

# **Complex Engineering Problem**

## **Computer Networks (Lab)**

**Talha Rehman**

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## Introduction

In this lab we have been given a complex engineering problem in which we have to design a software house. The company has 3 different building in three different cities. One Is the corporate office, in which there is an email server and 8 offices each having a laptop, printer and a PC. Second is the administrative building in which there is a storage server and a web server to provide the web services along with the 10 offices, in each office there is a PC and a smart phone. Then there is a third building, the programming building, in which there is a DHCP server for internal wireless devices, web cache server, also it contains 30 PCs connected via a switch. Class A, B and C IP addressing is followed in respective buildings.

All of this network is designed and configured in the cisco packet tracer. Physical layer is used to design the structure of the office building while the logical layer is used to configure whole of the networks. The PTRouters are used to establish a connection between different cities using the Fiber. These routers are the way for communication between the networks of the all the building in different cities.

At the end of the report the estimated cost for whole of the network is calculated.

## Hardware Overview

	Buildings			
Devices	Corporate	Administrative	Programming	Total
Servers	2	2	3	7
Switches	1	1	3	5
Smart phones	10	0	0	10
Routers	1	1	1	3
PCs	8	10	31	49
Laptops	8	10	0	18
Printers	8	2	0	10
Access points	1	1	3	5

*Figure 1: List of all the devices in three buildings of a software house*

## Software Overview

Corporate Building has following configurations:

1. Class A IP addressing (10.1.1.\*: 255.0.0.0)
2. DNS server (10.1.1.18) it contains the record of email server, web server, administrative building and programming building storage server.
3. Email server (domain name email.com; 10.1.1.17) The whole of the network all the building is different cities can use the email services.
4. 8 offices each has one laptop, printer and PC connected via a access point and a switch. Each has been given the IP address statically.
5. A PT-router is used to establish a connection intercity with the other two buildings using the Fiber connection. The inside IP address of router (10.1.1.30) is for the inner network and is also the default gateway of all the devices in the corporate office while the outer two lines have IP addresses (f4/0 172.16.1.2 and f5/0 172.16.2.2).

```

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

Gateway of last resort is not set

C    10.0.0.0/8 is directly connected, FastEthernet0/0
     126.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
S     126.1.0.0/16 [1/0] via 172.16.1.1
S     126.1.1.0/24 [1/0] via 172.16.1.1
     172.16.0.0/30 is subnetted, 2 subnets
C       172.16.1.0 is directly connected, FastEthernet4/0
C       172.16.2.0 is directly connected, FastEthernet5/0
S     194.168.1.0/24 [1/0] via 172.16.2.1

```

Figure 2: Corporate office router routing table

Administrative Building has following configuration:

1. Class B IP addressing (126.1.1.\*:255.255.0.0).
2. A web server (126.1.1.251) is placed in this office to provide the web services to all the devices in all three buildings.
3. A storage server (FTP with IP 126.1.1.252) is placed in this building to provide file sharing services.
4. 10 offices each has its own PC and smartphone connected via a switch and an access point respectively. Secondly, there are two wireless printers in the building also.
5. A PT-router is used to establish a connection intercity with the other two buildings using the Fiber connection. The inside IP address of router (126.1.1.121) is for the inner network and is also the default gateway of all the devices in the corporate office while the outer two lines have IP addresses (f4/0 172.16.0.1 and f5/0 172.16.1.2).

```

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

Gateway of last resort is not set

  10.0.0.0/8 is variably subnetted, 3 subnets, 3 masks
S       10.0.0.0/8 [1/0] via 172.16.1.2
S       10.0.0.0/16 [1/0] via 172.16.1.2
S       10.1.1.0/24 [1/0] via 172.16.1.2
 126.0.0.0/16 is subnetted, 1 subnets
C       126.1.0.0 is directly connected, FastEthernet0/0
 172.16.0.0/30 is subnetted, 2 subnets
C       172.16.0.0 is directly connected, FastEthernet4/0
C       172.16.1.0 is directly connected, FastEthernet5/0
S       194.168.1.0/24 [1/0] via 172.16.0.2

```

Figure 3: Administrative building route routing table

Programming Building has following configurations:

1. Class C IP addressing (194.168.1.\*:255.255.255.0).
2. A web cache server (194.168.1.250) is placed in this building.
3. Another storage server (FTP with IP 194.168.1.251) is placed in this building to provide file sharing services.
4. A DHCP server (194.168.1.252) is also in this building which is used to provide the IP addresses to the wireless devices only, it will select the IP address from the same pool of IP addresses as specified in the point number 1. The server automatically detect which IP is already in the network and will assign the unique IP address to any other device that connects wirelessly via an access point.
5. This building has 30 PCs connected via a LAN through switches. The Multilayer switch is used to connect all the server and switches together. Secondly, there is also a wireless PC available to test and check the DHCP services.
6. A PT-router is used to establish a connection intercity with the other two buildings using the Fiber connection. The inside IP address of router (194.168.1.120) is for the inner network and is also the default gateway of all the devices in the corporate office while the outer two lines have IP addresses (f4/0 172.16.0.2 and f5/0 172.16.2.1).

```

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

Gateway of last resort is not set

S    10.0.0.0/8 [1/0] via 172.16.2.2
    126.0.0.0/24 is subnetted, 1 subnets
S    126.1.1.0 [1/0] via 172.16.0.1
    172.16.0.0/30 is subnetted, 2 subnets
C    172.16.0.0 is directly connected, FastEthernet4/0
C    172.16.2.0 is directly connected, FastEthernet5/0
C    194.168.1.0/24 is directly connected, FastEthernet0/0

```

Figure 4: Programming Building router routing table

## Total Structure

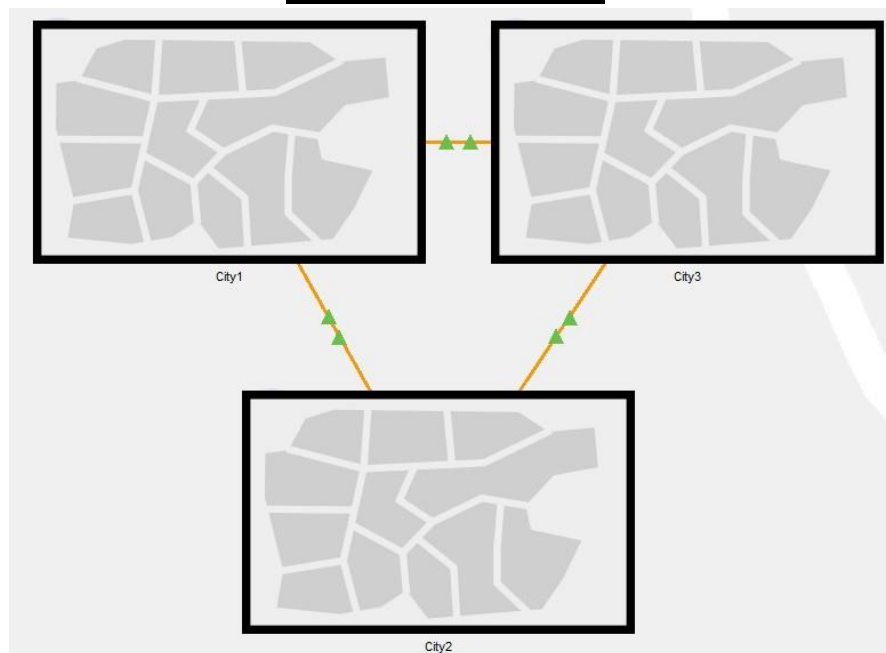
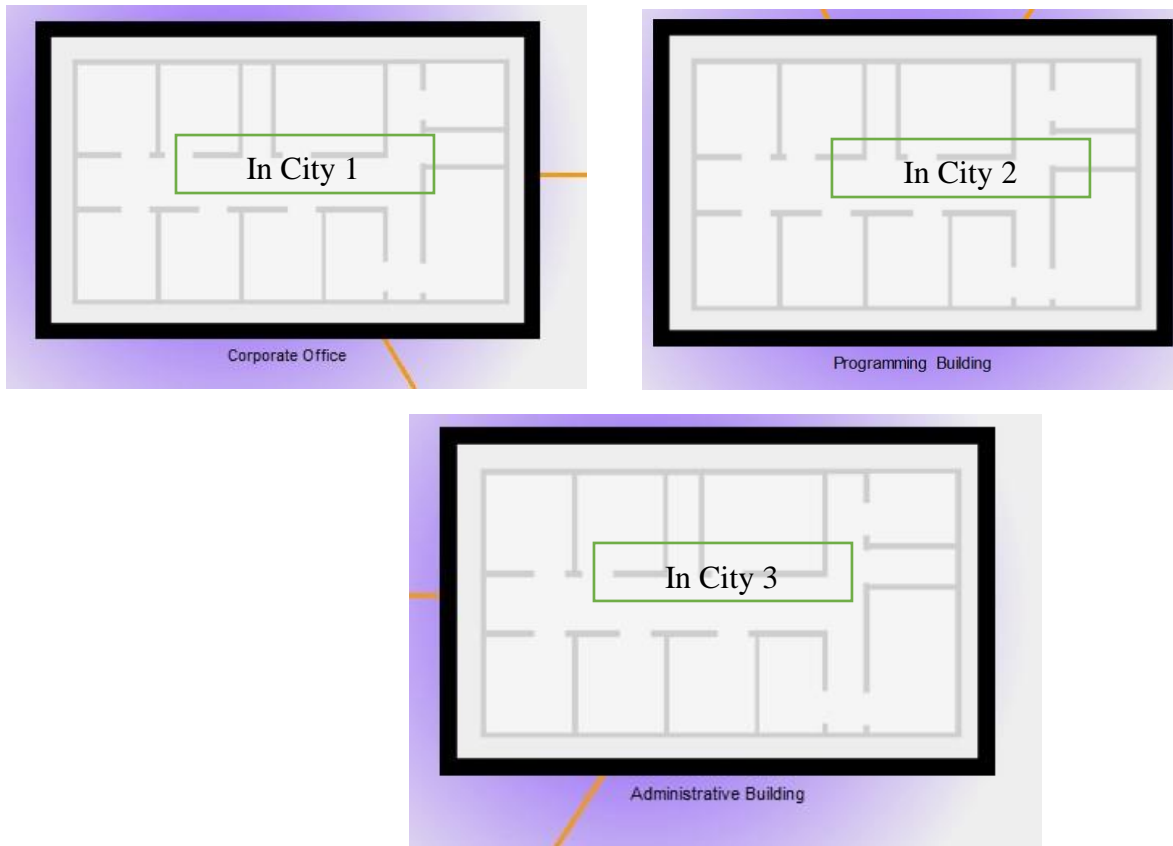


Figure 5: Total overview



## Corporate Building:





Figure 6; corporate office building inside structure all the 8 offices along with a server room is shown in the figure



Figure 7: CO server room inside; the two email and DNS server along with a switch and a PT router is shown in the figure.

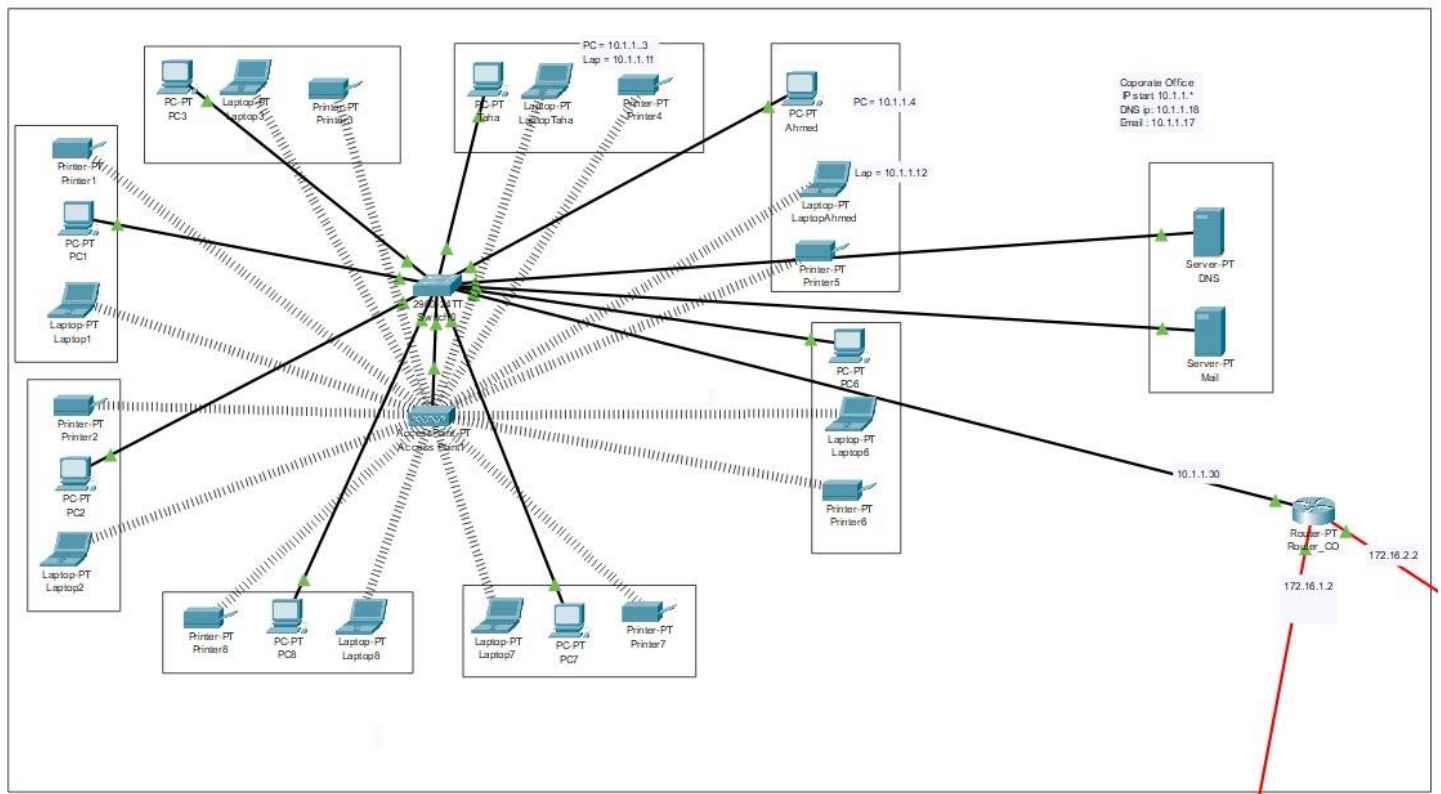


Figure 8; Logical topology of corporate building.



## Administrative Building



Figure 9: Administrative building, 10 offices and a server room is placed as shown in the figure

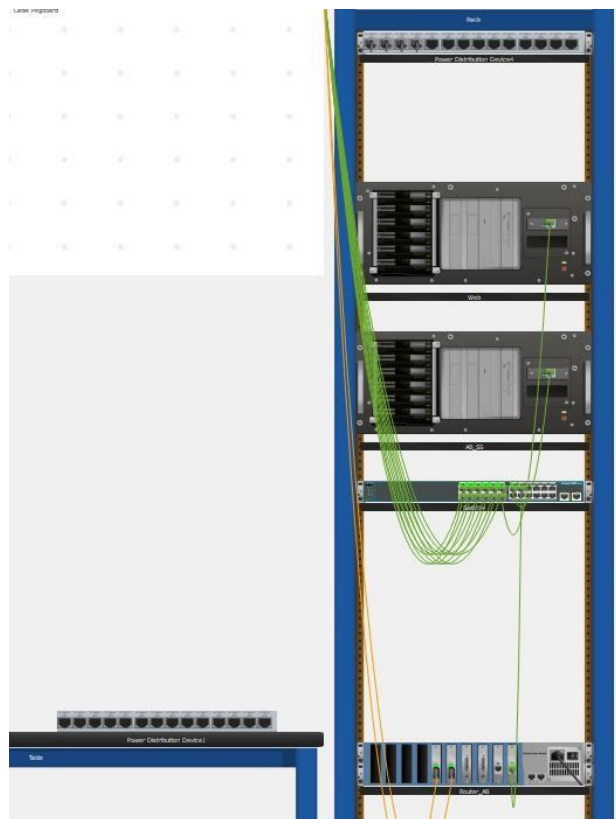


Figure 10: Administrative building server room

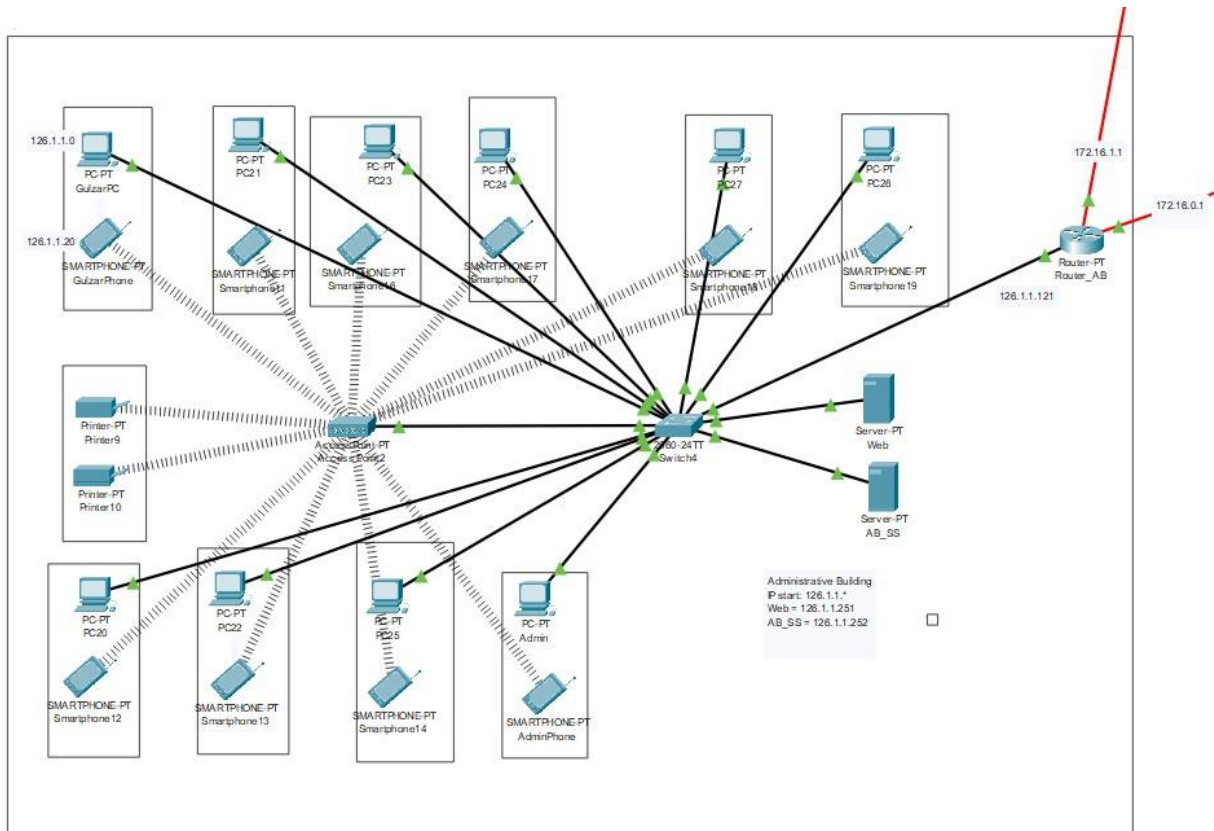


Figure 11: Administrative building logical topology

## Programming Building:



Figure 12: Programming building internal structure

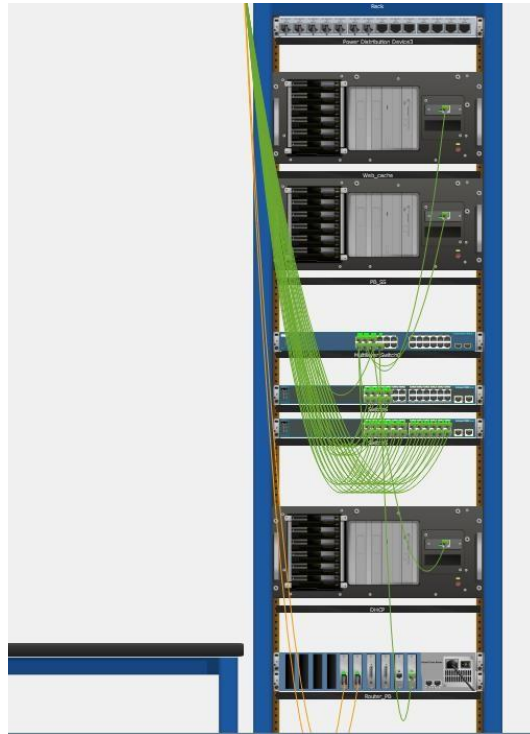


Figure 13: Programming building server room; three servers (ftp, DHCP, web cache) along with PT-router and three switches is placed here.

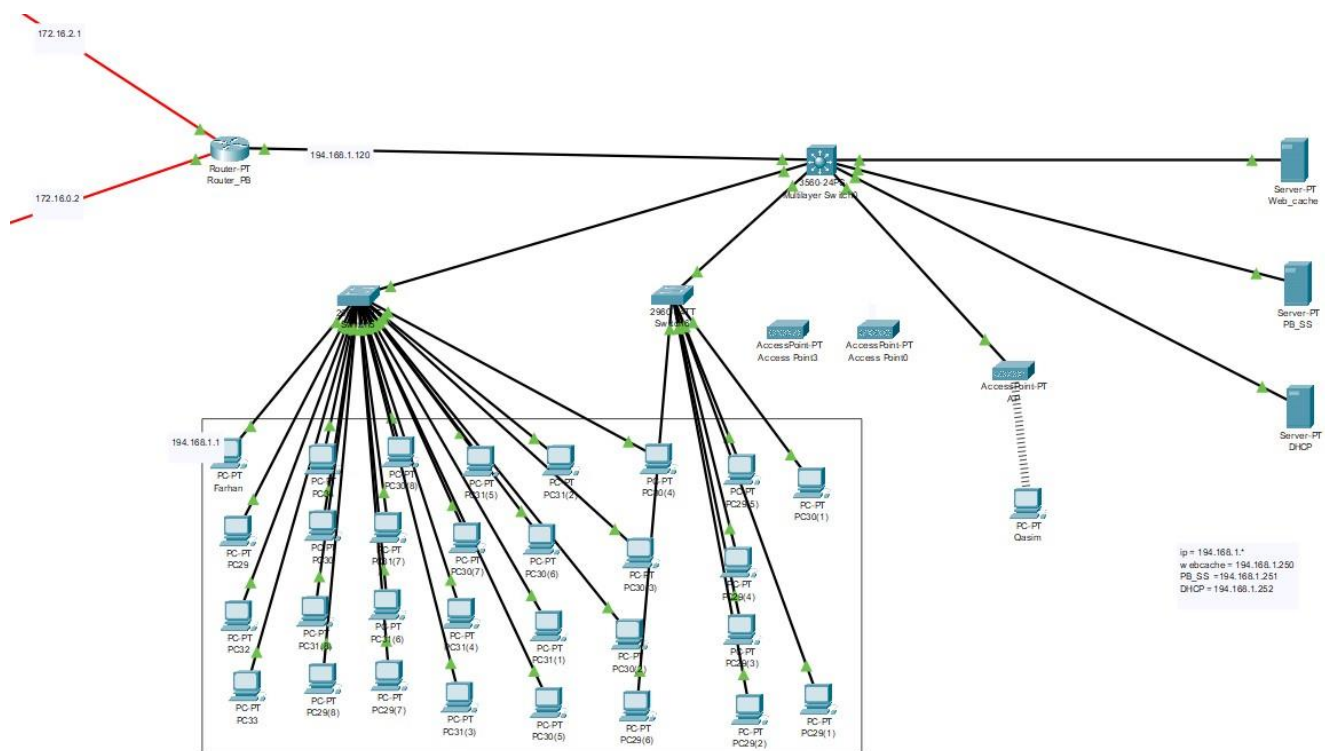


Figure 14: Programming office logical topology

**Logical topology:**

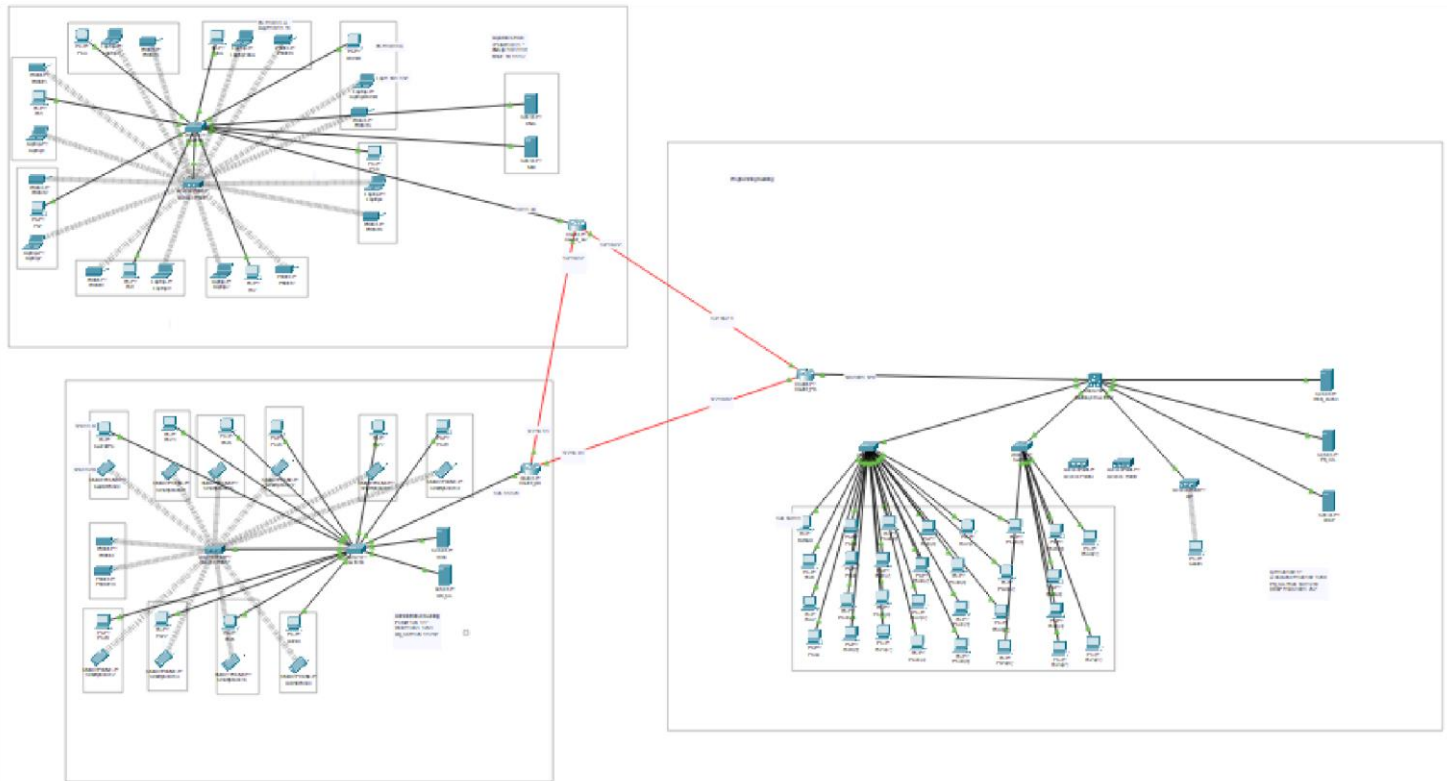


Figure 15: Complete logical topology of all three buildings

## DNS services

DNS

Physical Config **Services** Desktop Programming Attributes

**SERVICES**

- HTTP
- DHCP
- DHCPv6
- TFTP
- DNS**
- SYSLOG
- AAA
- NTP
- EMAIL
- FTP
- IoT
- VM Management
- Radius EAP

DNS

DNS Service ☒ On ☐ Off

Resource Records

Name  Type **A Record**

Address

No.	Name	Type	Detail
0	ab_ss	A Record	126.1.1.252
1	www.cisco.com	A Record	126.1.1.251
2	email.com	A Record	10.1.1.17
3	pb_ss	A Record	194.168.1.251
4	www.namal.com	A Record	194.168.1.250

Figure 16: DNS record of all the email, FTP and web servers

# DHCP Services

Physical Config **SERVICES** Desktop Programming Attributes

**SERVICES**

- HTTP
- DHCP**
- DHCPv6
- TFTP
- DNS
- SYSLOG
- AAA
- NTP
- EMAIL
- FTP
- IoT
- VM Management
- Radius EAP

**DHCP**

Interface: FastEthernet0 Service: ☒ On ☐ Off

Pool Name: serverPool

Default Gateway: 194.168.1.120

DNS Server: 10.1.1.18

Start IP Address: 194 168 1 0

Subnet Mask: 255 255 255 0

Maximum Number of Users: 255

TFTP Server: 0.0.0.0

WLC Address: 0.0.0.0

Buttons: Add Save Remove

Pool Name	Default Gateway	DNS Server	Start IP Address	Subnet Mask	Max User	TFTP Server	WLC Address
serverPool	194.168....	10.1.1.18	194.168....	255.255....	255	0.0.0.0	0.0.0.0

Figure 17: DHCP server (Used only by wireless devices)

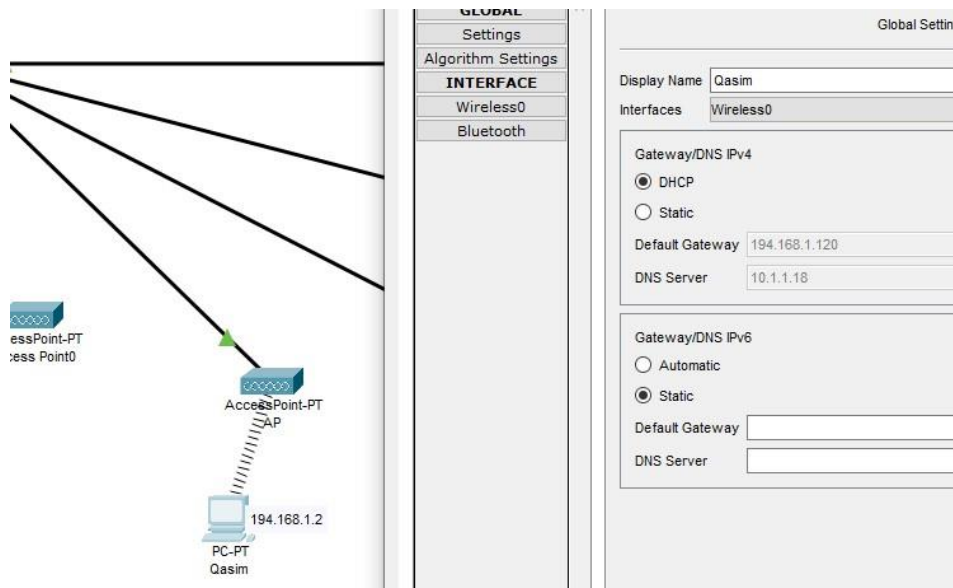


Figure 18: IP assign through DHCP to wireless device

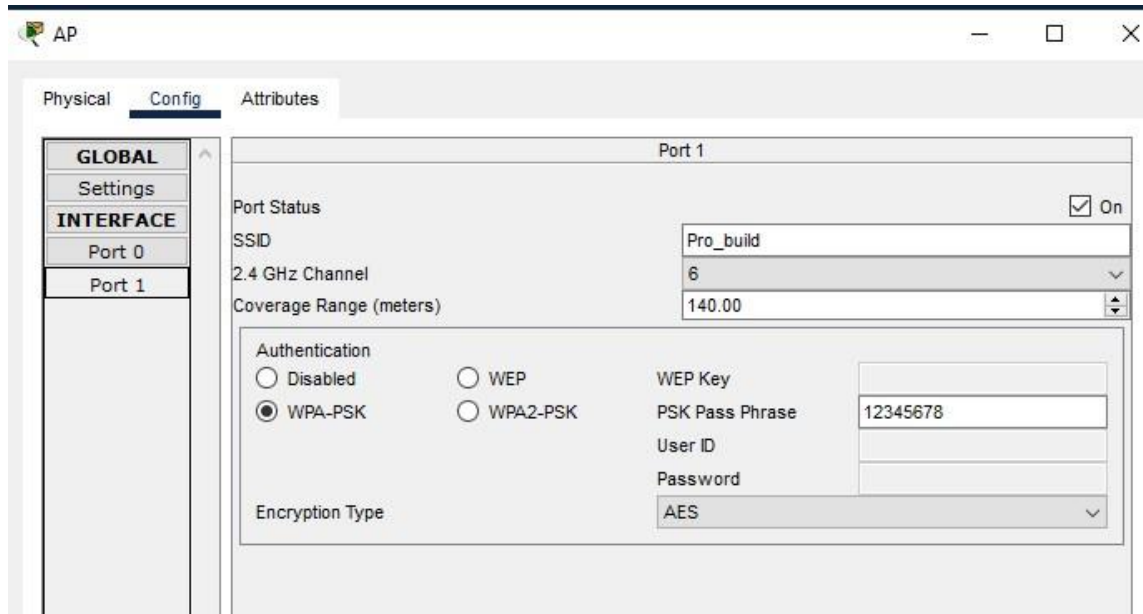


Figure 19: Access point authentication

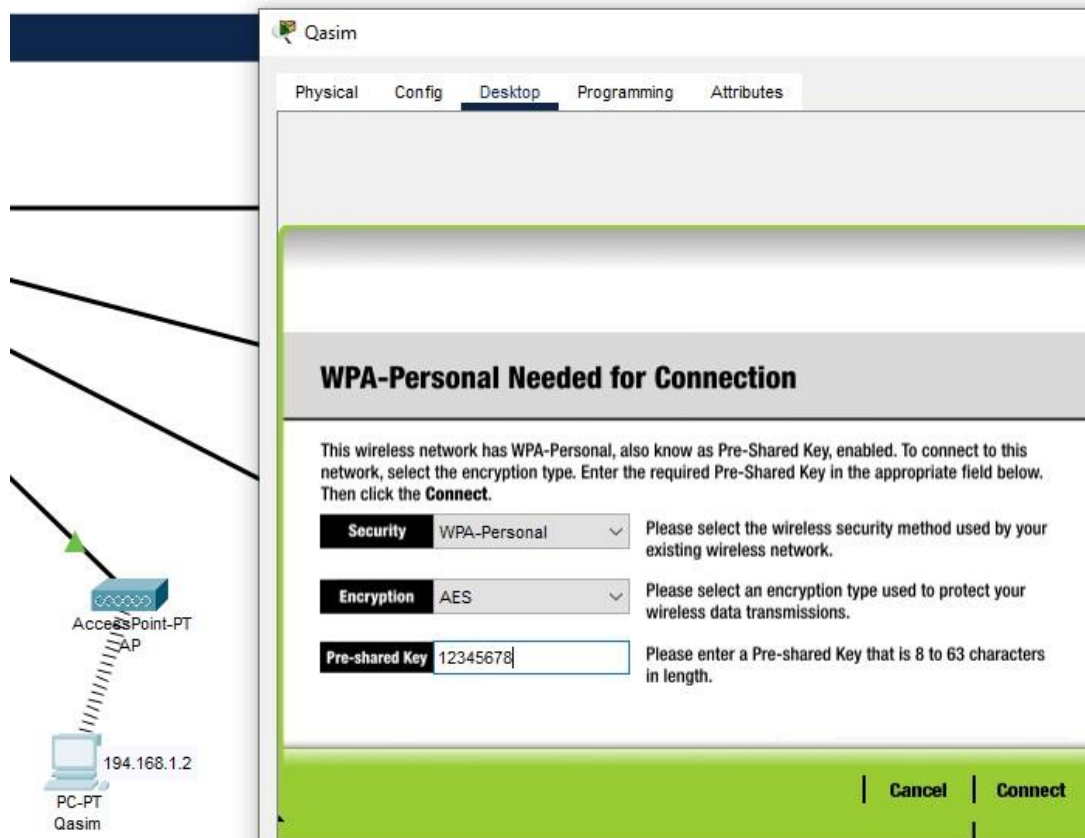


Figure 20: PC authentication for wireless connection



## Email services

Device	Person	BUILDING	Email	IP
Laptop	Taha	Corporate	<a href="mailto:taha@email.com">taha@email.com</a>	10.1.1.11
PC	Ahmed	Corporate	<a href="mailto:ahmed@email.com">ahmed@email.com</a>	10.1.1.4
PC	Gulzar	Administrative	<a href="mailto:gulzar@email.com">gulzar@email.com</a>	126.1.1.0
PC	Farhan	Programming	<a href="mailto:farhan@email.com">farhan@email.com</a>	194.168.1.1
Smartphone	Gulzar	Administrative	<a href="mailto:gulzar@email.com">gulzar@email.com</a>	126.1.1.20
Email server	Corporate office	10.1.1.17		
DNS	Corporate office	10.1.1.18		

Figure 21; Above is the email configured and used in this project

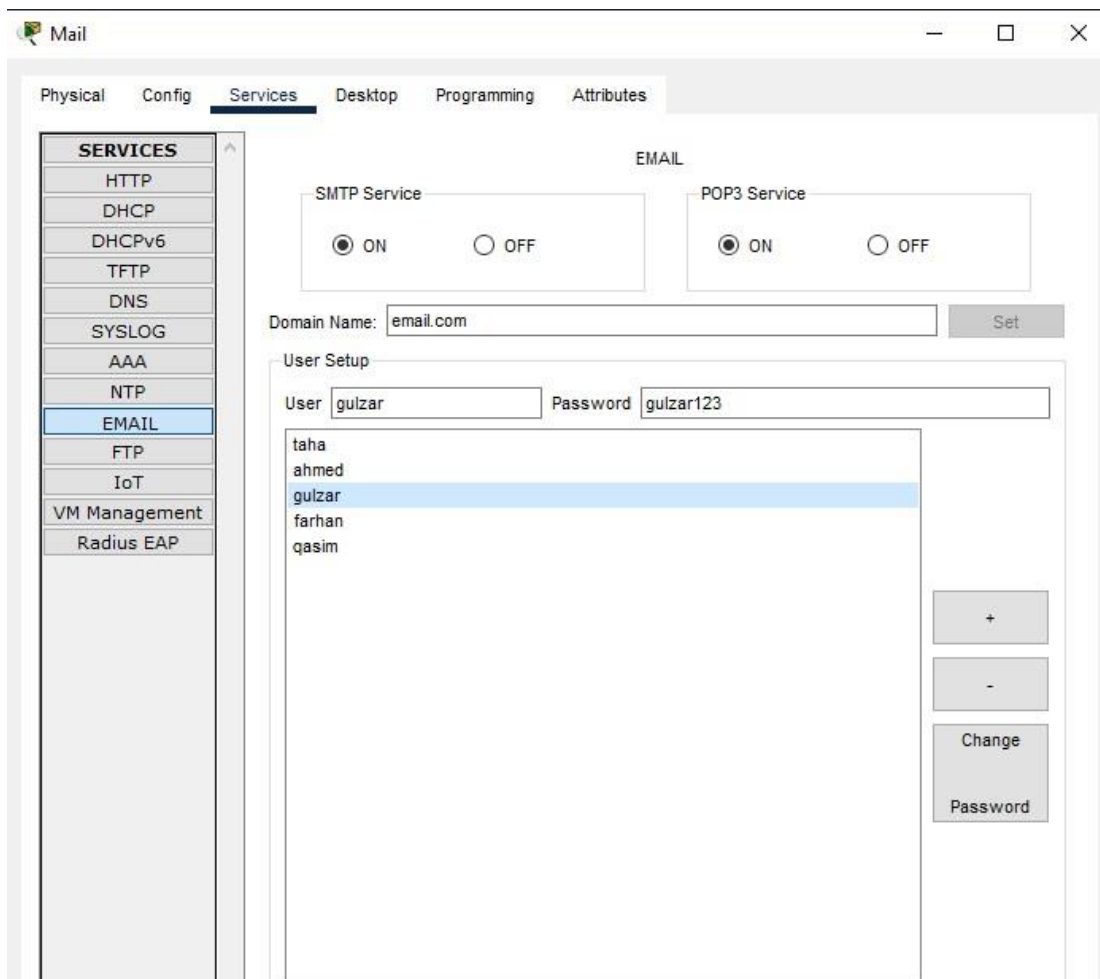


Figure 22: Emails were added in the email server

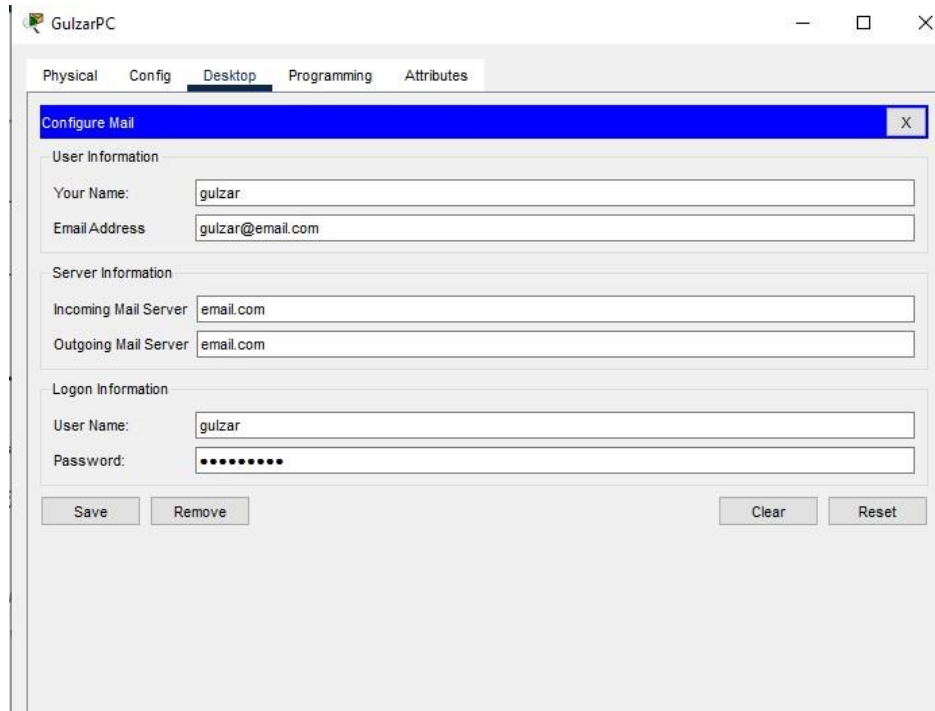


Figure 23: Each device was configured for email (using the authentic username and password)  
same as given above in the figure.

Email from Administrative building(AB) to Programming.

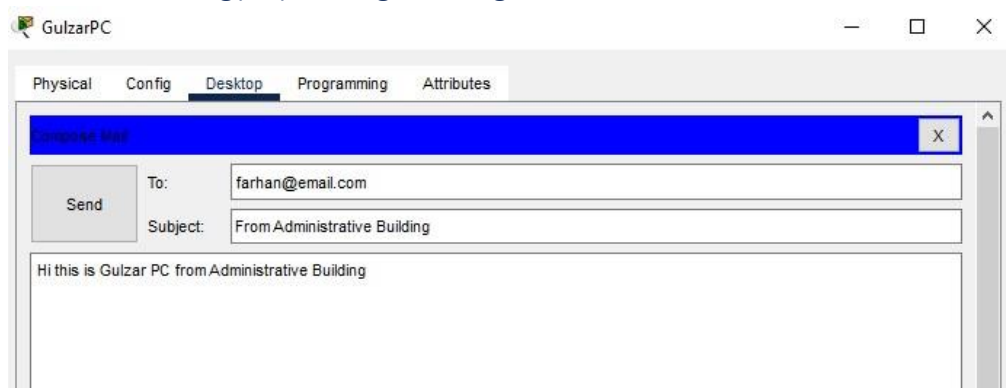


Figure 24: from PC Gulzar in AB to PC Farhan in PB

Email from Corporate office to Programming Building

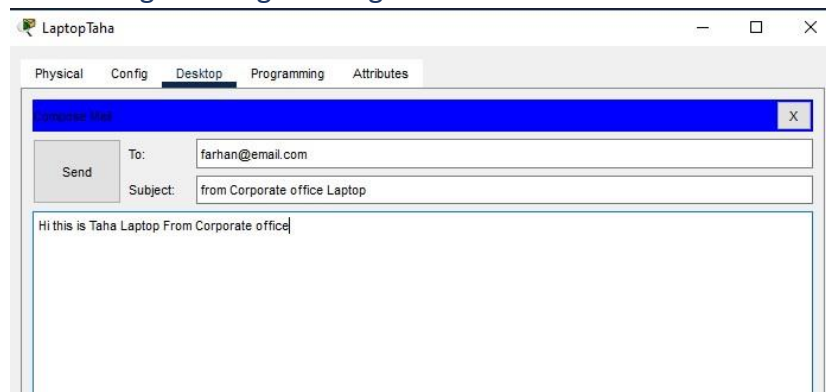


Figure 25: From Taha laptop in CO to Farhan PC in PB

## Email from Corporate office (CO) to administrative building (PB)

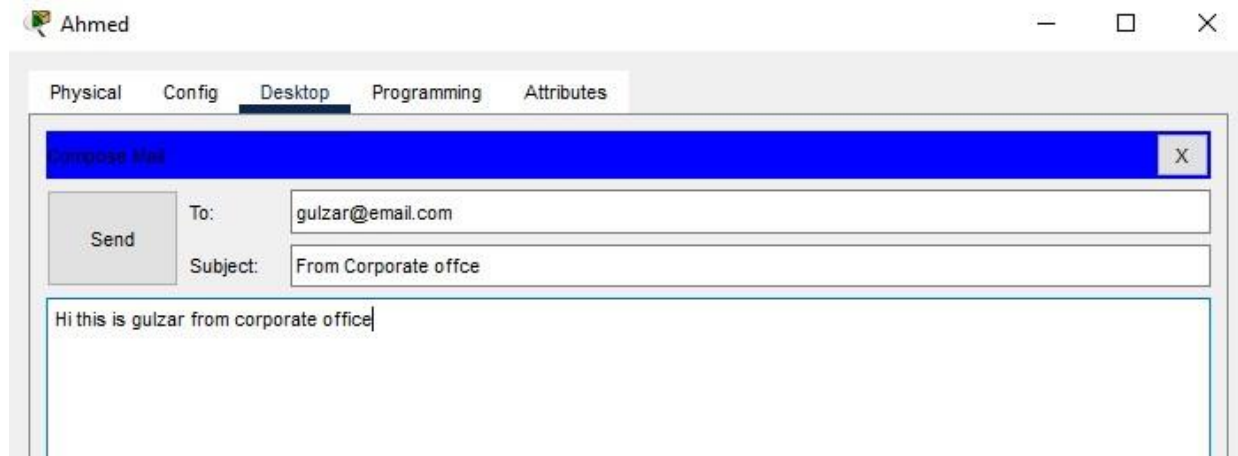


Figure 26: Email from Ahmed from CO to Gulzar in AB

## Received Emails:

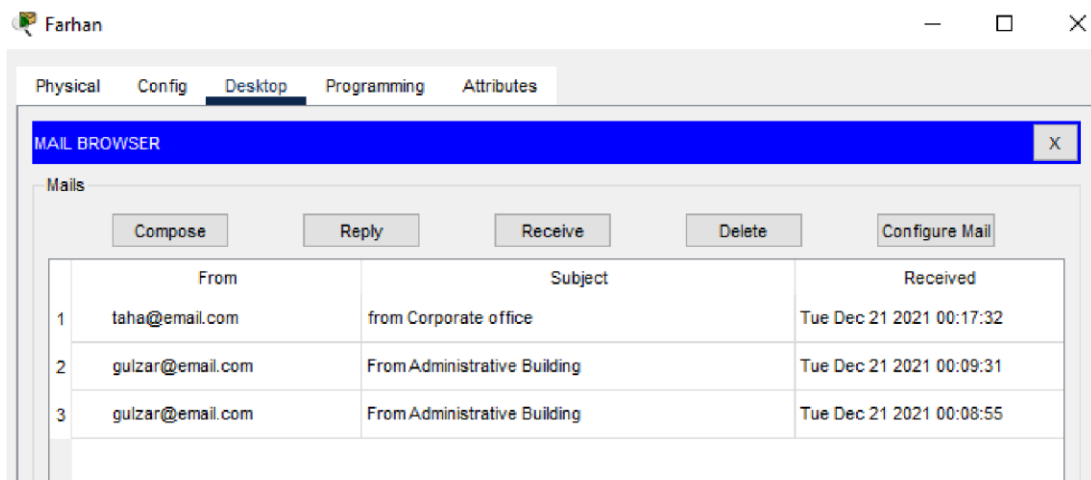


Figure 27: Email received at PB at Farhan PC

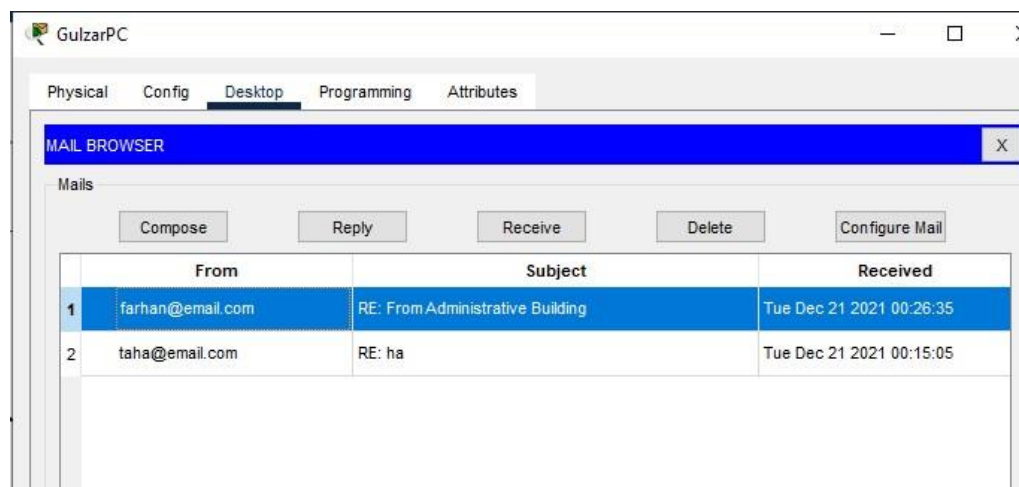


Figure 28: Reply received in AB of Farhan from PB

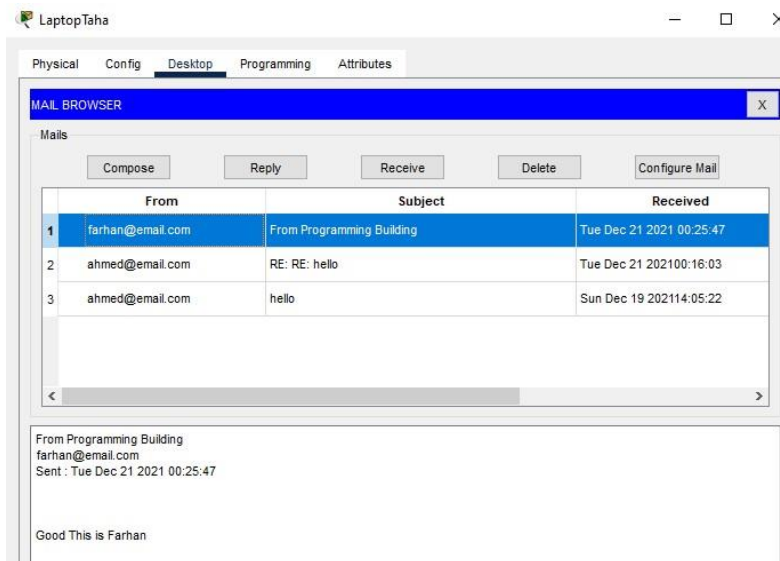


Figure 29: Reply from PB at the CO as well as the email received from Ahmed in the same CO

## Ping

### Inside Buildings

In Corporate office:

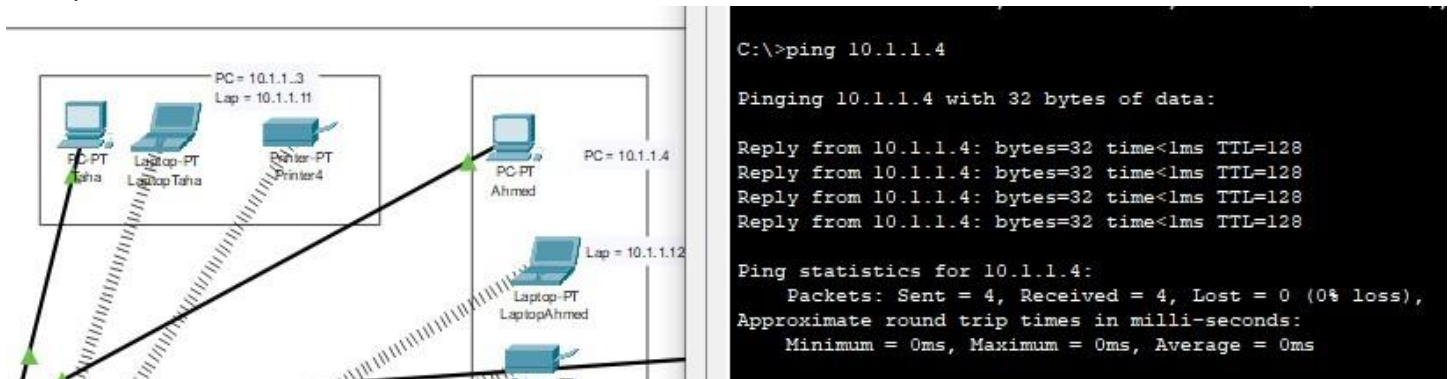


Figure 30: From Taha PC to Ahmed PC

In Programming Building (PB):

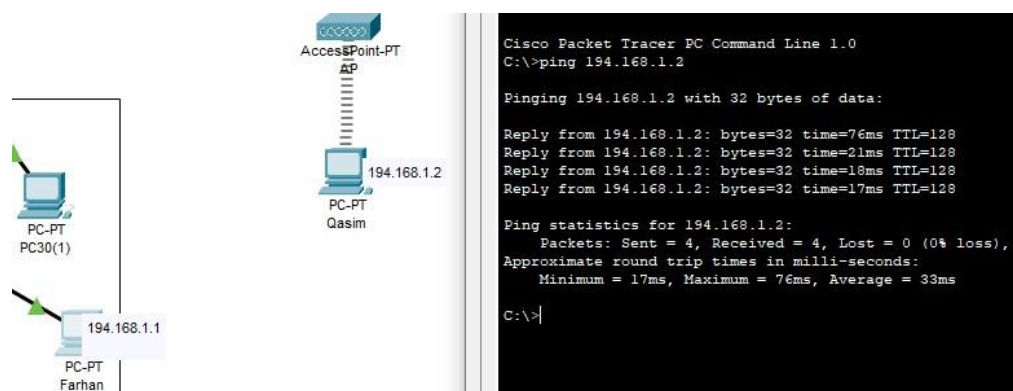


Figure 31: from Farhan to Qassim PC in PB

In Administrative Building (AB):

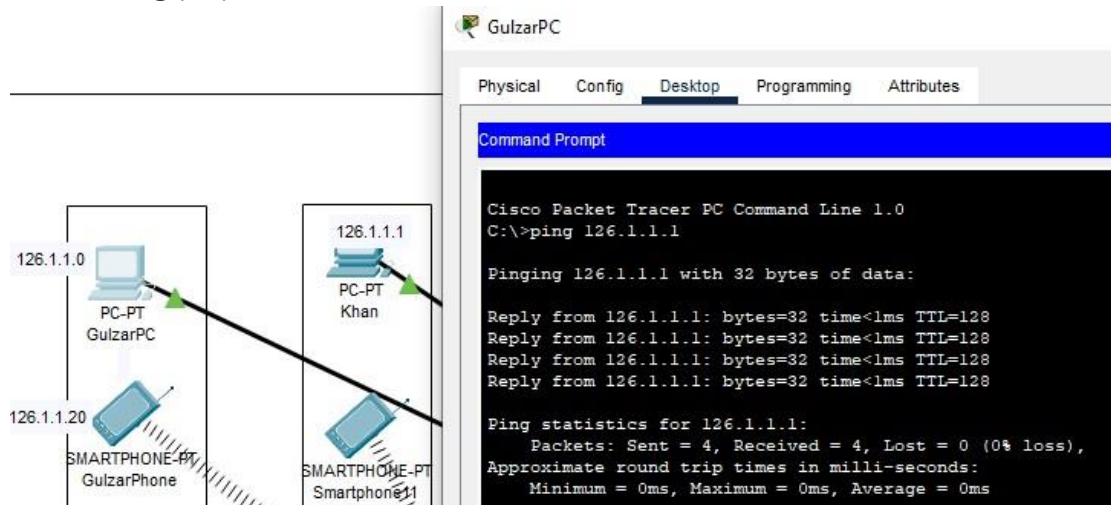


Figure 32: From Gulzar PC to Khan in the AB

## Within Different Buildings:

From Administrative to Corporate

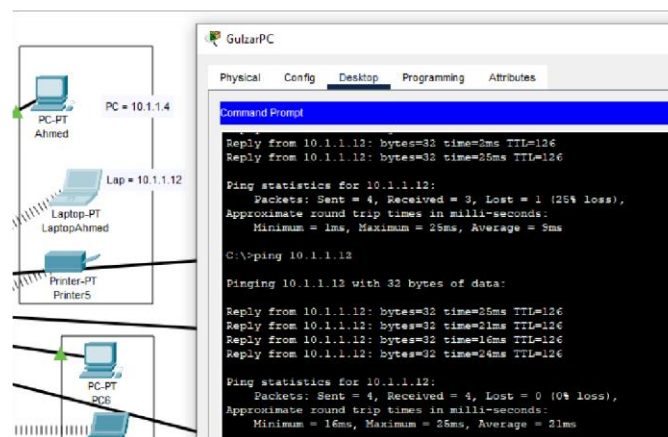


Figure 33: Ping Gulzar PC in AB to Ahmed laptop in CO

From Corporate to Administrative:

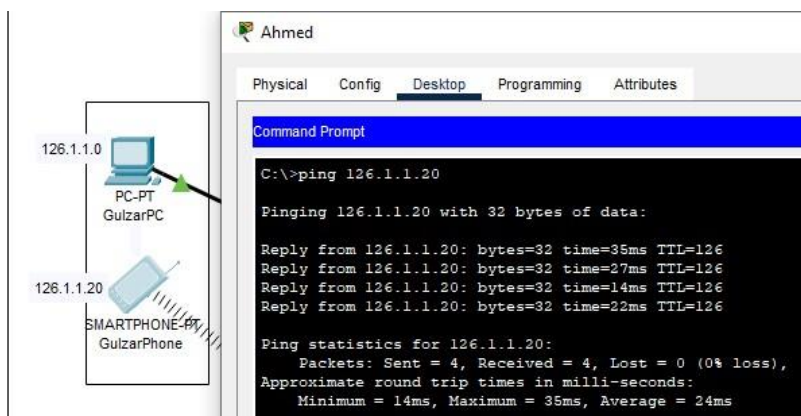




Figure 34: from Ahmed in CO to Gulzar phone in AB

## From Corporate to Programming:

```

C:\>ping 194.168.1.1

Pinging 194.168.1.1 with 32 bytes of data:

Reply from 194.168.1.1: bytes=32 time<1ms TTL=126
Reply from 194.168.1.1: bytes=32 time<1ms TTL=126
Reply from 194.168.1.1: bytes=32 time=1ms TTL=126
Reply from 194.168.1.1: bytes=32 time<1ms TTL=126

Ping statistics for 194.168.1.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 1ms, Average = 0ms

```

Figure 35: From Corporate office to Programming

## From Administrative to Programming:

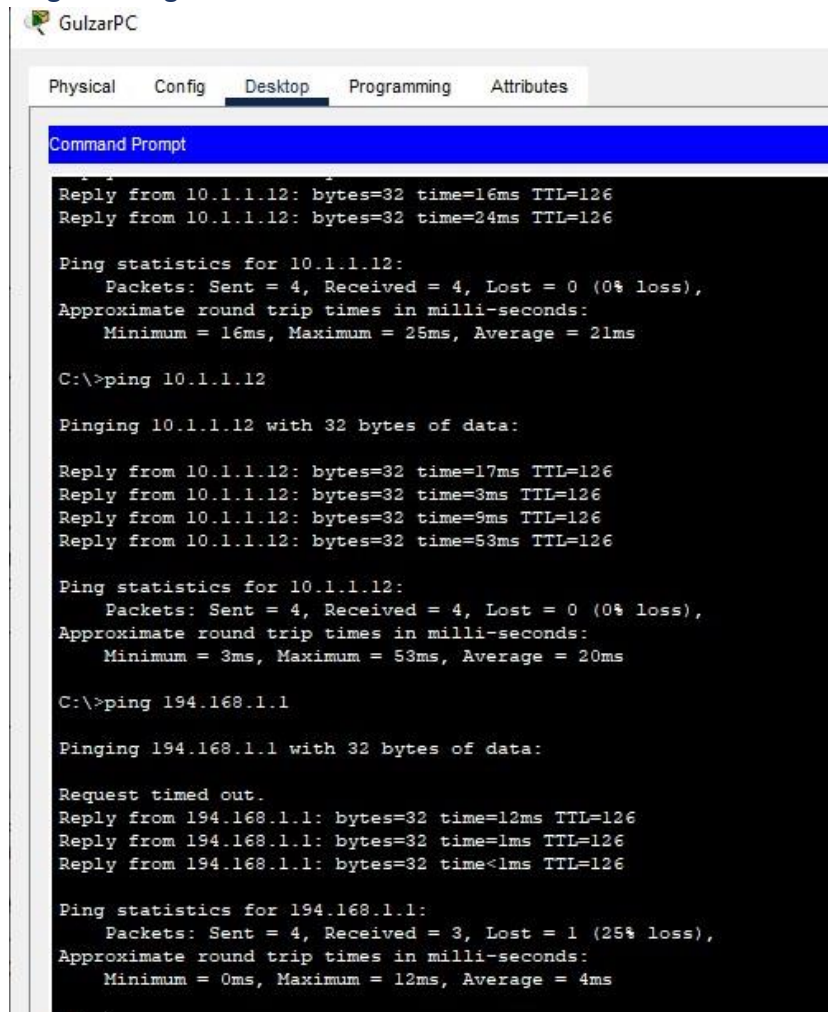


Figure 36: From AB to PB

## From Programming to Corporate and Administrative:



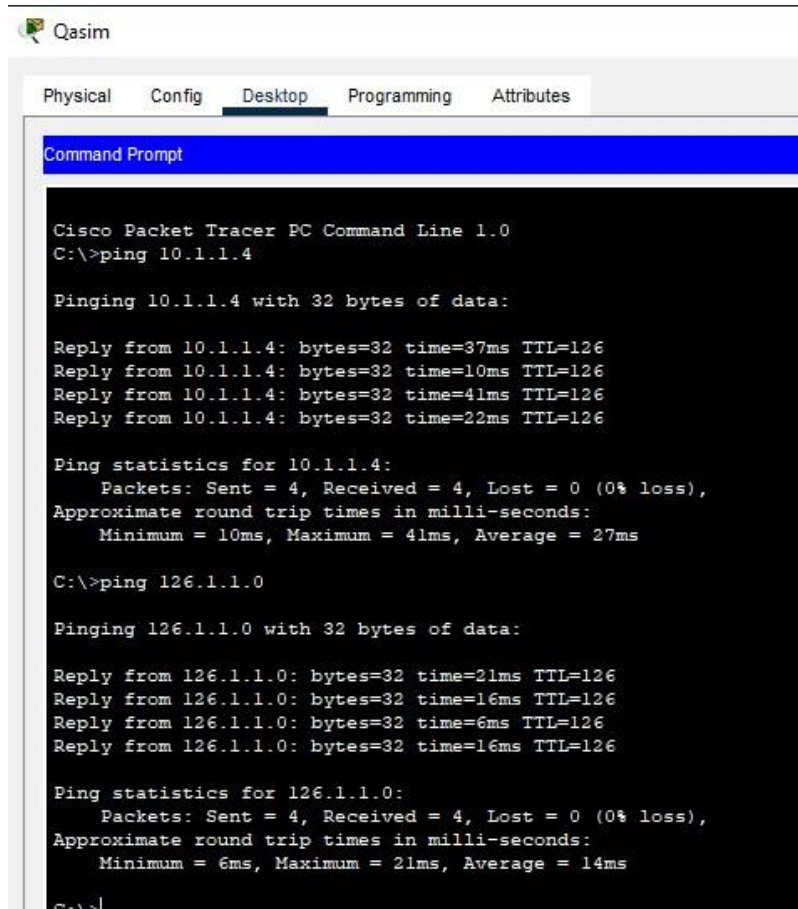


Figure 37: Ping from Qasim in PB to CO and AB

## FTP services

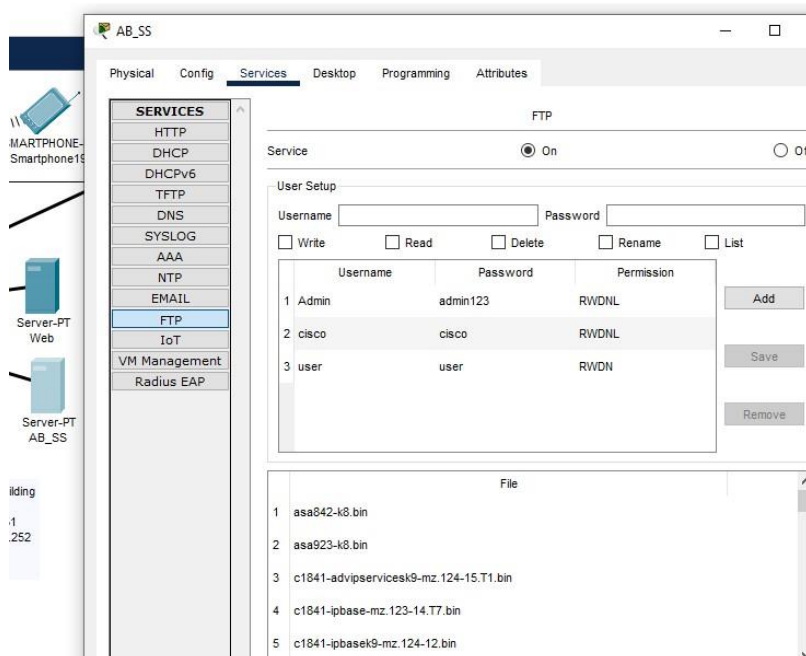


Figure 38: Administrative Building FTP server

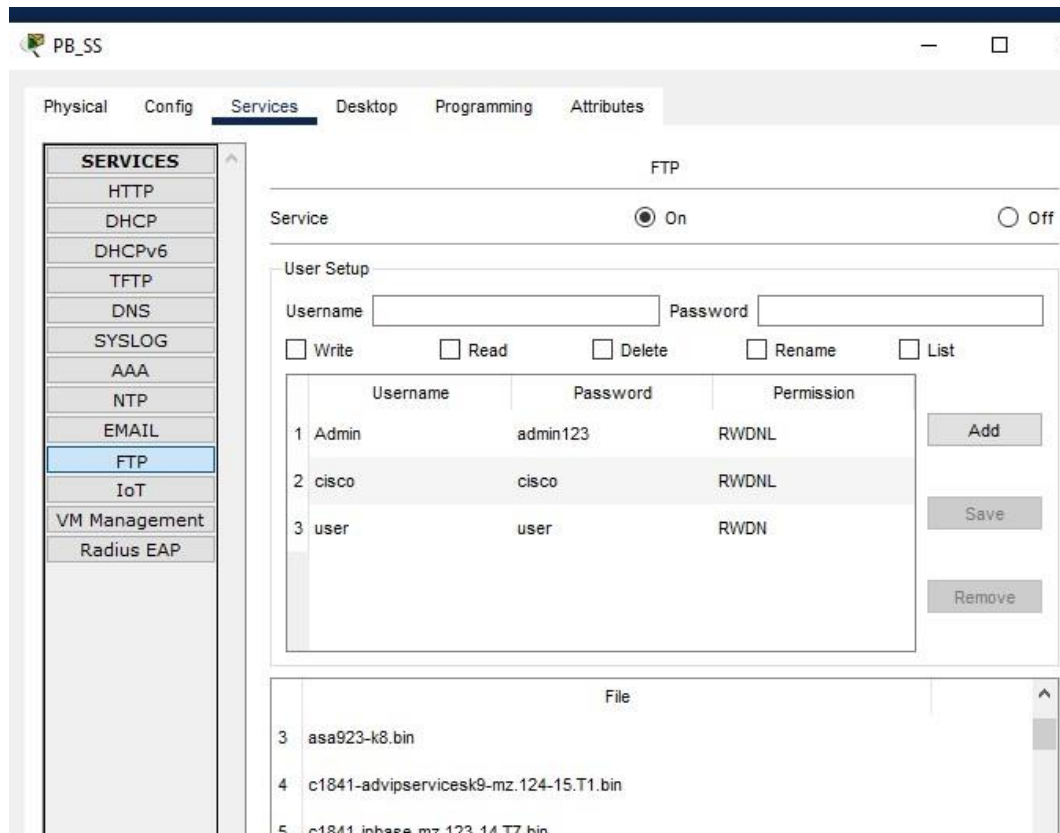


Figure 39: Programming Building FTP server

## File transfer from corporate office:

To administrative building storage server

```

C:\>ftp ab_ss
Trying to connect...ab_ss
Connected to ab_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put Corporate.txt

Writing file Corporate.txt to ab_ss:
File transfer in progress...

[Transfer complete - 29 bytes]

29 bytes copied in 0.152 secs (190 bytes/sec)
ftp>

```

Figure 40: putting file on AB ftp server from CO

To Programming building storage server:

```
C:\>ftp pb_ss
Trying to connect...pb_ss
Connected to pb_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put Corporate.txt

Writing file Corporate.txt to pb_ss:
File transfer in progress...

[Transfer complete - 29 bytes]

29 bytes copied in 0.081 secs (358 bytes/sec)
ftp>quit

221- Service closing control connection.
C:\>
```

Figure 41: Putting file on PB ftp server from CO

## File Transfer from Administrative:

To administrative building storage server:

```
C:\>ftp ab_ss
Trying to connect...ab_ss
Connected to ab_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put administrative.txt

Writing file administrative.txt to ab_ss:
File transfer in progress...

[Transfer complete - 37 bytes]

37 bytes copied in 0.076 secs (486 bytes/sec)
```

Figure 42: file transfer from AB-to-AB ftp server

To programming building storage server:

```

C:\>ftp pb_ss
Trying to connect...pb_ss
Connected to pb_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put administrative.txt

Writing file administrative.txt to pb_ss:
File transfer in progress...

[Transfer complete - 37 bytes]

37 bytes copied in 0.041 secs (902 bytes/sec)
ftp>quit

221- Service closing control connection.

```

Figure 43: file transfer From AB to PB ftp server

## File Transfer from Corporate:

To administrative building storage server:

```

C:\>ftp ab_ss
Trying to connect...ab_ss
Connected to ab_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put programming.txt

Writing file programming.txt to ab_ss:
File transfer in progress...

[Transfer complete - 34 bytes]

34 bytes copied in 0.053 secs (641 bytes/sec)
ftp>

```

Figure 44: file transfer From PB to AB ftp server

To programming building storage server:

```

C:\>ftp pb_ss
Trying to connect...pb_ss
Connected to pb_ss
220- Welcome to PT Ftp server
Username:user
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>put programming.txt

Writing file programming.txt to pb_ss:
File transfer in progress...

[Transfer complete - 34 bytes]

34 bytes copied in 0.08 secs (425 bytes/sec)
ftp>

```

Figure 45: file transfer from PB to Pb ftp server

## File received at servers:

At administrative building:

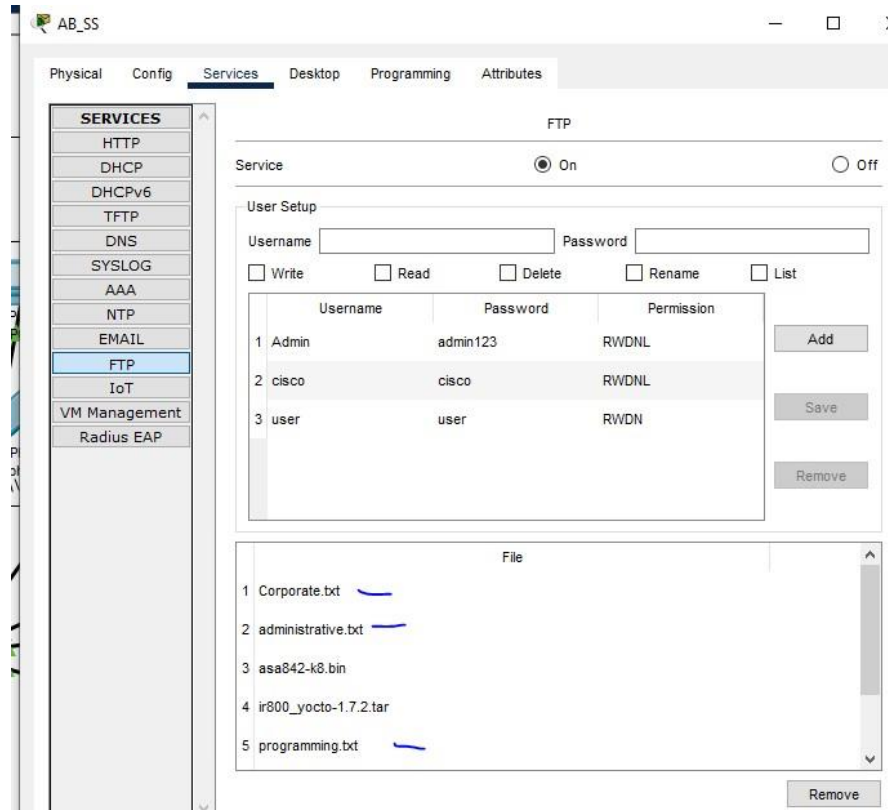


Figure 46; file is available on the AB ftp server

At programming building:

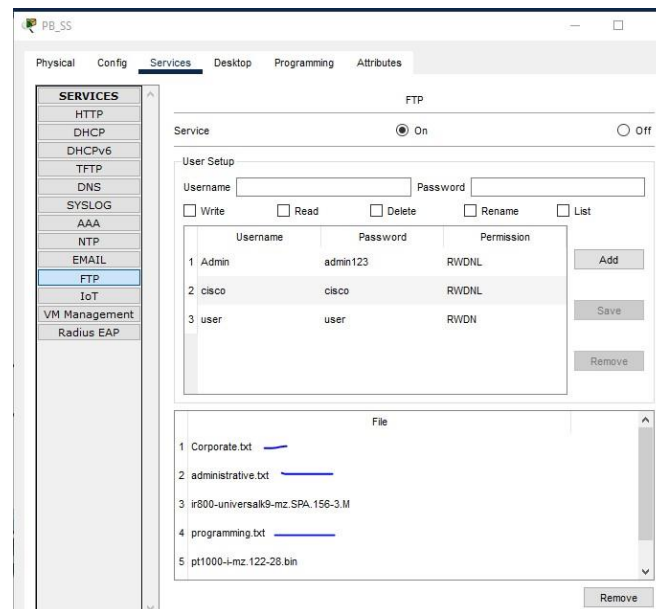


Figure 47: File is present in the server

Getting the file from the server:

```
C:\>ftp ab_ss
Trying to connect...ab_ss
Connected to ab_ss
220- Welcome to PT Ftp server
Username:Admin
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>get administrative.txt

Reading file administrative.txt from ab_ss:
File transfer in progress...

[Transfer complete - 37 bytes]

37 bytes copied in 0.001 secs (37000 bytes/sec)
ftp>|
```

Figure 48: Admin getting file from AB ftp server

```
C:\>ftp pb_ss
Trying to connect...pb_ss
Connected to pb_ss
220- Welcome to PT Ftp server
Username:Admin
331- Username ok, need password
Password:
230- Logged in
(passive mode On)
ftp>get Corporate.txt

Reading file Corporate.txt from pb_ss:
File transfer in progress...

[Transfer complete - 29 bytes]

29 bytes copied in 0.01 secs (2900 bytes/sec)
ftp>get programming.txt

Reading file programming.txt from pb_ss:
File transfer in progress...

[Transfer complete - 34 bytes]

34 bytes copied in 0.001 secs (34000 bytes/sec)
ftp>quit

221- Service closing control connection.
C:\>|
```

Figure 49: Admin getting file from PB ftp server



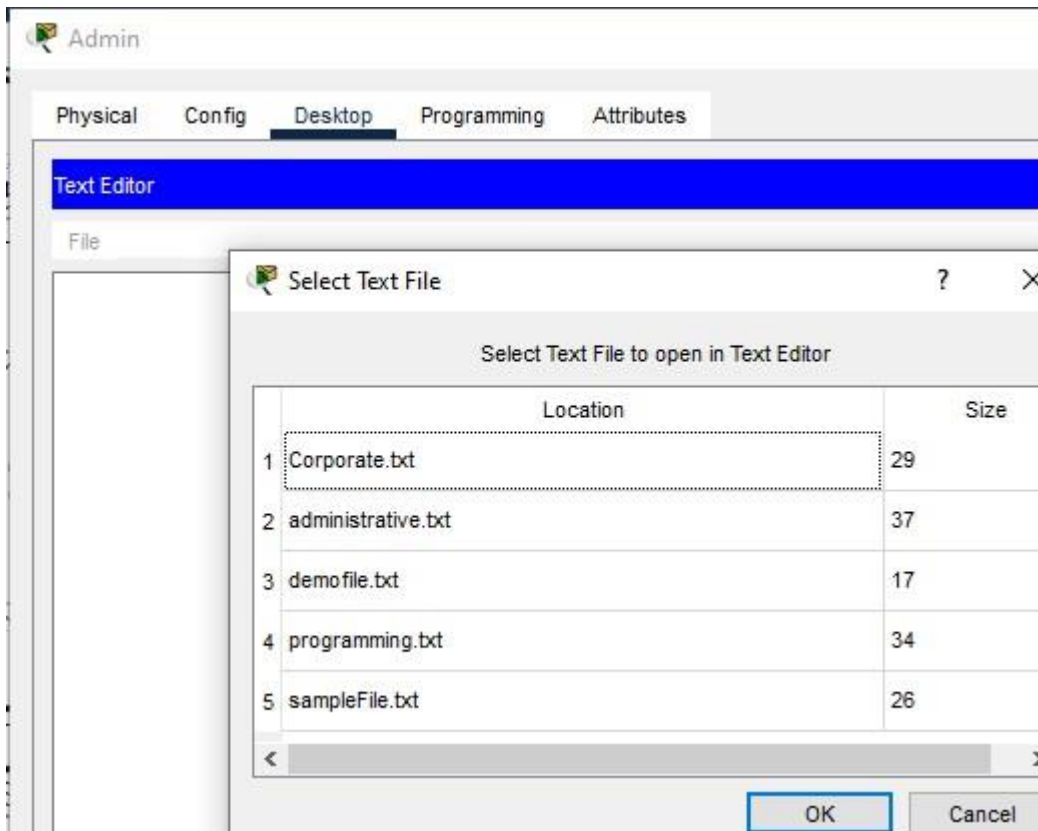


Figure 50: Files at admin PC

## HTTP Services

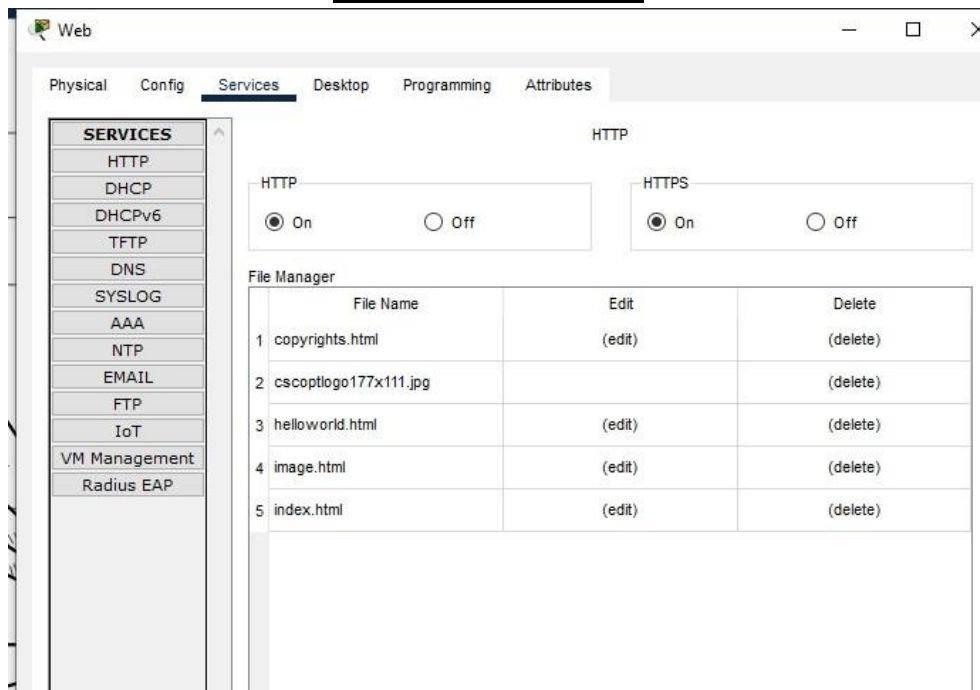


Figure 51: Web server in administrative building containing Cisco web page

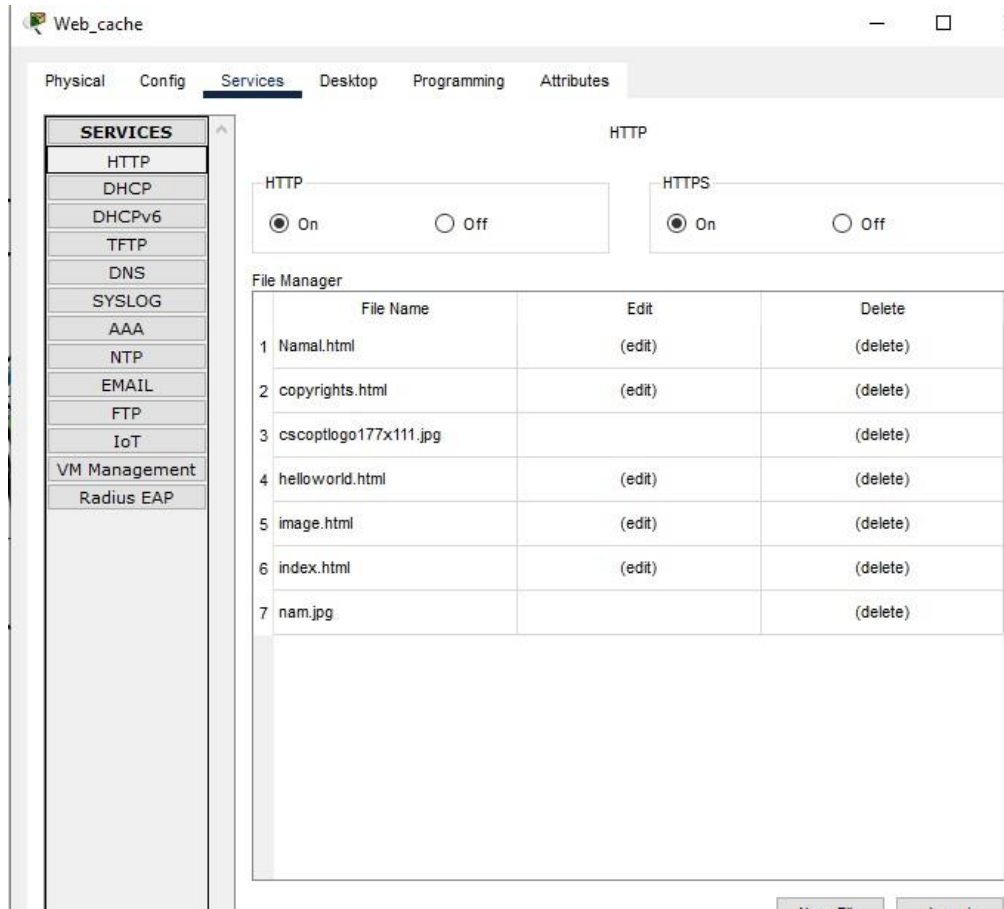


Figure 52: HTTP server in programming building with Namal website

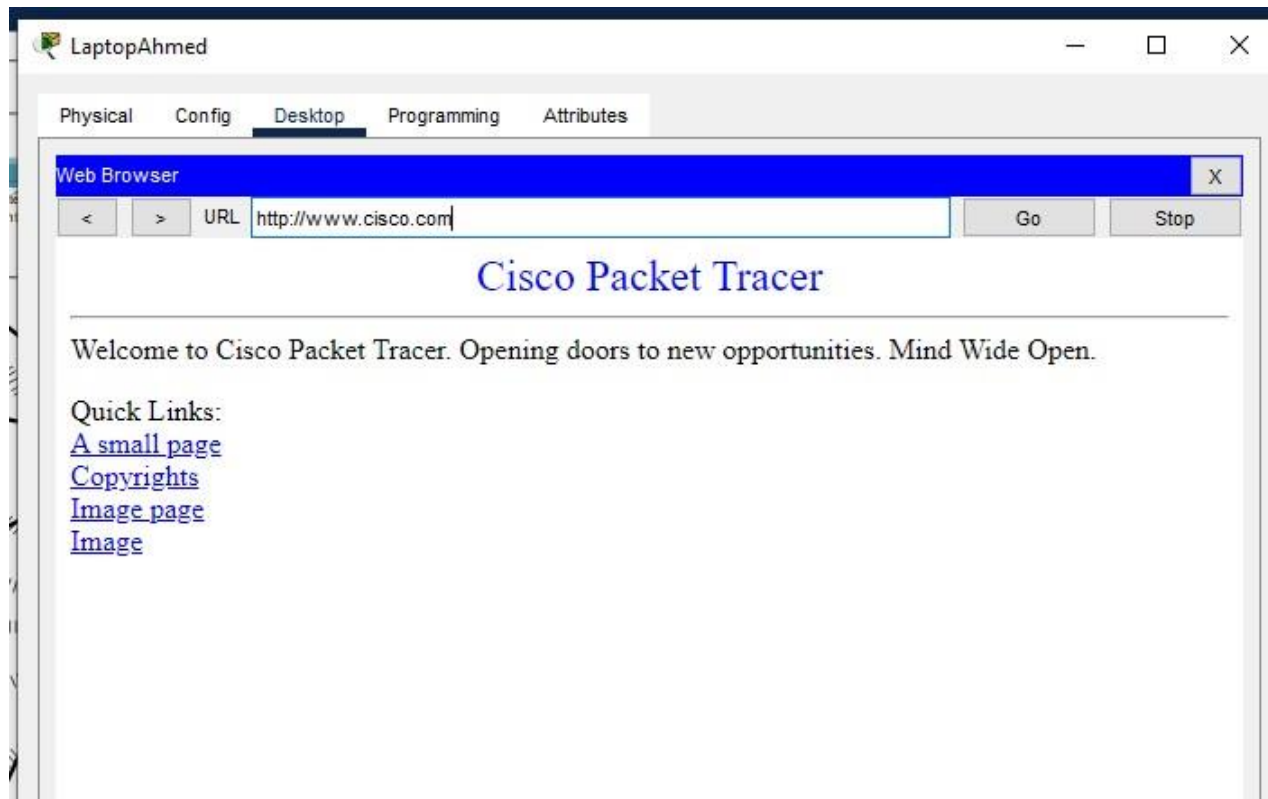


Figure 53: Accessing the cisco web page at corporate office from the webserver at AB

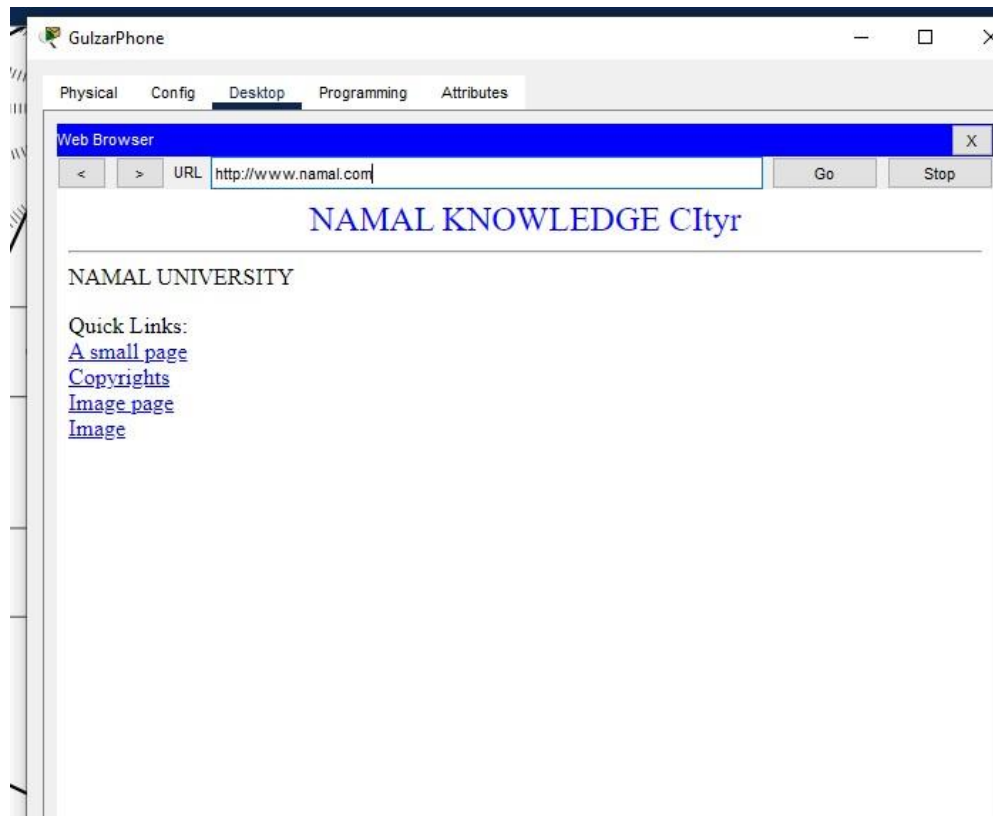


Figure 54: Accessing the Namal web page from administrative building through server at PB

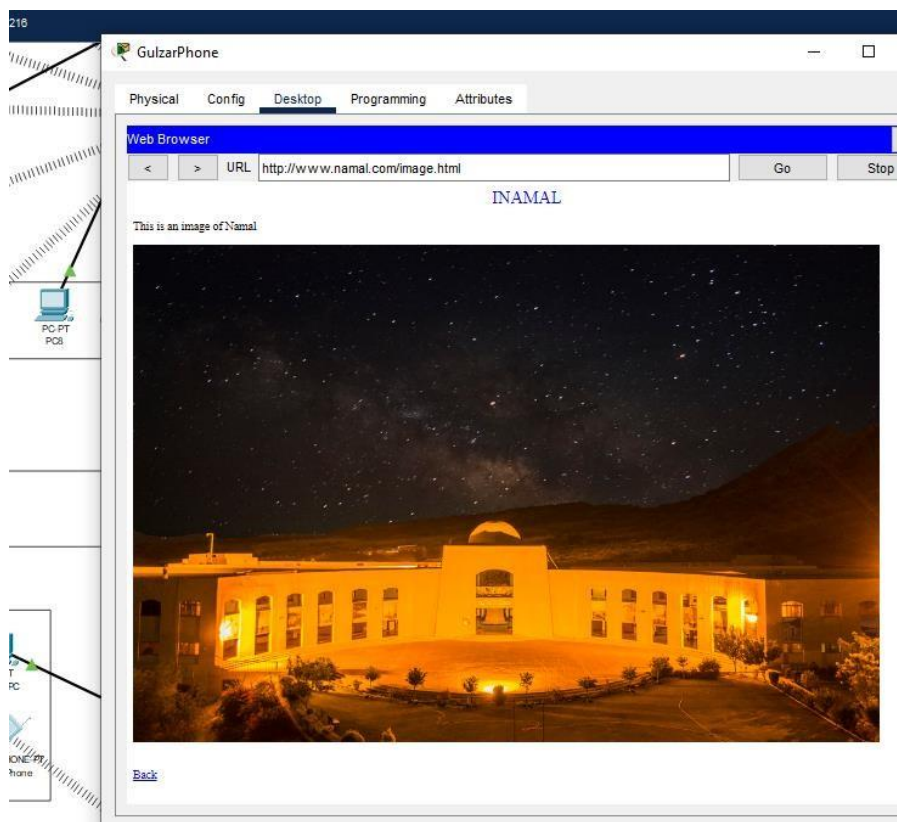


Figure 55: Namal image in the web page

## Cost

ESTIMATED COST				
Devices	Cost/unit	No. of Units	Total	Link
Router	569	3	1707	<a href="https://www.router-switch.com/cisco-900-routers-price.html">https://www.router-switch.com/cisco-900-routers-price.html</a>
Switches	221	4	884	<a href="https://www.router-switch.com/ws-c2960-24tt-l-p-429.html">https://www.router-switch.com/ws-c2960-24tt-l-p-429.html</a>
PC	600	49	29400	<a href="https://www.pcmag.com/picks/the-best-budget-desktop-computers">https://www.pcmag.com/picks/the-best-budget-desktop-computers</a>
Printer	1200	10	12000	<a href="https://www.loffler.com/buying-printer-office-copy-machine-cost">https://www.loffler.com/buying-printer-office-copy-machine-cost</a>
Accesspoint	16.5	5	82.5	<a href="https://www.mbcommunication.com.pk/101-wireless-access-point">https://www.mbcommunication.com.pk/101-wireless-access-point</a>
Server	8666.25	7	60663.75	<a href="https://itprice.com/cisco-gpl/server-%20pt">https://itprice.com/cisco-gpl/server-%20pt</a>
Multilayer switch	1500	1	1500	<a href="https://itprice.com/cisco-gpl/multilayer%20switch">https://itprice.com/cisco-gpl/multilayer%20switch</a>
Total (\$)			106237.25	
Total (RS)			18803993.25	

Figure 56: Estimated cost of network devices from internet

Devices	cost(\$)/unit	No. of units	Total Cost (\$)	Cost (Rs)
Switch-PT	1500	4	6000	1062000
Router-PT	150	3	450	79650
PC-PT	1000	49	49000	8673000
Laptop-PT	1000	18	18000	3186000
Printer-PT	1500	10	15000	2655000
Smartphone-PT	250	10	2500	442500
Accesspoint-PT	20	5	100	17700
Fibre	100	3	300	53100
Copper	10	50	500	88500
Multilayer Switch	1500	1	1500	265500
Server	2000	7	14000	2478000
		<b>Total</b>	<b>107350</b>	<b>19000950</b>

Figure 57: Estimated cost in Rs considering 1\$ =177Rs given by cisco software

## Potential Point of weakness and suggestions

- No firewall server is included which is a threat in security.
- The DHCP services is only in one building, the DHCP server can be included to give IP addresses to all the devices in the network but this might get costly due to added number of servers.

## Conclusion

Cisco Packet traces help us to implement the complex network and help us to develop, test and simulate the network. In this lab we have designed and connected three different buildings in three different cities. Cisco also provides the tools to physically implement the network in which we can manually design the offices and server room as described above. The prices were taken through internet of all the network devices and the estimated cost of all the network was calculated. The price is quite reasonable since the three buildings cost only 18,803,903Rs.