VIETNAM NATIONAL UNIVERSITY
HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY
Faculty of Computer Science and Engineering

Computer Network (CO3093)

NETWORK DESIGN AND SIMULATION FOR A CRITICAL LARGE COMPANY

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Contents

1 FIND OUT SUITABLE NETWORK STRUCTURES FOR BUILDINGS

1.1 Analyze the network system requirements of Headquarters and Branches

1.1.1 Functional requirements

- Provide connectivity for 120 workstations, 12 or more networking devices and 5 servers of 7 floors within the Headquarters.
- Provide connectivity for 30 workstations, 5 or more networking devices and 3 servers of 2 floors within the Branches.
- WAN connectivity to two Branches using leased lines (e.g., SD-WAN, MPLS).
- Internet access through xDSL with load balancing.
- Wired infrastructure using GPON and GigaEthernet (1GbE/10GbE).
- Wireless network to support internal staff and customer devices.
- Separates servers for software updates, web access, and database access, etc.
- Implement firewalls, intrusion detection/prevention systems (IPS/IDS), and phishing detection mechanisms.
- Site-to-site VPN configuration for secure branch connections.
- A surveillance camera system for monitoring all floors of the Headquarters and the Branches.
- Support for both licensed and open-source software.
- High security, high availability, robustness when problems occur, ease of upgrading.

1.1.2 Non-functional requirements

- The total download estimation is about 1000 MB/day and the upload estimate is 2000 MB/day as for servers.
- The total download estimation is about 500 MB/day and the upload estimate is 100 MB/day as for each workstation.
- The total download estimation is about 500 MB/day as for wifi-connected devices.
- Deal with a growth rate of 20% in 5 years.

1.2 Checklist to be surveyed at the installation locations

1.2.1 General Site Information

- Location accessibility (ease of transportation for equipment)
- Availability of IT rooms and Cabling Central Local (dimensions, access points)
- Power supply availability and backup
- Safety measures in place (e.g., fire extinguishers, secure rooms)

1.2.2 Physical Infrastructure

- Existing cabling infrastructure (fiber-optic, copper)
- Length and type of cables needed for wired connections
- Locations for patch panels and cable ducts
- Space for additional cable installations
- Availability of power sockets for workstations, servers, and networking devices
- Adequate racks for networking devices and servers
- Temperature, humidity, ventilation and air conditioning systems.

1.2.3 Networking Infrastructure

- Number and location of workstations
- Wi-Fi coverage for employees and customers
- Existing GPON or GigaEthernet cabling infrastructure
- Router/switch placement for effective cable management
- Backup internet connection points for load balancing

1.2.4 Security Systems

- Placement of firewalls, IPS/IDS, and other security devices
- Site-to-site VPN setup locations (Headquarters and Branches)
- Teleworker VPN access configuration (remote users)
- Locations for surveillance cameras (inside and outside the building)

1.2.5 Internet and Bandwidth

- Current internet service providers (ISPs) at each location
- Available bandwidth for xDSL and leased lines
- Peak-hour traffic estimation for internet usage
- Load-balancing requirements between multiple ISPs

1.2.6 Surveillance System

- Coverage area for cameras (entrances, workspaces, server rooms)
- Location for central monitoring system

1.2.7 Maintenance and Support

- Access to maintenance areas for networking equipment
- Local technical support availability

1.3 Areas with high load (network load) and selected appropriate device configuration

- Primary IT room at the Headquarters: This is the central hub for networking equipment, including servers, routers, and switches. All internal and external network traffic converges here. Therefore, a load balancer needs to be placed here.
- WAN links: During peak hours, WAN traffic from customer transactions and inter-branch communication causes load surges. A load balancer should be placed here as well.
- WiFi networks at Headquarters and Branches: Wireless traffic competes with internal wired traffic, increasing the overall load during peak hours. We can deploy access points with bandwidth management here.

1.4 Network structure that matches the building's architecture with convenience and aesthetics

1.4.1 Headquarters

Since the installation locations are buildings with many vertical floors, it is better to put a single "brain" on one floor for ease of management aesthetics of other floors. (1) Disaster-recovery is also easier, and this would be the highest floor, 7th floor.

Star Topology is applied between the floors. In detail, the servers and core networking devices of a branch are put at the 7th floor, each floor contains one switch to distribute the network to hosts, and there will be a central multilayer switch that connects all switches from floors.

7th Floor - Equipment: Houses core network and server infrastructure for centralized management.

- UPS (Uninterruptible power supply) and backup power generators.
- Multilayer switch.
- Load balancer for WAN and internet links.
- Fiber cabling patch panels and connections for GPON.
- 1 multilayer switch (core switch for VLAN routing and inter-floor communication).
- 1 router for WAN connection.
- Firewall (hardware or appliance-based, integrated with IPS/IDS).
- VPN Gateway for site-to-site VPN.

6th Floor - Surveillance and Management: Dedicated to top-level management and security monitoring.

- 10 workstations for executives
- 1 surveillance system server
- Screens for live CCTV feed monitoring (connected to surveillance server).
- 1 switch for floor-level connectivity.

5th Floor - Finance and Accounting: Department for financial operations.

- 15 workstations for finance and accounting staffs.
- 1 switch for floor-level connectivity.

4th Floor - Marketing and Sales: Handles client-facing roles, multimedia content creation, and sales operations.

- 15 workstations for employees.
- 1 switch for floor-level connectivity.

3rd Floor - Customer Service and Operations: Manages day-to-day banking operations and customer interaction.

- 15 workstations for customer service representatives.
- 1 switch for floor-level connectivity.

2nd Floor - Lobby: Entry point for visitors and customers.

- 20 workstations for employee.
- 30 PCs with internet access for customers.
- 1 WiFi access point for customers.
- Information kiosk with internet access.
- Surveillance cameras covering entry points and lobby.

1st Floor - IT room: Space for IT support and development teams to monitor and maintain systems.

- 5 servers (Database, Application, File, Web, and Backup).
- 15 workstations for IT staffs.
- 1 switch for floor-level connectivity.
- Cabling central local with patch panels for organizing fiber and Ethernet connections.

1.4.2 Branches

Designing the network for the branches (Da Nang and Ha Noi) should focus on simplicity, cost-efficiency, and integration with the headquarters. Each branch has fewer users and devices but must maintain secure and reliable connectivity to the headquarters via a WAN link (e.g., SD-WAN or MPLS). Here is our plan:

1st Floor - IT room: Space for IT support and development teams to monitor and maintain systems.

- 3 servers for internal uses.
- 5 workstations for IT personnel.
- 1 switch for floor-level connectivity.
- 1 routers with the leased DSL line.
- Cabling central local with patch panels for organizing fiber and Ethernet connections.

2nd Floor - Lobby and Customer services: Dedicated to customer-facing activities and general branch operations.

- 25 workstations for IT personnel.
- 1 switch for floor-level connectivity.
- 1 routers with the leased DSL line.
- Wireless access points for customers.
- Surveillance cameras for monitoring customer activity and security.

1.5 Network Design

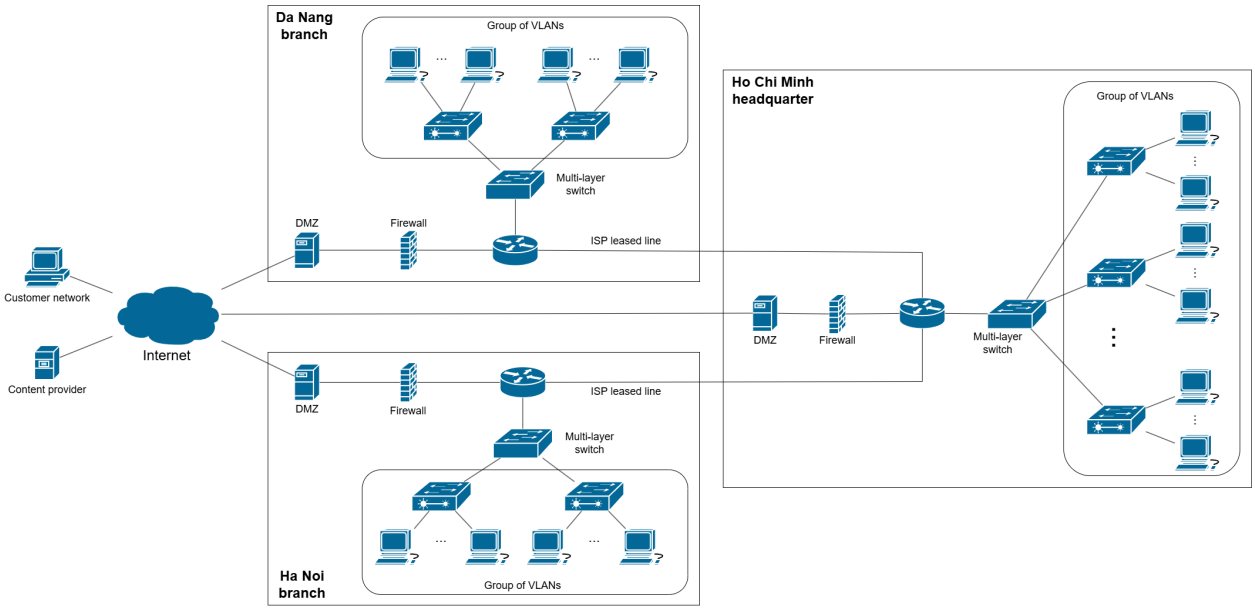

Figure 1: Network usage in a wireless environment

- Each branch is connected to the headquarters using ISP-leased lines for dedicated communication.
- DMZs are set up at each location to host public-facing services while isolating them from internal networks.
- Firewalls are placed at every location to provide network security and regulate traffic between the internal network, DMZ, and the internet.
- Customer networks and content providers communicate with the network through the internet, with appropriate security controls in place.

2 LIST OF MINIMUM EQUIPMENT, IP PLAN AND WIRING DIAGRAM (CABLING)

2.1 List of recommended equipment and typical specifications

Device name	Technical specifications	Amount	Cost
Cisco 4321 Integrated Services Router	Product Code: Cisco ISR4321/K9 Total throughput: 50 Mb/s-100 Mb/s Total number of on-board 10/100/1000 WAN or LAN ports: 2 Network Interface Module (NIM) slots: 2 Power Supply Options: External - AC and PoE Rack Height: 1U Dimensions (H x W x D): 44.55 x 369.57 x 294.64 mm Package Weight: 9.19 Kg	03	$3,482
Cisco WS-C2960-24TT-L Switch	Product Code: Cisco WS-C2960-24TT-L Ports: 24 Ethernet 10/100 ports Uplinks: 2 Ethernet 10/100/1000 ports VLAN IDs: 4000 Dimensions (H x W x D): 4.4 x 44.5 x 23.6 cm Weight: 3.6 kg Rack Height: 1 RU	13	$2,869
Cisco ASA5505-BUN-k9 Firewall	Firewall Users: 10 Maximum firewall throughput (Mbps): 150 Maximum connections: 10,000 Maximum connections/second: 3,000 Packets per second (64 byte): 85,000 Integrated ports: 8 port 10/100 switch with 2 Power over Ethernet ports Maximum virtual interfaces (VLANs): 3 (trunking disabled)	02	$1,078
Linksys Cloud Managed AX3600 WiFi 6 Indoor Wireless Access Point	Dual-Band 802.11AX (2.4GHz + 5GHz) 4x4:4 Internal Antennas for AX3600 Speeds (1200Mbps + 2400Mbps) UL/DL OFDMA, 1024-QAM, Target Wake Time BSS Coloring, Tx Beamforming 802.3at PoE+ Support Limited Lifetime Cloud Management TAA Compliant	10	$1,000
ANNKE 8CH H.265+ 3K Lite Surveillance Security Camera System	AI Human/Vehicle Detection 4 x 1920TVL 2MP Wired CCTV IP66 Cameras for Indoor Outdoor Use Remote Access 1TB Hard Drive Included		
Optical fiber cable & Copper cable supporting GigabitEthernet			
Optical fiber cable & Copper cable supporting FastEthernet			
Servers & Workstations	Selected by the bank.		

Table 1: Device List and Specifications

2.2 Schematic physical setup of the network

We have the headquarter locating in Ho Chi Minh city, and 2 other branches locating in Ha Noi and Da Nang. Google and Facebook service provider are assigned to be in USA.

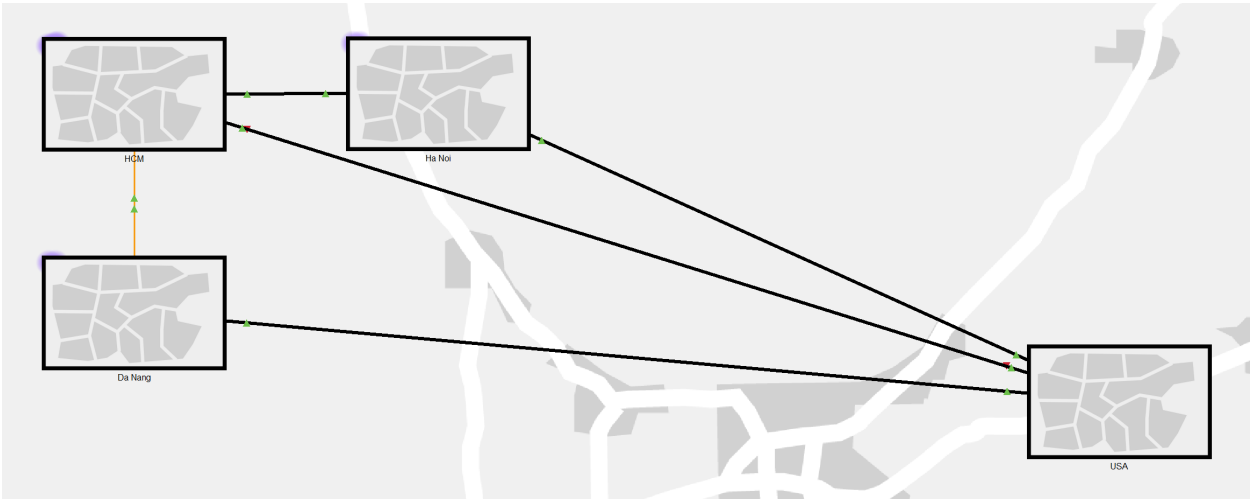

Figure 2: Physical map

Within the headquarter, there are seven floors in total, and the server room is located on the first floor.

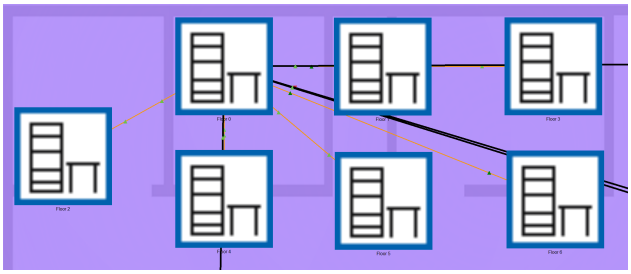

Figure 3: Internal structure of the headquarter building

Within each branch, there are 2 floors.

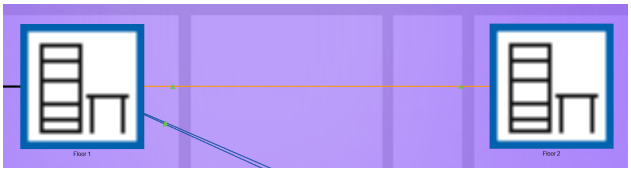

Figure 4: Internal structure of a branch building

Apart from the server room of each building, every floor shares the same set up with PCs, an access point for wifi, a surveillance camera and a switch for floor-level connectivity.

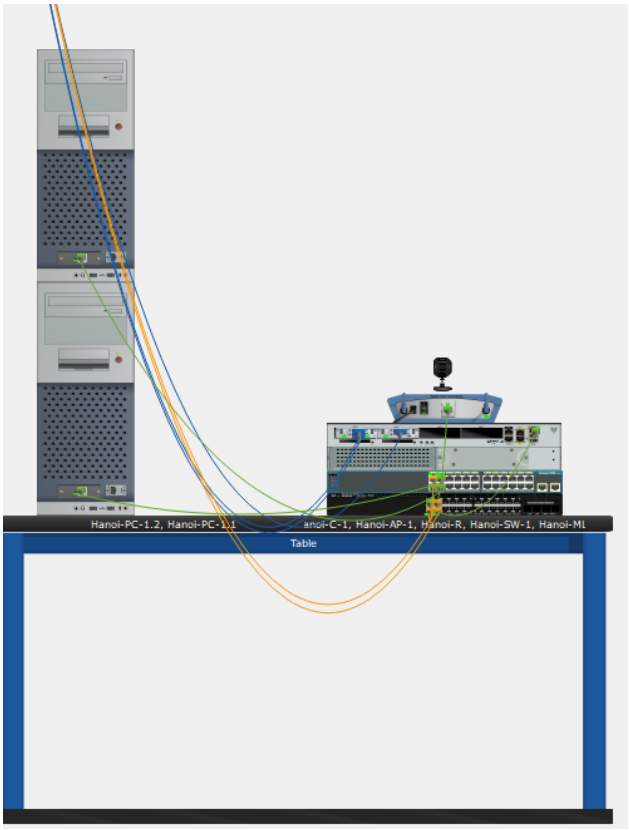

Figure 5: Physical setup of a normal floor

Figure 6: Server room of the headquarter

The server room of each building basically comprises all of that building's server machines, together with a switch for floor-level connectivity.

2.3 WAN connection diagram between Headquarters and Branches ((using new WAN technology such as SD-WAN, MPLS and OSPF routing protocol)

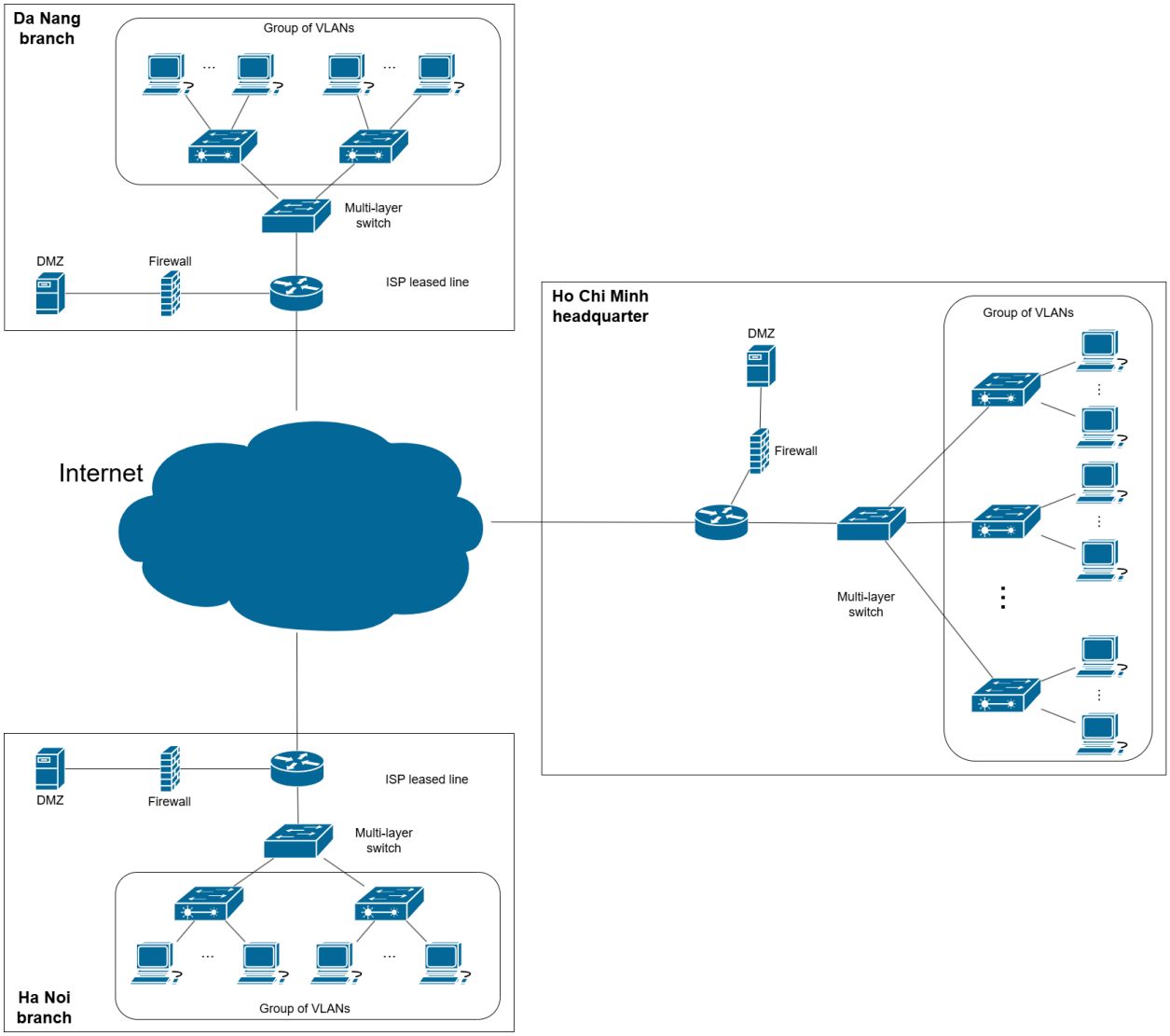

Figure 7: WAN connection diagram between Headquarters and Branches

3 Calculation and Suggestion

3.1 Calculate the required throughput, and expected bandwidth from ISP

3.1.1 Summary

The throughput of the headquarter is certainly higher than that of the branches. Therefore, we will calculate for our line based on the highest one, which is based on the headquarter. As for the headquarter, we have:

- Number of servers: $N_s = 5$
- Number of workstations: $N_w = 120$
- Server download: $D_s = 1000\,\text{MB/day}$
- Server upload: $U_s = 2000\,\text{MB/day}$
- Workstation download: $D_w = 500\,\text{MB/day}$
- Workstation upload: $U_w = 100\,\text{MB/day}$
- WiFi-connected devices total download: $\text{Data}_{wifi} = 500\,\text{MB/day}$
- Peak hours: 3 hours/day
- Network peak usage rate: 80%
- Growth rate: 20% increase in 5 years

3.1.2 Calculations

Total download:

$$N_s \cdot D_s + N_w \cdot D_w + \text{Data}_{wifi} = 5 \cdot 1000 + 120 \cdot 500 + 500 = 5000 + 60000 + 500 = 65500\,\text{MB/day}$$

Total upload:

$$N_s \cdot U_s + N_w \cdot U_w = 5 \cdot 2000 + 120 \cdot 100 = 10000 + 12000 = 22000\,\text{MB/day}$$

We have $1\,\text{MB} = 8\,\text{Mb}$ and $24 \cdot 3600 = 86400\,\text{seconds/day}$. Therefore:

$$\text{Average download throughput} = \frac{\text{Total download} \cdot 8}{86400} = \frac{65500 \cdot 8}{86400} \approx 6.06\,\text{Mbps}$$

$$\text{Average upload throughput} = \frac{\text{Total upload} \cdot 8}{86400} = \frac{22000 \cdot 8}{86400} \approx 2.04\,\text{Mbps}$$

During peak hours (80% usage over 3 hours), the peak throughput increases by:

$$\text{Peak factor} = \frac{24}{3} \cdot 0.8 = 6.4$$

Peak download throughput:

$$\text{Average download throughput} \cdot 6.4 = 6.06 \cdot 6.4 \approx 38.78\,\text{Mbps}$$

Peak upload throughput:

$$\text{Average upload throughput} \cdot 6.4 = 2.04 \cdot 6.4 \approx 13.06\,\text{Mbps}$$

Growth rate is 20% over 5 years. Therefore:

$$\text{Expected peak download throughput} = 38.78 \cdot 1.2 \approx 46.54\,\text{Mbps}$$

$$\text{Expected peak upload throughput} = 13.06 \cdot 1.2 \approx 15.67\,\text{Mbps}$$

The ISP must provide sufficient bandwidth for both download and upload during peak usage, thus total bandwidth required is:

$$\text{Expected peak download throughput} + \text{Expected peak upload throughput}$$
$$= 46.54 + 15.67 \approx 62.21\,\text{Mbps}$$

3.2 Suggested configuration for the company network

From the expected bandwidth, the ISP lease line from each branch should be 70 Mbps, which scales well for at least 5 years.

4 NETWORK DESIGN

4.1 Subnetting and IP addressing

4.1.1 Ho Chi Minh - Headquarter

Floor	VLAN	Network address	Subnet mask	Number of devices	Broadcast address
1	10	192.168.100.0	255.255.255.192/26	60	192.168.100.63
2	20	192.168.100.64	255.255.255.192/26	60	192.168.100.127
3	30	192.168.100.128	255.255.255.192/26	60	192.168.100.191
4	40	192.168.100.192	255.255.255.192/26	60	192.168.100.255
5	50	192.168.101.1	255.255.255.192/26	60	192.168.101.63
6	60	192.168.101.64	255.255.255.192/26	60	192.168.101.127
Server Room	70	192.168.102.64	255.255.255.192/28	14	192.168.102.79

Table 2: Headquarter's network configuration schema

4.1.2 Ha Noi - Branch

Floor	VLAN	Network address	Subnet mask	Number of devices	Broadcast address
1	80	192.168.101.128	255.255.255.192/27	28	192.168.100.159
2	90	192.168.101.160	255.255.255.192/27	28	192.168.100.191
Server Room	120	192.168.102.0	255.255.255.192/28	14	192.168.102.15

Table 3: Branch's network configuration schema

4.1.3 Da Nang - Headquarter

Floor	VLAN	Network address	Subnet mask	Number of devices	Broadcast address
1	10	192.168.101.192	255.255.255.192/27	60	192.168.101.223
2	20	192.168.101.224	255.255.255.192/27	60	192.168.101.255
Server Room	70	192.168.102.32	255.255.255.192/28	14	192.168.102.47

Table 4: Branch's network configuration schema

4.1.4 Internet and External Connection

Between	Network address	Subnet mask	Number of devices
Ho Chi Minh - Google	195.136.17.0	255.255.255.192/30	2
Ho Chi Minh - Google	195.136.17.4	255.255.255.192/30	2
Ha Noi - Google	195.136.17.8	255.255.255.192/30	2
Ha Noi - Google	195.136.17.12	255.255.255.192/30	2
Da Nang - Google	195.136.17.16	255.255.255.192/30	2
Da Nang - Google	195.136.17.20	255.255.255.192/30	2

Table 5: Internet configuration schema

4.2 Network Design

4.2.1 Overall Structure

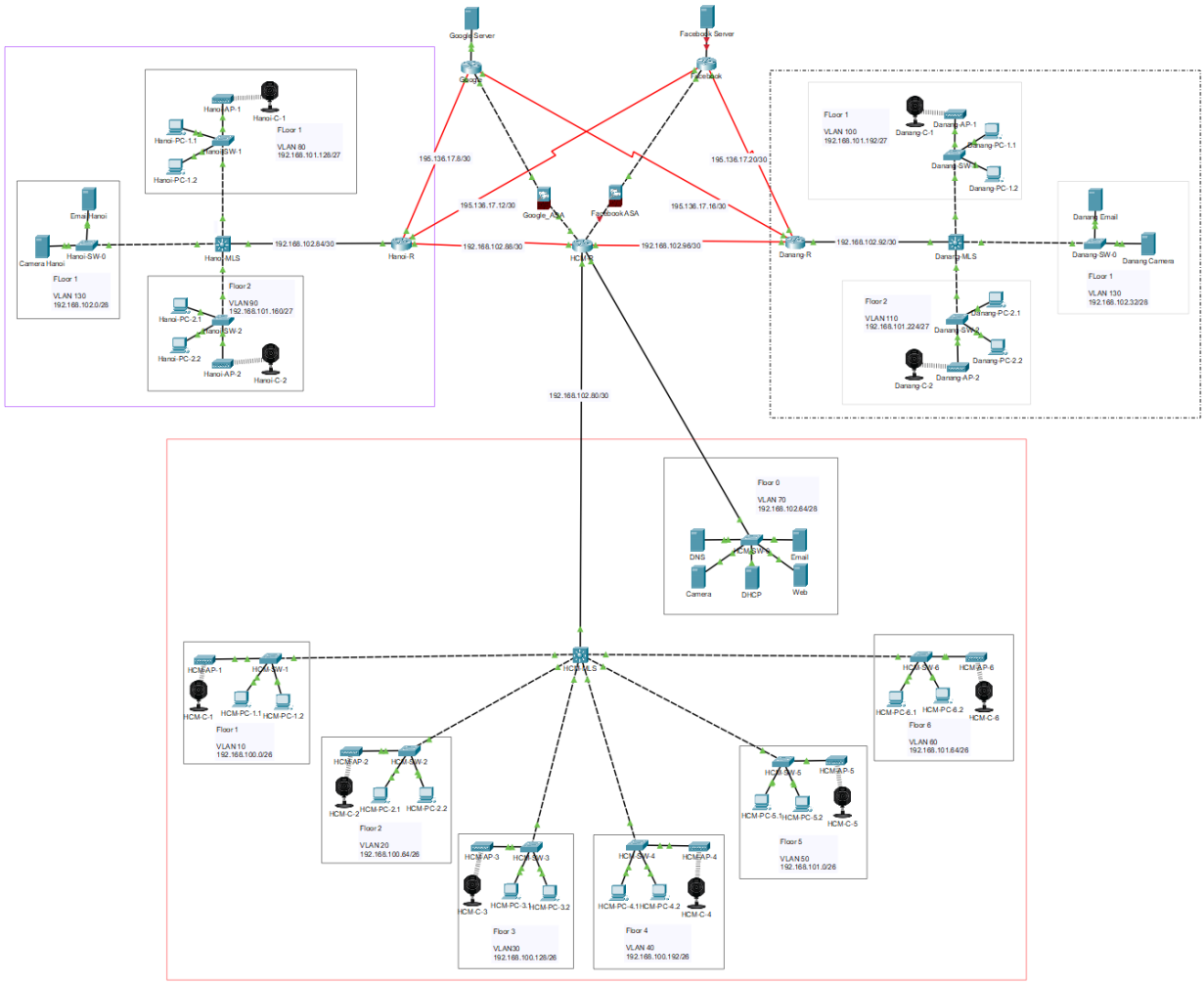

Figure 8: Overall design

4.2.2 Headquarter - Ho Chi Minh

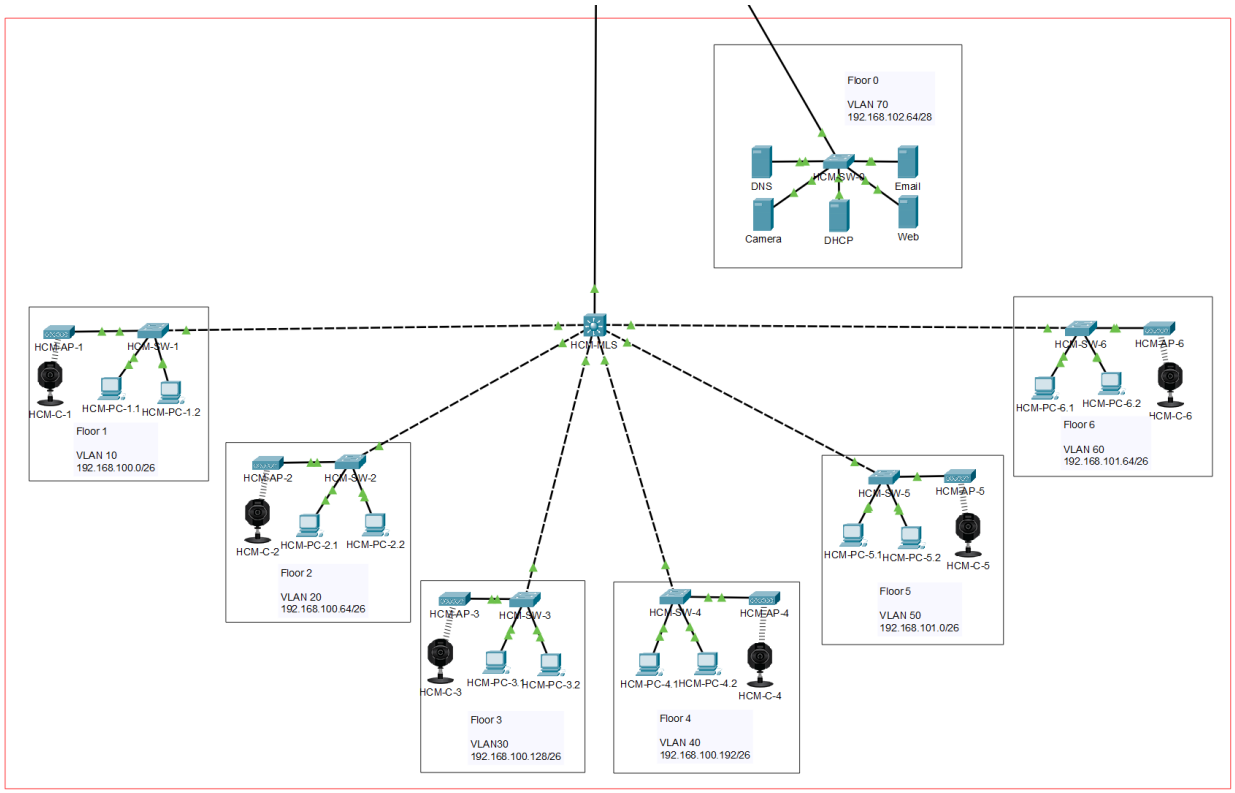

Figure 9: Headquarter internal network

4.2.3 Branch - Ha Noi

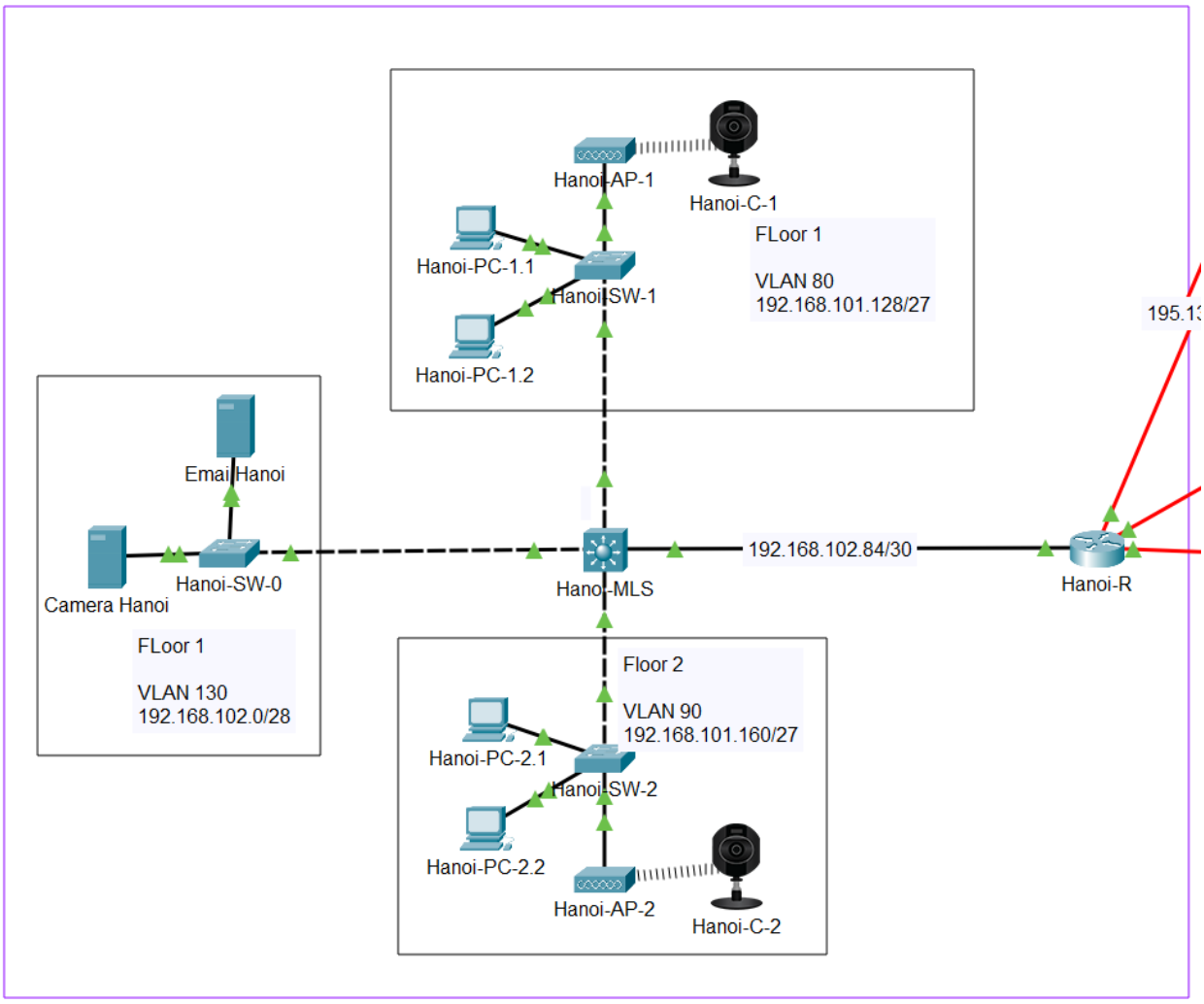

Figure 10: Ha Noi's branch internal network

4.2.4 Branch - Da Nang

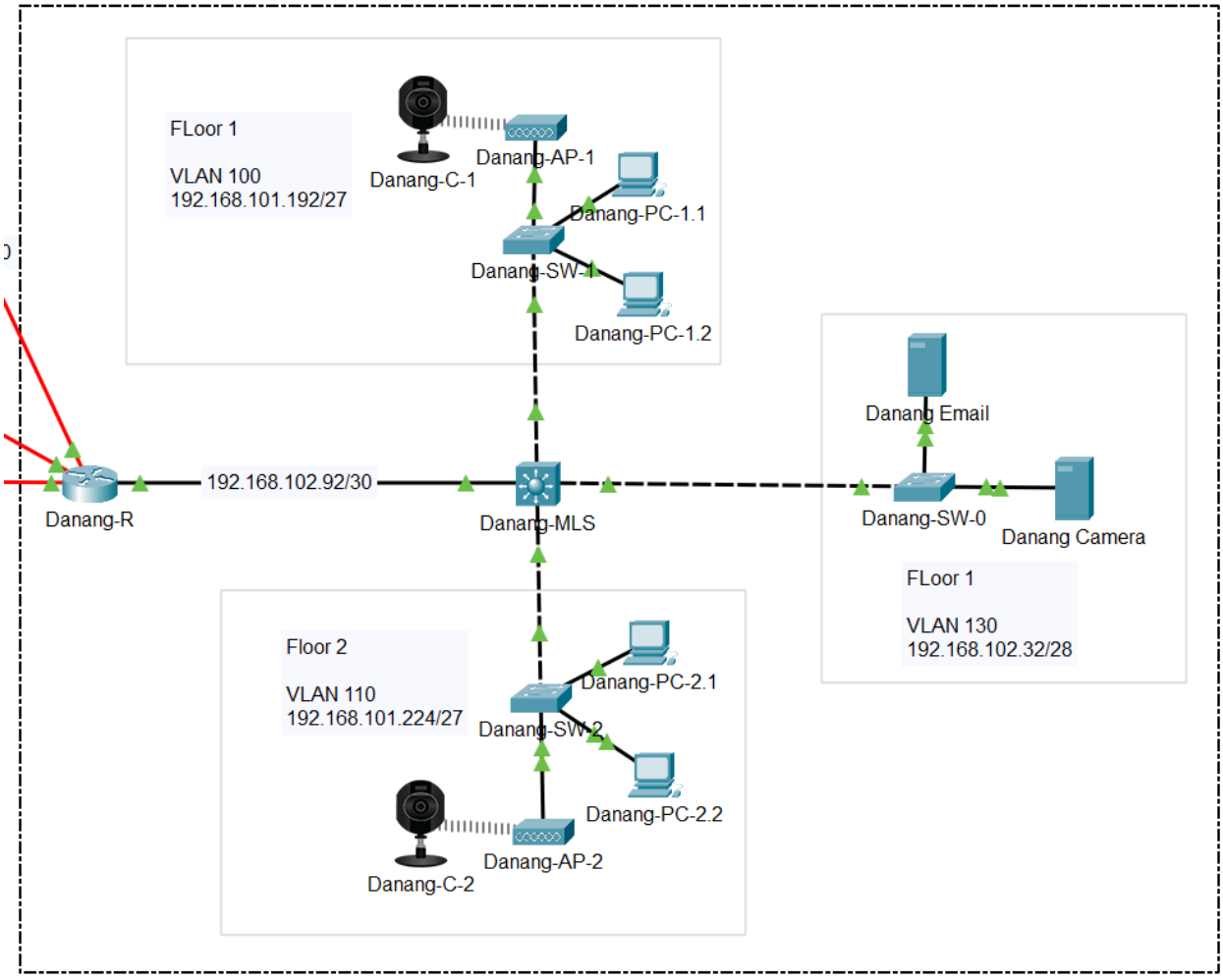

Figure 11: Da Nang's branch internal network

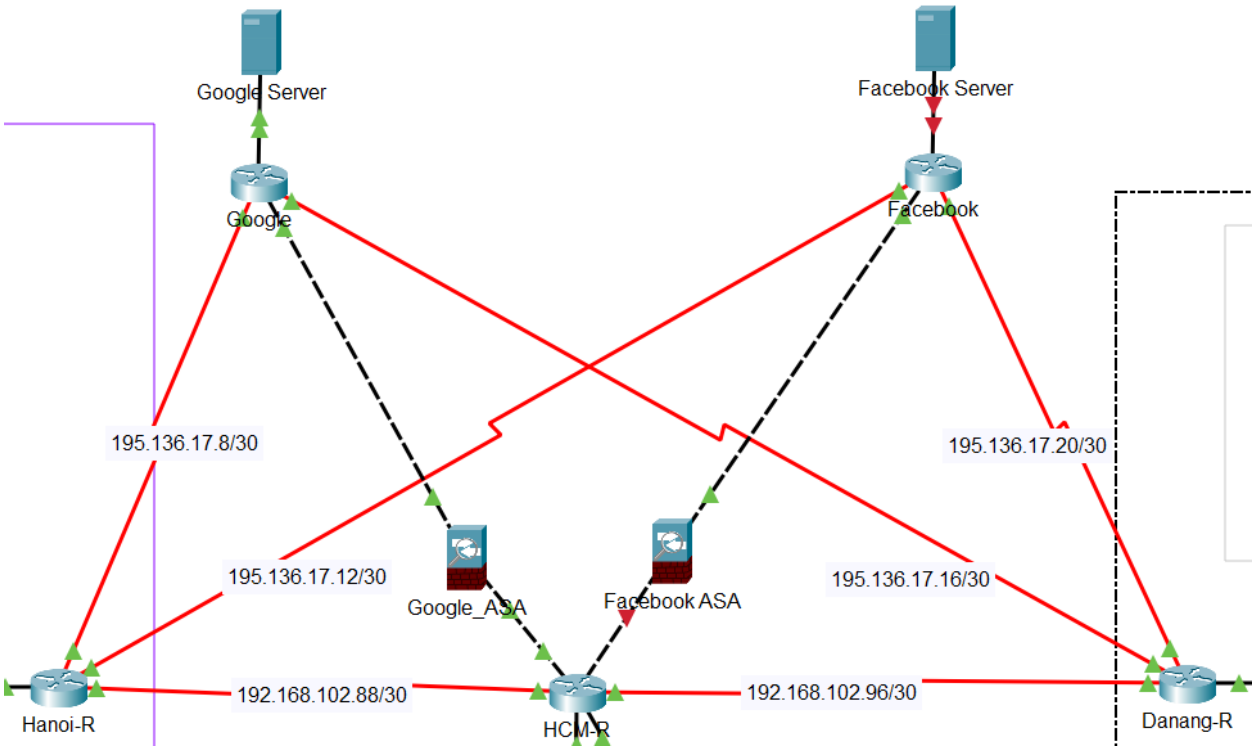

Figure 12: Google and Facebook ISP

4.2.5 Internet Service Provider

5 CONNECTION TESTING

5.1 Between devices within a same floor (VLAN)

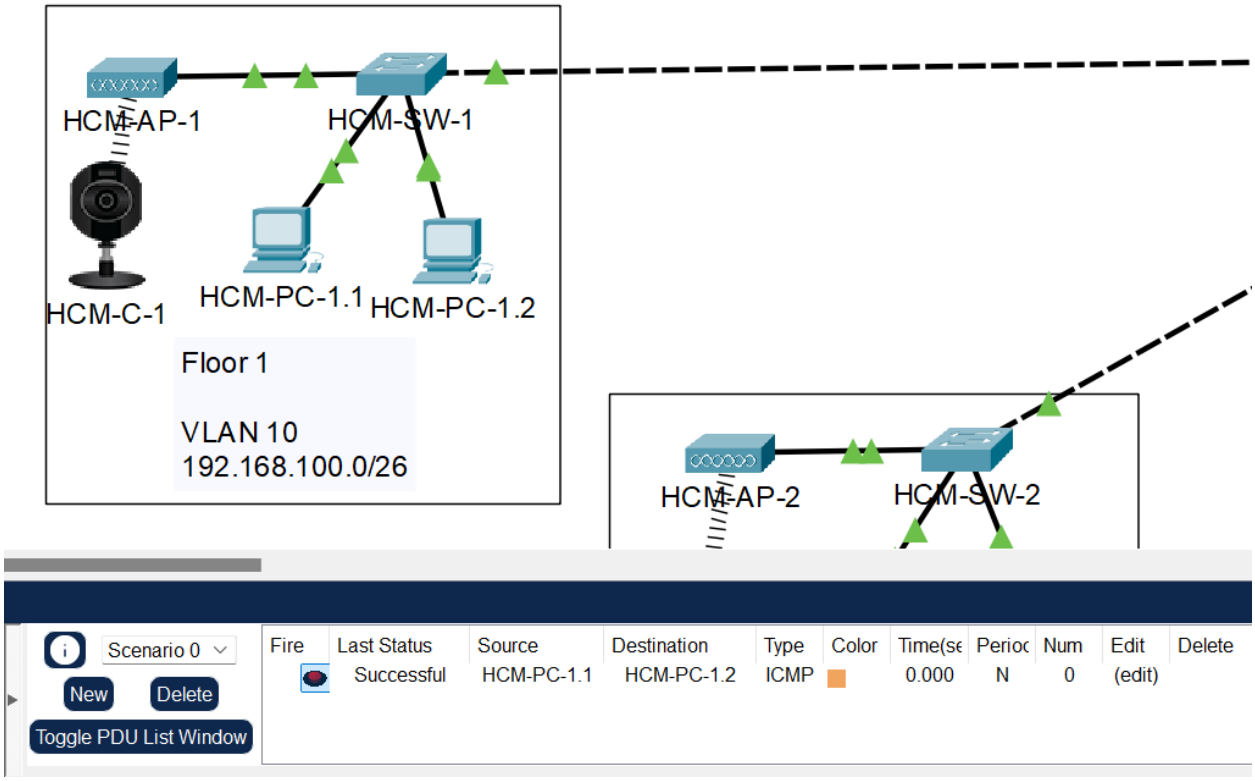

Figure 13: Connection between 2 PCs of a same floor

5.2 Between devices within a same building (VLANs)

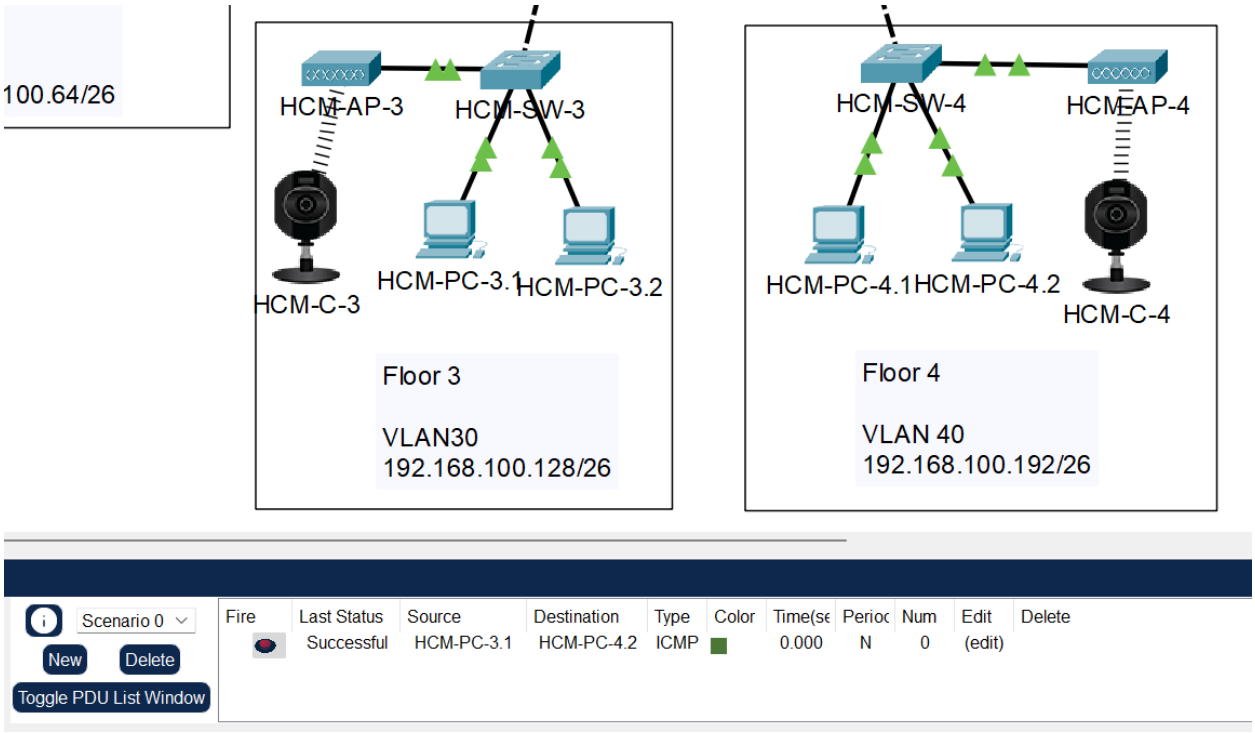

Figure 14: Connection between a PC from 3rd floor and another 4th floor

5.3 Between devices within different buildings

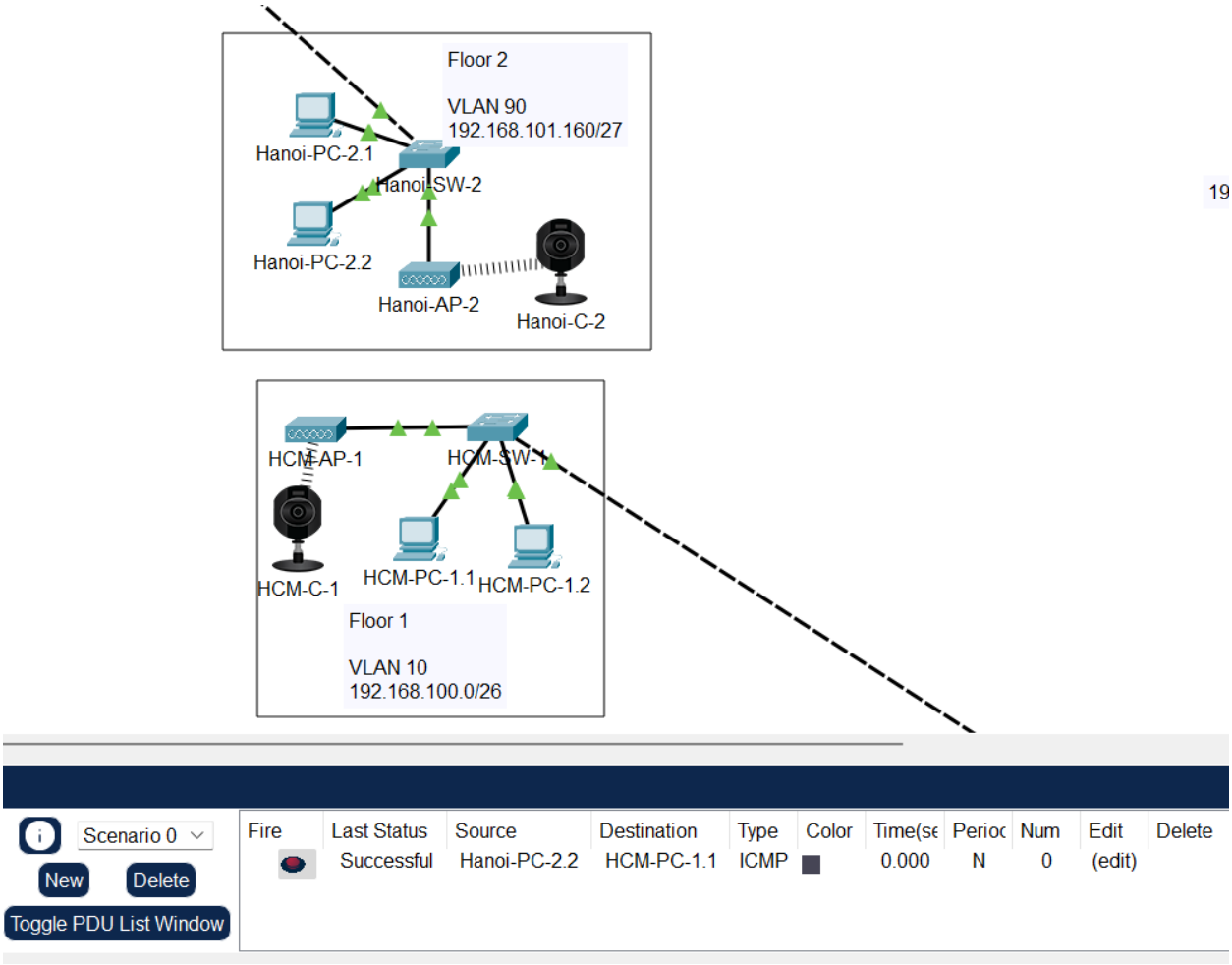

Figure 15: Connection between a PC from HCM and another from Ha Noi

5.4 Between a device and a server

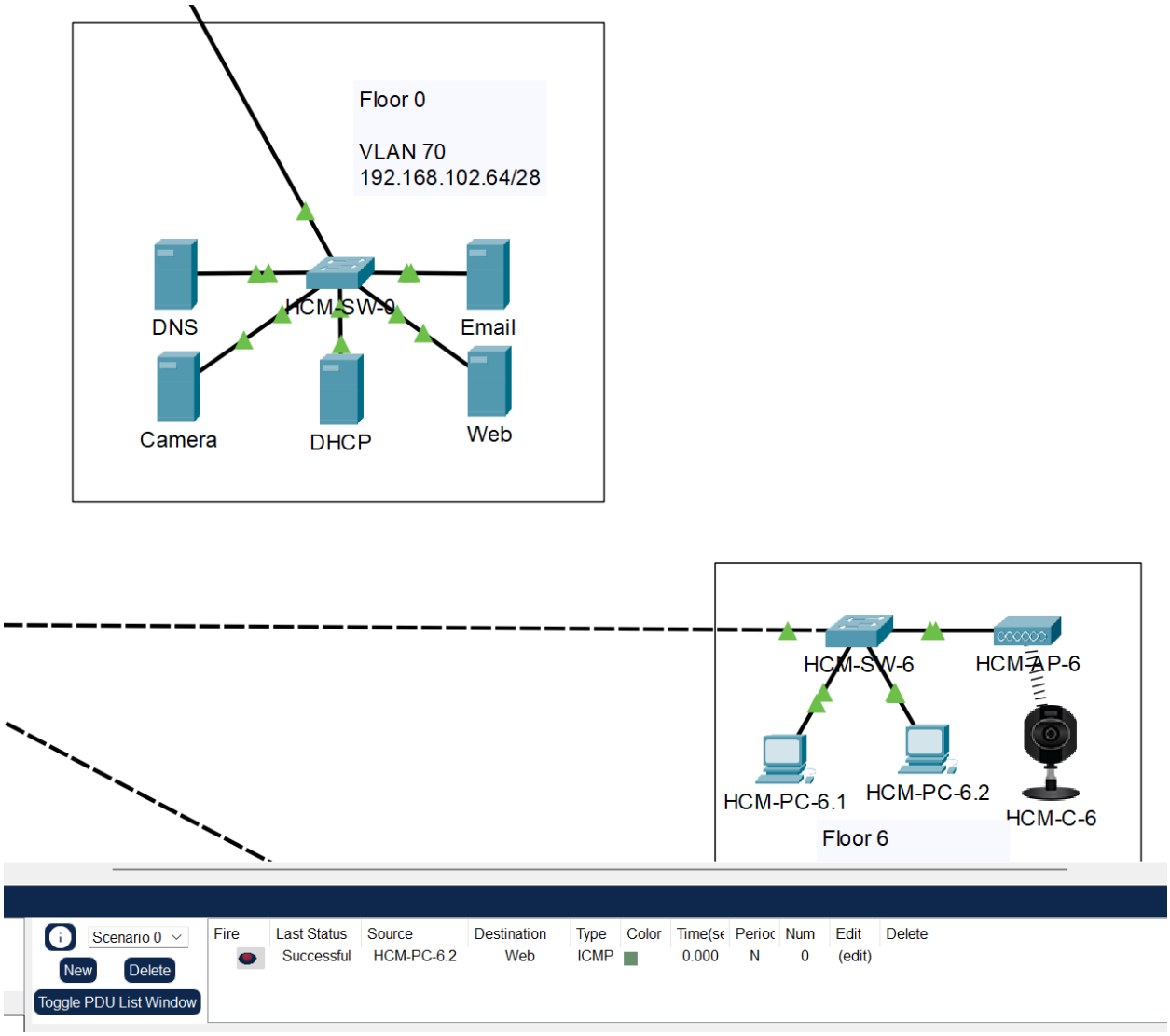

Figure 16: Connection from a PC to the Web server

5.5 From a device to an ISP

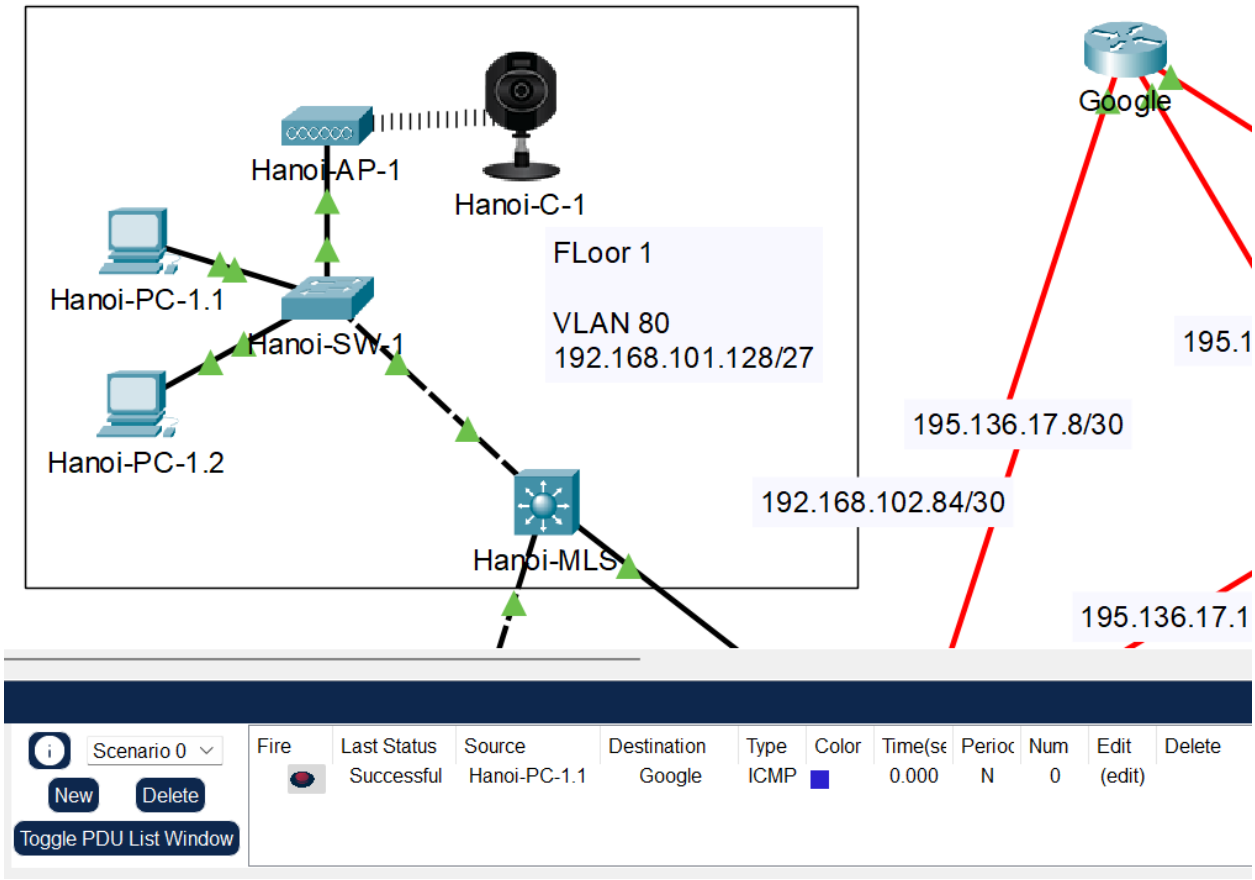

Figure 17: Connection from a PC to Google ISP

6 Re-evaluation

6.1 Looking back

- The network does not possess a backup mechanism, hence the high chance of losing packets.
- There is no load balancer implemented at the Gateway, the workload is not distributed between the branches.
- All traffic passes through one router at the Main Site, making it a potential congestion point.
- The network contains some Cisco devices no longer supported by Cisco.
- Only the DMZ at the headquarter is simulated.

6.2 What can be improved

- Implementation of a dual firewall mechanism for proper separation DMZ, allowing DMZ to be shared across branches for load balancing.
- Implementation of multiple routes between the network to avoid congestion and connection risks.
- Implementation of backup servers to maintain reliable data transfer on the network.

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