

CSCI 5160
Introduction to Enterprise Networks
Spring 2024
Final Practical Exam

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We have one ISP- Zomcast, ISP has control over the backbone; P1-P4 routers and Provider Edge (PEs); PE_1 - PE_99 routers. ISP is only IPv4 Aware. Only PE_99 edge router is aware of IPv6.

Site Specifications:

We have 4 customer Sites, SITE A - SITE D and they have control over CE routers.

Site A is V4 and V6 capable and CE_A <-> PE_1 link is V4/V6 aware.

Site B is V4 and V6 capable and CE_B <-> PE_2 link is only V4 aware.

Site C is V4 and V6 capable and CE_C <-> PE_3, CE_C <-> PE_5 link is only V4 aware. (multihomed to two PEs)

Site D is V4 and V6 capable and CE_D <-> PE_4 link is only V6 aware.

IP Addressing:

I used 2001:A7::/38 for public IPv6 and Public IPv4 block of 67.0.0.0/8 for all the customers.

IPv4:

Site A has 3 private networks- 192.168.1.0/24, 172.16. 0.0/16 and 10.0.1.0/8

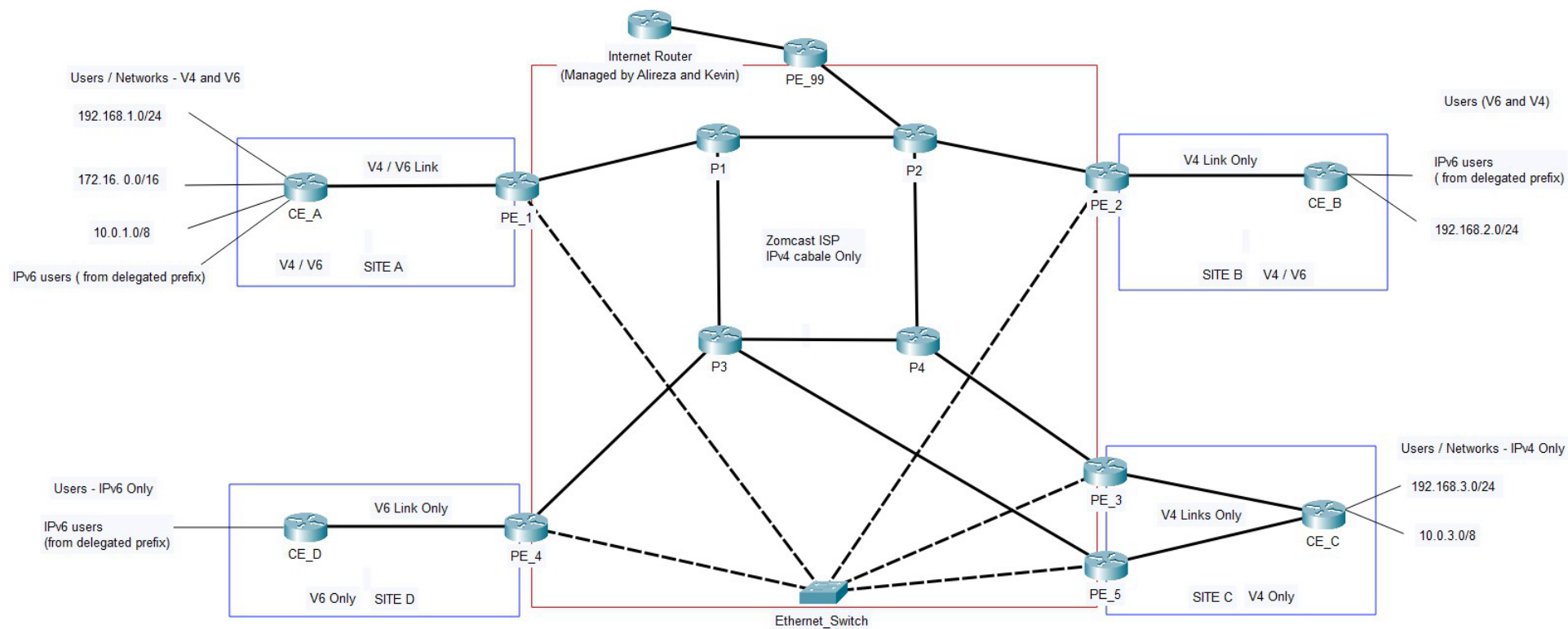
Site B has 1 private network - 192.168.2.0/24

Site C has 2 private networks- 192.168.3.0/24 and 10.0.3.0/8

IPv6:

PE4 router delegates IPv6 prefix to all the CEs. (CE_A, CE_B, CE_D)

All the users gets Ipv6 addresses “/64” prefix from their respective CE routers.



we have an Ethernet Switch that connects all the PEs, these Ethernet are P2P links that acts as full mesh connections between all PEs.

PE_1 - PE_2	→ VLAN10	67.255.255.100	67.255.255.101 - 67.255.255.102	67.255.255.103
PE_1 - PE_3	→ VLAN20	67.255.255.104	67.255.255.105 - 67.255.255.106	67.255.255.107
PE_1 - PE_4	→ VLAN30	67.255.255.108	67.255.255.109 - 67.255.255.110	67.255.255.111
PE_1 - PE_5	→ VLAN40	67.255.255.112	67.255.255.113 - 67.255.255.114	67.255.255.115
PE_2 - PE_3	→ VLAN50	67.255.255.116	67.255.255.117 - 67.255.255.118	67.255.255.119
PE_2 - PE_4	→ VLAN60	67.255.255.120	67.255.255.121 - 67.255.255.122	67.255.255.123
PE_2 - PE_5	→ VLAN70	67.255.255.124	67.255.255.125 - 67.255.255.126	67.255.255.127
PE_3 - PE_4	→ VLAN80	67.255.255.128	67.255.255.129 - 67.255.255.130	67.255.255.131
PE_3 - PE_5	→ VLAN90	67.255.255.132	67.255.255.133 - 67.255.255.134	67.255.255.135
PE_4 - PE_5	→ VLAN100	67.255.255.136	67.255.255.137 - 67.255.255.138	67.255.255.139

Switch:

Trunking:

```
interface range gigabitEthernet 2/0/1 - 5
switchport trunk encapsulation dot1q
switchport mode trunk
end
!
```

```
[Switch(config)#interface range gigabitEthernet 2/0/1 - 5
[Switch(config-if-range)#switchport trunk encapsulation dot1q
[Switch(config-if-range)#switchport mode trunk
[Switch(config-if-range)#end
```

Vlan:

```
vlan 10
name PE1_PE2
exit
vlan 20
name PE1_PE3
exit
vlan 30
name PE1_PE4
exit
vlan 40
name PE1_PE5
exit
vlan 50
name PE2_PE3
exit
vlan 60
name PE2_PE4
exit
vlan 70
name PE2_PE5
exit
vlan 80
```

```

name PE3_PE4
exit
vlan 90
name PE3_PE5
exit
vlan 100
name PE4_PE5
exit
!

```

Switch#show vlan brief

VLAN	Name	Status	Ports
1	default	active	Gi2/0/1, Gi2/0/2, Gi2/0/3 Gi2/0/4, Gi2/0/5, Gi2/0/6 Gi2/0/7, Gi2/0/8, Gi2/0/9 Gi2/0/10, Gi2/0/11, Gi2/0/12 Gi2/0/13, Gi2/0/14, Gi2/0/15 Gi2/0/16, Gi2/0/17, Gi2/0/18 Gi2/0/19, Gi2/0/20, Gi2/0/21 Gi2/0/22, Gi2/0/23, Gi2/0/24 Gi2/0/25, Gi2/0/26, Gi2/0/27 Gi2/0/28
10	PE1_PE2	active	
20	PE1_PE3	active	
30	PE1_PE4	active	
40	PE1_PE5	active	
50	PE2_PE3	active	
60	PE2_PE4	active	
70	PE2_PE5	active	
80	PE3_PE4	active	
90	PE3_PE5	active	
100	PE4_PE5	active	

IP assignment on ISP routers:

67.255.254.140	67.255.254.141 - 67.255.254.142	67.255.254.143
67.255.254.144	67.255.254.145 - 67.255.254.146	67.255.254.147
67.255.254.148	67.255.254.149 - 67.255.254.150	67.255.254.151
67.255.254.152	67.255.254.153 - 67.255.254.154	67.255.254.155
67.255.254.156	67.255.254.157 - 67.255.254.158	67.255.254.159
67.255.254.160	67.255.254.161 - 67.255.254.162	67.255.254.163
67.255.254.164	67.255.254.165 - 67.255.254.166	67.255.254.167
67.255.254.168	67.255.254.169 - 67.255.254.170	67.255.254.171
67.255.254.172	67.255.254.173 - 67.255.254.174	67.255.254.175
67.255.254.176	67.255.254.177 - 67.255.254.178	67.255.254.179

PE_1:

```

interface fastEthernet 2/0
no shutdown
exit
interface fastEthernet 2/0.10
encapsulation dot1Q 10
ip address 67.255.255.101 255.255.255.252
exit
interface fastEthernet 2/0.20
encapsulation dot1Q 20
ip address 67.255.255.105 255.255.255.252
exit
interface fastEthernet 2/0.30
encapsulation dot1Q 30
ip address 67.255.255.109 255.255.255.252
exit
interface fastEthernet 2/0.40
encapsulation dot1Q 40
ip address 67.255.255.113 255.255.255.252

```

```
exit
interface GigabitEthernet0/1
ip address 67.255.254.158 255.255.255.252
no shutdown
end
!
```

PE_2:

```
interface fastEthernet 1/0
no shutdown
exit
interface fastEthernet 1/0.10
encapsulation dot1Q 10
ip address 67.255.255.102 255.255.255.252
exit
interface fastEthernet 1/0.50
encapsulation dot1Q 50
ip address 67.255.255.117 255.255.255.252
exit
interface fastEthernet 1/0.60
encapsulation dot1Q 60
ip address 67.255.255.121 255.255.255.252
exit
interface fastEthernet 1/0.70
encapsulation dot1Q 70
ip address 67.255.255.125 255.255.255.252
exit
interface GigabitEthernet0/1
ip address 67.255.254.162 255.255.255.252
no shutdown
end
!
```

PE_3:

```
interface fastEthernet 2/0
no shutdown
exit
interface fastEthernet 2/0.20
encapsulation dot1Q 20
ip address 67.255.255.106 255.255.255.252
exit
interface fastEthernet 2/0.50
encapsulation dot1Q 50
ip address 67.255.255.118 255.255.255.252
exit
interface fastEthernet 2/0.80
encapsulation dot1Q 80
ip address 67.255.255.129 255.255.255.252
exit
```

```
interface fastEthernet 2/0.90
encapsulation dot1Q 90
ip address 67.255.255.133 255.255.255.252
exit
interface GigabitEthernet0/1
ip address 67.255.254.170 255.255.255.252
no shutdown
end
!
```

PE_4:

```
interface fastEthernet 1/0
no shutdown
exit
interface fastEthernet 1/0.30
encapsulation dot1Q 30
ip address 67.255.255.110 255.255.255.252
exit
interface fastEthernet 1/0.60
encapsulation dot1Q 60
ip address 67.255.255.122 255.255.255.252
exit
interface fastEthernet 1/0.80
encapsulation dot1Q 80
ip address 67.255.255.130 255.255.255.252
exit
interface fastEthernet 1/0.100
encapsulation dot1Q 100
ip address 67.255.255.137 255.255.255.252
exit
interface GigabitEthernet0/1
ip address 67.255.254.166 255.255.255.252
no shutdown
end
!
```

PE_5:

```
interface fastEthernet 1/0
no shutdown
exit
interface fastEthernet 1/0.40
encapsulation dot1Q 40
ip address 67.255.255.114 255.255.255.252
exit
interface fastEthernet 1/0.70
encapsulation dot1Q 70
ip address 67.255.255.126 255.255.255.252
exit
interface fastEthernet 1/0.90
encapsulation dot1Q 90
ip address 67.255.255.134 255.255.255.252
```

```
exit
interface fastEthernet 1/0.100
encapsulation dot1Q 100
ip address 67.255.255.138 255.255.255.252
exit
interface GigabitEthernet0/0
ip address 67.255.254.174 255.255.255.252
no shutdown
end
!
```

PE_99:

```
interface GigabitEthernet0/0
ip address 67.255.254.178 255.255.255.252
no shutdown
end
!
```

P1:

```
interface GigabitEthernet0/0
ip address 67.255.254.141 255.255.255.252
no shutdown
exit
interface GigabitEthernet0/1
ip address 67.255.254.154 255.255.255.252
no shutdown
exit
interface fastEthernet 1/0
ip address 67.255.254.157 255.255.255.252
no shutdown
end
!
```

P2:

```
interface GigabitEthernet0/0
ip address 67.255.254.142 255.255.255.252
no shutdown
exit
interface GigabitEthernet0/1
ip address 67.255.254.145 255.255.255.252
no shutdown
exit
interface fastEthernet 2/0
ip address 67.255.254.161 255.255.255.252
no shutdown
exit
interface fastEthernet 2/1
ip address 67.255.254.177 255.255.255.252
no shutdown
end
```


!

P3:

```
interface GigabitEthernet0/0
ip address 67.255.254.150 255.255.255.252
no shutdown
exit
interface GigabitEthernet0/1
ip address 67.255.254.153 255.255.255.252
no shutdown
exit
interface fastEthernet 1/0
ip address 67.255.254.165 255.255.255.252
no shutdown
exit
interface fastEthernet 2/0
ip address 67.255.254.173 255.255.255.252
no shutdown
end
!
```

P4:

```
interface GigabitEthernet0/0
ip address 67.255.254.149 255.255.255.252
no shutdown
exit
interface GigabitEthernet0/1
ip address 67.255.254.146 255.255.255.252
no shutdown
exit
interface fastEthernet 1/0
ip address 67.255.254.169 255.255.255.252
no shutdown
end
!
```

OSPF:

All:

```
router ospf 1
network 67.255.254.0 0.0.0.255 area 0
end
!
```

PE_1 - 5:

```
router ospf 1
network 67.255.254.0 0.0.0.255 area 0
network 67.255.255.0 0.0.0.255 area 0
```

```
end  
!
```

Loopback Interfaces:

PE_1:

```
interface loopback 1  
ip address 1.1.1.1 255.255.255.255  
exit  
router ospf 1  
network 1.1.1.1 0.0.0.0 area 0  
exit  
!
```

PE_2:

```
interface loopback 1  
ip address 2.2.2.2 255.255.255.255  
exit  
router ospf 1  
network 2.2.2.2 0.0.0.0 area 0  
exit  
  
!
```

PE_3:

```
interface loopback 1  
ip address 3.3.3.3 255.255.255.255  
exit  
router ospf 1  
network 3.3.3.3 0.0.0.0 area 0  
exit  
!
```

PE_4:

```
interface loopback 1  
ip address 4.4.4.4 255.255.255.255  
exit  
router ospf 1  
network 4.4.4.4 0.0.0.0 area 0  
exit  
!
```

PE_5:

```
interface loopback 1  
ip address 5.5.5.5 255.255.255.255  
exit  
router ospf 1  
network 5.5.5.5 0.0.0.0 area 0  
exit
```

!

PE_99:

```
interface loopback 1
ip address 9.9.9.9 255.255.255.255
exit
router ospf 1
network 9.9.9.9 0.0.0.0 area 0
exit
!
```

P_1:

```
interface loopback 1
ip address 11.11.11.11 255.255.255.255
exit
router ospf 1
network 11.11.11.11 0.0.0.0 area 0
exit
!
```

P_2:

```
interface loopback 1
ip address 22.22.22.22 255.255.255.255
exit
router ospf 1
network 22.22.22.22 0.0.0.0 area 0
exit
!
```

P_3:

```
interface loopback 1
ip address 33.33.33.33 255.255.255.255
exit
router ospf 1
network 33.33.33.33 0.0.0.0 area 0
exit
!
```

P_4:

```
interface loopback 1
ip address 44.44.44.44 255.255.255.255
exit
router ospf 1
network 44.44.44.44 0.0.0.0 area 0
exit
!
```

CE_A:

```
interface loopback 1
ip address 110.110.110.110 255.255.255.255
exit
!
```

CE_B:

```
interface loopback 1
ip address 120.120.120.120 255.255.255.255
exit
!
```

CE_C:

```
interface loopback 1
ip address 130.130.130.130 255.255.255.255
exit
!
```

Now we achieved connectivity between all routers in the IPS.

MPLS Tunnels:

ISP backbone will do only MPLS based switching between all PEs. (RSVP and/or LDP where mentioned)

Traffic Between PE should follow:

1st - Use TE Primary Path

2nd - Use TE Secondary Path

3rd - Use LDP over L2 switch - Ethernet P2P links

We have 6 MPLS TE Tunnels between PEs to prioritize the traffic.

PE1 -> PE2 (50MBs)

- Primary - PE1 -> P1 -> P3 -> P4 -> P2 -> PE2
- Backup - PE1 -> P1 -> P2 -> PE2

PE1 -> PE3 (50MBs)

- Primary - PE1 -> P1 -> P2 -> P4 -> PE3
- Backup - Dynamic

PE1 -> PE5 (50MBs)

- Primary - PE1 -> P1 -> P3 -> PE5
- Backup - Dynamic

PE2 -> PE1 (30MBs)

- Primary - PE2 -> P2 -> P4 -> P3 -> P1 -> PE1
- Backup - PE2 -> P2 -> P1 -> PE1

PE2 -> PE3 (30MBs)

- Primary - PE2 -> P2 -> P1 -> P3 -> P4 -> PE3
- Backup - Dynamic

PE2 -> PE5 (30MBs)

- Primary - PE2 -> P2 -> P4 -> P3 -> PE5
- Backup - Dynamic

MPLS:

```
mpls ldp router-id Loopback1 force
mpls ip
mpls label protocol ldp
mpls traffic-eng tunnels
```

PE_1:

```
interface fastEthernet 2/0.10
mpls ip
exit
interface fastEthernet 2/0.20
mpls ip
exit
interface fastEthernet 2/0.30
mpls ip
exit
interface fastEthernet 2/0.40
```

```
mpls ip
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

PE_2:

```
interface fastEthernet 1/0.10
mpls ip
exit
interface fastEthernet 1/0.50
mpls ip
exit
interface fastEthernet 1/0.60
mpls ip
exit
interface fastEthernet 1/0.70
mpls ip
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

PE_3:

```
interface fastEthernet 2/0.20
mpls ip
exit
interface fastEthernet 2/0.50
mpls ip
exit
interface fastEthernet 2/0.80
mpls ip
exit
interface fastEthernet 2/0.90
mpls ip
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

PE_4:

```
interface fastEthernet 1/0.30
mpls ip
exit
interface fastEthernet 1/0.60
mpls ip
exit
interface fastEthernet 1/0.80
mpls ip
exit
interface fastEthernet 1/0.100
mpls ip
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

PE_5:

```
interface fastEthernet 1/0.40
mpls ip
exit
interface fastEthernet 1/0.70
mpls ip
exit
interface fastEthernet 1/0.90
mpls ip
exit
interface fastEthernet 1/0.100
mpls ip
exit
interface GigabitEthernet0/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

P1:

```
interface GigabitEthernet0/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
```

```
exit
interface fastEthernet 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

P2:

```
interface GigabitEthernet0/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface fastEthernet 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

P3:

```
interface GigabitEthernet0/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface fastEthernet 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface fastEthernet 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```


P4:

```
interface GigabitEthernet0/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface GigabitEthernet0/1
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
exit
interface fastEthernet 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 10000000
end
!
```

OSPF on all ISP routers:

```
router ospf 1
mpls traffic-eng area 0
mpls traffic-eng router-id loopback 1
exit
!
```

PE1 -> PE2 (50MBs)

- **Primary - PE1 -> P1 -> P3 -> P4 -> P2 -> PE2**
- **Backup - PE1 -> P1 -> P2 -> PE2**

PE_1:

```
ip explicit-path name PE1_P1_P3_P4_P2_PE2 enable
next-address strict 11.11.11.11
next-address strict 33.33.33.33
next-address strict 44.44.44.44
next-address strict 22.22.22.22
next-address strict 2.2.2.2
exit
!
ip explicit-path name PE1_P1_P2_PE2 enable
next-address strict 11.11.11.11
next-address strict 22.22.22.22
next-address strict 2.2.2.2
exit
!
interface Tunnel 12
description Tunnel from PE_1 to PE_2
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 2.2.2.2
```

```
tunnel mpls traffic-eng bandwidth 50000
tunnel mpls traffic-eng path-option 1 explicit name
PE1_P1_P3_P4_P2_PE2
tunnel mpls traffic-eng path-option 2 explicit name PE1_P1_P2_PE2
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!
```

PE1 -> PE3 (50MBs)

- Primary - PE1 -> P1 -> P2 -> P4 -> PE3
- Backup - Dynamic

PE_1:

```
ip explicit-path name PE1_P1_P2_P4_PE3 enable
next-address strict 11.11.11.11
next-address strict 22.22.22.22
next-address strict 44.44.44.44
next-address strict 3.3.3.3
exit
!
interface Tunnel 13
description Tunnel from PE_1 to PE_3
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 3.3.3.3
tunnel mpls traffic-eng bandwidth 50000
tunnel mpls traffic-eng path-option 1 explicit name PE1_P1_P2_P4_PE3
tunnel mpls traffic-eng path-option 2 dynamic
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!
```

PE1 -> PE5 (50MBs)

- Primary - PE1 -> P1 -> P3 -> PE5
- Backup - Dynamic

PE_1:

```
ip explicit-path name PE1_P1_P3_PE5 enable
next-address strict 11.11.11.11
next-address strict 33.33.33.33
next-address strict 5.5.5.5
exit
!
interface Tunnel 15
description Tunnel from PE_1 to PE_5
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 5.5.5.5
tunnel mpls traffic-eng bandwidth 50000
```

```
tunnel mpls traffic-eng path-option 1 explicit name PE1_P1_P3_PE5
tunnel mpls traffic-eng path-option 2 dynamic
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!
```

PE2 -> PE1 (30MBs)

- Primary - PE2 -> P2 -> P4 -> P3 -> P1 -> PE1
- Backup - PE2 -> P2 -> P1 -> PE1

PE_2:

```
ip explicit-path name PE2_P2_P4_P3_P1_PE1 enable
next-address strict 22.22.22.22
next-address strict 44.44.44.44
next-address strict 33.33.33.33
next-address strict 11.11.11.11
next-address strict 1.1.1.1
exit
!
ip explicit-path name PE2_P2_P1_PE1 enable
next-address strict 22.22.22.22
next-address strict 11.11.11.11
next-address strict 1.1.1.1
exit
!
interface Tunnel 21
description Tunnel from PE_2 to PE_1
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 1.1.1.1
tunnel mpls traffic-eng bandwidth 30000
tunnel mpls traffic-eng path-option 1 explicit name
PE2_P2_P4_P3_P1_PE1
tunnel mpls traffic-eng path-option 2 explicit name PE2_P2_P1_PE1
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!
```

PE2 -> PE3 (30MBs)

- Primary - PE2 -> P2 -> P1 -> P3 -> P4 -> PE3
- Backup - Dynamic

PE_2:

```
ip explicit-path name PE2_P2_P1_P3_P4_PE3 enable
next-address strict 22.22.22.22
next-address strict 11.11.11.11
next-address strict 33.33.33.33
next-address strict 44.44.44.44
next-address strict 3.3.3.3
```

```

exit
!
interface Tunnel 23
description Tunnel from PE_2 to PE_3
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 3.3.3.3
tunnel mpls traffic-eng bandwidth 30000
tunnel mpls traffic-eng path-option 1 explicit name
PE2_P2_P1_P3_P4_PE3
tunnel mpls traffic-eng path-option 2 dynamic
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!

```

PE2 -> PE5 (30MBs)

- Primary - PE2 -> P2 -> P4 -> P3 -> PE5
- Backup - Dynamic

PE_2:

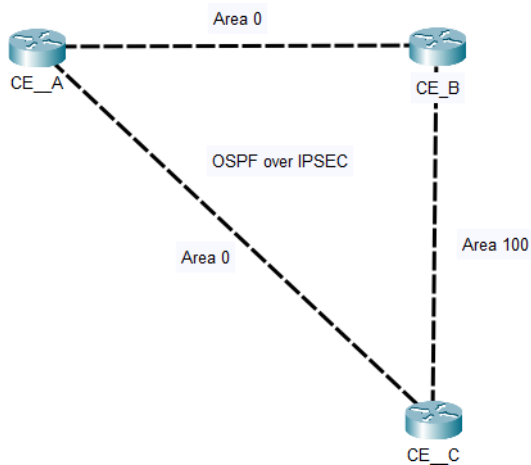
```

ip explicit-path name PE2_P2_P4_P3_PE5 enable
next-address strict 22.22.22.22
next-address strict 44.44.44.44
next-address strict 33.33.33.33
next-address strict 5.5.5.5
exit
!
interface Tunnel 25
description Tunnel from PE_2 to PE_5
ip unnumbered Loopback 1
tunnel mode mpls traffic-eng
tunnel destination 5.5.5.5
tunnel mpls traffic-eng bandwidth 30000
tunnel mpls traffic-eng path-option 1 explicit name PE2_P2_P4_P3_PE5
tunnel mpls traffic-eng path-option 2 dynamic
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng record-route
exit
!

```

Now we successfully configured all 6 MPLS tunnels. Everything is up and running.

Ipv4 Tunneling+Routing:



For our private IPv4 networks to communicate with each other, we have OSPF running over the IPSEC Tunnel between all the CE routers.

Assigning IPs on the Site:

SITE_A:

CE_A:

```
interface gigabitEthernet 0/0
ip address 67.0.1.1 255.255.255.252
no shutdown
exit
!
```

PE_1:

```
interface gigabitEthernet 0/0
ip address 67.0.1.2 255.255.255.252
no shutdown
exit
!
```

SITE_B:

CE_B:

```
interface gigabitEthernet 0/0
ip address 67.0.2.1 255.255.255.252
no shutdown
exit
!
```

PE_2:

```
interface gigabitEthernet 0/0
ip address 67.0.2.2 255.255.255.252
no shutdown
exit
!
```

SITE_C:

CE_C:

```
interface gigabitEthernet 0/0
ip address 67.0.3.1 255.255.255.252
no shutdown
exit
!
```

PE_3:

```
interface gigabitEthernet 0/0
ip address 67.0.3.2 255.255.255.252
no shutdown
exit
!
```

CE_C:

```
interface gigabitEthernet 0/1
ip address 67.0.4.1 255.255.255.252
no shutdown
exit
!
```

PE_5:

```
interface gigabitEthernet 0/1
ip address 67.0.4.2 255.255.255.252
no shutdown
exit
!
```

Setting Default Gateway:

CE_A:

```
ip route 0.0.0.0 0.0.0.0 67.0.1.2
```

CE_B:

```
ip route 0.0.0.0 0.0.0.0 67.0.2.2
```

Setting Static routes:

Site_A to Site_B:

PE_1:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
ip route 110.110.110.110 255.255.255.255 67.0.1.1
```

PE_2:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
ip route 120.120.120.120 255.255.255.255 67.0.2.1
```

Setting IPsec Site-to-Site tunnel:

CE_A to CE_B:

CE_A:

```
crypto isakmp policy 1
encryption aes
hash sha
authentication pre-share
group 2
exit
!
crypto isakmp key 0 MYPASSWORD address 120.120.120.120
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac
!
crypto ipsec profile primary
set transform-set MYTRANSFORMSET
exit
!
interface Tunnel 1
description IPsec Tunnel from CE_1 to CE_2
ip address 100.0.0.1 255.255.255.252
tunnel source 110.110.110.110
tunnel mode ipsec ipv4
tunnel destination 120.120.120.120
tunnel protection ipsec profile primary
exit
!
```

CE_B:

```
crypto isakmp policy 1
encryption aes
hash sha
authentication pre-share
group 2
exit
!
crypto isakmp key 0 MYPASSWORD address 110.110.110.110
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac
!
crypto ipsec profile primary
set transform-set MYTRANSFORMSET
exit
!
interface Tunnel 1
```

```
description IPsec Tunnel from CE_2 to CE_1
ip address 100.0.0.2 255.255.255.252
tunnel source 120.120.120.120
tunnel mode ipsec ipv4
tunnel destination 110.110.110.110
tunnel protection ipsec profile primary
exit
!
```

OSPF:

CE_A:

```
router ospf 1
router-id 110.110.110.110
network 100.0.0.0 0.0.0.255 area 0
network 192.168.1.0 0.0.0.255 area 0
network 172.16.0.0 0.0.255.255 area 0
network 10.0.1.0 0.255.255.255 area 0
exit
!
```

CE_B:

```
router ospf 1
router-id 120.120.120.120
network 100.0.0.0 0.0.0.255 area 0
network 192.168.2.0 0.0.0.255 area 0
exit
!
```

Setting Static routes:

Site_A to Site_C:

CE_C:

```
ip route 0.0.0.0 0.0.0.0 67.0.3.2
ip route 0.0.0.0 0.0.0.0 67.0.4.2
```

PE_1:

```
ip route 130.130.130.130 255.255.255.255 3.3.3.3
ip route 130.130.130.130 255.255.255.255 5.5.5.5
```

PE_3:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
ip route 130.130.130.130 255.255.255.255 67.0.3.1
```

PE_5:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
ip route 130.130.130.130 255.255.255.255 67.0.4.1
```


Setting IPsec Site-to-Site tunnel:

CE_A to CE_C:

CE_A:

```
crypto isakmp key 0 MYPASSWORD address 130.130.130.130
!  
interface Tunnel 2  
description IPsec Tunnel from CE_1 to CE_3  
ip address 200.0.0.1 255.255.255.252  
tunnel source 110.110.110.110  
tunnel mode ipsec ipv4  
tunnel destination 130.130.130.130  
tunnel protection ipsec profile primary  
exit  
!
```

CE_C:

```
crypto isakmp policy 1  
encryption aes  
hash sha  
authentication pre-share  
group 2  
exit  
!  
crypto isakmp key 0 MYPASSWORD address 110.110.110.110  
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac  
!  
crypto ipsec profile primary  
set transform-set MYTRANSFORMSET  
exit  
!  
interface Tunnel 2  
description IPsec Tunnel from CE_3 to CE_1  
ip address 200.0.0.2 255.255.255.252  
tunnel source 130.130.130.130  
tunnel mode ipsec ipv4  
tunnel destination 110.110.110.110  
tunnel protection ipsec profile primary  
exit  
!
```

OSPF:

CE_A:

```
router ospf 1  
network 200.0.0.0 0.0.0.255 area 0  
exit  
!
```

CE_C:

```
router ospf 1
router-id 130.130.130.130
network 200.0.0.0 0.0.0.255 area 0
network 192.168.3.0 0.0.0.255 area 0
network 10.0.3.0 0.255.255.255 area 0
exit
!
```

Setting Static routes:

Site_B to Site_C:

PE_2:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
ip route 130.130.130.130 255.255.255.255 3.3.3.3
```

PE_3:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
```

PE_5:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
```

Setting IPsec Site-to-Site tunnel:

CE_B to CE_C:

CE_B:

```
crypto isakmp key 0 MYPASSWORD address 130.130.130.130
!
interface Tunnel 3
description IPsec Tunnel from CE_2 to CE_3
ip address 150.0.0.1 255.255.255.252
tunnel source 120.120.120.120
tunnel mode ipsec ipv4
tunnel destination 130.130.130.130
tunnel protection ipsec profile primary
exit
!
```

CE_C:

```
crypto isakmp key 0 MYPASSWORD address 120.120.120.120
!
interface Tunnel 3
description IPsec Tunnel from CE_3 to CE_2
ip address 150.0.0.2 255.255.255.252
```

```
tunnel source 130.130.130.130
tunnel mode ipsec ipv4
tunnel destination 120.120.120.120
tunnel protection ipsec profile primary
exit
!
```

OSPF:

CE_B:

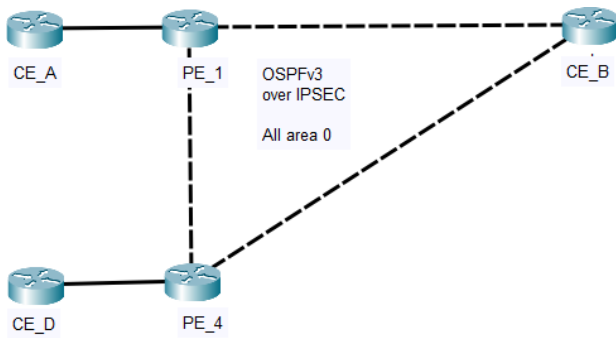
```
router ospf 1
network 150.0.0.0 0.0.0.255 area 100
network 192.168.2.0 0.0.0.255 area 100
exit
!
```

CE_C:

```
router ospf 1
network 150.0.0.0 0.0.0.255 area 100
network 192.168.3.0 0.0.0.255 area 100
network 10.0.3.0 0.255.255.255 area 100
exit
!
```

Successfully created the IPv4 tunnels. All the IPv4 sites have connectivity.

IPv6 Tunneling+Routing:



For our IPv6 networks to communicate with each other, we have OSPFv3 running over the IPSEC Tunnel.

Setting Static routes:

Site_B to Site_C:

PE_2:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
ip route 130.130.130.130 255.255.255.255 3.3.3.3
```

PE_3:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
```

PE_5:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
```

Setting IPsec Site-to-Site tunnel:

CE_B to CE_C:

CE_B:

```
crypto isakmp key 0 MYPASSWORD address 130.130.130.130
!
interface Tunnel 3
description IPsec Tunnel from CE_2 to CE_3
ip address 150.0.0.1 255.255.255.252
tunnel source 120.120.120.120
tunnel mode ipsec ipv4
tunnel destination 130.130.130.130
tunnel protection ipsec profile primary
exit
!
```

CE_C:

```
crypto isakmp key 0 MYPASSWORD address 120.120.120.120
```

```
!  
interface Tunnel 3  
description IPsec Tunnel from CE_3 to CE_2  
ip address 150.0.0.2 255.255.255.252  
tunnel source 130.130.130.130  
tunnel mode ipsec ipv4  
tunnel destination 120.120.120.120  
tunnel protection ipsec profile primary  
exit  
!
```

OSPF:

CE_B:

```
router ospf 1  
network 150.0.0.0 0.0.0.255 area 100  
network 192.168.2.0 0.0.0.255 area 100  
exit  
!
```

CE_C:

```
router ospf 1  
network 150.0.0.0 0.0.0.255 area 100  
network 192.168.3.0 0.0.0.255 area 100  
network 10.0.3.0 0.255.255.255 area 100  
exit  
!
```

Setting Static routes:

Site_A to Site_D:

PE_4:

```
ip route 110.110.110.110 255.255.255.255 1.1.1.1
```

Setting IPv6 Tunnel:

PE_4 to PE_1:

PE4:

```
ipv6 unicast-routing  
!  
crypto isakmp policy 1  
encryption aes  
hash sha  
authentication pre-share  
group 2  
exit  
!
```

```
crypto isakmp key 0 MYPASSWORD address 1.1.1.1
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac
!
crypto ipsec profile primary
set transform-set MYTRANSFORMSET
exit
!
interface Tunnel 4
description Tunnel from PE_4 to PE_1
ipv6 address 2001:db8:0:12::1/64
tunnel mode gre ip
tunnel source 4.4.4.4
tunnel destination 1.1.1.1
tunnel protection ipsec profile primary
exit
!
```

PE_1:

```
ipv6 unicast-routing
!
crypto isakmp policy 1
encryption aes
hash sha
authentication pre-share
group 2
exit
!
crypto isakmp key 0 MYPASSWORD address 4.4.4.4
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac
!
crypto ipsec profile primary
set transform-set MYTRANSFORMSET
exit
!
interface Tunnel 4
description Tunnel from PE_1 to PE_4
ipv6 address 2001:db8:0:12::2/64
tunnel mode gre ip
tunnel source 1.1.1.1
tunnel destination 4.4.4.4
tunnel protection ipsec profile primary
exit
!
```

OSPF:

PE_4:

```
ipv6 router ospf 1
router-id 4.4.4.4
exit
```

```
!  
interface Loopback1  
ipv6 address 2001::1/128  
ipv6 ospf 1 area 0  
exit  
!  
interface Tunnel 4  
ipv6 ospf 1 area 0  
ip mtu 1406  
ipv6 mtu 1406  
exit  
!
```

PE_1:

```
ipv6 router ospf 1  
router-id 1.1.1.1  
exit  
!  
interface Loopback1  
ipv6 address 2001::2/128  
ipv6 ospf 1 area 0  
exit  
!  
interface Tunnel 4  
ipv6 ospf 1 area 0  
ip mtu 1406  
ipv6 mtu 1406  
exit  
!
```

Setting Static routes:

PE_4:

```
ip route 120.120.120.120 255.255.255.255 2.2.2.2
```

Site_D to Site_B:

PE_4 to CE_B:

PE_4:

```
crypto isakmp key 0 MYPASSWORD address 120.120.120.120  
!  
interface Tunnel 6  
description Tunnel from PE_4 to CE_B  
ipv6 address 2001:db8:0:11::1/64  
tunnel mode gre ip  
tunnel source 4.4.4.4  
tunnel destination 120.120.120.120  
tunnel protection ipsec profile primary  
exit
```

```
!  
CE_B:  
ipv6 unicast-routing  
!  
crypto isakmp key 0 MYPASSWORD address 4.4.4.4  
!  
interface Tunnel 6  
description Tunnel from CE_B to PE_4  
ipv6 address 2001:db8:0:11::2/64  
tunnel mode gre ip  
tunnel source 120.120.120.120  
tunnel destination 4.4.4.4  
tunnel protection ipsec profile primary  
exit  
!
```

OSPF:

```
PE_4:  
  
interface Tunnel 6  
ipv6 ospf 1 area 0  
ip mtu 1406  
ipv6 mtu 1406  
exit  
!
```

```
CE_B:  
  
ipv6 router ospf 1  
router-id 120.120.120.120  
exit  
!  
interface Loopback1  
ipv6 address 2001::3/128  
ipv6 ospf 1 area 0  
exit  
!  
interface Tunnel 6  
ipv6 ospf 1 area 0  
ip mtu 1406  
ipv6 mtu 1406  
exit  
!
```

Site_A to Site_B:

```
PE_1 to CE_B:
```

```
PE_1:
```



```
ipv6 unicast-routing
!
crypto isakmp policy 1
encryption aes
hash sha
authentication pre-share
group 2
exit
!
crypto isakmp key 0 MYPASSWORD address 120.120.120.120
crypto ipsec transform-set MYTRANSFORMSET esp-aes esp-sha-hmac
!
crypto ipsec profile primary
set transform-set MYTRANSFORMSET
exit
!
interface Tunnel 5
description Tunnel from PE_1 to CE_B
ipv6 address 2001:db8:0:13::1/64
tunnel mode gre ip
tunnel source 1.1.1.1
tunnel destination 120.120.120.120
tunnel protection ipsec profile primary
exit
!
```

CE_B:

```
crypto isakmp key 0 MYPASSWORD address 1.1.1.1
!
interface Tunnel 5
description Tunnel from CE_B to PE_1
ipv6 address 2001:db8:0:13::2/64
tunnel mode gre ip
tunnel source 120.120.120.120
tunnel destination 1.1.1.1
tunnel protection ipsec profile primary
exit
!
```

OSPF:

PE_1:

```
ipv6 router ospf 1
router-id 1.1.1.1
exit
!
interface Loopback1
ipv6 address 2001::2/128
ipv6 ospf 1 area 0
exit
!
```

```
interface Tunnel 5
ipv6 ospf 1 area 0
ip mtu 1406
ipv6 mtu 1406
exit
!
```

CE_B:

```
ipv6 router ospf 1
router-id 120.120.120.120
exit
!
interface Loopback1
ipv6 address 2001::3/128
ipv6 ospf 1 area 0
exit
!
interface Tunnel 5
ipv6 ospf 1 area 0
ip mtu 1406
ipv6 mtu 1406
exit
!
```

Successfully created the IPv6 tunnels. All the IPv6 sites have connectivity.

Default Traffic exiting the topology:

All your customer traffic reaches the CEs.

From CE, Traffic should exit via respective PEs.

Inside backbone, IPv4 and IPv6 traffic exits via PE_99.

P-99 is the router that connects to the IPv4 and IPv6 internet, you must cross MPLS domain to reach them (use MPLS method of your preference) (NAT range is provided at the end for every student)

ISP will not speak dynamic routing protocol with customers, customer must use default routes to send traffic to ISP cloud.

Tunnels to the Internet:

PE_1 to PE_99:

PE_1:

```
interface Tunnel 199
description IPsec Tunnel from PE_1 to PE_99
ip address 11.0.0.1 255.255.255.252
tunnel source 1.1.1.1
tunnel destination 9.9.9.9
exit
!
```

PE_99:

```
interface Tunnel 199
description IPsec Tunnel from PE_99 to PE_1
ip address 11.0.0.2 255.255.255.252
tunnel source 9.9.9.9
tunnel destination 1.1.1.1
exit
!
```

PE_2 to PE_99:

PE_2:

```
interface Tunnel 299
description IPsec Tunnel from PE_2 to PE_99
ip address 12.0.0.1 255.255.255.252
tunnel source 2.2.2.2
tunnel destination 9.9.9.9
exit
!
```

PE_99:

```
interface Tunnel 299
description IPsec Tunnel from PE_99 to PE_2
ip address 12.0.0.2 255.255.255.252
tunnel source 9.9.9.9
tunnel destination 2.2.2.2
exit
```

!

PE_3 to PE_99:

PE_3:

```
interface Tunnel 399
description IPsec Tunnel from PE_3 to PE_99
ip address 13.0.0.1 255.255.255.252
tunnel source 3.3.3.3
tunnel destination 9.9.9.9
exit
!
```

PE_99:

```
interface Tunnel 399
description IPsec Tunnel from PE_99 to PE_3
ip address 13.0.0.2 255.255.255.252
tunnel source 9.9.9.9
tunnel destination 3.3.3.3
exit
!
```

PE_4 to PE_99:

PE_4:

```
interface Tunnel 499
description IPsec Tunnel from PE_4 to PE_99
ip address 14.0.0.1 255.255.255.252
tunnel source 4.4.4.4
tunnel destination 9.9.9.9
exit
!
```

PE_99:

```
interface Tunnel 499
description IPsec Tunnel from PE_99 to PE_4
ip address 14.0.0.2 255.255.255.252
tunnel source 9.9.9.9
tunnel destination 4.4.4.4
exit
!
```

PE_5 to PE_99:

PE_5:

```
interface Tunnel 599
description IPsec Tunnel from PE_5 to PE_99
ip address 15.0.0.1 255.255.255.252
tunnel source 5.5.5.5
```

```
tunnel destination 9.9.9.9
exit
!
```

PE_99:

```
interface Tunnel 599
description IPsec Tunnel from PE_99 to PE_5
ip address 15.0.0.2 255.255.255.252
tunnel source 9.9.9.9
tunnel destination 5.5.5.5
exit
!
```

Setting static routes (Internet):

PE_1:

```
ip route 0.0.0.0 0.0.0.0 11.0.0.2
```

PE_2:

```
ip route 0.0.0.0 0.0.0.0 12.0.0.2
```

PE_3:

```
ip route 0.0.0.0 0.0.0.0 13.0.0.2
```

PE_4:

```
ip route 0.0.0.0 0.0.0.0 14.0.0.2
```

PE_5:

```
ip route 0.0.0.0 0.0.0.0 15.0.0.2
```

PE_99:

```
ip route 192.168.1.0 255.255.255.0 11.0.0.1
ip route 172.16.0.0 255.255.0.0 11.0.0.1
ip route 10.0.1.0 255.255.255.0 11.0.0.1
!
ip route 192.168.2.0 255.255.255.0 12.0.0.1
!
ip route 192.168.3.0 255.255.255.0 13.0.0.1
ip route 10.0.3.0 255.255.255.0 13.0.0.1
ip route 192.168.3.0 255.255.255.0 15.0.0.1
ip route 10.0.3.0 255.255.255.0 15.0.0.1
```

PE_1:

```
ip route 192.168.1.0 255.255.255.0 67.0.1.1  
ip route 172.16.0.0 255.255.0.0 67.0.1.1  
ip route 10.0.1.0 255.255.255.0 67.0.1.1
```

PE_2:

```
ip route 192.168.2.0 255.255.255.0 67.0.2.1
```

PE_3:

```
ip route 192.168.3.0 255.255.255.0 67.0.3.1  
ip route 10.0.3.0 255.255.255.0 67.0.3.1
```

PE_5:

```
ip route 192.168.3.0 255.255.255.0 67.0.4.1  
ip route 10.0.3.0 255.255.255.0 67.0.4.1
```

Successfully configured default routes to the internet.