi0/0      cost    20000      rem hops 19
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr

```
A1#show spanning-tree blockedports
```

Name	Blocked Interfaces List
MST0	Gi0/1, Gi0/2, Gi0/3
MST1	Gi0/1, Gi0/2, Gi0/3
MST2	Gi0/1, Gi0/2, Gi0/3

```
Number of blocked ports (segments) in the system : 9
```

```
A1#
```

```
A1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
A1(config)#int range g0/0-1
A1(config-if-range)#sh
A1(config-if-range)#exit
A1(config)#int g
*Nov 6 16:40:07.959: %LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to administratively down
*Nov 6 16:40:07.974: %LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to administratively down
A1(config)#int g
*Nov 6 16:40:08.959: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to down
*Nov 6 16:40:08.974: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to down
A1(config)#int g0/1
A1(config-if)#spanning-tree mst 1 cost 1000
A1(config-if)#exit
A1(config)#int range g0/0-1
A1(config-if-range)#no sh
A1(config-if-range)#exit
A1(config)#
*Nov 6 16:40:39.006: %LINK-3-UPDOWN: Interface GigabitEthernet0/0, changed state to up
*Nov 6 16:40:39.138: %LINK-3-UPDOWN: Interface GigabitEthernet0/1, changed state to up
*Nov 6 16:40:40.006: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to up
A1(config)#
```

```
A1#show spanning-tree mst 1
```

```
##### MST1      vlans mapped: 2-3
Bridge          address 0ce8.79ea.0000 priority 32769 (32768 sysid 1)
Root            address 0c32.bb8c.0000 priority 32769 (32768 sysid 1)
                port    Gi0/1      cost    1000      rem hops 19
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Altn	BLK	20000	128.1	Shr
Gi0/1	Root	FWD	1000	128.2	Shr
Gi0/2	Desg	LRN	20000	128.3	Shr
Gi0/3	Desg	LRN	20000	128.4	Shr

```
A1#show spanning-tree blockedports
```

Name	Blocked Interfaces List
MST0	Gi0/1, Gi0/2, Gi0/3
MST1	Gi0/0
MST2	Gi0/1, Gi0/2, Gi0/3

```
Number of blocked ports (segments) in the system : 7
```

```
A1#
```

Step 5: Adjust port priority values to impact root port selection.

```
A1#show spanning-tree mst 2
```

```
##### MST2      vlans mapped: 4-5
Bridge          address 0ce8.79ea.0000 priority 32770 (32768 sysid 2)
Root            address 0c32.bb8c.0000 priority 28674 (28672 sysid 2)
                port    Gi0/0      cost    20000      rem hops 19
```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr

```
A1#
```

```

D2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D2(config)#int range g0/0-1
D2(config-if-range)#sh
D2(config-if-range)#exit
D2(config)#int
*Nov 6 16:42:09.839: %LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to administratively down
*Nov 6 16:42:09.866: %LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to administratively down
*Nov 6 16:42:10.839: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to down
D2(config)#int
*Nov 6 16:42:10.866: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to down
D2(config)#int g0/1
D2(config-if)#spanning-tree mst 2 port-priority 64
D2(config-if)#exit
D2(config)#int range g0/0-1
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#

```

```
A1#show spanning-tree mst 2
```

```

##### MST2      vlans mapped: 4-5
Bridge          address 0ce8.79ea.0000 priority 32770 (32768 sysid 2)
Root            address 0c32.bb8c.0000 priority 28674 (28672 sysid 2)
                port    Gi0/0      cost    20000      rem hops 19

```

Interface	Role	Sts	Cost	Prio.Nbr	Type
Gi0/0	Root	FWD	20000	128.1	Shr
Gi0/1	Altn	BLK	20000	128.2	Shr
Gi0/2	Altn	BLK	20000	128.3	Shr
Gi0/3	Altn	BLK	20000	128.4	Shr

```
A1#
```

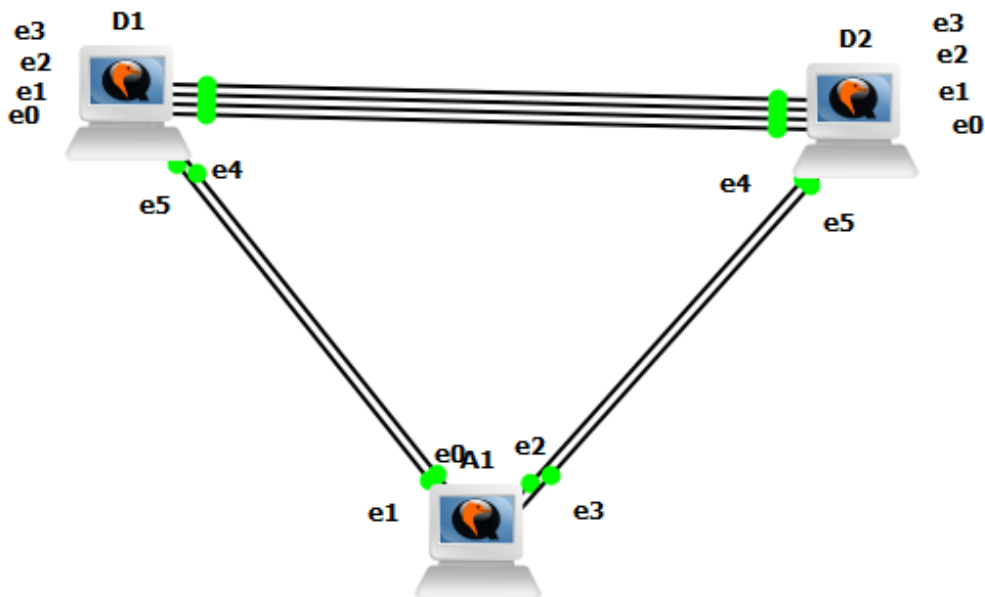
SDN Practical 6

1. Implement EtherChannel.
2. Tune and Optimise EtherChannel Operations

1. Implement EtherChannel.

Step 1: Install Layer 2 Switch from [here](#)

Step 2: Design the topology

**Step3: Configure Switches**

- D1

```
D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#hostname D1
D1(config)#banner motd #D1, Implement EtherChannel#
D1(config)#line con 0
D1(config-line)#exec-timeout 0 0
D1(config-line)#logging synchronous
D1(config-line)#exit
D1(config)#int range g0/0-3, g1/0-1
D1(config-if-range)#switchport trunk encapsulation dot1q
D1(config-if-range)#switchport mode trunk
D1(config-if-range)#no sh
D1(config-if-range)#exit
D1(config)#exit
D1#show
```


- D2

```
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname D2
D2(config)#banner motd #D2, Implement EtherChannel#
D2(config)#line con 0
D2(config-line)#exec-timeout 0 0
D2(config-line)#logging sync
*Nov  6 14:05:26.826: %PLATFORM-5-SIGNATURE_VERIFIED: Image 'flash0:/vios_l2-adventerprisek9-
tion
D2(config-line)#logging synchronous
D2(config-line)#exit
D2(config)#int range g0/0-3, g1/0-1
D2(config-if-range)#switchport trunk encapsulation dot1q
D2(config-if-range)#switchport mode trunk
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#exit
```

- A1

```
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname A1
A1(config)#banner motd #A1, Implement EtherChannel#
A1(config)#line con 0
A1(config-line)#exec-timeout 0 0
A1(config-line)#logging synchronous
A1(config-line)#exit
A1(config)#int range g0/0-3
A1(config-if-range)#switchport trunk encapsulation dot1q
A1(config-if-range)#switchport mode trunk
A1(config-if-range)#no sh
A1(config-if-range)#exit
A1(config)#exit
A1#
```

Step 4: Configure Static EtherChannel between D2 & A1

```
D2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D2(config)#int range g1/0-1
D2(config-if-range)#channel-group 1 mode on
Creating a port-channel interface Port-channel 1
```

```
A1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
A1(config)#int range g0/2-3
A1(config-if-range)#channel-group 1 mode on
Creating a port-channel interface Port-channel 1
```

```

A1#show etherchannel summary
Flags:  D - down          P - bundled in port-channel
        I - stand-alone  s - suspended
        H - Hot-standby (LACP only)
        R - Layer3       S - Layer2
        U - in use       f - failed to allocate aggregator

        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port

Number of channel-groups in use: 1
Number of aggregators:          1

Group  Port-channel  Protocol    Ports
-----+-----+-----+-----
1      Po1(SU)        -           Gi0/2(P)  Gi0/3(P)

A1#

```

Step 5: Make a change to the EtherChannel.

```

D2(config)#vlan 69
D2(config-vlan)#name CAT_VLAN
D2(config-vlan)#exit
D2(config)#int port-channel 1
D2(config-if)#switchport trunk native vlan 69
D2(config-if)#exit
D2(config)#exit
D2#

```

```

A1(config)#vlan 69
A1(config-vlan)#name CAT_VLAN
A1(config-vlan)#exit
A1(config)#int port-channel 1
A1(config-if)#switchport trunk native vlan 69
A1(config-if)#exit
A1(config)#exit

```

Step 6: Implement EtherChannel Using PAgP between D1 & A1

```

D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#int range g1/0-1
D1(config-if-range)#channel-group 2 mode desirable non-silent
Creating a port-channel interface Port-channel 2

D1(config-if-range)#exit
D1(config)#

```

```

A1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
A1(config)#int range g0/0-1
A1(config-if-range)#channel-group 2 mode desirable non-silent
Creating a port-channel interface Port-channel 2

A1(config-if-range)#exit

```

```
A1#show etherchannel summary
Flags:  D - down          P - bundled in port-channel
        I - stand-alone  s - suspended
        H - Hot-standby (LACP only)
        R - Layer3       S - Layer2
        U - in use       f - failed to allocate aggregator

        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port

Number of channel-groups in use: 2
Number of aggregators:          2

Group  Port-channel  Protocol    Ports
-----+-----+-----+-----
1      Po1(SU)        -           Gi0/2(P)   Gi0/3(P)
2      Po2(SU)        PAgP        Gi0/0(P)   Gi0/1(P)

A1#
```

Step 7: Make a change to the EtherChannel.

```
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#vlan 69
D1(config-vlan)#name CAT_VLAN
D1(config-vlan)#int port-channel 2
D1(config-if)#switchport trunk native vlan 69
D1(config-if)#exit
D1(config)#exit

D1#show int trunk | i Port|Po2
Port      Mode          Encapsulation  Status        Native vlan
Po2       on             802.1q         trunking      69
Port      Vlans allowed on trunk
Po2       1-4094
Port      Vlans allowed and active in management domain
Po2       1,69,100,200,300
Port      Vlans in spanning tree forwarding state and not pruned
Po2       1,69,100,200,300
D1#
```

Step 8: Implement EtherChannel using LACP between D1 & D2

```
D2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D2(config)#int range g0/0-3
D2(config-if-range)#channel-group 3 mode active
Creating a port-channel interface Port-channel 3

D2(config-if-range)#exit
D2(config)#exit
D2#
```

```
D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#int range g0/0-3
D1(config-if-range)#channel-group 3 mode active
Creating a port-channel interface Port-channel 3

D1(config-if-range)#exit
D1(config)#exit
```

```
D1#show etherchannel summary
Flags: D - down          P - bundled in port-channel
       I - stand-alone s - suspended
       H - Hot-standby (LACP only)
       R - Layer3        S - Layer2
       U - in use        f - failed to allocate aggregator

       M - not in use, minimum links not met
       u - unsuitable for bundling
       w - waiting to be aggregated
       d - default port
```

```
Number of channel-groups in use: 2
Number of aggregators:          2
```

Group	Port-channel	Protocol	Ports
2	Po2(SU)	PAGP	Gi1/0(P) Gi1/1(P)
3	Po3(SD)	LACP	Gi0/0(s) Gi0/1(s) Gi0/2(s) Gi0/3(s)

```
D1#
```

Step 8: Make a change to the EtherChannel.

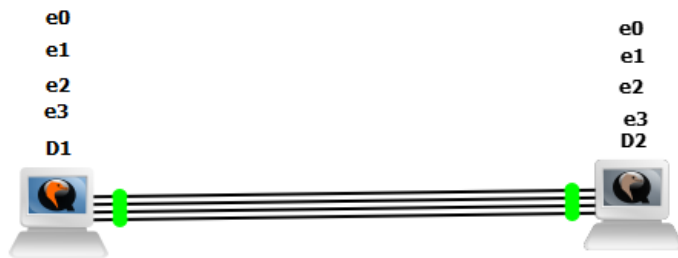
```
D2(config)#int port-channel 3
D2(config-if)#switchport trunk native vlan 69
D2(config-if)#exit
D2(config)#exit
```

```
D1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D1(config)#int port-channel 3
D1(config-if)#switchport trunk native vlan 69
D1(config-if)#exit
D1(config)#exit
```

```
D1#show int trunk | i Port|Po3
Port      Mode      Encapsulation  Status      Native vlan
Po3       on        802.1q         trunking    69
Port      Vlans allowed on trunk
Po3       1-4094
Port      Vlans allowed and active in management domain
Po3       1,69,100,200,300
Port      Vlans in spanning tree forwarding state and not pruned
Po3       1,69,100,200,300
D1#
```

2. Tune and Optimise EtherChannel Operations

Step 1: Design the topology



Step 2: Configure the Switches

- D1

```
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname D1
D1(config)#banner motd #D1, Optimise EtherChannel#
D1(config)#spanning-tree mode rapid-pvst
*Nov  6 14:50:18.643: %PLATFORM-5-SIGNATURE_VERIFIED: Image 'flash0:/vios_l2-ac
tion
D1(config)#spanning-tree mode rapid-pvst
D1(config)#line con 0
D1(config-line)#exec-timeout 0 0
D1(config-line)#logging synchronous
D1(config-line)#exit
D1(config)#int range g0/0-3
D1(config-if-range)#switchport trunk encapsulation dot1q
D1(config-if-range)#switchport mode trunk
D1(config-if-range)#no sh
D1(config-if-range)#exit
D1(config)#
```

- D2

```
vIOS-L2-01>en
vIOS-L2-01#conf t
Enter configuration commands, one per line. End with CNTL/Z.
vIOS-L2-01(config)#hostname D2
D2(config)#banned motd #D2 optimise EtherChannel#
^
% Invalid input detected at '^' marker.

D2(config)#banner motd #D2 optimise EtherChannel#
D2(config)#spanning-tree mode rapid-pvst
D2(config)#line con 0
D2(config-line)#exec-timeout 0 0
D2(config-line)#logging synchronous
D2(config-line)#exit
D2(config)#int range g0/0-3
D2(config-if-range)#switchport trunk encapsulation dot1q
D2(config-if-range)#switchport mode trunk
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#
```

Step 3: Configure master switch criteria.

```
D1#show lacp sys-id
32768, 0cce.e849.0000
D1#
```

```
D2#show lacp sys-id
32768, 0ca0.89e3.0000
```

Step 4: On D2, modify the lacp sys-id by changing the system priority.

```
D2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D2(config)#lacp system-priority 1
D2(config)#exit
D2#
*Nov  6 14:55:25.033: %SYS-5-CONFIG_I: Configured from console by console
D2#show lacp sys-id
      ^
% Invalid input detected at '^' marker.

D2#show lacp sys-id
1, 0ca0.89e3.0000
D2#
```

Step 5: Configure bundle size and member preferences.

```
D1(config)#int range g0/0-3
D1(config-if-range)#sh
D1(config-if-range)#channel-group 12 mode active
Creating a port-channel interface Port-channel 12
```

```
D2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D2(config)#int range g0/0-3
D2(config-if-range)#sh
D2(config-if-range)#
```

Step 6: Configure the connections between D1 and D2 into a single LACP EtherChannel bundle.

```
D1(config-if-range)#channel-group 12 mode active
D1(config-if-range)#no sh
D1(config-if-range)#exit
D1(config)#
```

```
D2(config-if-range)#channel-group 12 mode active
D2(config-if-range)#no sh
D2(config-if-range)#exit
D2(config)#
```

Step 7: Configure the port-channel 12 interface with a LACP minimum bundle size of 2 interfaces.

```
D1(config-if)#int port-channel 12
D1(config-if)#lacp max-bundle 3
D1(config-if)#
```

```
D2(config-if)#int port-channel 12
D2(config-if)#lacp max-bundle 3
D2(config-if)#
```

```
D1#show etherchannel summary
Flags:  D - down          P - bundled in port-channel
        I - stand-alone  s - suspended
        H - Hot-standby (LACP only)
        R - Layer3       S - Layer2
        U - in use       f - failed to allocate aggregator

        M - not in use, minimum links not met
        u - unsuitable for bundling
        w - waiting to be aggregated
        d - default port
```

```
Number of channel-groups in use: 1
Number of aggregators:          1
```

Group	Port-channel	Protocol	Ports
12	Po12(SU)	LACP	Gi0/0(P) Gi0/1(P) Gi0/2(P) Gi0/3(H)

```
D1#
```

```
D1#show lacp internal
Flags:  S - Device is requesting Slow LACPDUs
        F - Device is requesting Fast LACPDUs
        A - Device is in Active mode          P - Device is in Passive mode
```

```
Channel group 12
```

Port	Flags	State	LACP port Priority	Admin Key	Oper Key	Port Number	Port State
Gi0/0	SA	bndl	32768	0xC	0xC	0x1	0x3D
Gi0/1	SA	bndl	32768	0xC	0xC	0x2	0x3D
Gi0/2	SA	bndl	32768	0xC	0xC	0x3	0x3D
Gi0/3	SA	hot-sby	32768	0xC	0xC	0x4	0x5

```
D1#
```

Step 8: Explore EtherChannel Load Balancing

```
D1#show etherchannel load-balance
EtherChannel Load-Balancing Configuration:
      src-dst-ip

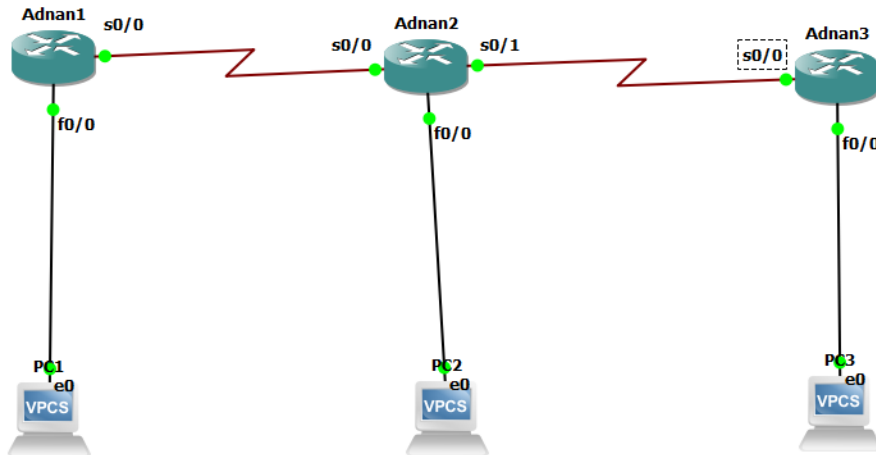
EtherChannel Load-Balancing Addresses Used Per-Protocol:
Non-IP: Source XOR Destination MAC address
IPv4:   Source XOR Destination IP address
IPv6:   Source XOR Destination IP address
```

```
D2#show etherchannel load-balance
EtherChannel Load-Balancing Configuration:
      src-dst-ip

EtherChannel Load-Balancing Addresses Used Per-Protocol:
Non-IP: Source XOR Destination MAC address
IPv4:   Source XOR Destination IP address
IPv6:   Source XOR Destination IP address
```

```
D2#
```

Step 1: Topology



Step 2: Setup Routers

- Setting up router 1

```

Adnan1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan1(config)#int fast
Adnan1(config)#int fastEthernet 0/0
Adnan1(config-if)#ip add 192.168.0.1 255.255.255.0
Adnan1(config-if)#no sh
Adnan1(config-if)#int serial
*Mar 1 00:00:45.319: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:00:46.319: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
Adnan1(config-if)#int serial 0/0
Adnan1(config-if)#ip add 10.0.0.1 255.255.255.0
Adnan1(config-if)#no sh
Adnan1(config-if)#

```

```

Adnan1#show ip int br

```

Interface	IP-Address	OK?	Method	Status	Protocol
FastEthernet0/0	192.168.0.1	YES	manual	up	up
Serial0/0	10.0.0.1	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
Serial0/3	unassigned	YES	unset	administratively down	down
Serial0/4	unassigned	YES	unset	administratively down	down
Serial0/5	unassigned	YES	unset	administratively down	down
Serial1/0	unassigned	YES	unset	administratively down	down
Serial1/1	unassigned	YES	unset	administratively down	down
Serial1/2	unassigned	YES	unset	administratively down	down

```

--More--

```

- Checking direct connection from pc 1 to router 1

```

PC1> ip 192.168.0.100/24 192.168.0.1
Checking for duplicate address...
PC1 : 192.168.0.100 255.255.255.0 gateway 192.168.0.1

PC1> ping 192.168.0.1
192.168.0.1 icmp_seq=1 timeout
84 bytes from 192.168.0.1 icmp_seq=2 ttl=255 time=15.785 ms
84 bytes from 192.168.0.1 icmp_seq=3 ttl=255 time=15.998 ms
84 bytes from 192.168.0.1 icmp_seq=4 ttl=255 time=15.524 ms
84 bytes from 192.168.0.1 icmp_seq=5 ttl=255 time=15.766 ms

```

- Setting up router 2


```

Adnan2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan2(config)#int fast
Adnan2(config)#int fastEthernet 0/0
Adnan2(config-if)#ip add 192.168.1.1 255.255.255.0
Adnan2(config-if)#no sh
Adnan2(config-if)#int serial 0
*Mar 1 00:01:05.727: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:01:06.727: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
Adnan2(config-if)#int serial 0/0
Adnan2(config-if)#ip add 10.0.0.2 255.255.255.0
Adnan2(config-if)#no sh
Adnan2(config-if)#
*Mar 1 00:01:23.683: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
*Mar 1 00:01:24.683: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
Adnan2(config-if)#int serial 0/1
Adnan2(config-if)#ip add 11.0.0.1 255.255.255.0
Adnan2(config-if)#no sh
Adnan2#show ip int br

```

Interface	IP-Address	OK?	Method	Status	Protocol
FastEthernet0/0	192.168.1.1	YES	manual	up	up
Serial0/0	10.0.0.2	YES	manual	up	up
FastEthernet0/1	unassigned	YES	unset	administratively down	down
Serial0/1	11.0.0.1	YES	manual	up	up
Serial0/2	unassigned	YES	unset	administratively down	down
Serial0/3	unassigned	YES	unset	administratively down	down
Serial0/4	unassigned	YES	unset	administratively down	down
Serial0/5	unassigned	YES	unset	administratively down	down
Serial1/0	unassigned	YES	unset	administratively down	down
Serial1/1	unassigned	YES	unset	administratively down	down
Serial1/2	unassigned	YES	unset	administratively down	down

```

--More--

```

- Checking direct connection from pc 2 to router 2

```

PC2> ip 192.168.1.100/24 192.168.1.1
Checking for duplicate address...
PC1 : 192.168.1.100 255.255.255.0 gateway 192.168.1.1

PC2> ping 192.168.1.1
192.168.1.1 icmp_seq=1 timeout
84 bytes from 192.168.1.1 icmp_seq=2 ttl=255 time=16.432 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=255 time=14.936 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=255 time=14.974 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=255 time=15.723 ms

```

- Setting up router 3

```

Adnan3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan3(config)#int fast
Adnan3(config)#int fastEthernet 0/0
Adnan3(config-if)#ip add 192.168.2.1 255.255.255.0
Adnan3(config-if)#no sh
Adnan3(config-if)#int serial 0.0
*Mar 1 00:01:43.067: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:01:44.067: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
Adnan3(config-if)#int serial 0/0
Adnan3(config-if)#ip add 11.0.0.2 255.255.255.0
Adnan3(config-if)#no sh
Adnan3(config-if)#

```

```

Adnan3#show ip int br
Interface                IP-Address      OK? Method Status        Protocol
FastEthernet0/0          192.168.2.1     YES manual up             up
Serial0/0                 11.0.0.2        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
Serial0/3                 unassigned      YES unset  administratively down down
Serial0/4                 unassigned      YES unset  administratively down down
Serial0/5                 unassigned      YES unset  administratively down down
Serial1/0                 unassigned      YES unset  administratively down down
Serial1/1                 unassigned      YES unset  administratively down down
Serial1/2                 unassigned      YES unset  administratively down down
--More--

```

- Checking direct connection from pc 3 to router 3

```

PC3> ip 192.168.2.100/24 192.168.2.1
Checking for duplicate address...
PC1 : 192.168.2.100 255.255.255.0 gateway 192.168.2.1

PC3> ping 192.168.2.1
192.168.2.1 icmp_seq=1 timeout
84 bytes from 192.168.2.1 icmp_seq=2 ttl=255 time=15.323 ms
84 bytes from 192.168.2.1 icmp_seq=3 ttl=255 time=15.678 ms
84 bytes from 192.168.2.1 icmp_seq=4 ttl=255 time=14.962 ms
84 bytes from 192.168.2.1 icmp_seq=5 ttl=255 time=15.723 ms

```

Step 3: Setting up ospf routing

- Router 1

```

Adnan1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan1(config)#router ospf 1
Adnan1(config-router)#network 192.168.0.0 0.0.0.255 area 1
Adnan1(config-router)#network 10.0.0.0 0.0.0.255 area 1
Adnan1(config-router)#exit
Adnan1#show 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 192.168.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.0.0.255 area 1
    192.168.0.0 0.0.0.255 area 1
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.1.1      110           00:00:02
    192.168.2.1      110           00:00:02
  Distance: (default is 110)

Adnan1#show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface
192.168.1.1 0 FULL/- 00:00:35 10.0.0.2 Serial0/0
Adnan1#show ip route ospf
11.0.0.0/24 is subnetted, 1 subnets
0       11.0.0.0 [110/128] via 10.0.0.2, 00:00:29, Serial0/0
0       192.168.1.0/24 [110/74] via 10.0.0.2, 00:00:29, Serial0/0
0       192.168.2.0/24 [110/138] via 10.0.0.2, 00:00:29, Serial0/0
Adnan1#

```

- Router 2

```

Adnan2(config)#router ospf 1
Adnan2(config-router)#network 192.168.1.0 0.0.0.255 area 1
Adnan2(config-router)#network 10.0.0.0 0.0.0.255 area 1
Adnan2(config-router)#
*Mar 1 00:11:32.179: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.0.1 on Serial0/0 from LOADING to FULL, Loading Done
Adnan2(config-router)#network 11.0.0.0 0.0.0.255 area 1

```

```

Adnan2#show ip protocol
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 192.168.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.0.0.255 area 1
    11.0.0.0 0.0.0.255 area 1
    192.168.1.0 0.0.0.255 area 1
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.0.1      110          00:01:01
    192.168.2.1      110          00:01:01
  Distance: (default is 110)

```

```
Adnan2#show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.2.1	0	FULL/ -	00:00:38	11.0.0.2	Serial0/1
192.168.0.1	0	FULL/ -	00:00:30	10.0.0.1	Serial0/0

```

Adnan2#show ip route ospf
0    192.168.0.0/24 [110/74] via 10.0.0.1, 00:01:24, Serial0/0
0    192.168.2.0/24 [110/74] via 11.0.0.2, 00:01:24, Serial0/1

```

- Router 3

```

Adnan3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Adnan3(config)#router ospf 1
Adnan3(config-router)#network 192.168.2.0 0.0.0.255 area 1
Adnan3(config-router)#network 11.0.0.0 0.0.0.255 area 1

```

```

Adnan3#show ip protocol
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 192.168.2.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    11.0.0.0 0.0.0.255 area 1
    192.168.2.0 0.0.0.255 area 1
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.1.1      110          00:02:17
    192.168.0.1      110          00:02:17
  Distance: (default is 110)

```

```
Adnan3#show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.1.1	0	FULL/ -	00:00:30	11.0.0.1	Serial0/0

```

Adnan3#show ip route ospf
    10.0.0.0/24 is subnetted, 1 subnets
0    10.0.0.0 [110/128] via 11.0.0.1, 00:02:30, Serial0/0
0    192.168.0.0/24 [110/138] via 11.0.0.1, 00:02:30, Serial0/0
0    192.168.1.0/24 [110/74] via 11.0.0.1, 00:02:30, Serial0/0

```

```
Adnan3#
```

Step 4: Checking via connections

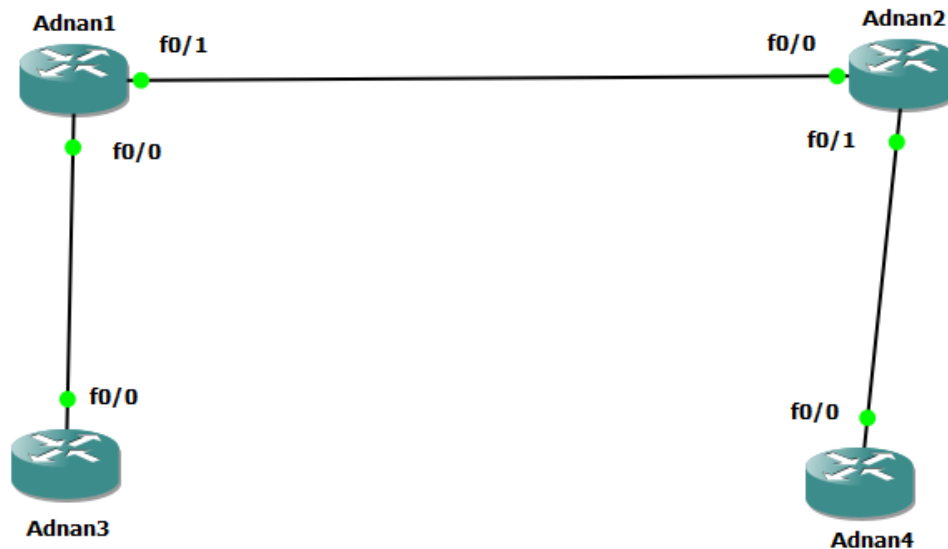
- **Pinging router 2 and PC 3 from pc 1**

```
PC1> ping 192.168.1.1
84 bytes from 192.168.1.1 icmp_seq=1 ttl=254 time=106.416 ms
84 bytes from 192.168.1.1 icmp_seq=2 ttl=254 time=61.635 ms
84 bytes from 192.168.1.1 icmp_seq=3 ttl=254 time=62.049 ms
84 bytes from 192.168.1.1 icmp_seq=4 ttl=254 time=60.320 ms
84 bytes from 192.168.1.1 icmp_seq=5 ttl=254 time=62.499 ms

PC1> ping 192.168.2.100
192.168.2.100 icmp_seq=1 timeout
192.168.2.100 icmp_seq=2 timeout
84 bytes from 192.168.2.100 icmp_seq=3 ttl=61 time=46.072 ms
84 bytes from 192.168.2.100 icmp_seq=4 ttl=61 time=45.744 ms
84 bytes from 192.168.2.100 icmp_seq=5 ttl=61 time=60.879 ms
```

SDN Practical 7 (Multi Area OSPF)

Step 1: Topology



Step 2: Setup Routers

• Setting up router 1

```
Adnan1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan1(config)#int fas
Adnan1(config)#int fastEthernet 0/0
Adnan1(config-if)#ip add 192.168.0.1 255.255.255.0
Adnan1(config-if)#do sh
Adnan1(config)#int fas
Adnan1(config)#int fastEthernet 0/1
Adnan1(config-if)#ip add 192.168.1.1 255.255.255.0
Adnan1(config-if)#no sh
```

• Setting up router 2

```
Adnan2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan2(config)#int fas
Adnan2(config)#int fastEthernet 0/0
Adnan2(config-if)#ip add 192.168.1.2 255.255.255.0
Adnan2(config-if)#no sh
Adnan2(config)#int fas
Adnan2(config)#int fastEthernet 0/1
Adnan2(config-if)#ip add 192.168.2.1 255.255.255.0
Adnan2(config-if)#no sh
```

- Setting up router 3

```
Adnan3(config)#
*Mar 1 00:02:14.331: %SYS-5-CONFIG_I: Configured from console by console
Adnan3(config)#int fas
Adnan3(config)#int fastEthernet 0/0
Adnan3(config-if)#ip add 192.168.0.2 255.255.255.0
Adnan3(config-if)#no sh
Adnan3(config-if)#
*Mar 1 00:02:35.471: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:02:36.471: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
Adnan3(config-if)#exit
Adnan3(config)#int loopb
Adnan3(config)#int loopback0
Adnan3(config-if)#
*Mar 1 00:03:50.591: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
Adnan3(config-if)#ip add 4.4.4.4 255.255.255.255
Adnan3(config-if)#no sh
```

- Setting up router 4

```
Adnan4#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Adnan4(config)#int fas
Adnan4(config)#int fastEthernet 0/0
Adnan4(config-if)#ip add 192.168.2.2 255.255.255.0
Adnan4(config-if)#no sh
Adnan4(config-if)#
*Mar 1 00:02:37.435: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:02:38.435: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
Adnan4(config-if)#exit
Adnan4(config)#int loopback0
Adnan4(config-if)#ip add
*Mar 1 00:04:12.487: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
Adnan4(config-if)#ip add 8.8.8.8 255.255.255.255
Adnan4(config-if)#no sh
```

Step 3: Setting up ospf routing

- Router 1

```
Adnan1(config)#router ospf 1
Adnan1(config-router)#network 192.168.0.0 0.0.0.255 area 0
Adnan1(config-router)#network 192.168.1.0 0.0.0.255 area 1
Adnan1(config-router)#
```

- Router 2

```
Adnan2(config)#router ospf 1
Adnan2(config-router)#network 192.168.1.0 0.0.0.255 area 1
Adnan2(config-router)#network 192.168.2.0 0.0
*Mar 1 00:07:37.195: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
Adnan2(config-router)#network 192.168.2.0 0.0.0.255 area 2
Adnan2(config-router)#end
Adnan2#
```

- Router 3

```
Adnan3(config)#router ospf 1
Adnan3(config-router)#network 192.168.0.0 0.0.0.255 area 0
Adnan3(config-router)#network 4.4.4.4 0.0.0.0
*Mar 1 00:08:13.311: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
Adnan3(config-router)#network 4.4.4.4 0.0.0.0 area 0
Adnan3(config-router)#end
```

- Router 4

```
Adnan4(config)#router ospf 1
Adnan4(config-router)#network 192.168.2.0 0.0.0.255 area 2
Adnan4(config-router)#net
*Mar 1 00:08:24.655: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.2.1 on FastEthernet0/0 from LOADING to FULL, Loading Done
Adnan4(config-router)#network 8.8.8.8 0.0.0.0 area 2
Adnan4(config-router)#end
```

Output:

- Router 1

```

Adnan1#show 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 192.168.1.1
  It is an area border router
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.0.0 0.0.0.255 area 0
    192.168.1.0 0.0.0.255 area 1
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    4.4.4.4          110          00:04:20
  Distance: (default is 110)

```

```

Adnan1#show ip ospf neighbor

```

Neighbor ID	Pri	State	Dead Time	Address	Interface
4.4.4.4	1	FULL/BDR	00:00:33	192.168.0.2	FastEthernet0/0
192.168.2.1	1	FULL/BDR	00:00:30	192.168.1.2	FastEthernet0/1

```

Adnan1#show ip route ospf
  4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/11] via 192.168.0.2, 00:04:38, FastEthernet0/0
Adnan1#

```

- Router 2

```

Adnan2#show 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 192.168.2.1
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.1.0 0.0.0.255 area 1
    192.168.2.0 0.0.0.255 area 2
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    8.8.8.8          110          00:09:47
    192.168.1.1      110          00:09:47
  Distance: (default is 110)

```

```

Adnan2#show ip ospf neighbor

```

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.1.1	1	FULL/DR	00:00:39	192.168.1.1	FastEthernet0/0
8.8.8.8	1	FULL/BDR	00:00:37	192.168.2.2	FastEthernet0/1

```

Adnan2#show ip route ospf
  4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4 [110/21] via 192.168.1.1, 00:10:02, FastEthernet0/0
  8.0.0.0/32 is subnetted, 1 subnets
O       8.8.8.8 [110/11] via 192.168.2.2, 00:10:02, FastEthernet0/1
O IA    192.168.0.0/24 [110/20] via 192.168.1.1, 00:10:02, FastEthernet0/0
Adnan2#

```

- Router 3

```

Adnan3#show 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 4.4.4.4
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    4.4.4.4 0.0.0.0 area 0
    192.168.0.0 0.0.0.255 area 0
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.1.1      110          00:11:12
  Distance: (default is 110)

Adnan3#show ip ospf neighbor
^
% Invalid input detected at '^' marker.

Adnan3#show ip ospf neighbor

Neighbor ID      Pri   State           Dead Time   Address        Interface
192.168.1.1      1     FULL/DR         00:00:33    192.168.0.1    FastEthernet0/0
Adnan3#show ip route ospf
O IA 192.168.1.0/24 [110/20] via 192.168.0.1, 00:11:33, FastEthernet0/0
Adnan3#

```

- Router 4

```

Adnan4#show 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 8.8.8.8
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    8.8.8.8 0.0.0.0 area 2
    192.168.2.0 0.0.0.255 area 2
  Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    Distance: (default is 110)

Adnan4#show ip ospf neighbor

Neighbor ID      Pri   State           Dead Time   Address        Interface
192.168.2.1      1     FULL/DR         00:00:36    192.168.2.1    FastEthernet0/0
Adnan4#

```


Practical 8

Aim: Implement BGP Communities

1. Implement eBGP for Ipv4

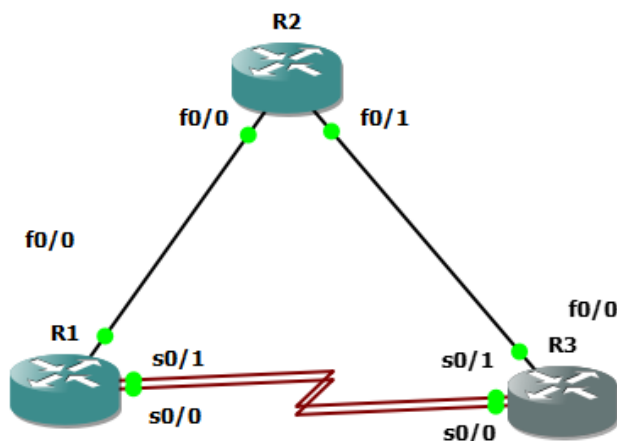
2. Implement MP(Multi protocol) -BGP(meaning it supports multiple protocol

eg:IPv6,ospf etc)-part 1& 2

3. Implement BGP path Manipulation

1. Implement eBGP for Ipv4

Step 1: Topology



Step 2:Configuring routers

R1

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#hostname R1
R1(config)#no ip domain lookup
R1(config)#line con 0
R1(config-line)#logging sync
R1(config-line)#exec-time 0 0
R1(config-line)#exit
R1(config)#int loopback 0
R1(config-if)#ip add 192.168.1.1 255.255.255.224
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int loopback 1
R1(config-if)#ip add 192.168.1.65 255.255.255.192
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int f0/0
R1(config-if)#ip add 10.1.2.1 255.255.255.0
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int serial 0/0
R1(config-if)#ip add 10.1.3.1 255.255.255.128
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int serial 0/1
R1(config-if)#ip add 10.1.3.129 255.255.255.128
R1(config-if)#no sh
R1(config-if)#exit
*Mar  1 00:02:06.011: %LINEPROTO-5-UPDOWN: Line protocol on Interface Lo
*Mar  1 00:02:06.447: %LINEPROTO-5-UPDOWN: Line protocol on Interface Lo
R1(config-if)#exit
R1(config)#
```

R2

```
R2#conf t
Enter configuration commands, one per line. End with CN
R2(config)#hostname R2
R2(config)#no ip domain lookup
R2(config)#line con 0
R2(config-line)#logging sync
R2(config-line)#exec-time 0 0
R2(config-line)#exit
R2(config)#int loopback 0
R2(config-if)#ip add 192.168.2.1 255.255.255.224
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int loopback 1
R2(config-if)#ip add 192.168.2.65 255.255.255.192
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int f0/0
R2(config-if)#ip add 10.1.2.2 255.255.255.0
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int f0/1
R2(config-if)#ip add 10.2.3.2 255.255.255.0
R2(config-if)#no sh
R2(config-if)#exit
*Mar  1 00:02:44.659: %LINEPROTO-5-UPDOWN: Line protocol
*Mar  1 00:02:45.083: %LINEPROTO-5-UPDOWN: Line protocol
R2(config-if)#exit
R2(config)#
```

R3

```
R3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R3(config)#hostname R3
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)#int loopback 0
R3(config-if)#ip add 192.168.3.1 255.255.255.224
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int loopback 1
R3(config-if)#ip add 192.168.3.65 255.255.255.192
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int f0/0
R3(config-if)#ip add 10.2.3.3 255.255.255.0
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int serial 0/0
R3(config-if)#ip add 10.1.3.3 255.255.255.128
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int serial 0/1
R3(config-if)#ip add 10.1.3.130 255.255.255.128
R3(config-if)#no sh
R3(config-if)#exit
*Mar  1 00:08:01.075: %SYS-5-CONFIG_I: Configured from console by console
R3(config-if)#exit
R3(config)#
```

Step 3: Implement BGP and neighbor relationships on R1

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)#
```

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
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)#
```

R3

```
R2(config)#router bgp 300
R2(config-router)#bgp router-id 3.3.3.3
R2(config-router)#no bgp default ipv4-unicast
R2(config-router)#neighbor 10.2.3.2 remote-as 500
R2(config-router)#neighbor 10.1.3.1 remote-as 1000
R2(config-router)#neighbor 10.1.3.129 remote-as 1000
R2(config-router)#
```

Step 4: Verifying BGP neighbor relationships. (patience 5/10 sec)

R1

```
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, 00:06:15
B       192.168.2.0/27 [20/0] via 10.1.2.2, 00:06:15
R1#
```

R2

```
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, 00:06:25
B       192.168.1.0/27 [20/0] via 10.1.2.1, 00:06:25
R2#
```

R3

```
R3#show ip route bgp
R3#
```

Notice the BGP state between R2 and R1 is established, while the BGP state between R2 and R3 is idle.

```

R3(config)#router bgp 300
R3(config-router)#address-family ipv4
R3(config-router-af)#
R3(config-router-af)#neighbor 10.1.3.1 activate
R3(config-router-af)#neighbor 10.1.3.129 activate
R3(config-router-af)#neighbor 10.2.3.2 activate
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)#

```

BGP in R3

```

R3#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 10.1.3.1, 00:00:47
B       192.168.1.0/27 [20/0] via 10.1.3.1, 00:00:47
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.2.64/26 [20/0] via 10.2.3.2, 00:00:16
B       192.168.2.0/27 [20/0] via 10.2.3.2, 00:00:16
R3#
*Mar  1 00:26:47.883: %SYS-5-CONFIG_I: Configured from console by console
R3#

```

Step 5: Verifying BGP operations.

```

R2#show ip bgp
BGP table version is 9, local router ID is 2.2.2.2
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   10.2.3.3             0           0 300 1000 i
*>                10.1.2.1             0           0 1000 i
* 192.168.1.64/26  10.2.3.3             0           0 300 1000 i
*>                10.1.2.1             0           0 1000 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  10.2.3.3             0           0 300 i
*                  10.1.2.1             0           0 1000 300 i
*> 192.168.3.64/26 10.2.3.3             0           0 300 i
*                  10.1.2.1             0           0 1000 300 i

R2#show 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 00:23:18
  Last read 00:00:18, last write 00:00:18, 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:         5         4
Keepalives:     25        25
Route Refresh:   0         0
Total:          31        30

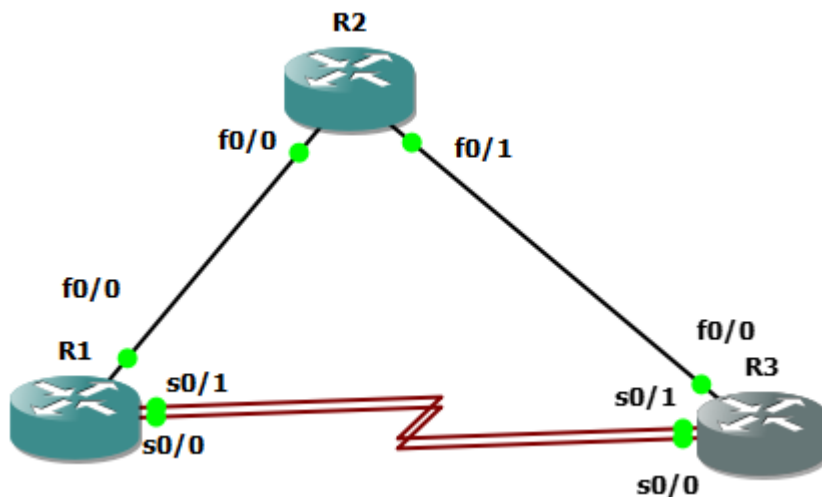
  Default minimum time between advertisement runs is 30 seconds

For address family: IPv4 Unicast
  BGP table version 9, neighbor version 9/0
  Output queue size : 0
--More--

```

2.Implement MP -BGP-part 1& 2

Step 1: Topology



Step 2: Configure Routers

R1

```

R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#no ip domain lookup
R1(config)#hostname R1
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
R1(config)#ipv6 unicast-routing
R1(config)#int f0/0
R1(config-if)#ip add 10.1.2.1 255.255.255.0
R1(config-if)#ipv6 add fe80::1:1 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1012::1/64
R1(config-if)#no sh
R1(config-if)#int s0/0
R1(config-if)#ip add 10.1.3.1 255.255.255.128
R1(config-if)#ipv6 add fe80::1:2 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1013::1/64
R1(config-if)#no sh
R1(config-if)#int s0/1
R1(config-if)#ip add 10.1.3.129 255.255.255.128
R1(config-if)#ipv6 add fe80::1:3 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1014::1/64
R1(config-if)#no sh
R1(config-if)#int loopback 0
R1(config-if)#ip add 192.168.1.1 255.255.255.224
R1(config-if)#ipv6 add fe80::1:4 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1000::1/64
R1(config-if)#no sh
R1(config-if)#int loopback 1
R1(config-if)#ip add 192.168.1.65 255.255.255.192
R1(config-if)#ipv6 add fe80::1:5 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1001::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#

```

R2

```
R2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#no ip domain lookup
R2(config)#hostname R2
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 add 10.1.2.2 255.255.255.0
R2(config-if)#ipv6 add fe80::2:1 link-local
R2(config-if)#ipv6 add 2001:db8:acad:1012::2/64
R2(config-if)#no sh
R2(config-if)#int f0/1
R2(config-if)#ip add 10.2.3.2 255.255.255.0
R2(config-if)#ipv6 add fe80::2:2 link-local
R2(config-if)#ipv6 add 2001:db8:acad:1023::2/64
R2(config-if)#no sh
R2(config-if)#int loopback 0
R2(config-if)#ip add 192.168.2.1 255.255.255.224
R2(config-if)#ipv6 add fe80::2:3 link-local
R2(config-if)#ipv6 add 2001:db8:acad:2000::1/64
R2(config-if)#no sh
R2(config-if)#int loopback 1
R2(config-if)#ip add 192.168.2.65 255.255.255.192
R2(config-if)#ipv6 add fe80::2:4 link-local
R2(config-if)#ipv6 add 2001:db8:acad:2001::1/64
R2(config-if)#no sh
R2(config-if)#exit
*Mar 1 00:40:48.203: %BGP-3-NOTIFICATION: sent to neighbor 10.0.0.0
R2(config-if)#exit FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF 002
0202 00
R2(config-if)#exit
```

R3

```
R3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R3(config)#no ip domain lookup
R3(config)#hostname R3
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 add 10.2.3.3 255.255.255.0
R3(config-if)#ipv6 add fe80::3:1 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1023::3/64
R3(config-if)#no sh
R3(config-if)#int s0/0
R3(config-if)#ip add 10.1.3.3 255.255.255.128
R3(config-if)#ipv6 add fe80::3:2 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1013::3/64
R3(config-if)#no sh
R3(config-if)#int s0/1
R3(config-if)#ip add 10.1.3.130 255.255.255.128
R3(config-if)#ipv6 add fe80::3:3 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1014::3/64
R3(config-if)#no sh
R3(config-if)#int loopback 0
R3(config-if)#ip add 192.168.3.1 255.255.255.224
R3(config-if)#ipv6 add fe80::3:4 link-local
R3(config-if)#ipv6 add 2001:db8:acad:3000::1/64
R3(config-if)#no sh
R3(config-if)#int loopback 1
R3(config-if)#ip add 192.168.3.65 255.255.255.192
R3(config-if)#ipv6 add fe80::3:5 link-local
R3(config-if)#ipv6 add 2001:db8:acad:3001::1/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
```


Step 3: Configure Multi-Protocol BGP on all Routers**R1**

```

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)#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)#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)#

```

R2

```

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:1012::1 activate
R2(config-router-af)#no neighbor 2001:db8:acad:1023::3 activate
R2(config-router-af)#exit
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:
*Mar  1 00:43:42.355: %BGP-3-NOTIFICATION: sent to neighbor 10.2.3.3 2
FFFF FFFF FFFF FFFF FFFF FFFF 002D 0104 012C 00B4 0202 0202 1002 0601
R2(config-router-af)#exit
R2(config-router)#

```

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 10.1.3.1 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)#neighbor 10.2.3.2 activate
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
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
R3(config-router-af)#neighbor 2001:db8:acad:1023::2 activate
R3(config-router-af)#exit
R3(config-router)#
*Mar  1 00:44:21.239: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Down Router
*Mar  1 00:44:21.243: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Down Router
*Mar  1 00:44:21.639: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Up
*Mar  1 00:44:21.935: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Up
R3(config-router)#

```

Step 4: Verifying MP BGP

```

R1#show bgp ipv4 unicast summary
BGP router identifier 1.1.1.1, local AS number 6500
BGP table version is 11, main routing table version 11
6 network entries using 702 bytes of memory
14 path entries using 728 bytes of memory
6/3 BGP path/bestpath attribute entries using 744 bytes of memory
4 BGP AS-PATH entries using 96 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 2270 total bytes of memory
BGP activity 13/1 prefixes, 33/5 paths, scan interval 60 secs

Neighbor      V    AS MsgRcvd MsgSent   TblVer  InQ  OutQ Up/Down  State/PfxRcd
10.1.2.2       4    500     33     33      11    0    0 00:25:13        4
10.1.3.3       4    300     38     37      11    0    0 00:01:49        4
10.1.3.130     4    300     37     36      11    0    0 00:01:50        4

```



```

R1#show 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 894 bytes of memory
14 path entries using 1064 bytes of memory
6/3 BGP path/bestpath attribute entries using 744 bytes of memory
4 BGP AS-PATH entries using 96 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 2798 total bytes of memory
BGP activity 13/1 prefixes, 33/5 paths, scan interval 60 secs

Neighbor      V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:ACAD:1012::2
                4    500      10      10       7    0    0 00:03:04      4
2001:DB8:ACAD:1013::3
                4    300       8       8       7    0    0 00:01:58      4
2001:DB8:ACAD:1014::3
                4    300       9       9       7    0    0 00:02:01      4
R1#show ip route bgp

```

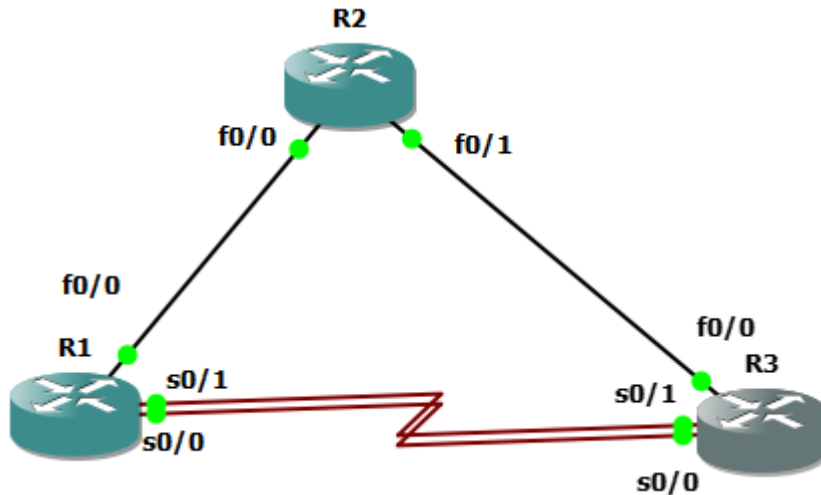
```

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, 00:22:41
B       192.168.2.0/27 [20/0] via 10.1.2.2, 00:22:41
    192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.3.64/26 [20/0] via 10.1.3.3, 00:01:10
B       192.168.3.0/27 [20/0] via 10.1.3.3, 00:01:10
R1#

```

3. Implement BGP path Manipulation

Step 1: Topology



Step 2: Configure Routers

R1

```

R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#no ip domain lookup
R1(config)#hostname R1
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
R1(config)#ipv6 unicast-routing
R1(config)#int f0/0
R1(config-if)#ip add 10.1.2.1 255.255.255.0
R1(config-if)#ipv6 add fe80::1:1 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1012::1/64
R1(config-if)#no sh
R1(config-if)#int s0/0
R1(config-if)#ip add 10.1.3.1 255.255.255.128
R1(config-if)#ipv6 add fe80::1:2 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1013::1/64
R1(config-if)#no sh
R1(config-if)#int s0/1
R1(config-if)#ip add 10.1.3.129 255.255.255.128
R1(config-if)#ipv6 add fe80::1:3 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1014::1/64
R1(config-if)#no sh
R1(config-if)#int loopback 0
R1(config-if)#ip add 192.168.1.1 255.255.255.224
R1(config-if)#ipv6 add fe80::1:4 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1000::1/64
R1(config-if)#no sh
R1(config-if)#int loopback 1
R1(config-if)#ip add 192.168.1.65 255.255.255.192
R1(config-if)#ipv6 add fe80::1:5 link-local
R1(config-if)#ipv6 add 2001:db8:acad:1001::1/64
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#
  
```

R2

```
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#no ip domain lookup
R2(config)#hostname R2
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 add 10.1.2.2 255.255.255.0
R2(config-if)#ipv6 add fe80::2:1 link-local
R2(config-if)#ipv6 add 2001:db8:acad:1012::2/64
R2(config-if)#no sh
R2(config-if)#int f0/1
R2(config-if)#ip add 10.2.3.2 255.255.255.0
R2(config-if)#ipv6 add fe80::2:2 link-local
R2(config-if)#ipv6 add 2001:db8:acad:1023::2/64
R2(config-if)#no sh
R2(config-if)#int loopback 0
R2(config-if)#ip add 192.168.2.1 255.255.255.224
R2(config-if)#ipv6 add fe80::2:3 link-local
R2(config-if)#ipv6 add 2001:db8:acad:2000::1/64
R2(config-if)#no sh
R2(config-if)#int loopback 1
R2(config-if)#ip add 192.168.2.65 255.255.255.192
R2(config-if)#ipv6 add fe80::2:4 link-local
R2(config-if)#ipv6 add 2001:db8:acad:2001::1/64
R2(config-if)#no sh
R2(config-if)#exit
*Mar  1 00:40:48.203: %BGP-3-NOTIFICATION: sent to neighbor 10.2.3.2
R2(config-if)#exit FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF 0020
0202 00
R2(config-if)#exit
```

R3

```
R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#no ip domain lookup
R3(config)#hostname R3
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 add 10.2.3.3 255.255.255.0
R3(config-if)#ipv6 add fe80::3:1 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1023::3/64
R3(config-if)#no sh
R3(config-if)#int s0/0
R3(config-if)#ip add 10.1.3.3 255.255.255.128
R3(config-if)#ipv6 add fe80::3:2 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1013::3/64
R3(config-if)#no sh
R3(config-if)#int s0/1
R3(config-if)#ip add 10.1.3.130 255.255.255.128
R3(config-if)#ipv6 add fe80::3:3 link-local
R3(config-if)#ipv6 add 2001:db8:acad:1014::3/64
R3(config-if)#no sh
R3(config-if)#int loopback 0
R3(config-if)#ip add 192.168.3.1 255.255.255.224
R3(config-if)#ipv6 add fe80::3:4 link-local
R3(config-if)#ipv6 add 2001:db8:acad:3000::1/64
R3(config-if)#no sh
R3(config-if)#int loopback 1
R3(config-if)#ip add 192.168.3.65 255.255.255.192
R3(config-if)#ipv6 add fe80::3:5 link-local
R3(config-if)#ipv6 add 2001:db8:acad:3001::1/64
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#
```

Step 3: Configure and Verify Multi-Protocol BGP on all Routers**R1**

```

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)#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)#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)#

```

R2

```

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:1012::1 activate
R2(config-router-af)#no neighbor 2001:db8:acad:1023::3 activate
R2(config-router-af)#exit
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:
*Mar  1 00:43:42.355: %BGP-3-NOTIFICATION: sent to neighbor 10.2.3.3 2
FFFF FFFF FFFF FFFF FFFF FFFF 002D 0104 012C 00B4 0202 0202 1002 0601
R2(config-router-af)#exit
R2(config-router)#

```

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 10.1.3.1 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)#neighbor 10.2.3.2 activate
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
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
R3(config-router-af)#neighbor 2001:db8:acad:1023::2 activate
R3(config-router-af)#exit
R3(config-router)#
*Mar  1 00:44:21.239: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Down Router
*Mar  1 00:44:21.243: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Down Router
*Mar  1 00:44:21.639: %BGP-5-ADJCHANGE: neighbor 10.1.3.129 Up
*Mar  1 00:44:21.935: %BGP-5-ADJCHANGE: neighbor 10.1.3.1 Up
R3(config-router)#

```

```

R1#show bgp ipv4 unicast summary
BGP router identifier 1.1.1.1, local AS number 6500
BGP table version is 11, main routing table version 11
6 network entries using 702 bytes of memory
14 path entries using 728 bytes of memory
6/3 BGP path/bestpath attribute entries using 744 bytes of memory
4 BGP AS-PATH entries using 96 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 2270 total bytes of memory
BGP activity 13/1 prefixes, 33/5 paths, scan interval 60 secs

Neighbor      V    AS MsgRcvd MsgSent   TblVer  InQ  OutQ Up/Down  State/PfxRcd
10.1.2.2      4    500     33     33      11    0    0 00:25:13      4
10.1.3.3      4    300     38     37      11    0    0 00:01:49      4
10.1.3.130    4    300     37     36      11    0    0 00:01:50      4

```

```
R1#show 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 894 bytes of memory
14 path entries using 1064 bytes of memory
6/3 BGP path/bestpath attribute entries using 744 bytes of memory
4 BGP AS-PATH entries using 96 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 2798 total bytes of memory
BGP activity 13/1 prefixes, 33/5 paths, scan interval 60 secs

Neighbor      V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:DB8:ACAD:1012::2
                4    500      10      10        7    0    0 00:03:04      4
2001:DB8:ACAD:1013::3
                4    300       8       8        7    0    0 00:01:58      4
2001:DB8:ACAD:1014::3
                4    300       9       9        7    0    0 00:02:01      4
R1#show ip route bgp
```

```
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, 00:22:41
B       192.168.2.0/27 [20/0] via 10.1.2.2, 00:22:41
      192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
B       192.168.3.64/26 [20/0] via 10.1.3.3, 00:01:10
B       192.168.3.0/27 [20/0] via 10.1.3.3, 00:01:10
R1#
```

Step 4: Configure an AS-PATH ACL to filter routes being advertised.

R1

```
R1#conf t
Enter configuration commands, one per line. End with a dot.
R1(config)#ip as-path access-list 1 permit ^$
R1(config)#
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)#exit
R1(config-router)#exit
R1(config)#exit
R1#
R1#clear bgp ipv4 unicast 500 out
*Mar  1 00:53:55.927: %SYS-5-CONFIG_I: Configured from console
R1#clear bgp ipv4 unicast 500 out
R1#
```

R2

```
R2#show bgp ipv4 unicast | i 6500
* 192.168.1.0/27 10.2.3.3 0 300 6500 i
*> 10.1.2.1 0 0 6500 i
* 192.168.1.64/26 10.2.3.3 0 300 6500 i
*> 10.1.2.1 0 0 6500 i
R2#
```


Step 5: Configure IPv6 prefix-list-based route filtering.**R1**

```
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
* 2001:DB8:ACAD:3000::/64
      2001:DB8:ACAD:1012::2
                        0 500 300 i
* 2001:DB8:ACAD:3001::/64
      2001:DB8:ACAD:1012::2
                        0 500 300 i

Total number of prefixes 4
R1#
```

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

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
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)#
```

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
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)#exit
R1(config-router)#exit
R1(config)#exit
R1#clear bgp ipv6 unicast 500 in
*Mar 1 00:58:38.499: %SYS-5-CONFIG_I: Configured from console by console
R1#clear bgp ipv6 unicast 500 in
R1#
```

```
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 6: Configure BGP path attribute manipulation to effect routing.**R1**

```
R1#show bgp ipv4 unicast 192.168.3.0
BGP routing table entry for 192.168.3.0/27, version 11
Paths: (3 available, best #3, table Default-IP-Routing-Table)
  Advertised to update-groups:
    1
  300
    10.1.3.130 from 10.1.3.130 (3.3.3.3)
      Origin IGP, metric 0, localpref 100, valid, external
  500 300
    10.1.2.2 from 10.1.2.2 (2.2.2.2)
      Origin IGP, 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#
```

ip prefix-list PREFERRED_IPV4_PATH seq 5 permit 192.168.3.0/24 le 27

```
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#ip prefix-list PREFERRED_IPV4_PATH seq 5 permit 192.168.3.0/24 le 27
*Mar  1 01:01:51.787: %SYS-5-CONFIG_I: Configured from console by console
R1(config)#ip prefix-list PREFERRED_IPV4_PATH seq 5 permit 192.168.3.0/24 le 27
R1(config)#
```

```
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
R1(config-route-map)#
```

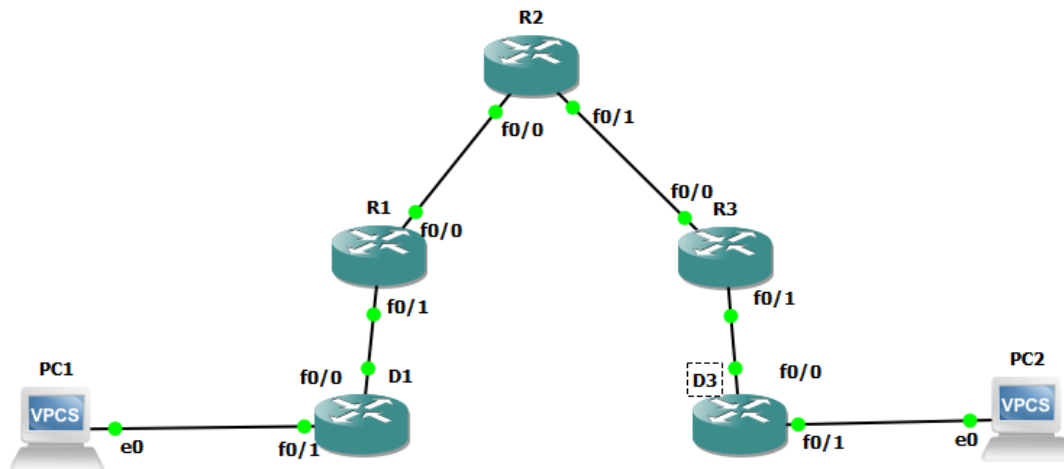
```
R1(config)#router bgp 6500
R1(config-router)#address-family ipv4 unicast
R1(config-router-af)#neighbor 10.1.3.130 route-map USE_THIS_PATH_FOR_IPV4 in
R1(config-router-af)#exit
R1(config-router)#exit
R1(config)#exit
R1#clear bgp ipv4 unicast 300 in
*Mar  1 01:03:00.883: %SYS-5-CONFIG_I: Configured from console by console
R1#clear bgp ipv4 unicast 300 in
R1#
```

```
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 10.1.3.130, 00:00:15
B       192.168.2.0/27 [20/0] via 10.1.3.130, 00:00:15
      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, 00:00:15
B       192.168.3.0/27 [20/0] via 10.1.3.130, 00:00:15
R1#
```


SDN Practical 9

Aim: Implement IPsec Site-to Site VPNs

Step 1: Topology



Step 2: Configure the network

R1

```

R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#hostname R1
R1(config)#no ip domain lookup
R1(config)#line con 0
R1(config-line)#logging sync
R1(config-line)#exec-time 0 0
R1(config-line)#exit
R1(config)#$ # This is R1, Implement GRE over IPsec Site-to-Site VPNs #
R1(config)#int f0/0
R1(config-if)#description Connection to R2
R1(config-if)#ip add 64.100.0.2 255.255.255.252
R1(config-if)#no sh
R1(config-if)#exit
R1(config)#int f0/1
R1(config-if)#description Connection to D1
R1(config-if)#ip address 10.10.0.1 255.255.255.252
R1(config-if)#no sh
R1(config-if)#exit
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
*Mar  1 00:04:55.151: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state
*Mar  1 00:04:55.483: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state
*Mar  1 00:04:56.151: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthe
R1(config)#ip route 0.0.0.0 0.0.0.0 64.100.0.1
*Mar  1 00:04:56.483: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthe
R1(config)#ip route 0.0.0.0 0.0.0.0 64.100.0.1
R1(config)#

```

R2

```

R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#hostname R2
R2(config)#no ip domain lookup
R2(config)#line con 0
R2(config-line)#logging sync
R2(config-line)#exec-time 0 0
R2(config-line)#exit
R2(config)#$ # This is R2, Implement GRE over IPsec Site-to-Site VPNs #
R2(config)#int f0/0
R2(config-if)#description Connection to R1
R2(config-if)#ip add 64.100.0.1 255.255.255.252
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int f0/1
R2(config-if)#description Connection to R3
R2(config-if)#ip address 64.100.1.1 255.255.255.252
R2(config-if)#no sh
R2(config-if)#exit
R2(config)#int lo0
R2(config-if)#description Internet simulated address
R2(config-if)#ip add 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
*Mar 1 00:04:43.255: %LINEPROTO-5-UPDOWN: Line protocol on Interface Lo
*Mar 1 00:04:43.811: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed
*Mar 1 00:04:44.143: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed
*Mar 1 00:04:44.811: %LINEPROTO-5-UPDOWN: Line protocol on Interface Fa
R2(config)#
*Mar 1 00:04:45.143: %LINEPROTO-5-UPDOWN: Line protocol on Interface Fa
R2(config)#

```

R3

```

R3#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)#hostname R3
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 R3, Implement GRE over IPsec Site-to-Site VPNs #
R3(config)#int f0/0
R3(config-if)#description Connection to R2
R3(config-if)#ip add 64.100.1.2 255.255.255.252
R3(config-if)#no sh
R3(config-if)#exit
R3(config)#int f0/1
R3(config-if)#description Connection to D3
R3(config-if)#ip address 10.10.4.1 255.255.255.252
R3(config-if)#no sh
R3(config-if)#exit
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)#
*Mar 1 00:04:57.543: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state
*Mar 1 00:04:57.607: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state
*Mar 1 00:04:58.543: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEther
R3(config)#
*Mar 1 00:04:58.607: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEther
R3(config)#

```

D1

```
D1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
D1(config)#hostname D1
D1(config)#no ip domain lookup
D1(config)#line con 0
D1(config-line)#exec-timeout 0 0
D1(config-line)#logging synchronous
D1(config-line)#exit
D1(config)#$ # This is D1, Implement GRE over IPsec Site-to-Site VPNs #
D1(config)#int f0/0
D1(config-if)#description Connection to R1
D1(config-if)#ip address 10.10.0.2 255.255.255.252
D1(config-if)#no sh
D1(config-if)#exit
D1(config)#int f0/1
D1(config-if)#description Connection to PC1
D1(config-if)#ip address 10.10.1.1 255.255.255.0
D1(config-if)#no sh
D1(config-if)#exit
D1(config)#int Lo2
D1(config-if)#description Loopback to simulate an OSPF network
D1(config-if)#ip add 10.10.2.1 255.255.255.0
D1(config-if)#ip ospf network point-to-point
D1(config-if)#exit
D1(config)#int Lo3
D1(config-if)#description Loopback to simulate an OSPF network
D1(config-if)#ip add 10.10.3.1 255.255.255.0
D1(config-if)
*Mar  1 00:03:14.227: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback2, changed
*Mar  1 00:03:14.803: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar  1 00:03:14.847: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback3, changed
*Mar  1 00:03:15.111: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar  1 00:03:15.803: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, c
*Mar  1 00:03:16.111: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, c
point-to-point
D1(config-if)#exit
D1(config)#ip routing
D1(config)#router ospf 123
D1(config-router)#router-id 1.1.1.2
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)#
*Mar  1 00:03:25.123: %OSPF-5-ADJCHG: Process 123, Nbr 1.1.1.1 on FastEthernet0/0 from L
```

D3

```
D3#conf t
Enter configuration commands, one per line. End with CNTL/Z.
D3(config)#hostname D3
D3(config)#no ip domain lookup
D3(config)#line con 0
D3(config-line)#logging sync
D3(config-line)#exec-time 0 0
D3(config-line)#exit
D3(config)#$ # This is D3, Implement GRE over IPsec Site-to-Site VPNs #
D3(config)#int f0/0
D3(config-if)#description Connection to R3
D3(config-if)#ip address 10.10.4.2 255.255.255.252
D3(config-if)#no sh
D3(config-if)#exit
D3(config)#int f0/1
D3(config-if)#description Connection to PC3
D3(config-if)#ip address 10.10.5.1 255.255.255.0
D3(config-if)#no sh
D3(config-if)#exit
D3(config)#int Lo16
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.16.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config)#int Lo16
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.16.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo17
D3(config-if)#description Loopback to sim
*Mar 1 00:04:13.079: %SYS-5-CONFIG_I: Configured from console by console
D3(config-if)#ip add 10.10.17.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo18
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.18.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo19
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.19.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo20
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.20.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo21
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.21.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo22
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.22.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
D3(config)#int Lo23
D3(config-if)#description Loopback to simulate an OSPF network
D3(config-if)#ip add 10.10.23.1 255.255.255.0
D3(config-if)#ip ospf network point-to-point
D3(config-if)#exit
```

```
D3(config)#ip routing
D3(config)#router ospf 123
D3(config-router)#router-id 3.3.3.2
D3(config-router)#auto-cost reference-bandwidth 1000
D3(config-router)#network 10.10.4.0 0.0.1.255 area 0
D3(config-router)#network 10.10.16.0 0.0.7.255 area 0
D3(config-router)#exit
D3(config)#
```

Step 3: Configure PC1 and PC3 with IP addressing.

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>
```

PC2

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

Step 4: verify end-to-end connectivity.

```
PC1> ping 10.10.5.10

84 bytes from 10.10.5.10 icmp_seq=1 ttl=59 time=92.983 ms
84 bytes from 10.10.5.10 icmp_seq=2 ttl=59 time=77.440 ms
84 bytes from 10.10.5.10 icmp_seq=3 ttl=59 time=83.640 ms
84 bytes from 10.10.5.10 icmp_seq=4 ttl=59 time=78.487 ms
84 bytes from 10.10.5.10 icmp_seq=5 ttl=59 time=118.299 ms

PC1>

PC1> ping 10.10.16.1

84 bytes from 10.10.16.1 icmp_seq=1 ttl=251 time=106.241 ms
84 bytes from 10.10.16.1 icmp_seq=2 ttl=251 time=79.968 ms
84 bytes from 10.10.16.1 icmp_seq=3 ttl=251 time=73.064 ms
84 bytes from 10.10.16.1 icmp_seq=4 ttl=251 time=69.597 ms
84 bytes from 10.10.16.1 icmp_seq=5 ttl=251 time=80.726 ms

PC1> ping 209.165.200.225

84 bytes from 209.165.200.225 icmp_seq=1 ttl=253 time=43.036 ms
84 bytes from 209.165.200.225 icmp_seq=2 ttl=253 time=32.342 ms
84 bytes from 209.165.200.225 icmp_seq=3 ttl=253 time=44.442 ms
84 bytes from 209.165.200.225 icmp_seq=4 ttl=253 time=73.780 ms
84 bytes from 209.165.200.225 icmp_seq=5 ttl=253 time=40.909 ms
```

Step 5: Verify the routing table of R1 and R3.

R1

```
R1#show 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, 00:09:34, FastEthernet0/1
O    10.10.2.0/24 [110/101] via 10.10.0.2, 00:09:34, FastEthernet0/1
O    10.10.3.0/24 [110/101] via 10.10.0.2, 00:09:34, FastEthernet0/1
R1#
```

R3

```
R3#show 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, 00:08:34, FastEthernet0/1
O    10.10.16.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.17.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.18.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.19.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.20.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.21.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.22.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
O    10.10.23.0/24 [110/101] via 10.10.4.2, 00:08:34, FastEthernet0/1
R3#
```

Step 6: Configure GRE over IPsec using a Crypto Map on R1

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

```
R1(config)#crypto isakmp policy 10
R1(config-isakmp)#encryption aes 256
R1(config-isakmp)#hash sha
R1(config-isakmp)#authentication pre-share
R1(config-isakmp)#group 5
R1(config-isakmp)#lifetime 3600
R1(config-isakmp)#exit
R1(config)#crypto isakmp key cisco123 address 64.100.1.2
A pre-shared key for address mask 64.100.1.2 255.255.255.255 already exists!
R1(config)#
```

On R1, configure the transform set and VPN ACL.

```
R1(config)#crypto ipsec transform-set GRE-VPN esp-aes 256 esp-sha-hmac
R1(cfg-crypto-trans)#mode transport
R1(cfg-crypto-trans)#exit
R1(config)#ip access-list extended GRE-VPN-ACL
R1(config-ext-nacl)#permit gre host 64.100.0.2 host 64.100.1.2
R1(config-ext-nacl)#exit
R1(config)#
```

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

```
R1(config)#crypto map GRE-CMAP 10 ipsec-isakmp
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)#interface f0/0
R1(config-if)#crypto map GRE-CMAP
R1(config-if)#
```

On R1, configure the GRE tunnel interface.

```
R1(config)#interface Tunnel1
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)#end
*Mar 1 00:25:42.759: %LINEPROTO-5-UPDOWN: Line protocol
R1(config-if)#end
R1#
```

Step 7: Configure GRE over IPsec using a Tunnel IPsec Profile on R3

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


```
R3(config)#crypto isakmp policy 10
R3(config-isakmp)#encryption aes 256
R3(config-isakmp)#hash sha
R3(config-isakmp)#authentication pre-share
R3(config-isakmp)#group 5
R3(config-isakmp)#lifetime 3600
R3(config-isakmp)#exit
R3(config)#crypto isakmp key cisco123 address 64.100.0.2
R3(config)#
```

On R3, configure the IPsec profile.

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

On R3, configure the tunnel interface.

```
R3(config)#interface Tunnel1
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 64.100.1.2
R3(config-if)#tunnel destination 64.100.0.2
R3(config-if)#tunnel protection ipsec profile GRE-PROFILE
R3(config-if)#end
R3#
```

Step 8: On R1 and R3, enable OSPF routing on the tunnel interface.
R1

```
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 = 60/68/80 ms
R1#show crypto ipsec sa | include encrypt|decrypt
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
R1#trace 10.10.16.1

Type escape sequence to abort.
Tracing the route to 10.10.16.1

 0  10.10.0.1  0 msec 0 msec 0 msec
 1  64.100.0.1 16 msec 20 msec 20 msec
 2  64.100.1.2 40 msec 44 msec 20 msec
 3  10.10.4.2 44 msec 44 msec 68 msec
R1#
```

```
R1(config)#router ospf 123
R1(config-router)#network 172.16.1.0 0.0.0.3 area 0
R1(config-router)#
```

R3

```
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)#
```


Step 9: Verify the GRE over IPsec Tunnel on R1 and R3

R1

```
R1#show interfaces 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, DLY 5000000 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 00:00:03, output 00:00:01, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: 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
    13 packets input, 1700 bytes, 0 no buffer
    Received 0 broadcasts, 0 runs, 0 giants, 0 throttles
    0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
    19 packets output, 2232 bytes, 0 underruns
    0 output errors, 0 collisions, 0 interface resets
    0 output buffer failures, 0 output buffers swapped out
R1#
R1#
```

R3

```
R3#show inter tunnel 1 | include is up|Internet address|Enc|Tunnel protocol
Tunnel1 is up, line protocol is up
  Internet address is 172.16.1.2/30
  Encapsulation TUNNEL, loopback not set
  Tunnel protocol/transport GRE/IP
R3#
*Mar  1 00:35:26.107: %SYS-5-CONFIG_I: Configured from console by console
R3#
```

Step 10: On R1 and R3, verify the crypto settings.

R1

```
R1#show 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#
```

R3

```

R3#show 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#

```

Step 11: On R1 and R3, verify OSPF routing.

R1

```

R1#show ip ospf int br
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#

R1#show ip ospf nei
Neighbor ID    Pri   State           Dead Time   Address        Interface
3.3.3.1        0     FULL/-          00:00:35    172.16.1.2     Tunnel1
1.1.1.2        1     FULL/BDR        00:00:39    10.10.0.2      FastEthernet0/1
R1#

R1#show 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, 00:05:27, FastEthernet0/1
O        10.10.2.0/24 [110/101] via 10.10.0.2, 00:05:27, FastEthernet0/1
O        10.10.3.0/24 [110/101] via 10.10.0.2, 00:05:27, FastEthernet0/1
O        10.10.4.0/30 [110/350] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.5.0/24 [110/450] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.16.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.17.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.18.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.19.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.20.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.21.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.22.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
O        10.10.23.0/24 [110/351] via 172.16.1.2, 00:05:27, Tunnel1
R1#show 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

```

R3#show ip ospf int br
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#show ip ospf nei
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
1.1.1.1	0	FULL/ -	00:00:32	172.16.1.1	Tunnel1
3.3.3.2	1	FULL/BDR	00:00:38	10.10.4.2	FastEthernet0/1

```
R3#
```

```
R3#show 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, 00:05:36, Tunnel1
O    10.10.1.0/24 [110/450] via 172.16.1.1, 00:05:36, Tunnel1
O    10.10.2.0/24 [110/351] via 172.16.1.1, 00:05:36, Tunnel1
O    10.10.3.0/24 [110/351] via 172.16.1.1, 00:05:36, Tunnel1
O    10.10.5.0/24 [110/200] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.16.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.17.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.18.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.19.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.20.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.21.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.22.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
O    10.10.23.0/24 [110/101] via 10.10.4.2, 00:05:36, FastEthernet0/1
```

```
R3#show 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#
```

Step 12: Test the GRE over IPsec VPN tunnel.

D1

```
D1#trace 10.10.16.1
```

```
Type escape sequence to abort.
```

```
Tracing the route to 10.10.16.1
```

```
 0 10.10.0.1 8 msec 32 msec 64 msec
 1 10.10.0.1 8 msec 32 msec 64 msec
 2 172.16.1.2 64 msec 68 msec 48 msec
 3 10.10.4.2 88 msec 48 msec 72 msec
```

```
D1#
```

R1

```
R1#show crypto ipsec sa | include encrypt|decrypt
```

```
#pkts encaps: 72, #pkts encrypt: 72, #pkts digest: 72
```

```
#pkts decaps: 66, #pkts decrypt: 66, #pkts verify: 66
```

```
R1#
```