VIETNAM NATIONAL UNIVERSITY - HO CHI MINH CITY
HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY
FACULTY OF COMPUTER SCIENCE AND ENGINEERING

Computer Network (CO3094)

ASSIGNMENT 2

NETWORK DESIGN AND SIMULATION FOR A CRITICAL LARGE HOSPITAL

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1 Member list & Workload

No.	Fullname	Student ID	Tasks	Percentage
1	Tran Xuan Hao	2252191	- Design and test the network map	100%
2	Nguyen Minh Quan	2252683	- Re-evaluate the system and Report	100%
3	Nguyen Minh Tien	2150033	- Analyze network structures	100%

Contents

2 Introduction

In this report, we delve into the comprehensive design and simulation of a robust and scalable network for a critical large hospital currently under construction. The project's goal is to develop a network that efficiently connects multiple buildings within the main site and two auxiliary sites while ensuring high performance, reliability, and security. Using Cisco Packet Tracer as the primary simulation tool, the proposed design incorporates cutting-edge technologies such as GPON fiber cabling, VLANs, and WAN connectivity through SD-WAN or MPLS. This network aims to support the hospital's diverse IT requirements, including data centers, medical devices, wireless connectivity, and software systems like HIS and PACS. With a focus on optimizing network load, security, and future growth potential, this design serves as a model for large-scale hospital networks.

3 Find out suitable network structures for buildings

3.1 Analyze the network system requirements of the main Site and the two Auxiliary Sites

3.1.1 Main Site:

- Two buildings:

	Building A	Building B
Number Floors	5	5
Number Rooms/ Floors	10	10
Equipment	Computers and Medical devices	Computers and Medical devices

Table 1: Building A and Building B

- Data center, IT and cabling central local:

	Data center	IT	Cabling central local
Type	Separate room	Separate room	Separate room
Need	x	x	Patch panels

Table 2: Data center, IT and cabling central local

- Scale Network:

	Workstations	Servers	Network devices	Security devices
Quantity	600	10	12	optional

Table 3: Scale Network

- Modern technologies:

	Connection	Fiber Cable	Ethernet
Type	Wire and wireless	GPON	High-speed: 1GbE/ 10GbE/ 40GbE

Table 4: Modern technologies

- Sub-network:

	Site DBP	Site BHTQ
Connection	Leased line (SD-WAN/MPLS)	Leased line (SD-WAN/MPLS)

Table 5: Sub-network

- Software acquisition:

	Hospital software	Others
Software	HIS RIS-PACS LIS CRM	Office applications Client-server systems Multimedia tools

Table 6: Software acquisition

- Scalability and security:

	Scalability	Security	Availability
Information	Growth rate of 20% in 5 years	Firewall, IPS/IDS, phishing detection, encryption	Robustness and fault tolerance

Table 7: Scalability and security

- Features:

	VPN Configuration	Surveillance System
Information	Site-to-site VNP (connecting to Auxiliary Sites) Teleworker VNP for remote access	Centralized camera system covering critical area

Table 8: Features

3.1.2 Auxiliary Sites Requirements:

- Each site has:

+ Building:

	First floor	Second floor
Contain	IT, Cabling Central Local	x

Table 9: Building

+ Scalability:

	Workstations	Servers	Networking devices
Quantity	60	2	At least 5

Table 10: Scalability

+ Technology with Main Site:

	Connection with Main Site
Methods	SD-WAN MPLS Leased Line VPN Hybrid (SD-WAN + MPLS)

Table 11: Technology with Main Site

In this assignment, we decide to use **SD-WAN**, here is its strength and weakness:

Strength	Weakness
Easy to improve Good security Cheap to maintain and improve Connection Packet distribution	Slow Initial cost may be high

Table 12: SD-WAN Pros and Cons

3.1.3 Network Load Analysis:

	Server	Workstation	Wi-fi devices
Peak hours	9:00AM-11:00AM 3:00PM-4:00PM 80% usage	9:00AM-11:00AM 3:00PM-4:00PM 80% usage	9:00AM-11:00AM 3:00PM-4:00PM 80% usage
Download	1000 MB/day	(500MB/day)/workstation	x
Upload	2000 MB/day	(100MB/day)/workstation	x
Customer access	x	x	500MB/day
Future growth	+ 20%/ 5 years	+ 20%/ 5 years	+ 20%/ 5 years

Table 13: Network Load

Notes:

- Full wi-fi coverage is required for the entire Main Site.
- VLAN structure: should be segmented for different departments.
- 2 xDSL with load-balancing performance.
- All internet traffic routed through the Main Site subnet.

3.2 Check List:

Category	Checklist Item
Site Preparation	Verify physical space, environmental conditions, and electrical power.
Network Equipment Setup	Check routers, switches, patch panels, cabling, and wireless APs.
Network Design	Confirm VLAN, IP addressing, and subnetting setup.
WAN Connectivity	Ensure WAN link setup (SD-WAN, MPLS, VPN) and bandwidth adequacy
Security Measures	Configure firewall, IPS/IDS, VPN, ACLs, and physical security.
Wireless Network Setup	Ensure Wi-Fi coverage, SSID security, and signal strength.
Data Center & Servers	Verify server racks, cooling, and proper server configuration.
Backup & Redundancy	Ensure UPS, backup solutions, and disaster recovery plan are in place.
Documentation & Labeling	Label devices and cables, and provide network diagrams.
Final Testing	Conduct connectivity, speed, security, and UAT tests.
Training & Handover	Train staff and provide documentation for network management.

Table 14: Check List

3.3 High-load Area:

- Server.

- Workstation.

- Wi-fi access point (when it is in peak hour).

3.4 Choose network structure

Two best options: **hierarchical structure** and server-client structure

But in this assignment, we choose **the first one** because

Features	Hierarchical	Server-Client
Scale	Can afford with large number of items: + 600 workstations + 10 servers + 12 networking devices	Just use in small scale
Improvement	Easier to expand the scale	Hard
Design	Easy to connect with WAN and SD-WAN/MPLS	Hard

Table 15: Hierarchical and Server-Client Structure Comparison

3.5 Design network usage

- Main Site:

For main sites we have 12 networking devices, but the requirements are that wireless connection has to be covered for the whole Site → We must distribute the access points, switches suitably. Here is our distribution plan:

- Because the building A and B are nearly the same, so each has 2 access points located in 2^{nd} floor and 4^{th} floor, two are connected with a router located in the 3rd floor to save the cost for length of the cable.
- For the yard (outside building A, B and functional room), we should have 2 access points for the wide connection.
- We have 1 router, 1 core switch, 2 switch access.

With 10 servers (all are located in separated room), we decide to choose:

- Application Server
- Database Server
- VNP and Gateway Server
- Web Server
- Monitoring and Security Server
- Surveillance management Server
- Load Balancer Server
- Mail and Communication Server
- Authentication Server
- DHCP Server

Overall, we have the below table like this:

Devices	Building A	Building B	Functional room	Outside
Router	0	0	1	0
Core switch	0	0	1	0
Access switch	1	1	2	0
Access Point	2	2	0	2

Table 16: Summary Table

To ensure the network security, we set up to partition VLAN which is only used when allowed (in wireless environment):

+ Functional Building:

Type of user	Floor	VLAN
External DMZ Server	1	VLAN 10
Internal Services VLAN Server	1	VLAN 11
Camera	1	VLAN 12
Staff	1	VLAN 13

Table 17: Functional Building

+ Building A:

Type of user	VLAN
Clinical Department	VLAN 21
Laboratory	VLAN 22
Administrative Department	VLAN 23
Patient Care	VLAN 24
Camera	VLAN 25
Sensors	VLAN 26
Access Point	VLAN 27
Customer	VLAN 28

Table 18: Building A

+ Building B:

Type of user	VLAN
Clinical Department	VLAN 21
Pharmacy	VLAN 31
Security and Surveillance	VLAN 32
Finance and Accounting	VLAN 33
Patient Care	VLAN 34
Camera	VLAN 36
Sensors	VLAN 37
Access Point	VLAN 27
Customer	VLAN 28

Table 19: Building B

- Two Auxiliary Site:

+ The requirement is to contain 5 networking devices, so we decide to design as follow:

- First Floor: 1 router, 1 access switch, 1 access point
- Second floor: 1 access point
- Outside building: 1 access point

+ Each building should have exactly 2 servers:

- DHCP Server
- Database Server

+ Each building has 10 rooms on the second floors → Each room has 6 computers and medical devices

Overall, we have the below table like this:

Devices	DBP Site	BHTQ Site	Outside each site
Router	1	1	0
Switch	2	2	0
Access Point	1	1	1

Table 20: Summary Table

To ensure the network security, we set up to partition VLAN which is only used when allowed (in wireless environment):

+ DBP Site:

Type of user	VLAN
Camera	VLAN 41
Staff	VLAN 42
Sensors	VLAN 43
Access Point	VLAN 44
Server	VLAN 45
Customer	VLAN 46
Clinical Department	VLAN 47
Laboratory	VLAN 48
Administrative Department	VLAN 49
Patient Care	VLAN 50
Pharmacy	VLAN 51
Security and Surveillance	VLAN 52
Finance and Accounting	VLAN 53

Table 21: DBP Site

+ BHTQ Site:

Type of user	VLAN
Camera	VLAN 60
Staff	VLAN 61
Sensors	VLAN 62
Access Point	VLAN 63
Server	VLAN 64
Customer	VLAN 65
Clinical Department	VLAN 66
Laboratory	VLAN 67
Administrative Department	VLAN 68
Patient Care	VLAN 69
Pharmacy	VLAN 70
Security and Surveillance	VLAN 71
Finance and Accounting	VLAN 72

Table 22: BHTQ Site

+ Moreover, in order to connect between 3 sites together, we configure VPN through router located in IT room with two subsites or through VPN server for Main Site.

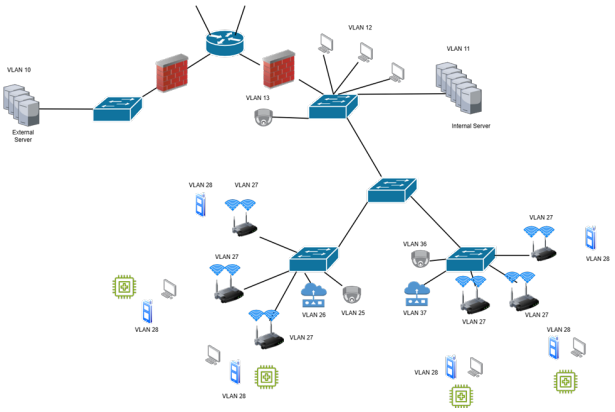

Figure 1: Logical Design in Main Site

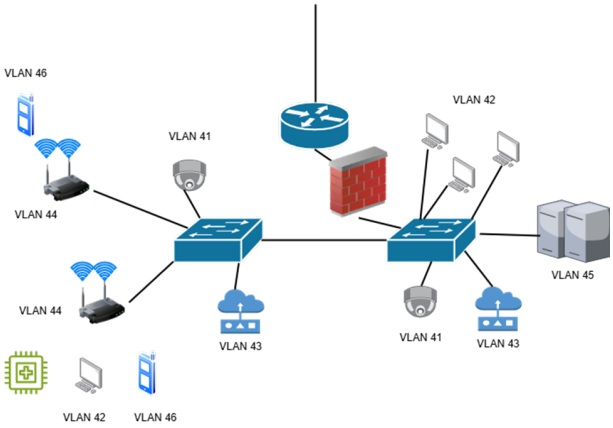

Figure 2: Logical Design in DBP Site

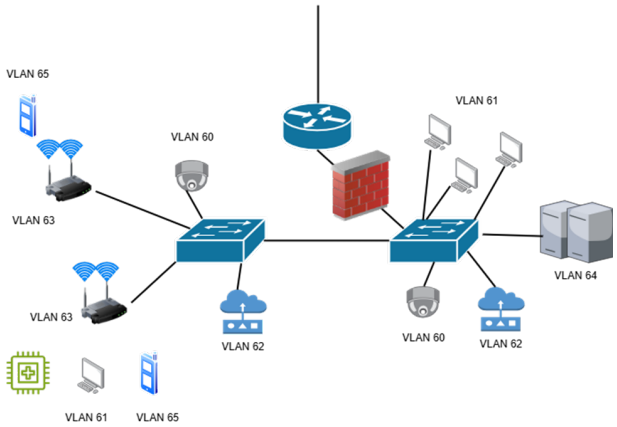

Figure 3: Logical Design in BHTQ Site

4 List of minimum equipment, IP plan, and wiring diagram (cabling)

4.1 List of recommended equipment and typical specifications

4.1.1 Firewall (Next-Generation Firewall - NGFW)

- **Model**: Fortinet FortiGate 100F

- **New Technologies**:

  - Supports Deep Packet Inspection (DPI).
  - Integrated IDS/IPS.
  - Built-in SD-WAN.

- **Price**: ∼150,000,000 VND.

4.1.2 Router (with Load-Balancing)

- **Model**: Cisco ISR 4331

- **New Technologies**:

  - Dual WAN support with Load Balancing.
  - Site-to-Site VPN integration.
  - Hardware optimized for SD-WAN.

- **Price**: ∼80,000,000 VND.

4.1.3 Core Switch

- **Model**: Cisco Catalyst 9500-40X

- **New Technologies**:

  - Supports up to 40 10GbE or 25GbE ports.
  - 256-bit MACsec security.
  - Integrated StackWise Virtual technology.

- **Price**: ∼300,000,000 VND.

4.1.4 Distribution Switch

- **Model**: Cisco Catalyst 9200-48P-E

- **New Technologies**:

  - PoE+ (Power over Ethernet) support.
  - Managed through Cisco DNA Center (AI-driven automation).
  - Layer 3 Routing.

- **Price**: ∼100,000,000 VND.

4.1.5 Access Switch

- **Model**: Aruba 2930F 24G PoE+

- **New Technologies**:

  - QoS for traffic optimization.
  - Static Routing support.
  - PoE+ for network and IoT devices.

- **Price**: ~50,000,000 VND.

4.1.6 Access Point (with Security - Wi-Fi 6E)

- **Model**: Cisco Meraki MR46

- **New Technologies**:

  - Wi-Fi 6E with 6GHz band.
  - WPA3 security and Zero Trust Network Access.
  - Cloud management via Meraki platform.

- **Price**: ~20,000,000 VND.

4.1.7 Fiber Cabling (GPON)

- **Model**: Single-Mode OS2 Fiber Cable

- **New Technologies**:

  - Speeds up to 10Gbps over long distances.
  - EMI (Electromagnetic Interference) resistance.

- **Price**: ~10,000,000 VND/km.

4.1.8 GigaEthernet (Cat 6A or Cat 8)

- **Model**: Ethernet Cable Cat 8

- **New Technologies**:

- Supports speeds up to 40Gbps.
- Optimal length: 30m.

- **Price**: ∼15,000 VND/m.

4.1.9 Patch Panel

- **Model**: Patch Panel 24-Port Cat 6A

- **New Technologies**:

- PoE+ support over Ethernet ports.
- Cross-talk protection.

- **Price**: ∼3,000,000 VND.

4.1.10 SD-WAN Gateway

- **Model**: Cisco vEdge 1000

- **New Technologies**:

- Dynamic routing with SLA prioritization.
- Security integration with SD-WAN.
- Remote management via Cisco vManage.

- **Price**: ∼200,000,000 VND.

4.1.11 PC (Enterprise-Grade)

- **Model**: Dell OptiPlex 5090

- **New Technologies**:

- Intel i7 12th Gen CPU.
- Built-in TPM 2.0 security.
- High-speed NVMe SSD.

- **Price**: ∼30,000,000 VND.

4.1.12 Surveillance Camera

- **Model**: Hikvision DS-2CD2087G2

- **New Technologies**:

  - ColorVu technology for full-color night vision.
  - AI-based motion detection.
  - PoE connectivity.

- **Price**: ~7,000,000 VND.

4.1.13 Sensor (IoT Sensor)

- **Model**: ZigBee Temperature Sensor

- **New Technologies**:

  - ZigBee connectivity for low power consumption.
  - Real-time temperature monitoring

- **Price**: ~1,000,000 VND.

4.1.14 Medical Devices (IoMT)

- **Model**: IoMT ECG Machine

- **New Technologies**:

  - Patient data transmission via Wi-Fi.
  - Integration with HIS systems.

- **Price**: ~200,000,000 VND.

4.2 Server

4.2.1 Application Server

Model: HPE ProLiant DL360 Gen10

Specifications:

- Processor: Dual Intel Xeon Silver 4210R (10 cores, 2.4 GHz)
- RAM: 32 GB DDR4 (upgradable to 3 TB)
- Storage: 2 x 1 TB SSD, RAID 1
- Network: 2 x 10GbE, 4 x 1GbE ports
- Power Supply: Dual 500W redundant power supplies
- Price: ~80,000,000 VND

4.2.2 Database Server

Model: Dell PowerEdge R740

Specifications:

- Processor: Dual Intel Xeon Scalable Gold 6248 (20 cores, 2.5 GHz)
- RAM: 64 GB DDR4 (upgradable to 3 TB)
- Storage: 4 x 1 TB SSD, RAID 10
- Network: 2 x 10GbE ports, 2 x 1GbE ports
- Power Supply: Dual 750W redundant power supplies
- Price: ~120,000,000 VND

4.2.3 VPN and Gateway Server

Model: HPE ProLiant DL380 Gen10 Plus

Specifications:

- Processor: Dual Intel Xeon Gold 6242 (16 cores, 2.8 GHz)
- RAM: 64 GB DDR4 (upgradable to 3 TB)
- Storage: 2 x 500 GB SSD, RAID 1
- Network: 4 x 1GbE, 2 x 10GbE ports
- Power Supply: Dual 800W redundant power supplies
- Price: ~150,000,000 VND

4.2.4 Web Server

Model:

Specifications:

- Processor:
- RAM:
- Storage:
- Network:
- Power Supply:
- Price: ~150,000,000 VND

4.2.5 Monitoring and Security Server

Model: Dell EMC PowerEdge T340

Specifications:

- Processor: Intel Xeon E-2236 (6 cores, 3.4 GHz)
- RAM: 32 GB DDR4 (upgradable to 128 GB)
- Storage: 2 x 2 TB HDD, RAID 1
- Network: 2 x 1GbE ports
- Power Supply: 500W power supply
- Price: ~85,000,000 VND

4.2.6 Surveillance Management Server

Model: HPE ProLiant ML350 Gen10

Specifications:

- Processor: Dual Intel Xeon Silver 4214 (12 cores, 2.2 GHz)
- RAM: 64 GB DDR4 (upgradable to 3 TB)
- Storage: 4 x 1 TB SSD, RAID 10
- Network: 4 x 1GbE ports, 2 x 10GbE ports
- Power Supply: Dual 800W redundant power supplies
- Price: ~130,000,000 VND

4.2.7 Load Balancer Server

Model: F5 BIG-IP i2600

Specifications:

- Processor: Intel Xeon E5-2660 v3 (10 cores, 2.6 GHz)
- RAM: 16 GB DDR4 (upgradable to 32 GB)
- Storage: 2 x 500 GB SSD (RAID 1)
- Network: 2 x 1GbE ports, 2 x 10GbE ports
- Power Supply: Dual 400W power supplies
- Price: ∼200,000,000 VND

4.2.8 Mail and Communication Server

Model: Dell PowerEdge R650

Specifications:

- Processor: Dual Intel Xeon Scalable Silver 4316 (16 cores, 2.1 GHz)
- RAM: 32 GB DDR4 (upgradable to 3 TB)
- Storage: 2 x 1 TB SSD, RAID 1
- Network: 2 x 10GbE ports, 2 x 1GbE ports
- Power Supply: Dual 750W redundant power supplies
- Price: ∼100,000,000 VND

4.2.9 Authentication Server

Model: HPE ProLiant DL20 Gen10

Specifications:

- Processor: Intel Xeon E-2236 (6 cores, 3.4 GHz)
- RAM: 16 GB DDR4 (upgradable to 64 GB)
- Storage: 1 x 500 GB SSD, RAID 1
- Network: 2 x 1GbE ports
- Power Supply: 500W power supply
- Price: ∼60,000,000 VND

4.2.10 DHCP Server

Model: Lenovo ThinkSystem ST250

Specifications:

- Processor: Intel Xeon E-2236 (6 cores, 3.4 GHz)
- RAM: 32 GB DDR4 (upgradable to 64 GB)
- Storage: 2 x 500 GB SSD, RAID 1
- Network: 2 x 1GbE ports
- Power Supply: 350W power supply
- Price: ~65,000,000 VND

Device	**Model**	**Number**	**Price**
Firewall	Fortinet FortiGate 100F	4	150,000,000 VND
Core Switch	Cisco Catalyst 9500-40X	2	300,000,000 VND
Distribution Switch	Cisco Catalyst 9200-48P-E	2	100,000,000 VND
Access Switch	Aruba 2930F 24G PoE+	4	50,000,000 VND
Access Point (with Security - Wi-Fi 6E)	Cisco Meraki MR46	10	20,000,000 VND
Cable: Fiber Cabling (GPON)	Single-Mode OS2 Fiber Cable	10	15,000,000 VND/km
Cable: GigaEthernet (Cat 6A or Cat 8)	Ethernet Cable Cat 8	100	15,000 VND/m
Patch Panel	Patch Panel 24-Port Cat 6A	3	3,000,000 VND
SD-WAN Gateway	Cisco vEdge 1000	3	200,000,000 VND
PC (Enterprise-Grade)	Dell OptiPlex 5090	480	30,000,000 VND
Surveillance Camera	Hikvision DS-2CD2087G2	147	7,000,000 VND
Sensor (IoT Sensor)	ZigBee Temperature Sensor	147	1,000,000 VND
Medical Devices (IoMT)	IoMT ECG Machine	240	200,000,000 VND
Application Server	HPE ProLiant DL360 Gen10	1	80,000,000 VND
Database Server	Dell PowerEdge R740	1	120,000,000 VND

VPN and Gateway Server	HPE ProLiant DL380 Gen10 Plus	3	150,000,000 VND
Web Server	Lenovo ThinkSystem SR250	1	70,000,000 VND
Monitoring and Security Server	Dell EMC PowerEdge T340	1	85,000,000 VND
Surveillance Management Server	HPE ProLiant ML350 Gen10	1	130,000,000 VND
Load Balancer Server	F5 BIG-IP i2600	1	200,000,000 VND
Mail and Communication Server	Dell PowerEdge R650	1	100,000,000 VND
Authentication Server	HPE ProLiant DL20 Gen10	1	60,000,000 VND
DHCP Server	Lenovo ThinkSystem ST250	3	65,000,000 VND
Total Amount			69,126,500,000 VND
Total Amount of Network Device			5,550,500,000 VND

4.3 IP Plan

First, we decide to distribute the building as follow:

- Building 1:

+ Floor 1:

- 12 cameras (1 for each room and 2 for corridors)
- 12 sensors (1 for each room and 2 for corridors)
- 1 Administration Department
- 3 Patient Care rooms
- 6 Clinic Departments

+ Floor 2:

- 12 cameras (1 for each room and 2 for corridors)

- 12 sensors (1 for each room and 2 for corridors)
- 1 Laboratory
- 3 Patient Care rooms
- 6 Clinic Departments
- 1 Access Point

+ Floor 3:

- 12 cameras (1 for each room and 2 for corridors)
- 12 sensors (1 for each room and 2 for corridors)
- 3 Patient Care rooms
- 7 Clinic Departments
- 1 Switch

+ Floor 4:

- 12 cameras (1 for each room and 2 for corridors)
- 12 sensors (1 for each room and 2 for corridors)
- 3 Patient Care rooms
- 7 Clinic Departments
- 1 Access Point

+ Floor 5:

- 12 cameras (1 for each room and 2 for corridors)
- 12 sensors (1 for each room and 2 for corridors)
- 3 Patient Care rooms
- 7 Clinic Departments

+ Functional Room:

- 1 SD-WAN
- 1 external switch
- 1 internal switch
- 3 computers
- 1 camera
- 1 sensor
- 6 internal servers

- 4 external servers

+ Outside:

- 2 access points

- Two auxiliary Site:

+ Floor 1:

- 1 SD-WAN
- 1 switch
- 2 servers
- 1 camera
- 1 sensor
- 3 computers

+ Floor 2:

- 10 rooms
- Each room has 3 computers, 2 sensors, 1 camera
- 1 access point
- 2 sensors in corridor
- 2 cameras in corridor
- 1 switch access

+ Outside:

- 1 access point

- Physical Diagram: Building A and B are the same

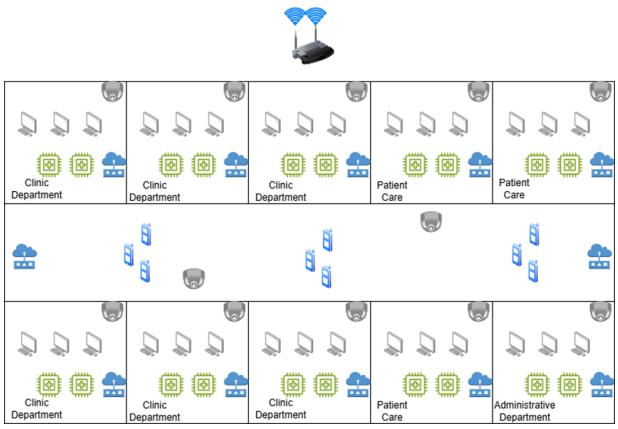

Figure 4: Floor 1

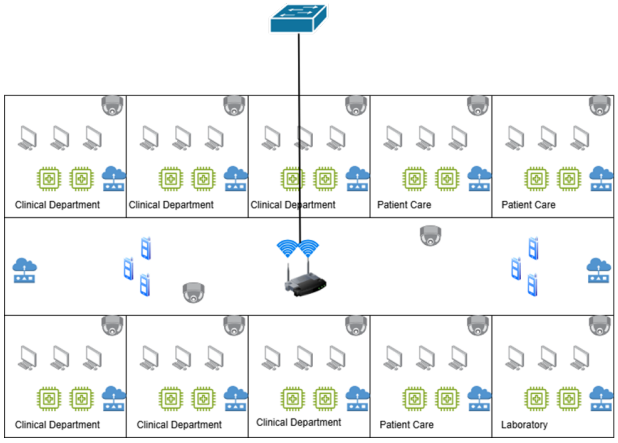

Figure 5: Floor 2

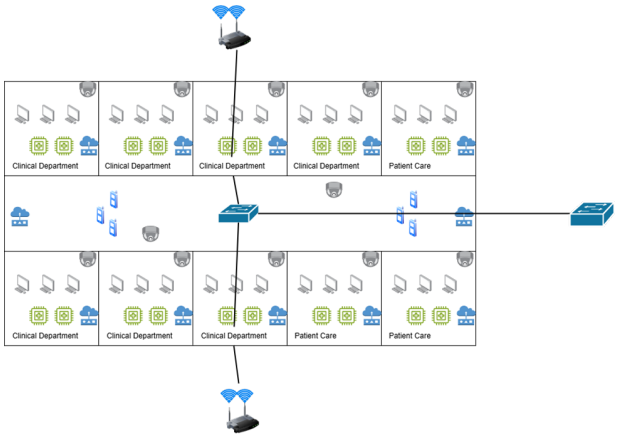

Figure 6: Floor 3

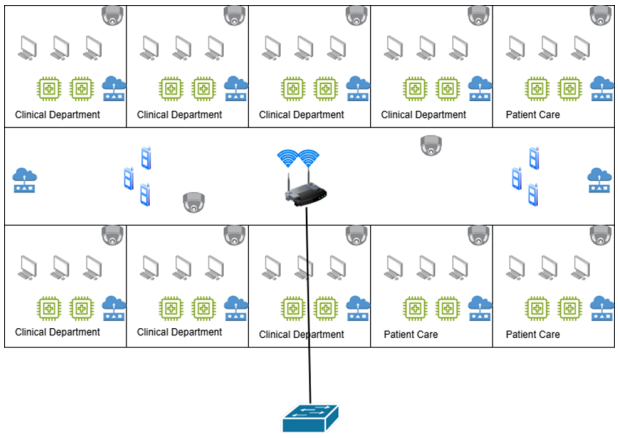

Figure 7: Floor 4

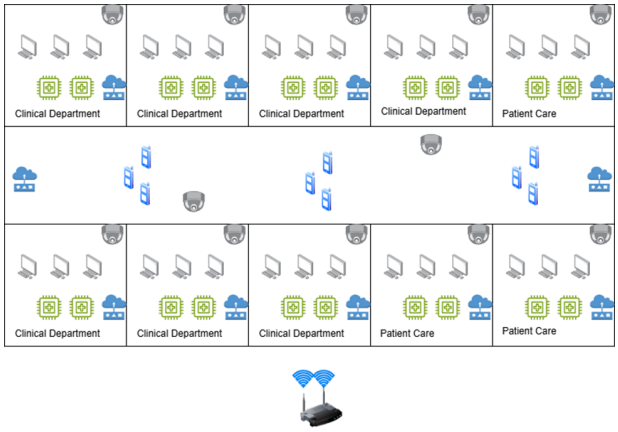

Figure 8: Floor 5

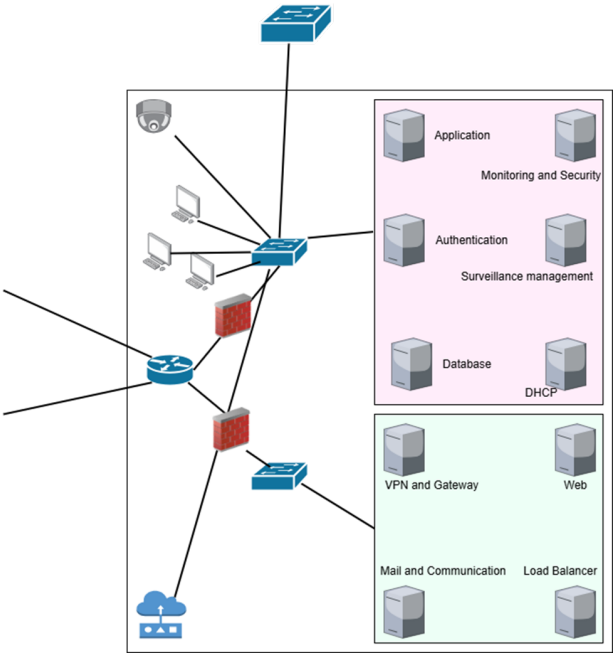

Figure 9: Separate Room

- Two Auxiliary Sites are the same:

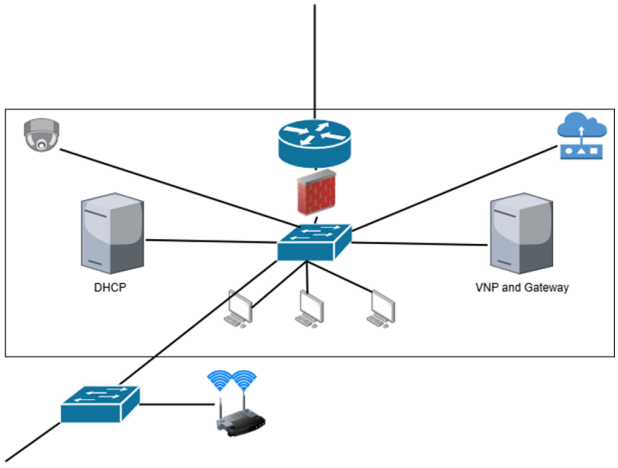

Figure 10: Floor 1

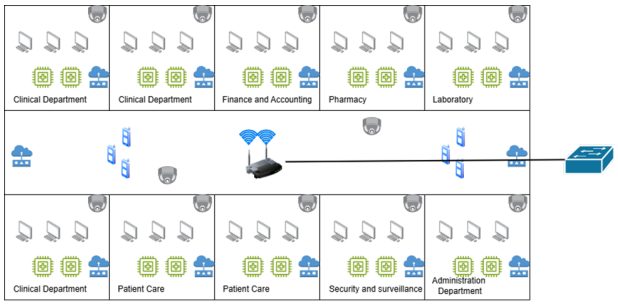

Figure 11: Floor 2

4.4 Physical Diagram for the whole network:

- IP for main site:

Category	Building	VLAN	IP Format
External DMZ Server	Functional Room	VLAN 10	192.168.10.0/24
Internal Services VLAN Server	Functional Room	VLAN 11	192.168.11.0/24
Camera	Functional Room	VLAN 12	192.168.12.0/24
Staff	Functional Room	VLAN 13	192.168.13.0/24
Clinical Department	A and B	VLAN 21	192.168.21.0/24
Access Point	A and B	VLAN 27	192.168.27.0/24
Customer	A and B	VLAN 28	192.168.28.0/24
Laboratory	A	VLAN 22	192.168.22.0/24
Administrator Department	A	VLAN 23	192.168.23.0/24
Patient Care	A	VLAN 24	192.168.24.0/24
Camera	A	VLAN 25	192.168.25.0/24
Sensors	A	VLAN 26	192.168.26.0/24
Pharmacy	B	VLAN 31	192.168.31.0/24
Security and Surveillance	B	VLAN 32	192.168.32.0/24
Finance and Accounting	B	VLAN 33	192.168.33.0/24
Patient Care	B	VLAN 34	192.168.34.0/24
Camera	B	VLAN 36	192.168.36.0/24
Sensors	B	VLAN 37	192.168.37.0/24

Table 24: IP Configuration for Main Site

- IP for DBP Site:

Type of User	VLAN	IP Format
Camera	VLAN 41	192.168.41.0/24
Staff	VLAN 42	192.168.42.0/24
Sensors	VLAN 43	192.168.43.0/24
Access Point	VLAN 44	192.168.44.0/24
Server	VLAN 45	192.168.45.0/24
Customer	VLAN 46	192.168.46.0/24
Clinical Department	VLAN 47	192.168.47.0/24
Laboratory	VLAN 48	192.168.48.0/24
Administrative Department	VLAN 49	192.168.49.0/24
Patient Care	VLAN 50	192.168.50.0/24
Pharmacy	VLAN 51	192.168.51.0/24
Security and Surveillance	VLAN 52	192.168.52.0/24
Finance and Accounting	VLAN 53	192.168.53.0/24

Table 25: IP Configuration for DBP Site

- IP for BHTQ Site:

Type of User	VLAN	IP Format
Camera	VLAN 60	192.168.60.0/24
Staff	VLAN 61	192.168.61.0/24
Sensors	VLAN 62	192.168.62.0/24
Access Point	VLAN 63	192.168.63.0/24
Server	VLAN 64	192.168.64.0/24
Customer	VLAN 65	192.168.65.0/24
Clinical Department	VLAN 66	192.168.66.0/24
Laboratory	VLAN 67	192.168.67.0/24
Administrative Department	VLAN 68	192.168.68.0/24
Patient Care	VLAN 69	192.168.69.0/24
Pharmacy	VLAN 70	192.168.70.0/24
Security and Surveillance	VLAN 71	192.168.71.0/24
Finance and Accounting	VLAN 72	192.168.72.0/24

Table 26: IP Configuration for BHTQ Site

Use the first IP for the Gateway Ex: 192.168.xx.1

Gateway between sites:

Site	IP for Main ↔ DBP	IP for Main ↔ BHTQ	Default Gateway to Internet
Main Site	10.0.0.1 (Main ↔ DBP)	10.0.0.5 (Main ↔ BHTQ)	203.0.113.1 (ISP 1), 203.0.113.2 (ISP 2)
DBP Site	10.0.0.2 (DBP ↔ Main)	10.0.0.5 (DBP ↔ Main)	10.0.0.1 (or 10.0.0.5 from Main Site)
BHTQ Site	10.0.0.5 (BHTQ ↔ Main)	10.0.0.6 (BHTQ ↔ Main)	10.0.0.5 (or 10.0.0.1 from Main Site)

Table 27: IP Configuration Between Sites

SD-WAN connection:

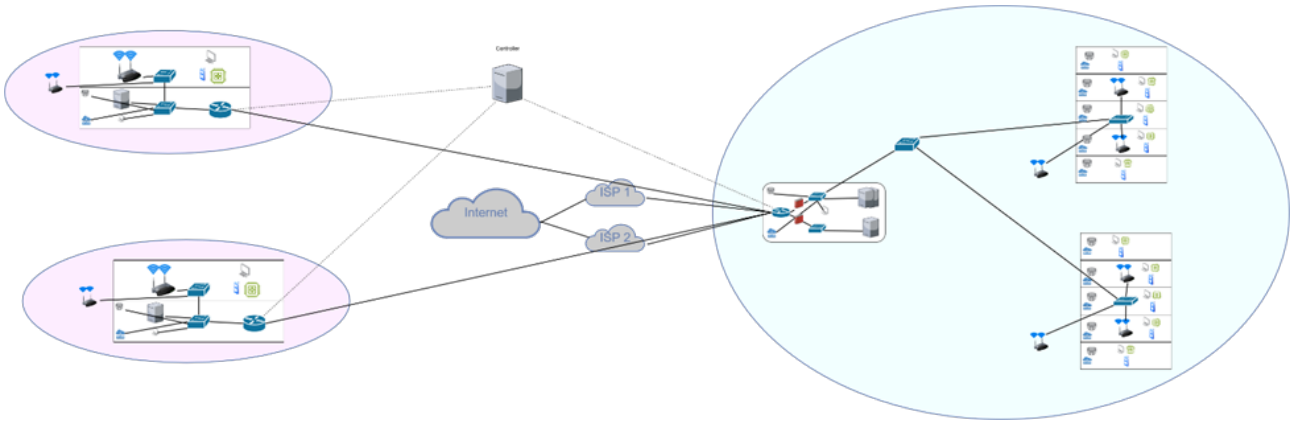

Figure 12: SD-WAN Connection

5 Calculate the required throughput, and expected bandwidth from ISP, then suggest the configuration for the hospital network

Required throughput:

- Main Site:

+ Server:

- Throughput for download: $\frac{1000 * 8}{86400} = 0.0926$ Mbps
- Throughput for upload: $\frac{2000 * 8}{86400} = 0.1852$ Mbps

+ Workstation:

- Throughput for download: $\frac{600 * 500 * 8}{86400} = 27.7778$ Mbps
- Throughput for upload: $\frac{600 * 100 * 8}{86400} = 5.5556$ Mbps

+ Wi-fi:

- Throughput for download: $\frac{500 * 8}{86400} = 0.0463$ Mbps

+ Total:

- Download: $0.0926 + 27.7778 + 0.0463 = 27.9167$ Mbps
- Upload: $0.1852 + 5.5556 = 5.7412$ Mbps

+ At peak:

- Download: 27.9167*0.8 = 22.3334 Mbps
- Upload: 5.7412*0.8 = 4.5929 Mbps

- Auxiliary Site:

+ Server:

- Throughput for download: $\frac{1000 * 8}{86400} = 0.0926$ Mbps
- Throughput for upload: $\frac{2000 * 8}{86400} = 0.1852$ Mbps

+ Workstation:

- Throughput for download: $\frac{60 * 500 * 8}{86400} = 2.77778$ Mbps
- Throughput for upload: $\frac{60 * 100 * 8}{86400} = 0.55556$ Mbps

+ Wi-fi:

- Throughput for download: $\frac{500 * 8}{86400} = 0.0463$ Mbps

+ Total:

- Download: $0.0926 + 2.7778 + 0.0463 = 2.9167$ Mbps
- Upload: $0.1852 + 0.5556 = 0.7408$ Mbps

+ At peak:

- Download: 2.9167*0.8 = 2.3334 Mbps
- Upload: 0.7408*0.8 = 0.5926 Mbps

All network:

Total throughput all sites:

- Upload = 5.7412 + 6.7408*2 = 7.2228 Mbps
- Download = 27.9167 + 2.9167*2 = 39.7501 Mbps

Expected bandwidth:

- Upload = 7.2228 * 1.2 = 8.6674 Mbps
- Download = 33.7501 * 1.2 = 40.5001 Mbps

Configuration for hospital network:

- Security: Firewall, VPN, IDS/IPS
- Management: Monitoring
- WAN and Internet: Load balancing
- Redundancy and high availability: HA configuration

6 Design the network map using Packet Tracer or GNS3 simulation software

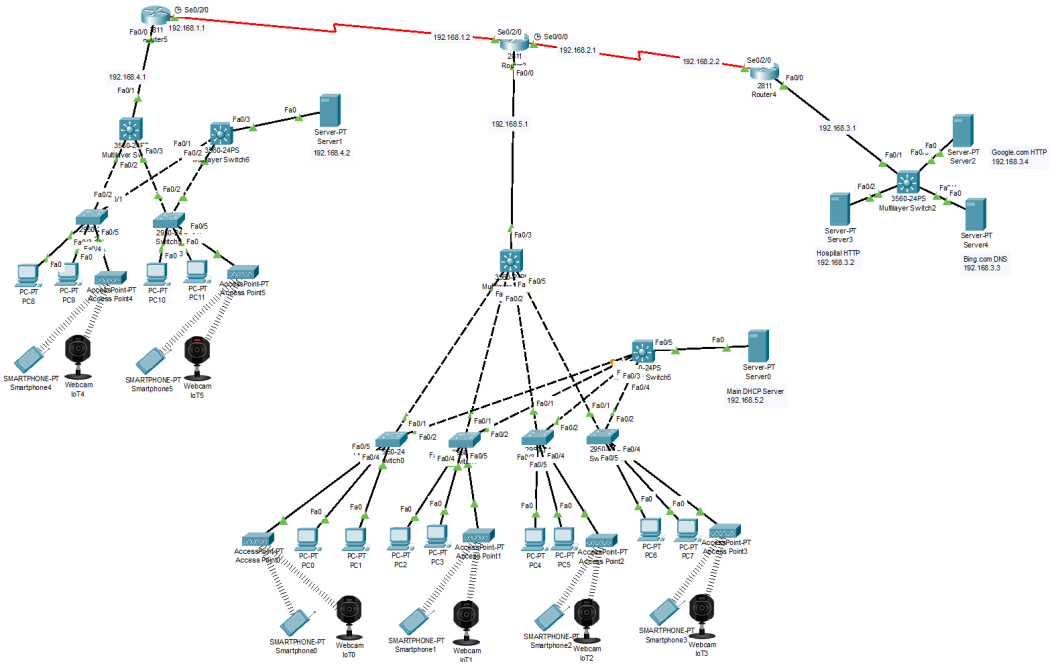

Figure 13: Network Map

7 Test the system with popular tools such as ping, traceroute, etc. on the simulated system

In this assignment, we will use ping to test the system:

Connect between PCs in the same VLAN:

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 192.168.5.14

Pinging 192.168.5.14 with 32 bytes of data:

Reply from 192.168.5.14: bytes=32 time<1ms TTL=128
Reply from 192.168.5.14: bytes=32 time<1ms TTL=128
Reply from 192.168.5.14: bytes=32 time<1ms TTL=128
Reply from 192.168.5.14: bytes=32 time=2ms TTL=128

Ping statistics for 192.168.5.14:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 2ms, Average = 0ms
```

Connect PCs between VLANs:

```
C:\>ping 192.168.5.16

Pinging 192.168.5.16 with 32 bytes of data:

Reply from 192.168.5.16: bytes=32 time<1ms TTL=128
Reply from 192.168.5.16: bytes=32 time<1ms TTL=128
Reply from 192.168.5.16: bytes=32 time<1ms TTL=128
Reply from 192.168.5.16: bytes=32 time<1ms TTL=128

Ping statistics for 192.168.5.16:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

8 Re-evaluate the designed network system through the following features: reliability, ease of upgrade, diverse support software, safety, network security, etc.

8.1 Reliability

- Evaluate the system's fault tolerance by simulating network failures (e.g., server downtime, router failure).
- Ensure that load-balancing mechanisms effectively distribute traffic to prevent single points of failure.

8.2 Ease of Upgrade

- Assess whether the current architecture supports modular upgrades (e.g., adding new VLANs, servers, or auxiliary sites).
- Verify the use of scalable technologies like SD-WAN for WAN connectivity and GPON for high-speed communication.

8.3 Diverse Support Software

- Confirm that the system can support both licensed and open-source software (HIS, RIS-PACS, CRM, etc.) seamlessly.

- Check interoperability between client-server and database systems across the main and auxiliary sites.

8.4 Safety and Security

- Review and test VLAN partitioning, DMZ isolation, and access control lists (ACLs).
- Ensure VPNs for site-to-site and teleworker connections are correctly configured and encrypted.

8.5 Remaining Issues

- Network Congestion: High traffic during peak hours may cause delays. Load balancers and traffic prioritization need further optimization.
- Cisco devices are of high quality but the price is quite high compared to the market.
- The system is built on assumptions so it may not be accurate with reality.

8.6 Future Development Directions

- Can replace devices that do not play a major role in the system with cheaper devices if the cost is too high.
- Need to adjust the system to be accurate with reality through testing.
- Advanced Security: Can configure additional security methods to increase the security of the system, especially develop a firewall to prevent attack from outside.

9 Conclusion

The proposed network design demonstrates an effective solution for addressing the IT and communication needs of the critical hospital facility. By integrating advanced technologies and adhering to best practices for network security and scalability, the system ensures seamless connectivity between sites, reliable access to essential software, and support for high-demand workloads. Through simulations and testing, we validated the network's performance, robustness, and adaptability for future expansion. The design not only meets the current operational requirements but also positions the hospital for technological advancements, ensuring a secure and efficient environment for patient care and administrative operations.

10 References

1.