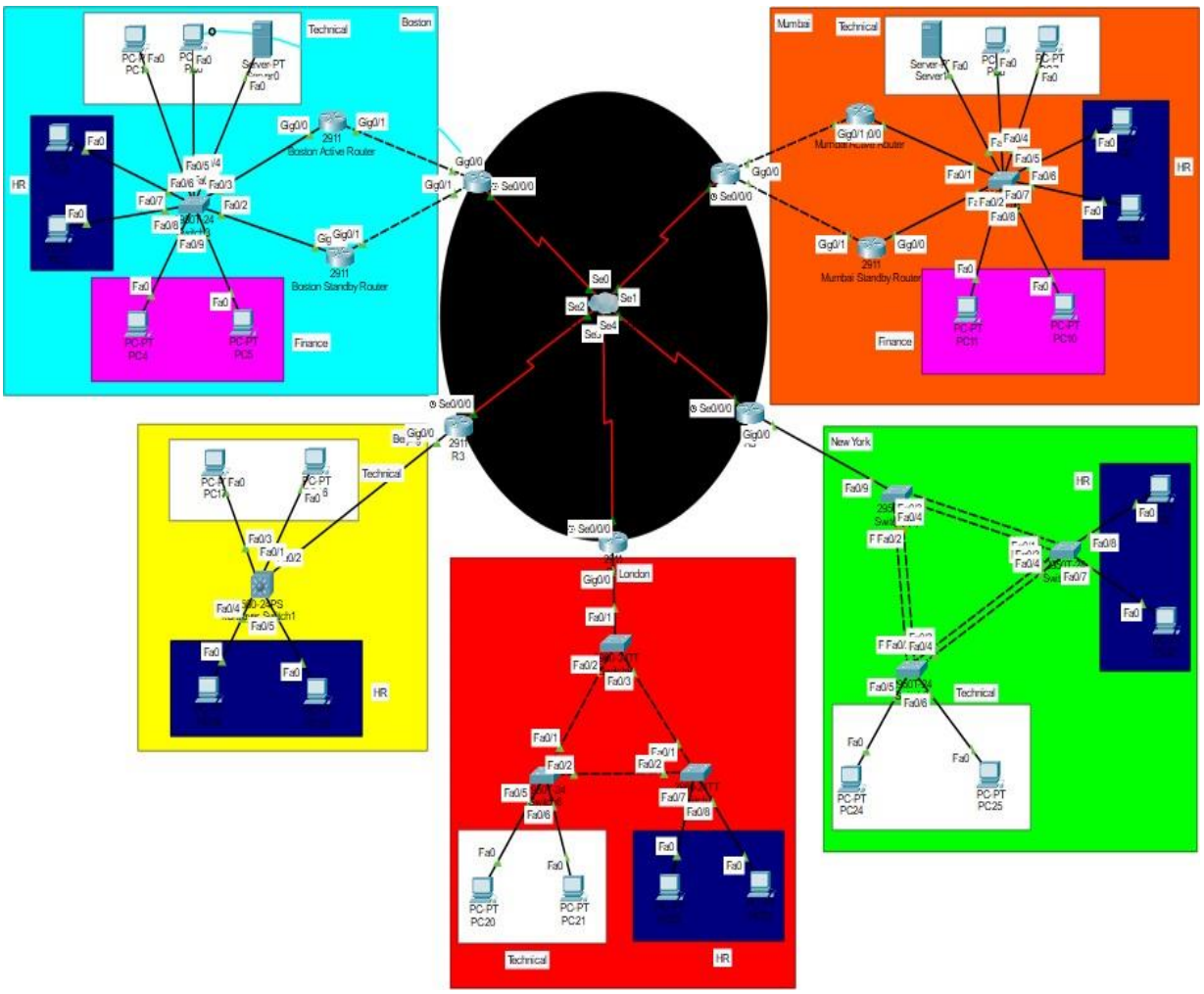
Enterprise Network Design using Cisco Packet Tracer

1. Project Design:

An inter-networking strategy is designed and implemented for a small and stable organization. This organization consists of five offices with headquarters located in Boston and Mumbai and three other offices located in Beijing, London and New York. The network design for this organization is explained with a high-level network infrastructure diagram below.

- **High-Level Network Infrastructure Diagram:**



2. Network Optimization:

- **Cost Optimization of Network:**

Instead of allocating a separate switch for each department in an office, each department is grouped into separate VLAN's within a single switch.

- **Detailed Network Architecture:**

The headquarters located in Boston and Mumbai will have three departments i.e. Technical department, HR department and Finance department whereas the offices at all other locations will have two departments only i.e. Technical department and HR department.

Within these offices, each host connected to the network is assigned an IP address using a DHCP server dynamically. The hosts within the Boston office get IP addresses from a local DHCP sever. The DHCP server also assigns IP addresses to hosts in the Mumbai office. Similarly, the hosts in Beijing, London and New York offices get IP addresses from a DHCP server located in Mumbai. Each department in an office is on a separate VLAN and the DHCP servers in Boston and Mumbai office are within the VLAN of their Technical Department. In order to implement inter-VLAN communication and dynamic allocation of IP addresses, the router on stick concept is utilized. Each department is identified through an individual VLAN number

Boston Office:

- Technical Department – VLAN 10

- HR Department – VLAN 20
- Finance Department – VLAN 30

Mumbai Office:

- Technical Department – VLAN 10
- HR Department – VLAN 20
- Finance Department – VLAN 30

Beijing Office:

- Technical Department – VLAN 10
- HR Department – VLAN 20

London Office:

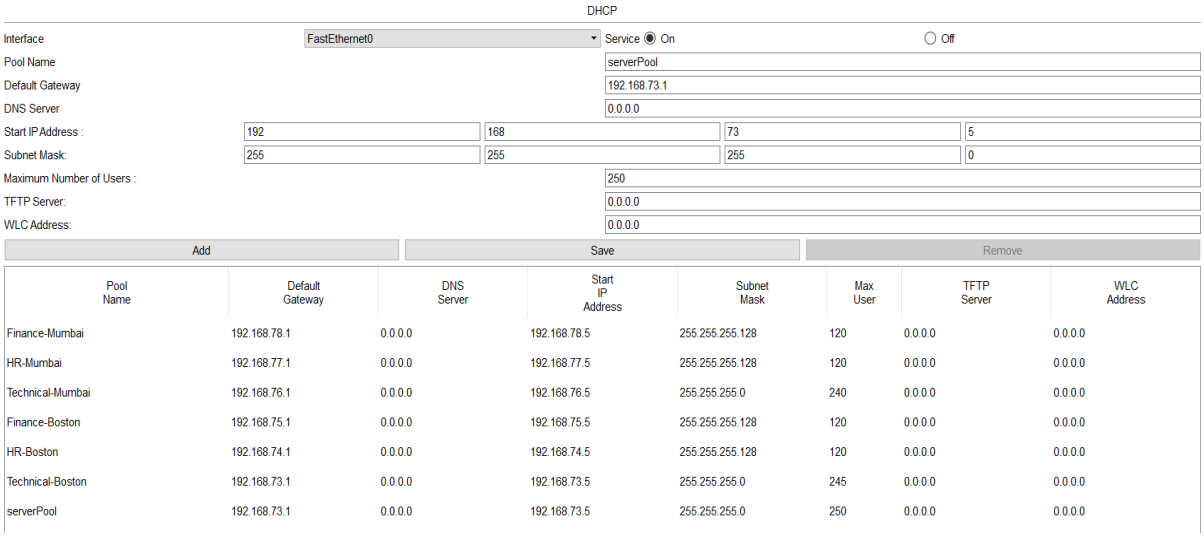
- Technical Department – VLAN 10
- HR Department – VLAN 20

New York Office:

- Technical Department – VLAN 10
- HR Department – VLAN 20

DHCP Server - Boston:

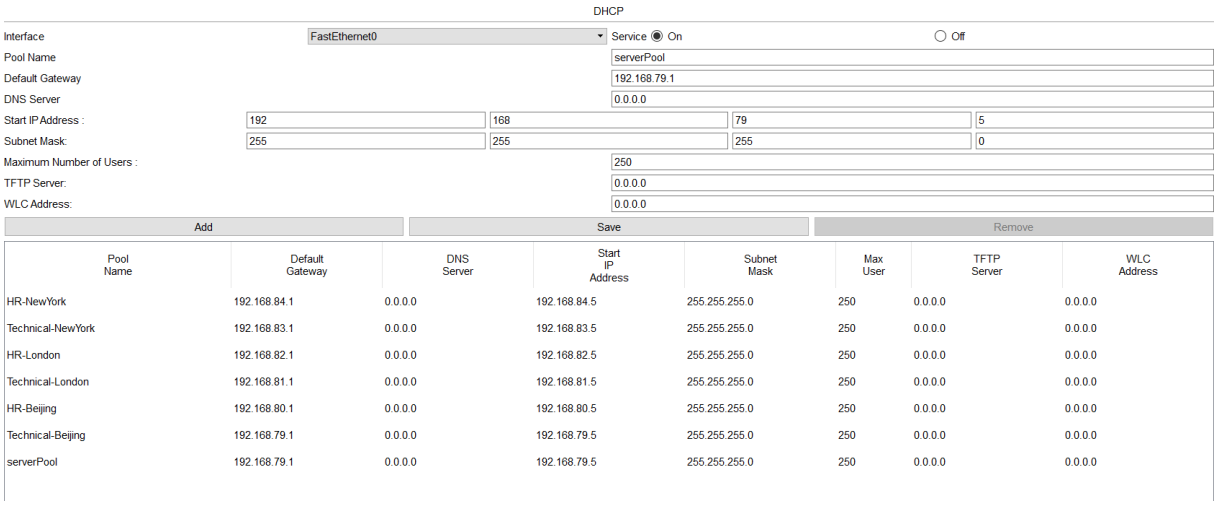
IP address of DHCP server: 192.168.73.2



Pool Name	Default Gateway	DNS Server	Start IP Address	Subnet Mask	Max User	TFTP Server	WLC Address
Finance-Mumbai	192.168.78.1	0.0.0.0	192.168.78.5	255.255.255.128	120	0.0.0.0	0.0.0.0
HR-Mumbai	192.168.77.1	0.0.0.0	192.168.77.5	255.255.255.128	120	0.0.0.0	0.0.0.0
Technical-Mumbai	192.168.76.1	0.0.0.0	192.168.76.5	255.255.255.0	240	0.0.0.0	0.0.0.0
Finance-Boston	192.168.75.1	0.0.0.0	192.168.75.5	255.255.255.128	120	0.0.0.0	0.0.0.0
HR-Boston	192.168.74.1	0.0.0.0	192.168.74.5	255.255.255.128	120	0.0.0.0	0.0.0.0
Technical-Boston	192.168.73.1	0.0.0.0	192.168.73.5	255.255.255.0	245	0.0.0.0	0.0.0.0
serverPool	192.168.73.1	0.0.0.0	192.168.73.5	255.255.255.0	250	0.0.0.0	0.0.0.0

DHCP Server - Mumbai:

IP address of DHCP server: 192.168.76.2



DHCP

Interface	FastEthernet0	Service	On	Off
Pool Name	serverPool			
Default Gateway	192.168.79.1			
DNS Server	0.0.0.0			
Start IP Address :	192	168	79	5
Subnet Mask:	255	255	255	0
Maximum Number of Users :	250			
TFTP Server:	0.0.0.0			
WLC Address:	0.0.0.0			

Add | Save | Remove

Pool Name	Default Gateway	DNS Server	Start IP Address	Subnet Mask	Max User	TFTP Server	WLC Address
HR-NewYork	192.168.84.1	0.0.0.0	192.168.84.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-NewYork	192.168.83.1	0.0.0.0	192.168.83.5	255.255.255.0	250	0.0.0.0	0.0.0.0
HR-London	192.168.82.1	0.0.0.0	192.168.82.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-London	192.168.81.1	0.0.0.0	192.168.81.5	255.255.255.0	250	0.0.0.0	0.0.0.0
HR-Beijing	192.168.80.1	0.0.0.0	192.168.80.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-Beijing	192.168.79.1	0.0.0.0	192.168.79.5	255.255.255.0	250	0.0.0.0	0.0.0.0
serverPool	192.168.79.1	0.0.0.0	192.168.79.5	255.255.255.0	250	0.0.0.0	0.0.0.0

DHCP Pool – Beijing:

HR-Beijing	192.168.80.1	0.0.0.0	192.168.80.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-Beijing	192.168.79.1	0.0.0.0	192.168.79.5	255.255.255.0	250	0.0.0.0	0.0.0.0

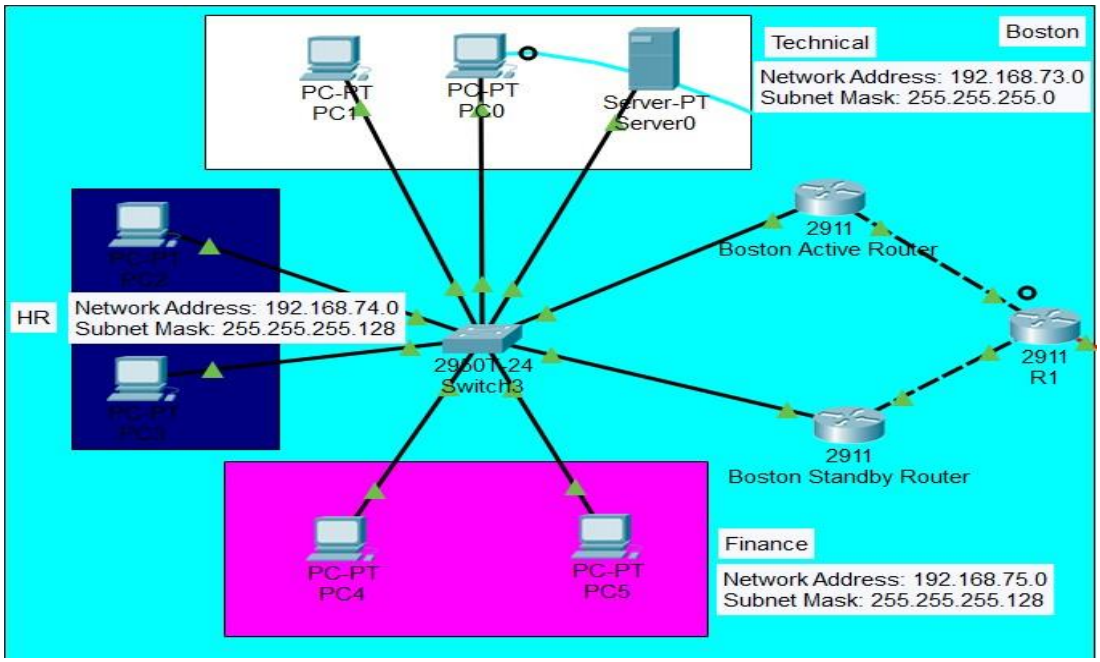
DHCP Pool – London:

HR-London	192.168.82.1	0.0.0.0	192.168.82.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-London	192.168.81.1	0.0.0.0	192.168.81.5	255.255.255.0	250	0.0.0.0	0.0.0.0

DHCP Pool – New York:

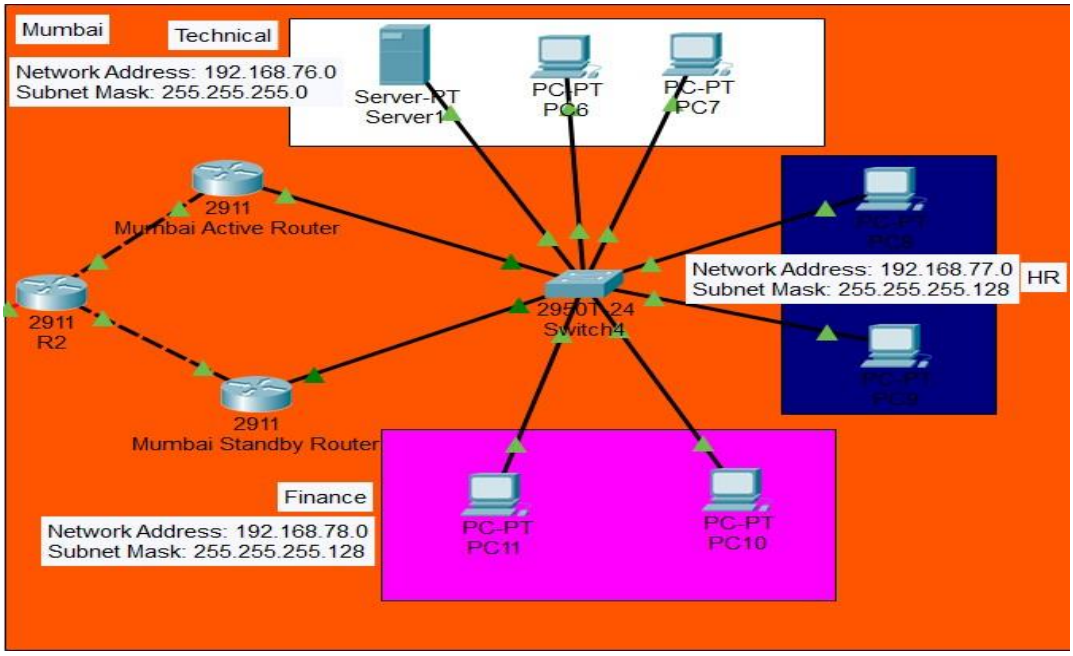
HR-NewYork	192.168.84.1	0.0.0.0	192.168.84.5	255.255.255.0	250	0.0.0.0	0.0.0.0
Technical-NewYork	192.168.83.1	0.0.0.0	192.168.83.5	255.255.255.0	250	0.0.0.0	0.0.0.0

- **Individual Office Network:**
  Boston Office (Headquarters):
  - Technical Department Network : 192.168.73.0/24
  - HR Department Network : 192.168.74.0/25
  - Finance Department Network : 192.168.75.0/25



Mumbai Office (Headquarters):

- Technical Department Network : 192.168.76.0/24
- HR Department Network : 192.168.77.0/25
- Finance Department Network : 192.168.78.0/25



Beijing Office:

- Technical Department Network : 192.168.79.0/24
- HR Department Network : 192.168.80.0/25

London Office:

- Technical Department Network : 192.168.81.0/24
- HR Department Network : 192.168.82.0/25

New York Office:

- Technical Department Network : 192.168.83.0/24
- HR Department Network : 192.168.84.0/25

Router and Switch Configuration:

Boston Active Router:

```
!
spanning-tree mode pvst
!
!
!
!
!
!
interface GigabitEthernet0/0
no ip address
duplex auto
speed auto
!
interface GigabitEthernet0/0.10
```

```
encapsulation dot1Q 10
ip address 192.168.73.3 255.255.255.0
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.73.1
standby 1 priority 140
standby 1 preempt
standby 0 timers 2 6
!
interface GigabitEthernet0/0.20
encapsulation dot1Q 30 native
ip address 192.168.74.3 255.255.255.128
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.74.1
standby 1 priority 140
standby 1 preempt
standby 0 timers 2 6
!
interface GigabitEthernet0/0.30
encapsulation dot1Q 20
ip address 192.168.75.3 255.255.255.0
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.75.1
```

```
standby 1 priority 140
standby 1 preempt
standby 0 timers 2 6
!
interface GigabitEthernet0/1
ip address 10.10.0.5 255.255.255.0
duplex auto
speed auto
!
interface GigabitEthernet0/2
no ip address
duplex auto
speed auto
shutdown
!
interface Serial0/0/0
no ip address
clock rate 2000000
shutdown
!
interface Serial0/0/1
no ip address
clock rate 2000000
!
interface Vlan1
```

```
no ip address
shutdown
!
router ospf 1
log-adjacency-changes
network 192.168.73.0 0.0.0.255 area 1
network 192.168.74.0 0.0.0.127 area 1
network 192.168.75.0 0.0.0.127 area 1
network 10.10.0.0 0.0.0.255 area 0
!
ip classless
!
ip flow-export version 9
!
!
access-list 101 permit ip host 192.168.73.2 any
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.78.0 0.0.0.127
access-list 101 permit ip any any
!
!
```

!

!

!

!

line con 0

!

line aux 0

!

line vty 0 4

login

Boston Standby Router:

!

spanning-tree mode pvst

!

!

!

!

!

!

interface GigabitEthernet0/0

no ip address

duplex auto

speed auto

!

```
interface GigabitEthernet0/0.10
encapsulation dot1Q 10
ip address 192.168.73.4 255.255.255.0
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.73.1
standby 0 timers 2 6
!
interface GigabitEthernet0/0.20
encapsulation dot1Q 30 native
ip address 192.168.74.4 255.255.255.128
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.74.1
standby 0 timers 2 6
!
interface GigabitEthernet0/0.30
encapsulation dot1Q 20
ip address 192.168.75.4 255.255.255.128
ip helper-address 192.168.73.2
ip access-group 101  in
standby 1 ip 192.168.75.1
standby 0 timers 2 6
!
interface GigabitEthernet0/1
```

ip address 16.16.0.5 255.255.255.0

duplex auto

speed auto

!

interface GigabitEthernet0/2

no ip address

duplex auto

speed auto

shutdown

!

interface Serial0/0/0

no ip address

clock rate 2000000

shutdown

!

interface Serial0/0/1

no ip address

clock rate 2000000

!

interface Vlan1

no ip address

shutdown

!

router ospf 1

log-adjacency-changes

```
network 192.168.73.0 0.0.0.255 area 1
network 192.168.74.0 0.0.0.127 area 1
network 192.168.75.0 0.0.0.127 area 1
network 16.16.0.0 0.0.0.255 area 0
!
router rip
!
ip classless
!
ip flow-export version 9
!
!
access-list 101 permit ip host 192.168.73.2 any
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.78.0 0.0.0.127
access-list 101 permit ip any any
!
!
!
!
!
```

!

line con 0

!

line aux 0

!

line vty 0 4

login

Boston ABR:

!

spanning-tree mode pvst

!

!

!

!

!

!

interface GigabitEthernet0/0

ip address 10.10.0.3 255.255.255.0

duplex auto

speed auto

!

interface GigabitEthernet0/1

ip address 16.16.0.3 255.255.255.0

duplex auto

```
speed auto
!
interface GigabitEthernet0/2
no ip address
duplex auto
speed auto
shutdown
!
interface Serial0/0/0
no ip address
encapsulation frame-relay
clock rate 2000000
!
interface Serial0/0/0.102 point-to-point
bandwidth 64
ip address 17.0.0.1 255.255.255.0
frame-relay interface-dlci 102
clock rate 2000000
!
interface Serial0/0/0.103 point-to-point
bandwidth 64
ip address 17.0.1.1 255.255.255.0
frame-relay interface-dlci 103
clock rate 2000000
!
```

```
interface Serial0/0/0.104 point-to-point
bandwidth 64
ip address 17.0.2.1 255.255.255.0
frame-relay interface-dlci 104
clock rate 2000000
!
interface Serial0/0/0.105 point-to-point
bandwidth 64
ip address 17.0.3.1 255.255.255.0
frame-relay interface-dlci 105
clock rate 2000000
!
interface Serial0/0/1
no ip address
clock rate 2000000
!
interface Vlan1
no ip address
shutdown
!
router ospf 1
router-id 20.20.0.1
log-adjacency-changes
network 17.0.0.0 0.0.0.255 area 0
network 17.0.1.0 0.0.0.255 area 0
```

network 17.0.2.0 0.0.0.255 area 0

network 17.0.3.0 0.0.0.255 area 0

network 10.10.0.0 0.0.0.255 area 0

network 16.16.0.0 0.0.0.255 area 0

!

ip classless

!

ip flow-export version 9

!

!

!

!

!

!

!

!

!

line con 0

!

line aux 0

!

line vty 0 4

login

Boston Switch:

!

```
spanning-tree mode pvst
spanning-tree extend system-id
!
interface FastEthernet0/1
switchport trunk native vlan 30
switchport mode trunk
!
interface FastEthernet0/2
switchport trunk native vlan 30
switchport mode trunk
!
interface  FastEthernet0/3
switchport access vlan 10
switchport mode access
!
interface FastEthernet0/4
switchport access vlan 10
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0030.A3E9.17CC
spanning-tree portfast
spanning-tree bpduguard enable
!
```

```
interface FastEthernet0/5
switchport access vlan 10
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0090.2B01.D324
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/6
switchport access vlan 30
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 00E0.F914.9317
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/7
switchport access vlan 30
switchport mode access
switchport port-security
switchport port-security maximum 5
```

```
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0030.A36D.E3D3
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/8
switchport access vlan 20
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0040.0B0A.0C01
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/9
switchport access vlan 20
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 000A.F3BE.0A2B
spanning-tree portfast
spanning-tree bpduguard enable
!
```

```
interface Vlan1
no ip address
!
interface Vlan10
mac-address 00d0.97ac.0501
no ip address
!
interface Vlan20
mac-address 00d0.97ac.0502
no ip address
!
interface Vlan30
mac-address 00d0.97ac.0503
no ip address
!
!
!
!
line con 0
!
line vty 0 4
login
line vty 5 15
login
```

Mumbai ABR:

```
!
spanning-tree mode pvst
!
!
!
!
!
!
interface GigabitEthernet0/0
ip address 11.11.0.3 255.255.255.0
duplex auto
speed auto
!
interface GigabitEthernet0/0.201
no ip address
shutdown
!
interface GigabitEthernet0/1
ip address 18.18.0.3 255.255.255.0
duplex auto
speed auto
!
interface GigabitEthernet0/2
no ip address
```

```
duplex auto
speed auto
shutdown
!
interface Serial0/0/0
no ip address
encapsulation frame-relay
clock rate 2000000
!
interface Serial0/0/0.201 point-to-point
bandwidth 64
ip address 17.0.0.2 255.255.255.0
frame-relay interface-dlci 201
clock rate 2000000
!
interface Serial0/0/0.203 point-to-point
bandwidth 64
ip address 17.0.4.1 255.255.255.0
frame-relay interface-dlci 203
clock rate 2000000
!
interface Serial0/0/0.204 point-to-point
bandwidth 64
ip address 17.0.5.1 255.255.255.0
frame-relay interface-dlci 204
```

clock rate 2000000

!

interface Serial0/0/0.205 point-to-point

bandwidth 64

ip address 17.0.6.1 255.255.255.0

frame-relay interface-dlci 205

clock rate 2000000

!

interface Serial0/0/1

no ip address

clock rate 2000000

!

interface Vlan1

no ip address

shutdown

!

router ospf 1

router-id 20.20.0.2

log-adjacency-changes

network 17.0.0.0 0.0.0.255 area 0

network 17.0.4.0 0.0.0.255 area 0

network 17.0.5.0 0.0.0.255 area 0

network 17.0.6.0 0.0.0.255 area 0

network 11.11.0.0 0.0.0.255 area 0

network 18.18.0.0 0.0.0.255 area 0

!

ip classless

!

ip flow-export version 9

!

!

!

!

!

!

!

!

!

line con 0

!

line aux 0

!

line vty 0 4

login

Mumbai Switch:

!

spanning-tree mode pvst

spanning-tree extend system-id

!

interface FastEthernet0/1

```
switchport trunk native vlan 30
switchport mode trunk
!
interface FastEthernet0/2
switchport trunk native vlan 30
switchport mode trunk
!
interface  FastEthernet0/3
switchport access vlan 10
switchport mode access
!
interface FastEthernet0/4
switchport access vlan 10
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 0060.2FC3.3408
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/5
switchport access vlan 10
switchport mode access
switchport port-security
```

switchport port-security maximum 5

switchport port-security mac-address sticky

switchport port-security mac-address sticky 0030.F2D9.8592

spanning-tree portfast

spanning-tree bpduguard enable

!

interface FastEthernet0/6

switchport access vlan 30

switchport mode access

switchport port-security

switchport port-security maximum 5

switchport port-security mac-address sticky

switchport port-security mac-address sticky 00E0.F7D1.341D

spanning-tree portfast

spanning-tree bpduguard enable

!

interface FastEthernet0/7

switchport access vlan 30

switchport mode access

switchport port-security

switchport port-security maximum 5

switchport port-security mac-address sticky

switchport port-security mac-address sticky 0001.9792.007D

spanning-tree portfast

spanning-tree bpduguard enable

```
!
interface FastEthernet0/8
switchport access vlan 20
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 000C.85C7.C33A
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/9
switchport access vlan 20
switchport mode access
switchport port-security
switchport port-security maximum 5
switchport port-security mac-address sticky
switchport port-security mac-address sticky 00D0.BCAD.50CC
spanning-tree portfast
spanning-tree bpduguard enable
!
interface Vlan1
no ip address
!
interface Vlan10
```

mac-address 0060.4798.be01

no ip address

!

interface Vlan20

mac-address 0060.4798.be02

no ip address

!

interface Vlan30

mac-address 0060.4798.be03

no ip address

!

!

!

!

line con 0

!

line vty 0 4

login

line vty 5 15

login

Beijing ABR:

!

spanning-tree mode pvst

!

```
!
!
!
!
!
interface GigabitEthernet0/0
no ip address
duplex auto
speed auto
!
interface GigabitEthernet0/0.10
encapsulation dot1Q 10
ip address 192.168.79.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
!
interface GigabitEthernet0/0.20
encapsulation dot1Q 20 native
ip address 192.168.80.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
!
interface GigabitEthernet0/1
no ip address
duplex auto
```

speed auto

shutdown

!

interface GigabitEthernet0/2

no ip address

duplex auto

speed auto

shutdown

!

interface Serial0/0/0

no ip address

encapsulation frame-relay

clock rate 2000000

!

interface Serial0/0/0.301 point-to-point

bandwidth 64

ip address 17.0.1.2 255.255.255.0

frame-relay interface-dlci 301

clock rate 2000000

!

interface Serial0/0/0.302 point-to-point

bandwidth 64

ip address 17.0.4.2 255.255.255.0

frame-relay interface-dlci 302

clock rate 2000000

```
!
interface Serial0/0/0.304 point-to-point
bandwidth 64
ip address 17.0.7.1 255.255.255.0
frame-relay interface-dlci 304
clock rate 2000000
!
interface Serial0/0/0.305 point-to-point
bandwidth 64
ip address 17.0.8.1 255.255.255.0
frame-relay interface-dlci 305
clock rate 2000000
!
interface Serial0/0/1
no ip address
clock rate 2000000
shutdown
!
interface Vlan1
no ip address
shutdown
!
interface Vlan10
mac-address 0003.e4e9.ac01
no ip address
```

```
!
router ospf 1
router-id 20.20.0.3
log-adjacency-changes
network 192.168.79.0 0.0.0.255 area 3
network 192.168.80.0 0.0.0.255 area 3
network 17.0.1.0 0.0.0.255 area 0
network 17.0.4.0 0.0.0.255 area 0
network 17.0.7.0 0.0.0.255 area 0
network 17.0.8.0 0.0.0.255 area 0
!
ip classless
!
ip flow-export version 9
!
!
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.79.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.80.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.79.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.80.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 permit ip any any
!
!
```

```
!
!
!
!
line con 0
!
line aux 0
!
line vty 0 4
login
```

Beijing Multi-Layer Switch:

```
ip routing
!
spanning-tree mode pvst
!
!
!
!
!
!
interface FastEthernet0/1
switchport trunk native vlan 20
switchport trunk encapsulation dot1q
switchport mode trunk
```

```
!
interface FastEthernet0/2
switchport access vlan 10
switchport mode access
switchport nonegotiate
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/3
switchport access vlan 10
switchport mode access
switchport nonegotiate
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/4
switchport access vlan 20
switchport mode access
switchport nonegotiate
spanning-tree portfast
spanning-tree bpduguard enable
!
interface  FastEthernet0/5
switchport access vlan 20
switchport mode access
```

```
switchport nonegotiate
spanning-tree portfast
spanning-tree bpduguard enable
!
interface Vlan1
no ip address
shutdown
!
interface Vlan10
mac-address 000c.8566.4b01
ip address 192.168.79.1 255.255.255.0
!
interface Vlan20
mac-address 000c.8566.4b02
ip address 192.168.80.1 255.255.255.0
!
router ospf 1
log-adjacency-changes
network 192.168.79.0 0.0.0.255 area 3
network 192.168.80.0 0.0.0.255 area 3
!
ip classless
!
ip flow-export version 9
!
```

!

!

!

!

!

!

!

line con 0

!

line aux 0

!

line vty 0 4

login

London ABR:

!

spanning-tree mode pvst

!

!

!

!

!

!

interface GigabitEthernet0/0

no ip address

```
duplex auto
speed auto
!
interface GigabitEthernet0/0.10
encapsulation dot1Q 10
ip address 192.168.81.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
!
interface GigabitEthernet0/0.20
encapsulation dot1Q 20 native
ip address 192.168.82.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
!
interface GigabitEthernet0/1
no ip address
duplex auto
speed auto
shutdown
!
interface GigabitEthernet0/2
no ip address
duplex auto
speed auto
```

```
shutdown
!
interface Serial0/0/0
no ip address
encapsulation frame-relay
clock rate 2000000
!
interface Serial0/0/0.401 point-to-point
bandwidth 64
ip address 17.0.2.2 255.255.255.0
frame-relay interface-dlci 401
clock rate 2000000
!
interface Serial0/0/0.402 point-to-point
bandwidth 64
ip address 17.0.5.2 255.255.255.0
frame-relay interface-dlci 402
clock rate 2000000
!
interface Serial0/0/0.403 point-to-point
bandwidth 64
ip address 17.0.7.2 255.255.255.0
frame-relay interface-dlci 403
clock rate 2000000
!
```

```
interface Serial0/0/0.405 point-to-point
bandwidth 64
ip address 17.0.9.1 255.255.255.0
frame-relay interface-dlci 405
clock rate 2000000
!
interface Serial0/0/1
no ip address
clock rate 2000000
shutdown
!
interface Vlan1
no ip address
shutdown
!
router ospf 1
router-id 20.20.0.4
log-adjacency-changes
network 192.168.81.0 0.0.0.255 area 4
network 192.168.82.0 0.0.0.255 area 4
network 17.0.2.0 0.0.0.255 area 0
network 17.0.5.0 0.0.0.255 area 0
network 17.0.7.0 0.0.0.255 area 0
network 17.0.9.0 0.0.0.255 area 0
!
```

```
ip classless
!
ip flow-export version 9
!
!
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.81.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.82.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.81.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.82.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 permit ip any any
!
!
!
!
!
!
line con 0
!
line aux 0
!
line vty 0 4
login
```

London Switch:

```
!
spanning-tree mode rapid-pvst
spanning-tree extend system-id
!
interface FastEthernet0/1
switchport trunk native vlan 20
switchport mode trunk
!
interface FastEthernet0/2
switchport trunk native vlan 20
switchport mode trunk
!
interface FastEthernet0/3
!
interface FastEthernet0/4
!
interface FastEthernet0/5
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/6
switchport access vlan 10
```

```
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface Vlan1
no ip address
!
interface Vlan10
mac-address 0001.97b3.2901
no ip address
!
interface Vlan20
mac-address 0001.97b3.2902
no ip address
!
!
!
!
line con 0
!
line vty 0 4
login
line vty 5 15
login
```

New York ABR:

```
!
spanning-tree mode pvst
!
!
!
!
!
!
interface GigabitEthernet0/0
no ip address
duplex auto
speed auto
!
interface GigabitEthernet0/0.10
encapsulation dot1Q 10
ip address 192.168.83.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
!
interface GigabitEthernet0/0.20
encapsulation dot1Q 20 native
ip address 192.168.84.1 255.255.255.0
ip helper-address 192.168.76.2
ip access-group 101 in
```

```
!
interface GigabitEthernet0/0.30
no ip address
shutdown
!
interface GigabitEthernet0/1
no ip address
duplex auto
speed auto
shutdown
!
interface GigabitEthernet0/2
no ip address
duplex auto
speed auto
shutdown
!
interface Serial0/0/0
no ip address
encapsulation frame-relay
clock rate 2000000
!
interface Serial0/0/0.501 point-to-point
bandwidth 64
ip address 17.0.3.2 255.255.255.0
```

```
frame-relay interface-dlci 501
clock rate 2000000
!
interface Serial0/0/0.502 point-to-point
bandwidth 64
ip address 17.0.6.1 255.255.255.0
frame-relay interface-dlci 502
clock rate 2000000
!
interface Serial0/0/0.503 point-to-point
bandwidth 64
ip address 17.0.8.2 255.255.255.0
frame-relay interface-dlci 503
clock rate 2000000
!
interface Serial0/0/0.504 point-to-point
bandwidth 64
ip address 17.0.9.2 255.255.255.0
frame-relay interface-dlci 504
clock rate 2000000
!
interface Serial0/0/1
no ip address
clock rate 2000000
!
```

```
interface Vlan1
no ip address
shutdown
!
router ospf 1
router-id 20.20.0.5
log-adjacency-changes
network 192.168.83.0 0.0.0.255 area 5
network 192.168.84.0 0.0.0.255 area 5
network 17.0.3.0 0.0.0.255 area 0
network 17.0.6.0 0.0.0.255 area 0
network 17.0.8.0 0.0.0.255 area 0
network 17.0.9.0 0.0.0.255 area 0
!
ip classless
!
ip flow-export version 9
!
!
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.83.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.84.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.83.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.84.0 0.0.0.255 192.168.78.0 0.0.0.127
```

access-list 101 permit ip any any

!

!

!

!

!

!

line con 0

!

line aux 0

!

line vty 0 4

login

New York Switch:

!

spanning-tree mode rapid-pvst

spanning-tree extend system-id

!

interface Port-channel1

switchport trunk native vlan 20

switchport mode trunk

!

interface Port-channel2

switchport trunk native vlan 20

```
switchport mode trunk
!
interface FastEthernet0/1
switchport trunk native vlan 20
switchport mode trunk
channel-group 1 mode active
!
interface FastEthernet0/2
switchport trunk native vlan 20
switchport mode trunk
channel-group 1 mode active
!
interface FastEthernet0/3
switchport trunk native vlan 20
switchport mode trunk
channel-group 2 mode active
!
interface FastEthernet0/4
switchport trunk native vlan 20
switchport mode trunk
channel-group 2 mode active
!
interface  FastEthernet0/5
switchport access vlan 10
switchport mode access
```

```
!
interface  FastEthernet0/6
switchport access vlan 10
switchport mode access
!
interface FastEthernet0/7
switchport access vlan 20
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/8
switchport access vlan 20
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/9
switchport trunk native vlan 20
switchport mode trunk
interface Vlan1
no ip address
shutdown
!
interface Vlan10
```

mac-address 0001.967d.7701

no ip address

!

interface Vlan20

mac-address 0001.967d.7702

no ip address

!

!

!

!

line con 0

!

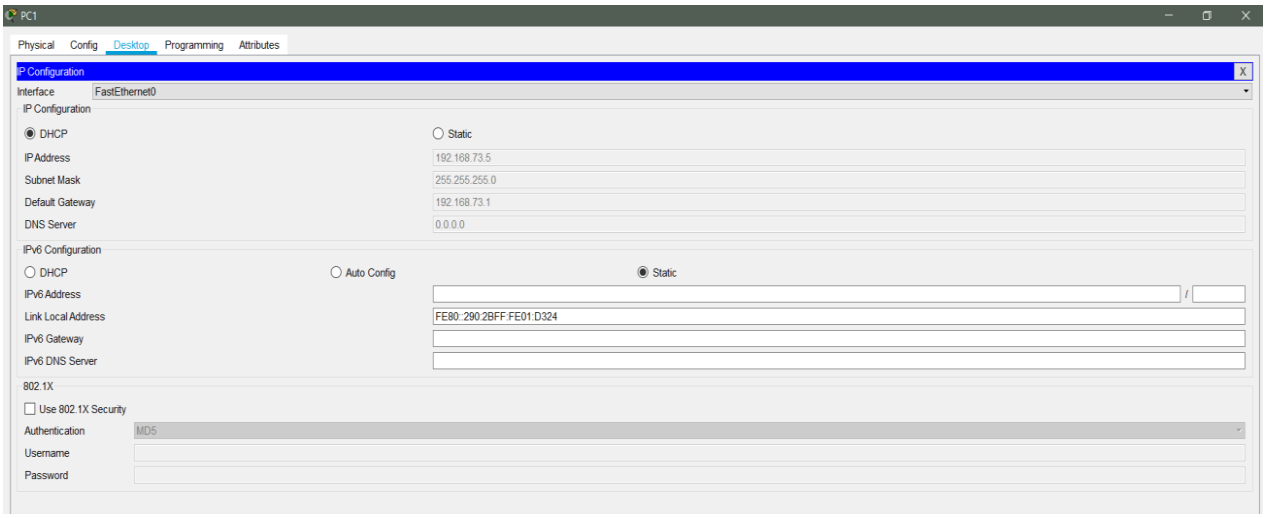
line vty 0 4

login

line vty 5 15

login

- **Assignment of IP addresses:**
  IP address is dynamically assigned for each PC connected to the network in all offices through a DHCP server. Hosts in Boston get IP addresses from the Boston DHCP server through the assigned pools for each department. Hosts in Mumbai get IP addresses from Boston's DHCP server as well. However, hosts in Beijing, London and New York get IP addresses from Mumbai's DHCP server. Thus, there are only two DHCP servers in total for the entire organization. A sample allocation of IP address dynamically through a DHCP server for a host in Boston's technical department is shown below.



3. Takeaway Questions:

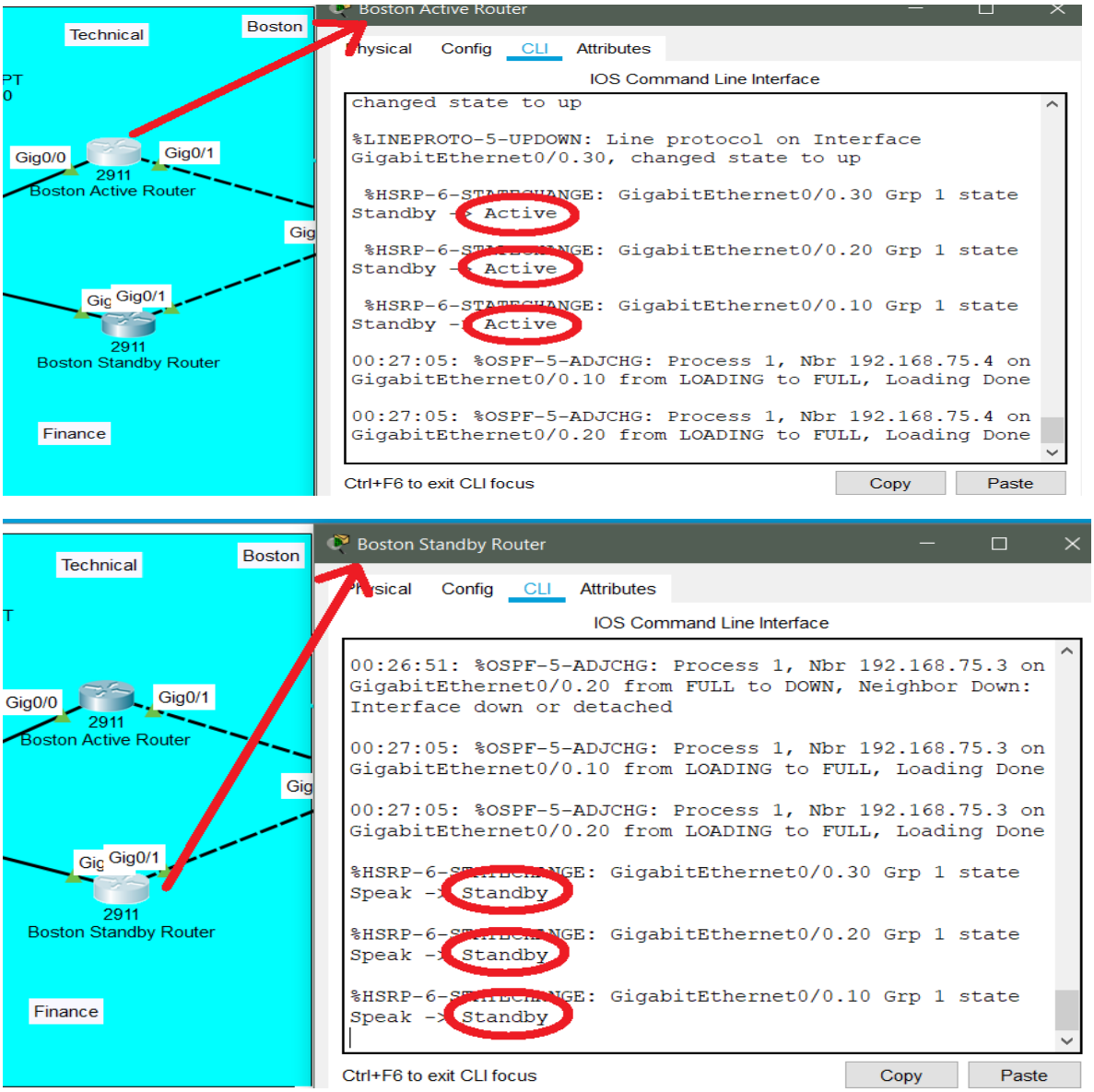
- OSPF is the better routing protocol. In RIPv2 there is a considerable consumption of bandwidth due to the period broadcast of the routing table and the convergence is slow. Due to periodic update of routing table every 30 seconds, there might be a considerable overhead on the link. RIPv2 is inefficient on large networks and hierarchical networks. Moreover, the hop count is limited to 15 thus any router beyond this hop count is considered as infinity. OSPF is a high-performance classless routing protocol which provides the shortest routing path. The overhead on the link is minimum. It keeps track of the entire database of all connections in the network by creating a topological map which is necessary for large networks. Only when a change occurs, the network is notified, and this reduces traffic on the network while effectively calculating the shortest path.
- Area concept is used in OSPF to reduce complexity. As a single network grows larger the shortest path calculations become hectic and take a longer time to compute. Thus, in OSPF, each large network can be divided into an area or a sub-domain. Each router within the area maintains a database only for the area to which it belongs and doesn't have a detailed network topology of the networks outside its area. This reduces size and complexity of the network database each router has to maintain. Area concept comes in handy when the network becomes too large and unmanageable. Splitting networks into areas can help reduce the traffic on the network. Every area has one connection that is connected to area 0 which is called as the backbone of the network.

- In large networks with many areas it is difficult to establish connectivity between all areas as this will increase both the cost and complexity. Each router in an area is restricted with only the topological information of devices within its area. However, in order to communicate with a router of another area, the router will need to know the routing path to reach that destination. The area 0 network contains this information i.e. paths to reach all other areas. This router will contain the routing information of the shortest routes to all other areas. Thus, the area 0 network is configured as the backbone network thus serving as the center point of traffic forwarding between routers in different areas.
- The different types of LSA in OSPF are:
    - Router LSA: LSA packets sent between the routers in the same area range will not leave the area.
    - Network LSA: LSA packets are generated by designated routers and sent to the neighboring routers within the same area.
    - Summary LSA: LSA packets are generated by Area Border Routers. LSA advertisement is done from one area to the rest of the areas.
    - ASBR Summary LSA: LSA packets from one area is injected into area 0.
    - ASBR External LSA: In this type, LSA packets are sent by ASBR for the advertisement of external redistributed routes into the OSPF's autonomous system.
    - Group Membership LSA: This type of LSA is used for multicast routing through OSPF.
    - Not So Stubby Area External LSA: These type of LSA packets are used for special area types which do not allow external distributed routes to go through them.
    - External Attributes LSA/Link Local LSA: These type of LSA's are used to send BGP attributes through the OSPF network.
    - Link Scope Opaque/ Intra Area Prefix LSA: In this type, a communication prefix for a special area called Stub area is sent.
    - Area Scope Opaque LSA: This type is used to advertise MPLS and other such protocols.
    - Scope Opaque LSA: This is same as Area Scope Opaque LSA, but these packets are not sent into special area types such as Stub areas.

- For security ACL is used and for redundancy HSRP protocol and redundant switches are used. We have been given with conditions that the Technical and HR departments from any office should not be able to access the Finance department of any office, but the reverse should be possible. In order to implement these conditions access control list permissions are used. Access Control Lists are network traffic filters that act as firewalls to block, restrict or allow packets from a particular source to a particular destination. When an ACL statement is specified in the router, all traffic flowing through it will be compared with the ACL. This provides security to the network by restricting or blocking unwanted traffic. A sample access control list from one of the routers in Boston office is shown below.

```
!
access-list 101 permit ip host 192.168.73.2 any
access-list 101 permit icmp any 192.168.75.0 0.0.0.127 echo-reply
access-list 101 permit icmp any 192.168.78.0 0.0.0.127 echo-reply
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.75.0 0.0.0.127
access-list 101 deny ip 192.168.73.0 0.0.0.255 192.168.78.0 0.0.0.127
access-list 101 deny ip 192.168.74.0 0.0.0.127 192.168.78.0 0.0.0.127
access-list 101 permit ip any any
!
```

HSRP is a Cisco proprietary protocol in which redundancy is provided for a local subnet. Using this protocol, we can configure two or more routers as standby routers while one router remains in active mode all the time. Together they give an illusion of a single virtual router. A virtual IP is assigned as the default gateway for all local hosts in the network. Hello messages are exchanged between the routers according to the default hold down timer in order to detect their respective states. The router with the highest priority will always remain or become the active router. The state through which the standby router becomes the active one is called preempt state. Hence, in order to prevent a single point of failure between routers in both the headquarters HSRP protocol is implemented using two routers where one router is in active mode and another is in standby mode. A sample from the both routers in Boston office is shown below



- If two or more switches are connected together, then the initial broadcast packet will be forwarded out of all the ports from all the switches infinitely forming a loop. STP prevents looping by blocking one or more of the links depending upon the number of switches. If one of the link goes down, then the link which was initially blocked is brought up back. Initially when each switch hears BPDU, spanning tree algorithm is implemented and there is an election of the root bridge through which all data is transmitted. The, each switch connected to the root switch will determine the shortest path

to the root switch. After that a second election happens where each LAN elects a designated switch i.e. the switch closest to the root switch. This switch will forward all packets from the LAN to the root switch. Each switch will select a root port i.e. the port that is going to be used to send data to the root bridge. Out of all the redundant links, STP blocks one link by examining the STP cost of each link. The link with a higher cost is blocked by STP whereas the other links are transitioned to forwarding state. When any of the links in the forwarding state go down, the blocked link is transitioned into forwarding state.

- STP is topology that provides loop free paths for networks with redundant links. PVST is Cisco's enhancement of STP that provides each VLAN in the network to have a separate spanning tree instance i.e. STP is run in each VLAN. MSTP maps multiple VLAN's in the network with different spanning tree domains into the same spanning tree instance.

4. Test Plan for the Network:

- Test VLAN:
  - Boston and Mumbai Office:

```
Switch#show vlan brief

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

- Beijing Office:

```
Switch#show vlan brief

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

- London Office:

```
Switch#show vlan brief

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

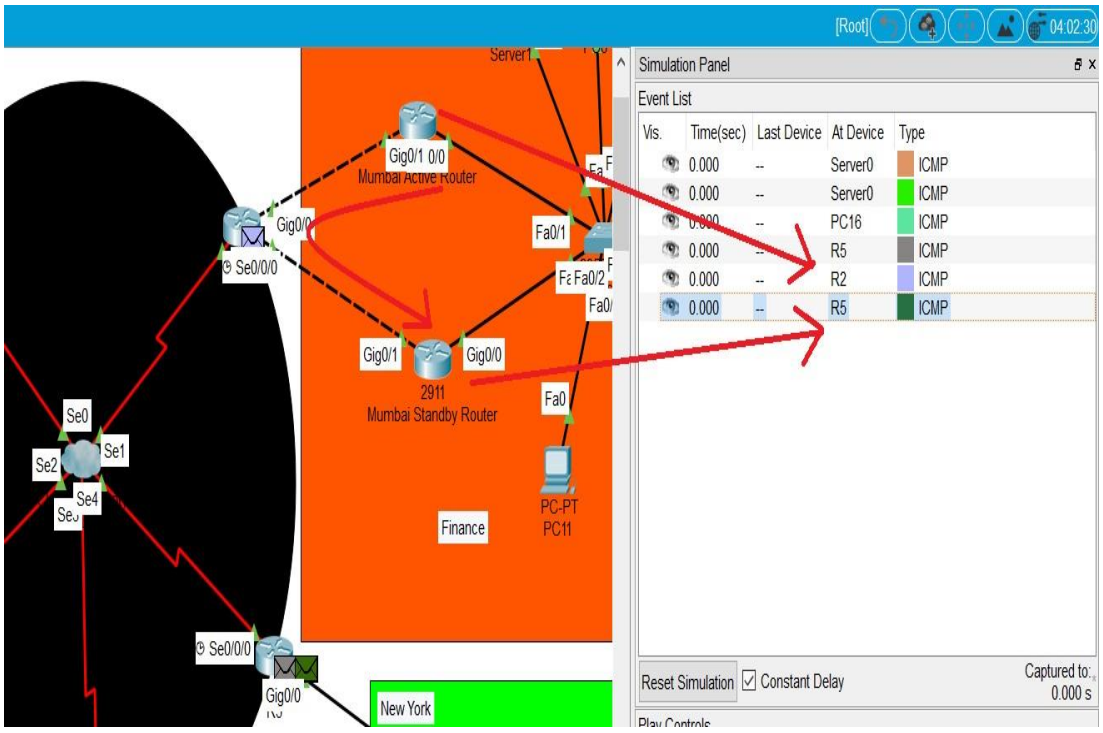
- New York Office:

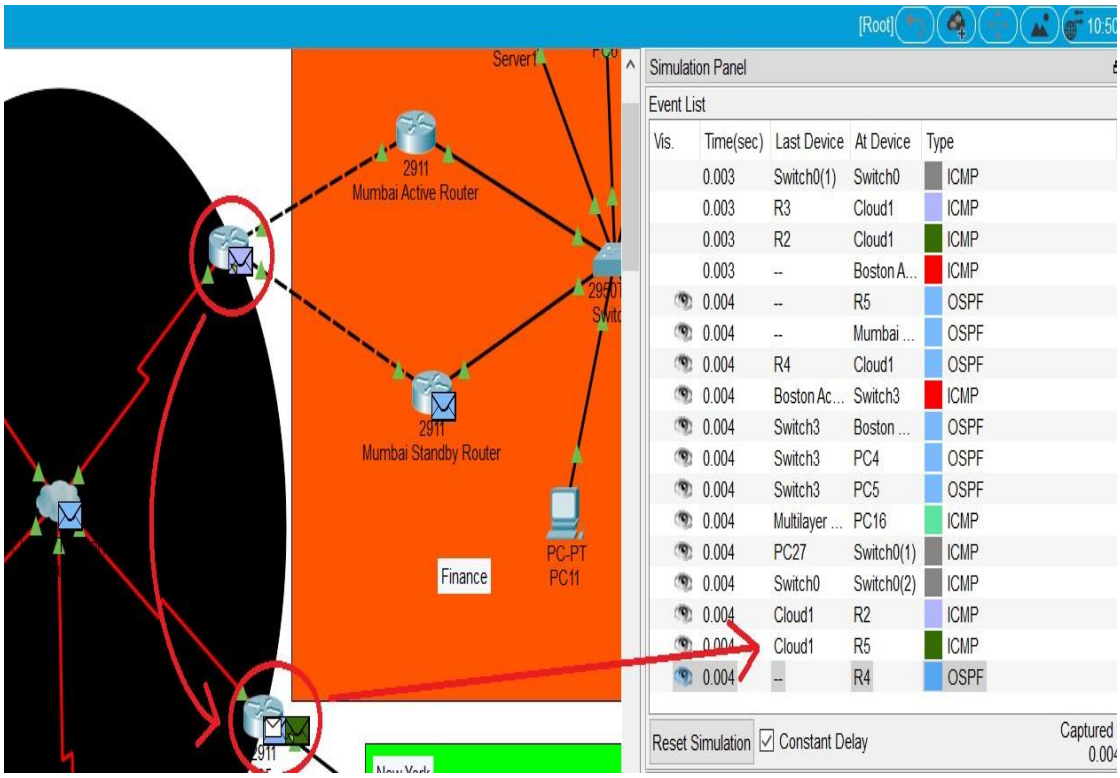
```
Switch#show vlan brief

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

- Test Routing Protocol:

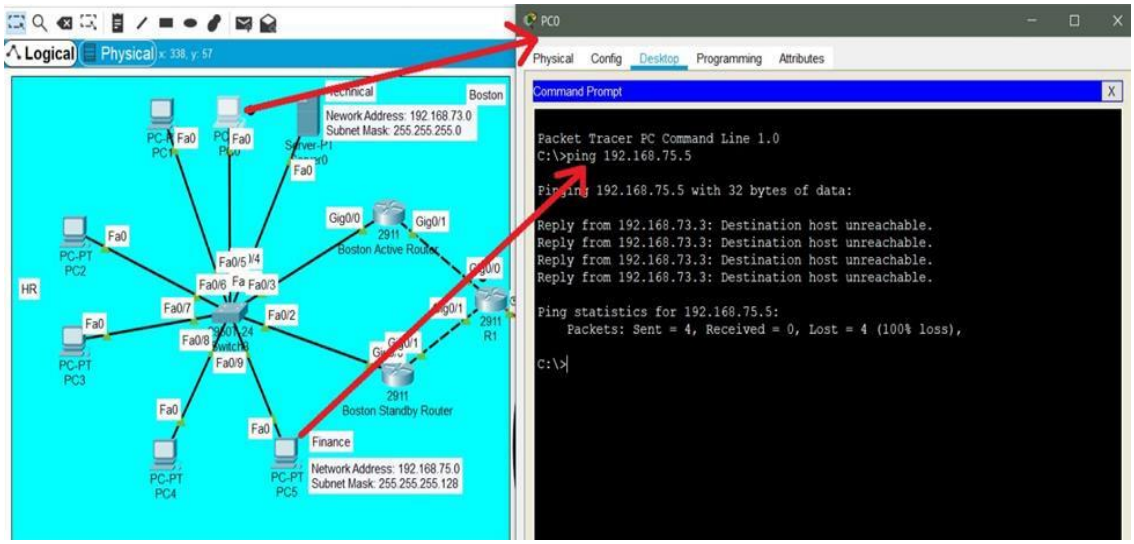
OSPF is the routing protocol that has been implemented in all routers to enable communication across a WAN network. A sample image is shown below where we ping from ABR of Mumbai to ABR of New York i.e. R2 to R5 and the ping is successful due to the OSPF routing protocol.



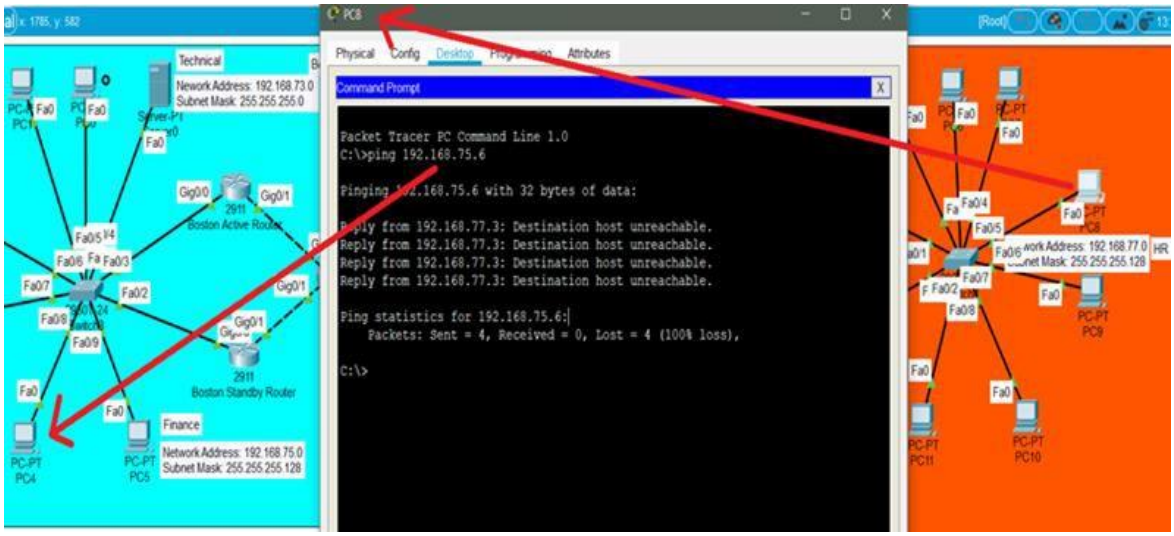


- Test Security Plan:

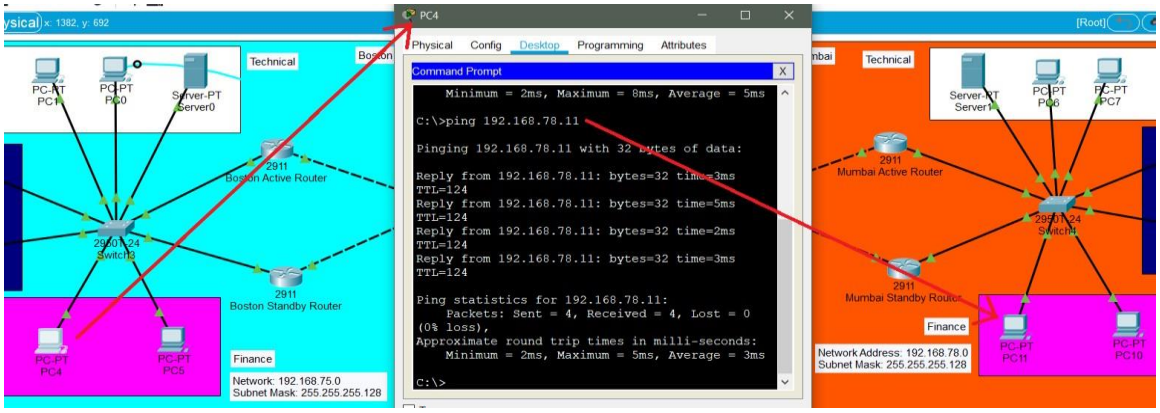
In the below example, we try to ping a host of finance department from the technical department and the ping is not successful. This is due to the access control list that has been enabled in both routers of the Boston office.



Similarly, when we try to ping from the HR department of Mumbai office to the Finance department of Boston office, the ping is unsuccessful.

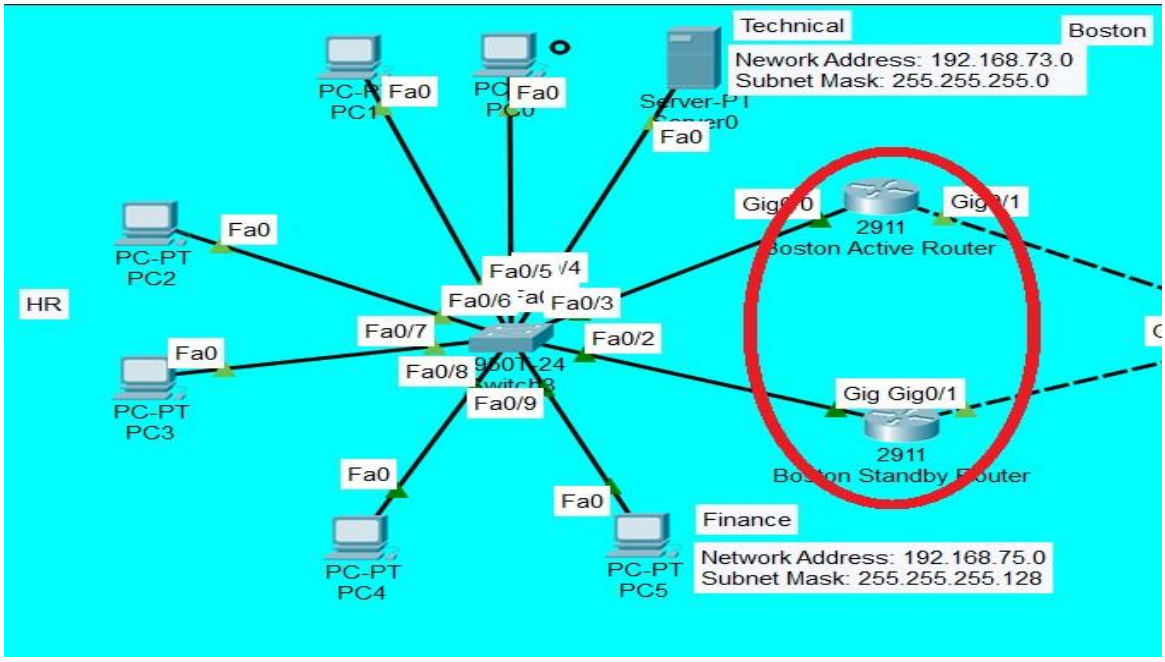


However, we can ping between two finance departments.

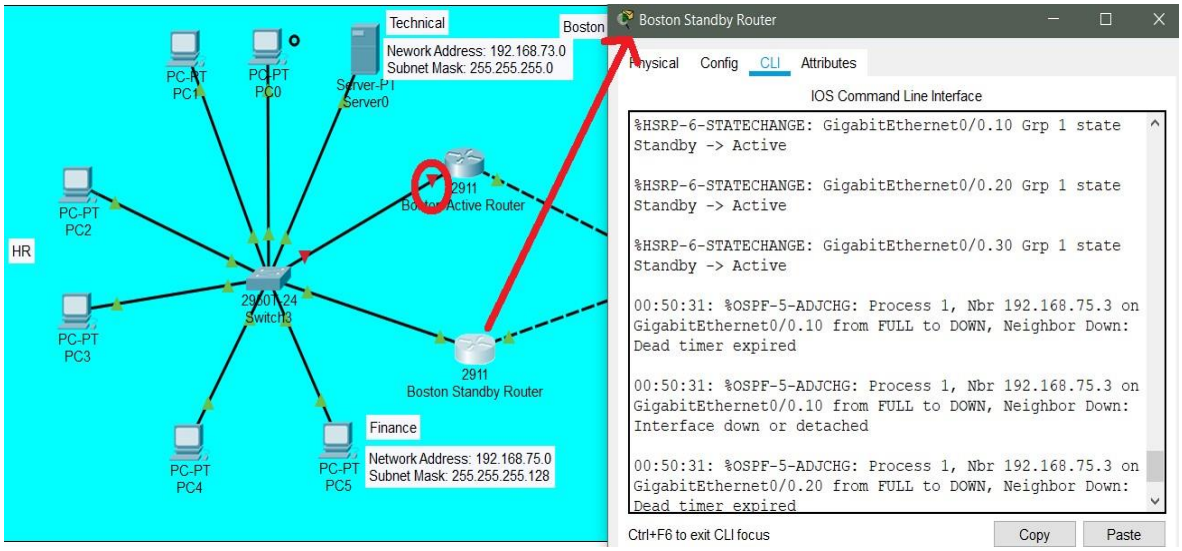


- Test Redundancy Plan:

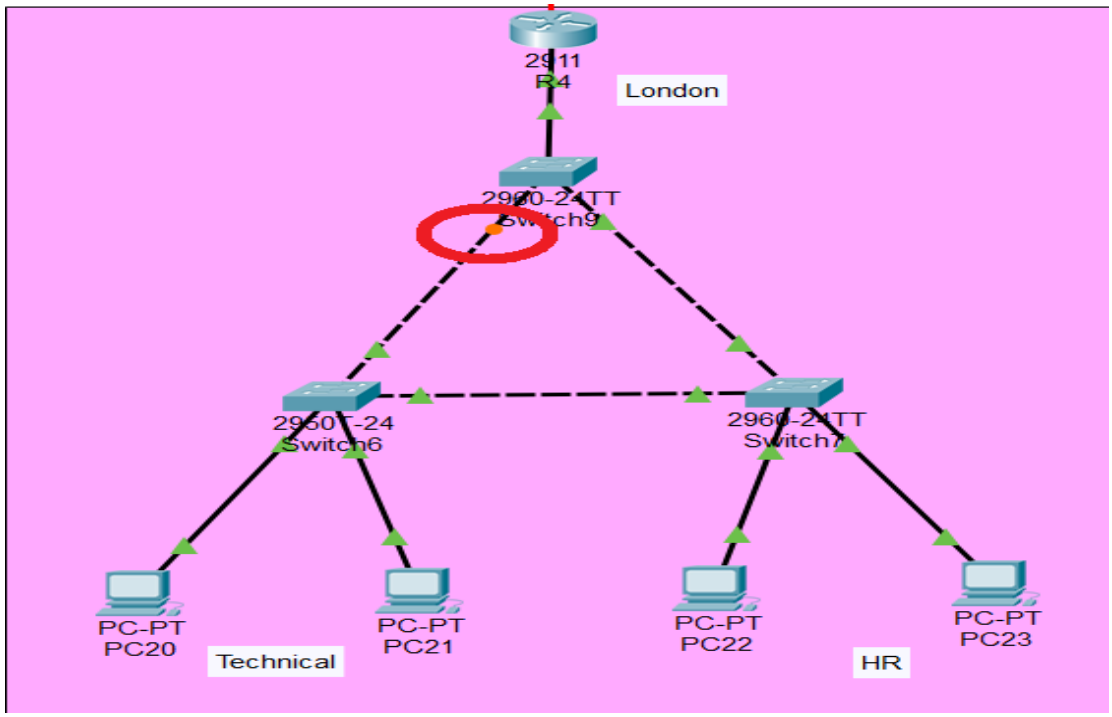
There are two routers in Boston Office to enable redundancy in the form of HSRP. One is in active state whereas the other is in standby state. The standby router changes to active mode when the main router goes down.



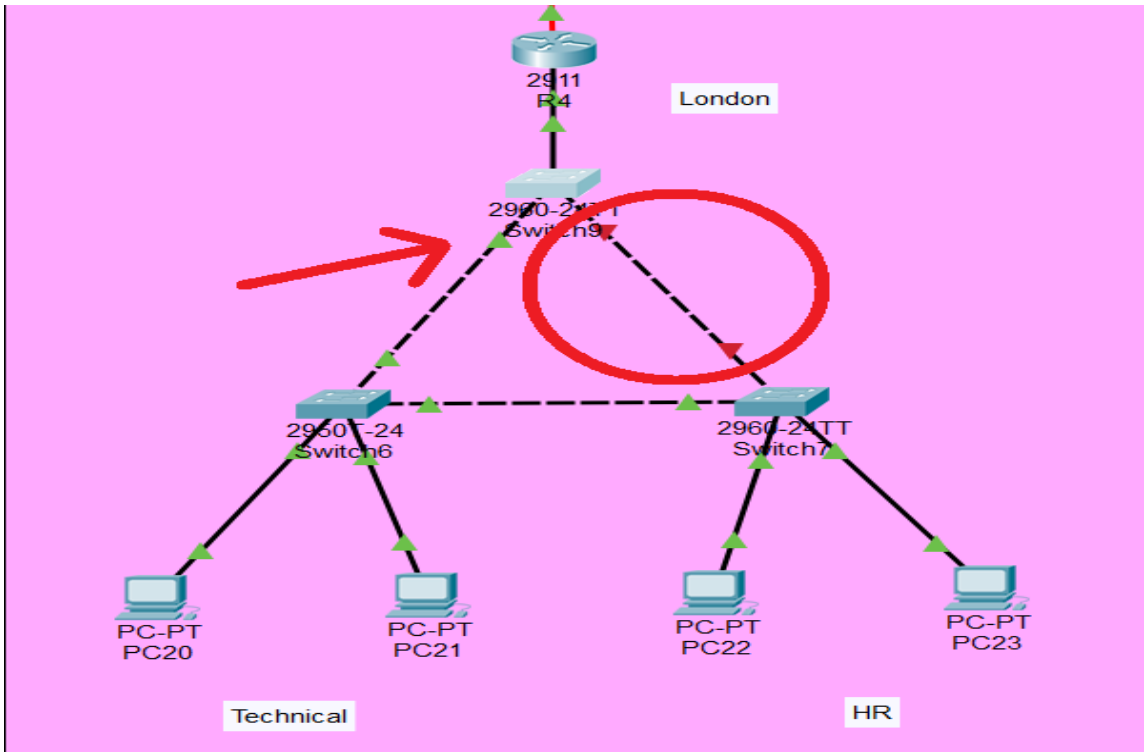
When the link on one router goes down, we can see from the below image that the standby router has transitioned into active mode.



Switch Redundancy is implemented in London and New York Offices. RSTP protocol is implemented on all redundant switches.



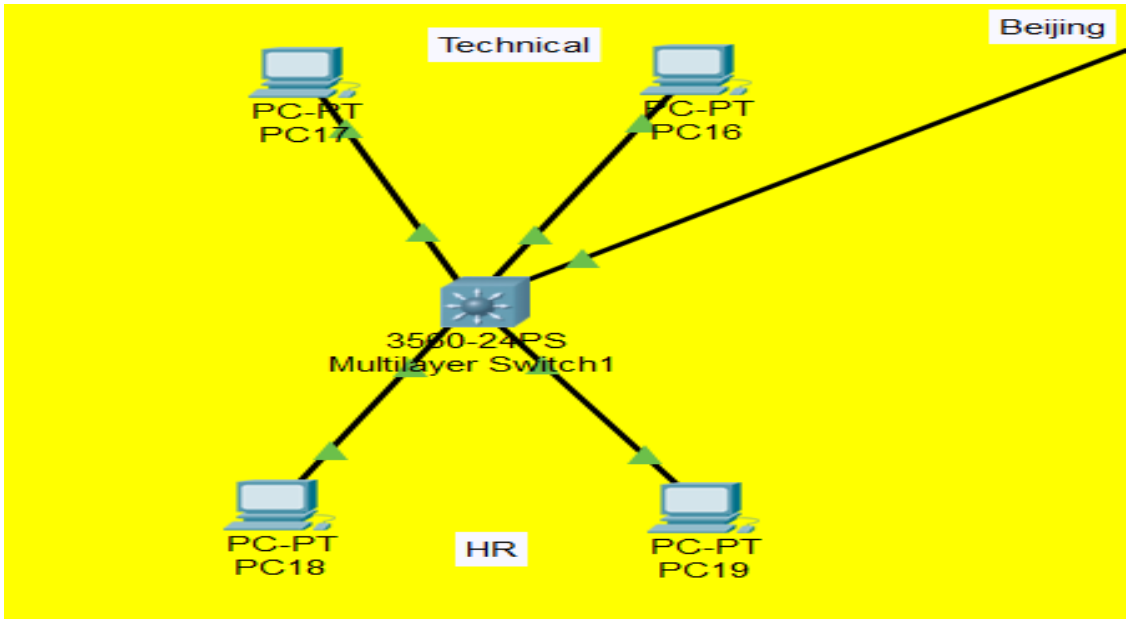
From the below image we can observe that when one active link goes down, the blocked link transitions into forwarding state.

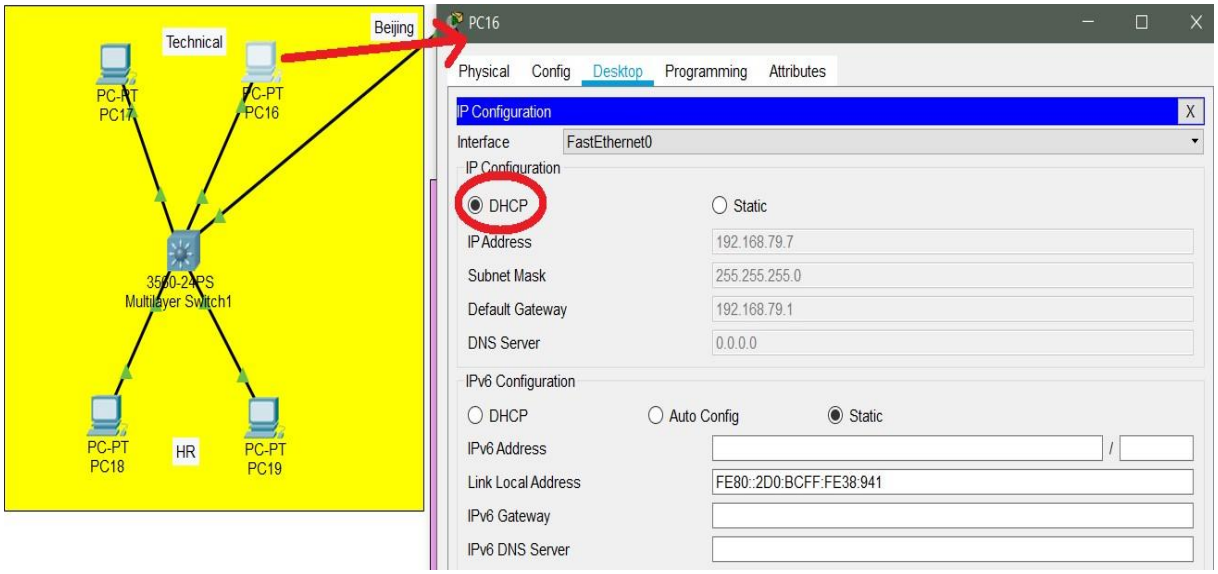


- Test Add ons:

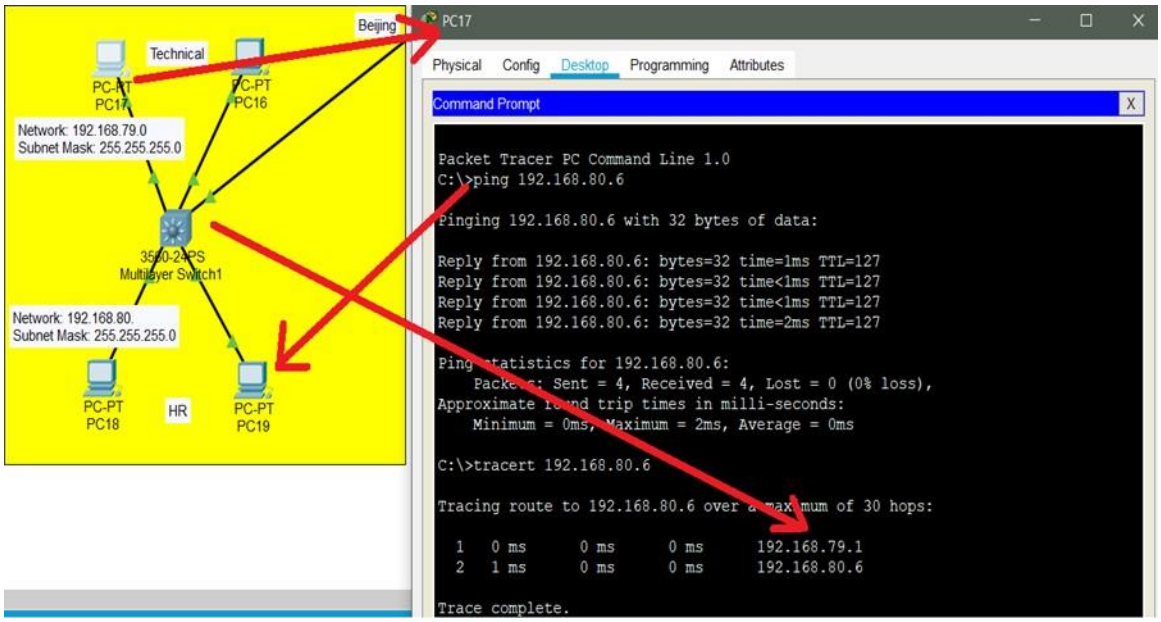
Beijing Office:

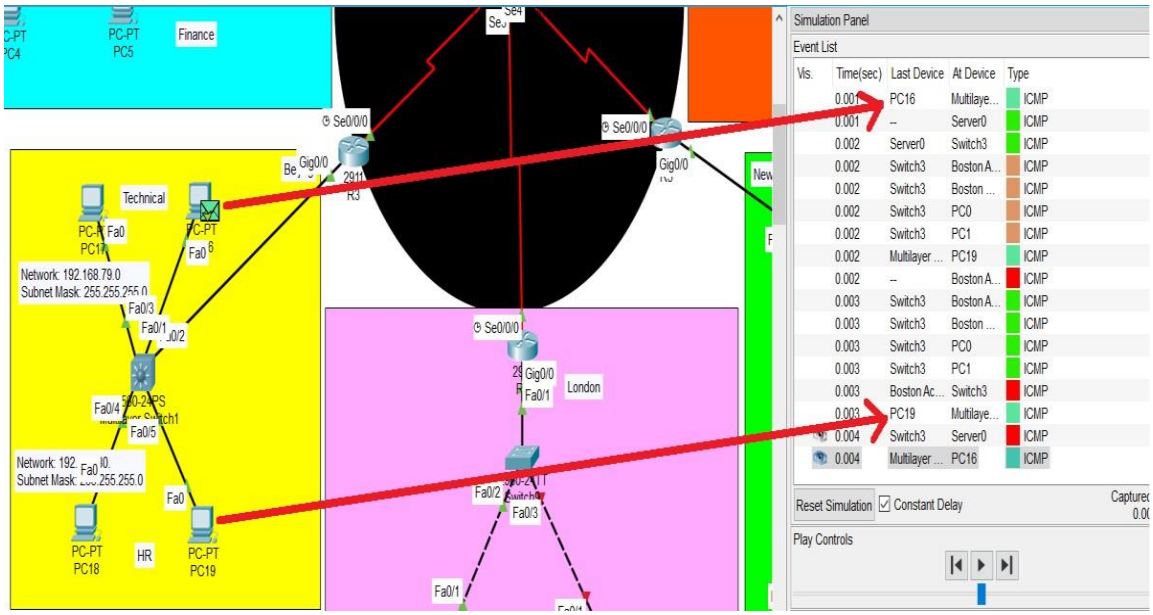
A multi-layer switch is implemented in Beijing office.





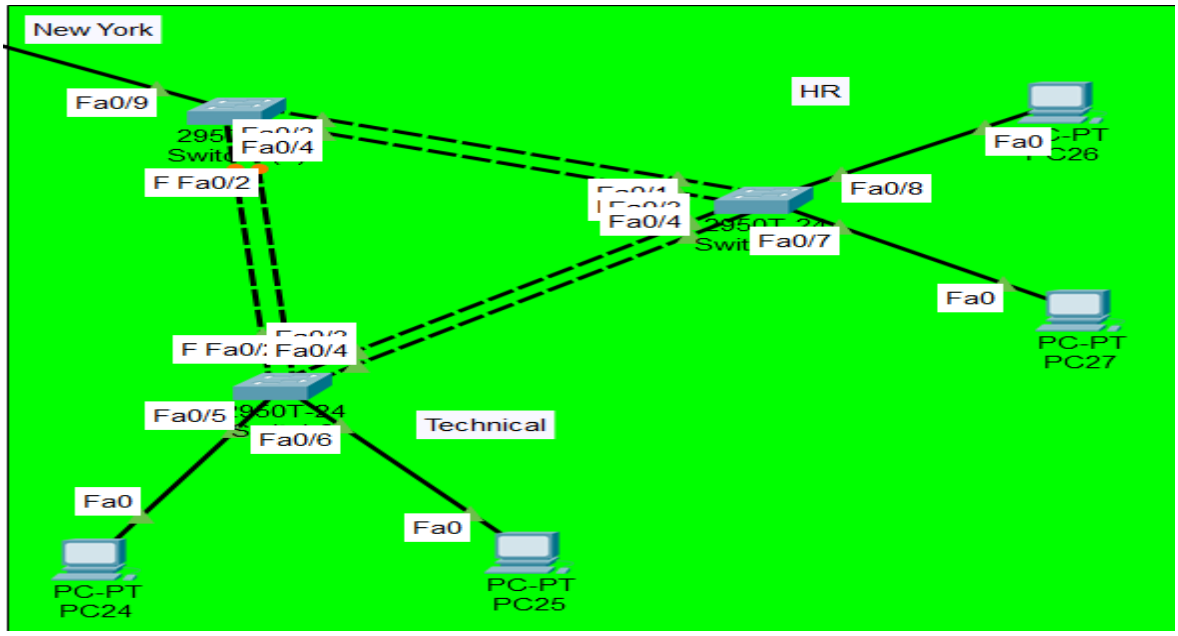
When we ping from one PC in the Technical department to one in the HR department, we can see that the routing happens within the multi-layer switch as seen below.





New York Office:

EtherChannel with LACP protocol is implemented in all the redundant switches in New York office.



A sample from the one of the switches in New York where EtherChannel is configured with LACP protocol is shown below.

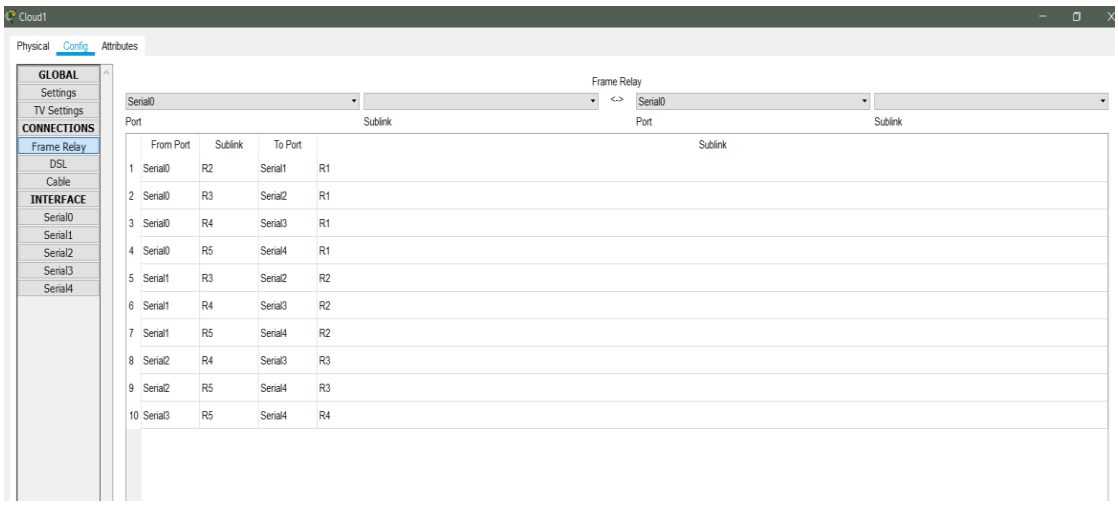
```
interface FastEthernet0/1
 switchport trunk native vlan 20
 switchport mode trunk
 channel-group 1 mode active
!
interface FastEthernet0/2
 switchport trunk native vlan 20
 switchport mode trunk
 channel-group 1 mode active
!
interface FastEthernet0/3
 switchport trunk native vlan 20
 switchport mode trunk
 channel-group 2 mode active
!
interface FastEthernet0/4
 switchport trunk native vlan 20
 switchport mode trunk
 channel-group 2 mode active
```

```
Switch#show etherchannel
                Channel-group listing:
                ----------------------

Group: 1
----------
Group state = L2
Ports: 2 Maxports = 16
Port-channels: 1 Max Port-channels = 16
Protocol:   LACP

Group: 2
----------
Group state = L2
Ports: 2 Maxports = 16
Port-channels: 1 Max Port-channels = 16
Protocol:   LACP
```

- Frame Relay:



5. Concepts learned during the project:

This project establishes a clear idea of how communication in an enterprise network works. Dynamic allocation of IP addresses has helped in learning the concept of subnetting IPv4 addresses. Separating different VLAN's for each department has provided a path for implementing inter-VLAN communication using a router. The distribution of offices in different geographical locations brings the WAN communication concept using Frame Relay into our network. HSRP is implemented to prevent a single point of failure in the two headquarters.

Switch Redundancy also provides a redundant link in case of failure. RSTP is used to prevent looping between the redundant switches and helps in transitioning a blocked link to forwarding state immediately. EtherChannel with LACP protocol is used to bundle up two or more individual cables as one single virtual cable to utilize the full potential of the bandwidth available in the network. OSPF(Link-State) routing protocol is used to determine shortest path to a destination.

6. Conclusion:

Thus, an enterprise network is designed by implementing various protocols and the working of each protocol is tested and verified and produced as results