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SECR 1213 NETWORK COMMUNICATIONS

SECTION 02

Network Design for Faculty of Computing Block N28B

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Abstract

This project was initiated to overcome the challenge faced by our client, Faculty of Computing, UTM, which is projected to have a 15% increase in students and staff over the next four years. To accommodate this growth, a new two-storey-building, N28B, is being designed and included 4 new labs, a video conferencing room, a hybrid classroom and a student lounge. The project started with creating a floor plan for N28B, doing research on user requirements, choosing the appropriate device for the networking planning, connecting the devices and ended with an IP addressing scheme. Even though there are some constraints such as budget and scalability requirements, the project aims to deliver a network system in line with the goals of the Fourth Industrial Revolution (4IR).

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1.0 Introduction

1.1 Project Overview

This project is to design a network for the N28B, Faculty of Computing, Universiti Teknologi Malaysia (UTM). The project began with understanding the requirements of the client and designing the network under the allocated budget and building structure given.

In this project,

- a floor plan for N28B is created to understand the structure of each floor
- a preliminary analysis is conducted on requirements of the client to decide on the devices to be used
- research on different network devices is carried out to evaluate their usability and costs
- internetworking device connections are established on the floor plan to determine the exact amount of cabling required and to ensure the success of the networking
- the subnetwork is divided for all the labs and rooms

At the end of this project, the task's outcomes were compiled, and the solution was presented.

1.2 Objective

The objectives of this project is:

- to design a networking solution that fits N28B’s building plan within budget allocated
- to ensure that there is sufficient scalability to cope with a 15% increase in users over the following four years
- to provide a internetworking device connection with reliable performance to the client

1.3 Assumption

Below are some assumption of this project:

- The network can handle regular academic usage without overloading, including video conferencing, access to learning platforms and web-browsing.
- The power supply is reliable for all devices in the building.
- The layout and dimensions of N28B will remain unchanged during the network implementation.

2.0 Project Background & Client Overview

2.1 Background of the Problem

The Faculty of Computing, UTM made the decision to construct a new building, N28B in order to accommodate their needs, which include a 15% increase in the number of students and academic staffs over the following 4 years. This 2-storey-building is planned to house:

- 4 new labs, each with 30 workstation
    - 2 general-purpose lab over general use
    - a Cisco Network Lab offering teaching and hands-on practical
    - an Embedded Lab for IoT, Digital System, etc.
- a video conferencing room enabling virtual meeting, online classes and collaborative session
- a hybrid classroom optimized for modern Teaching and Learning (T&L) modes
- a student lounge as a place for the students to relax

The student lounge and each lab will measure 14 m by 10 m, which provides enough space for workstations, equipment, and student study areas. To align with the goals of the Fourth Industrial Revolution (4IR), all the labs should be equipped with high-speed internet. Additionally, the new network system must be:

- cost-effective
- easy to maintain and manage, in order to support future growth
- having improved overall performance compared to the current system
- providing protection against network breaches
- able to handle high network traffic, especially under heavy load situations

2.2 Client's Current Status and Challenges

The Faculty of Computing will be facing a challenge of anticipating a 15% increase in both students and academic staffs over the next four years. However, the existing building lacks the scalability to overcome this growth. To address these issues, the Faculty plans to build a 2-storeys building that accommodates the requirement.

2.3 Contextual Understanding

With the advancement of technology, the Internet is now a part and parcel of our lives. Thus, networking is mandatory to be considered in the building design.

3.0 Project Setup

3.1 Ground Floor Plan

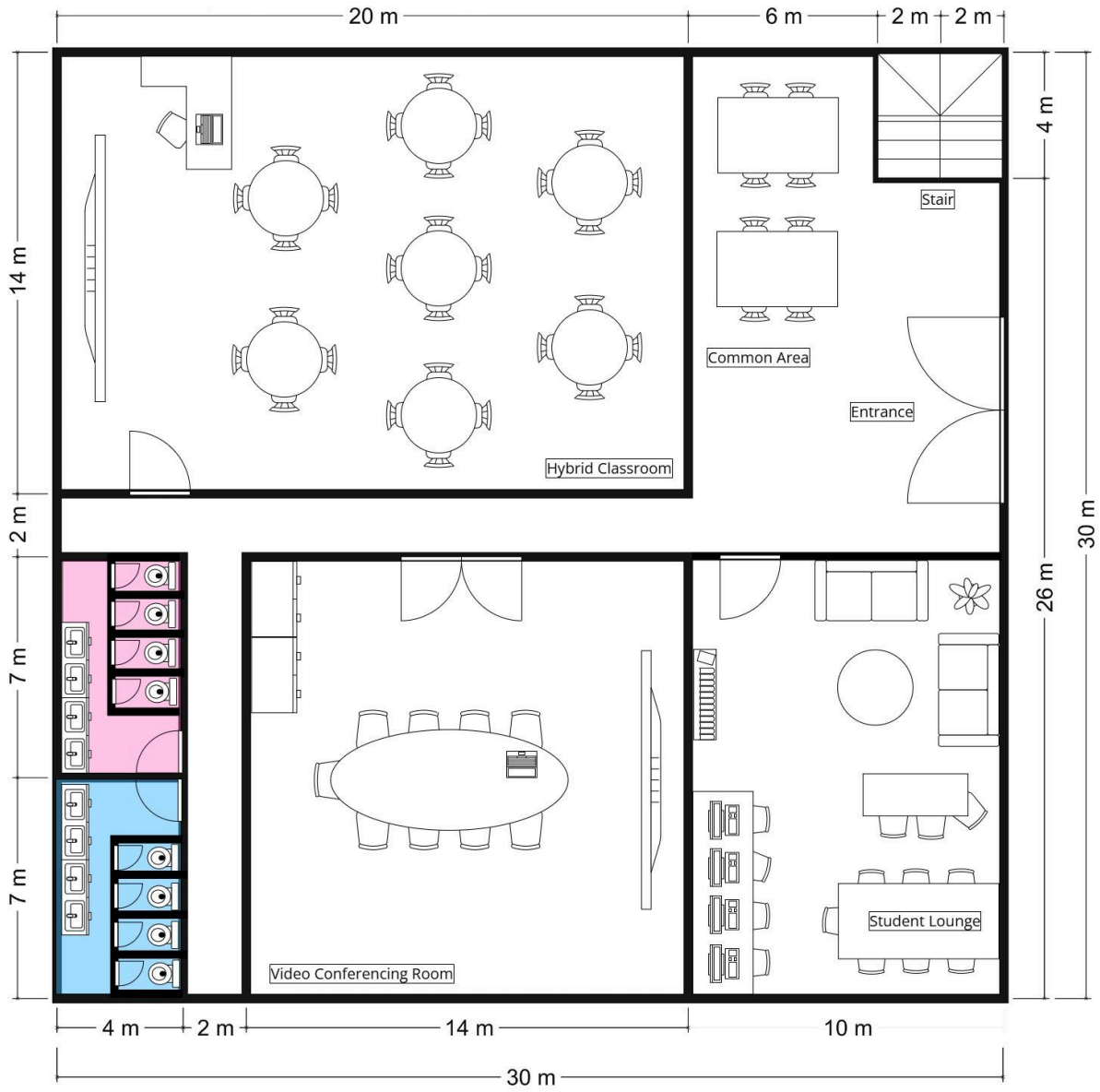

Figure 1.1: Ground Floor Plan

As you step into the ground floor, there is a common area on the right, offering students a comfortable space for relaxation and collaboration. To the left, a student lounge, measuring 10m x 14m, provides students with an ideal spot for studying and group discussions. Beside it is a video conferencing room that is 14m x 14m in size, designed for virtual meetings and interactive sessions. Across the video conferencing room there are two restrooms.

3.2 First Floor Plan

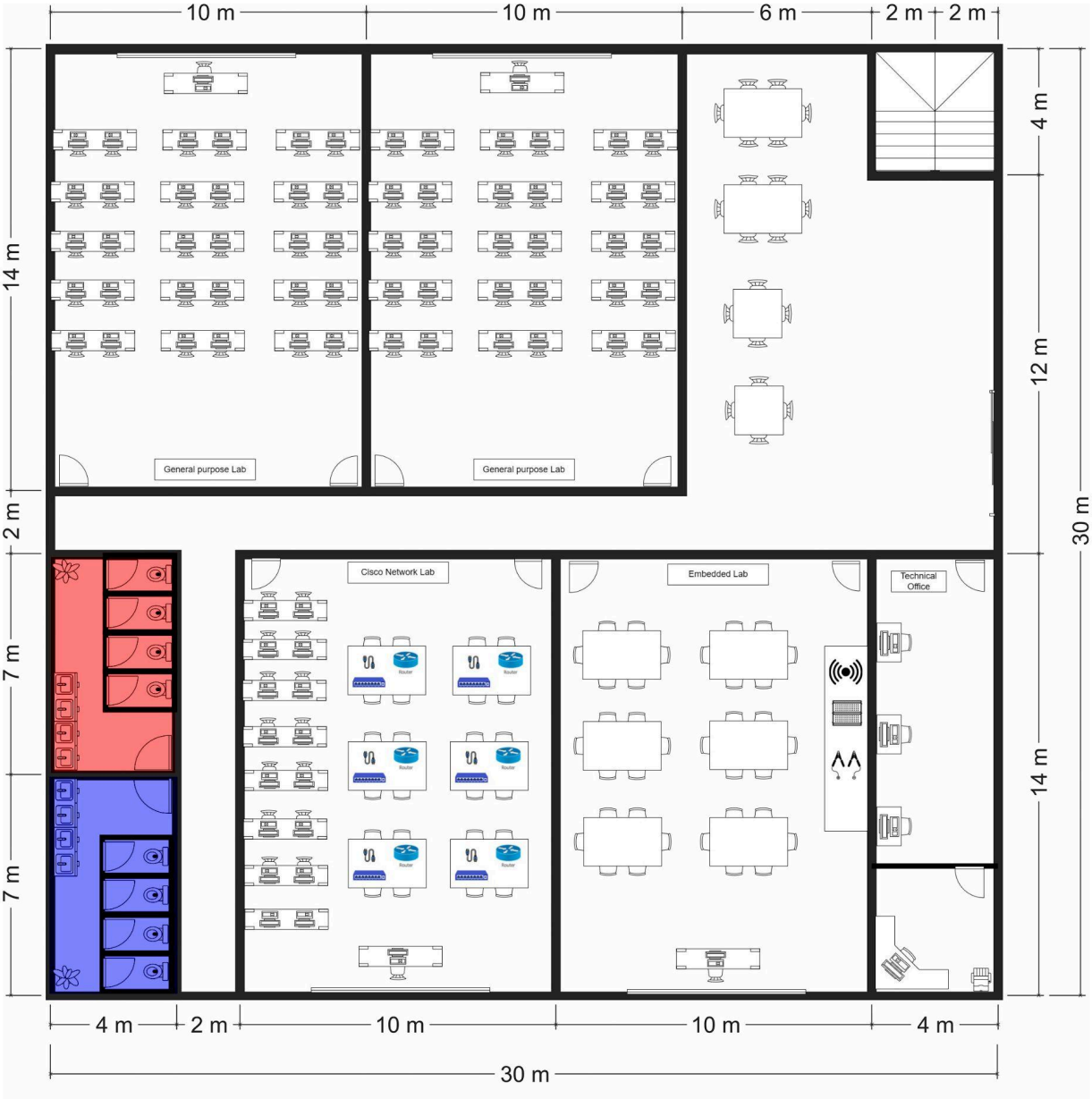

Figure 1.2: First Floor Plan

On the first floor, located all the 4 labs including two general purpose labs, a Cisco Network Lab and an Embedded Lab. Besides, considering that there would be technical issues that may require assistance, a room for IT staff is also added to the building.

4.0 Initial Design - Preliminary Analysis

4.1 Question and Answer

1. **What specific networking devices are required for teaching purposes?**

   Routers are essential devices of every network lab, as they manage data transit between several networks. In T&L, routers allow students to interact with IP addressing and routing protocols such as Routing Information Protocol (RIP) and Open Shortest Path First (OSPF), which help them understand how data moves between networks [1]. Besides, **switches** enable learning about VLANs, data flow and network organisation by connecting devices within a network. They are needed for debugging and managing LANs.

   By monitoring data traffic, **firewalls** protect networks and give students the ability to set up VPNs, access control and security settings. **Wireless Access Points (APs)** enable students to explore wireless networks setup and security. They are necessary to understand wireless networking.

2. **How should network connectivity be distributed within each lab, given the presence of 30 workstations per lab?**

   Wired connectivity is more suitable for a lab with 30 workstations. It offers steady speeds and fewer interference. Using ethernet cables and switches provides all workstations with stable, high-speed connectivity. It is more suitable for handling large network loads and provides better security. Wireless networks are flexible and convenient, but they can be affected by congestion and signal strength. It might not have enough bandwidth for 30 workstations, especially in a busy environment. It can result in increased security issues and slower speeds. However, considering that students will be also using wireless devices such as mobile phones, tablets and laptops, wireless networks shall also be implemented in the lab.

3. **What are the backup requirements for the network, especially for the labs and video conferencing room?**

   First, using cloud or offsite storage for **data backup** is both cost-effective and simple to set up, but regular backups of network device configurations are required. Uninterruptible Power Supplies (UPS) for **power backup** provide continuity during blackouts, however the upfront cost can be high and require frequent maintenance. For **video conferencing**, implementing Quality of Service (QoS) and cloud-based platforms ensures reliable service, but specialist equipment might require additional costs. Overall, these solutions are useful, but must be modified to the specific needs and budget of the network setup.

4. **What kind of security measurements will be required for the deployment of the network plan both physically and digitally?**

   The digital security measurements taken are **firewall protections.** Firewall should be installed at the network entry points to monitor and control both incoming and outgoing networks, blocking students from accessing unauthorised websites such as online games by application-based blocking [2]. A **Virtual Private Network (VPN)** should be deployed to encrypt the data that faculty students and staff send and receive to make sure the data are secure from external threats. A **Secure Authentication Method** should be implemented to let only the authorised users access the network. It should include a username and password given to all faculty students and staff, that requires login every 12 hours.

   For the physical security concerns, network devices such as router, server and switches should be placed in a secured place that are inaccessible to unauthorised individuals. Besides, it should be placed at a well ventilated place, away from humidity or direct sunlight, to prevent damage of the network devices from water exposure or overheating. Each network device should be equipped with uninterrupted power supply to protect against power outage, thus preventing data loss.

5. **What bandwidth and performance requirements are expected?**

   Bandwidth and low latency are critical for high-performance networks, especially for cloud computing and real-time applications. Applications such as online video streaming require fast data transfer (typically hundreds of Mbps to Gbps) to keep connections smooth and avoid delays. Browser-based video conferencing solutions [3], however, can adapt to available network bandwidth at both ends of a call, adjusting quality to maintain stability.

6. **How can we allocate Internet bandwidth effectively across the faculty?**

   High-Capacity Links should be set up such as a 10 Gbps main Internet link, and 2 more backup links to handle the extra demand in the faculty of computing and provide high speed access for every student and staff. A **Gigabit fibre-optic backbone** should be used for the building in the Faculty of Computing to ensure fast data transfer and Internet communication between the new building and N28, N28a building. Lastly, use a **network monitoring system** to keep track of the traffic, identify issues, and adjust network usage as needed. **Bandwidth shaping** can be applied to prioritise important traffic, ensuring smoother and fair access for everyone in FC.

7. **How to maintain Internet uptime?**

   Routine **maintenance** should be scheduled to troubleshoot the network, ensuring security and minimising risk that could lead to downtime. For example, network hardware and software should be compatible with the latest standards. Network administrators should

be hired to manage and solve problems as the on-call support service, to reduce downtime of a sudden Internet down.

8. **Are there any environmental factors or physical layout considerations?**

   Yes, certain features of UTM's buildings can affect network performance. Concrete walls and reinforced structures in older buildings can block Wi-Fi signals, creating dead zones where extra routers or repeaters are needed to maintain coverage. Tall glass windows in some of the newer buildings may reflect signals and cause interference, so placing routers carefully is important.

   The mix of building heights and green spaces between old and new buildings in the Faculty of Computing also affects network planning. Tall trees and high humidity can weaken outdoor Wi-Fi signals between buildings, and temperature changes near server areas need monitoring to prevent overheating. For reliable and more complete coverage, careful cabling and shielding in busy areas, such as student lounges or labs with a lot of equipment, can help keep connections smooth.

9. **Are there any specific data storage or server requirements?**

   To accommodate the rapid development of technology and research and development purposes, a server is required to anticipate high-performance computing (HPC). Both the Cisco Network Lab and Embedded Lab may involve HPC workloads. Thus, a high-speed data storage system is required to handle large datasets for simulation, programming and analysis. The Cisco Network Lab requires dedicated servers for simulating network traffic, running network simulations, and supporting virtual labs. On top of that, the Embedded Lab would require servers that can support Iot devices and simulation software.

10. **What is the power requirement for the building?**

In the hybrid classroom, there will be one desktop PC and audio-visual equipment.

Table 1.1: Power Assumption for Hybrid Classroom

Item	Power Consumption	Quantity	Sum
Desktop PCs	300 W	1	300 W
Wireless Router	30 W	1	30 W
Ethernet Switch	30 W	1	30 W
Audio-visual equipment - Camera for video conferencing - Ceiling-mounted mics	 10 W 5 W	 2 6	 20 W 30 W

- Speakers - Interactive whiteboard	30 W 100 W	1 1	30 W 100 W
Projector	200 W	1	200 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	2980 W

In the video conferencing room, there will be one desktop PC and audio-visual equipment.

Table 1.2: Power Assumption for Video Conferencing Room

Item	Power Consumption	Quantity	Sum
Desktop PCs	300 W	1	300 W
Wireless Router	30 W	1	30 W
Ethernet Switch	30 W	1	30 W
Audio-visual equipment - Camera for video conferencing - Lapel mics - Speakers - Interactive whiteboard	 10 W 5 W 30 W 100 W	 2 10 1 1	 20 W 50 W 30 W 100 W
Projector	200 W	2	400 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	3200 W

In the student lounge, there are 4 workstations with a standard desktop PC for students.

Table 1.3: Power Assumption for Student Lounge

Item	Power Consumption	Quantity	Sum
Desktop PCs	300 W	4	1200 W
Wi-Fi Router	30 W	1	30 W

Ethernet Switch	30 W	1	30 W
Projector	200 W	1	200 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	3700 W

In each general purpose lab, there are 30 workstations and a lecturer's workstation. Assuming each workstation is a standard desktop PC. There will be 62 workstations in both the general purpose labs.

Table 1.4: Power Assumption for General Purpose Labs

Item	Power Consumption	Quantity	Sum
Desktop PCs	300 W	31	9300 W
Router	30 W	1	30 W
Wireless Access Point	30 W	1	30 W
Ethernet Switch	30 W	1	30 W
Projector	200 W	1	200 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	11830 W

In the Cisco Network Lab, assuming that students will be working in pairs, there will be at least 16 sets of hardware including the hardware for demonstration purposes. According to the layout, the lab has 17 PCs. Besides, there will be 16 routers, 16 switches and up to 5 virtual servers.

Table 1.5: Power Assumption for Cisco Network Lab

Item	Power Consumption	Quantity	Sum
Routers (for teaching and learning)	150 W	16	2400 W
Switches (for teaching and learning)	120 W	16	1920 W

Firewalls (for teaching and learning)	100 W	1	100 W
Desktop PCs	300 W	17	5100 W
Ethernet Switch	30 W	1	30 W
Projector	200 W	1	200 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	11990 W

In the Embedded Lab, assuming that students will be working in pairs, there will be at least 16 sets of hardware including the hardware for demonstration purposes. There will then be 16 Arduino Uno boards, 16 PCs, sensors and peripherals and power supply.

Table 1.6: Power Assumption for Embedded Lab

Item	Power Consumption	Quantity	Sum
Arduino Uno	0.5 W	16	15.5 W
Desktop PCs	300 W	16	4800 W
Wireless router	30 W	1	30 W
Ethernet Switch	30 W	1	30 W
Sensors and Peripherals - LEDs - Small motors - Sensors	 1 W 1 W 1 W	 16 32 32	 16 W 32 W 32 W
Power Supply for Arduino Uno	5 W	16	80 W
Projector	200 W	1	200 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	7475.5W

In the technician office, there are 4 PCs. Besides, the firewall is also located in the technician office.

Table 1.7: Power Assumption for Technician Office

Item	Power Consumption	Quantity	Sum
Desktop PCs	300 W	4	1200 W
Ethernet Switch	30 W	1	30 W
Firewall	650 W	1	650 W
Lighting	15 W	16	240 W
Air Conditioning	2000 W	1	2000 W
		Total	4120 W

Other than the closed area, the corridors, common area, toilets and surrounding of the building also require lighting and fans.

Table 1.8: Power Assumption for OtherAreas

Item	Power Consumption	Quantity	Sum
Lighting - Ground floor - First floor - Toilet - Outside of building	15 W	 10 10 16 4	600 W
Fan	75 W	2	150 W
Core Switch	30 W	1	30 W
		Total	780 W

Total power consumption

Table 1.9: Total Power Consumption

Room / Area	Power Consumption	Power Consumption for Networking Devices (Does not include end Devices)
Hybrid Classroom	2980 W	60 W
Video Conferencing Room	3200 W	60 W
Student Lounge	3700 W	60 W

General Purpose Lab 1	11830 W	90 W
General Purpose Lab 2	11830 W	90 W
Cisco Network Lab	11990 W	30 W
Embedded Lab	7475.5W	60 W
Technician Office	4120 W	680 W
Others	780 W	30 W
Total	57905.5 W	1160 W

As power supply efficiency usually ranges from 60% to 95% [4]. By assuming an efficiency of 80%, the adjusted power requirement is adjusted as follow:

$\frac{57905.5W}{0.8} = 72381.875W \approx 73kW$

To ensure the building can handle power fluctuations and additional loads, a 20% buffer is added above the estimated power requirement.

$73kW \times 1.2 = 87.8kW$

4.2 Feasibility

1. **Technical Feasibility**

   The building layout includes General Purpose Laboratory, Cisco Network Lab, Embedded Lab, Hybrid Classroom, Video Conferencing Room and Student Lounge, each equipped with multiple end systems and network devices. The building provides a great learning environment, as well as a network-based laboratory for practical sessions.

   To support stable, high-speed connections, wired connectivity via Ethernet cables and switches is required in each lab. Wired connections reduce interference and maintain high speeds, which are essential for handling lab activities without interruption.

2. **Operational Feasibility**

   The building is supported by the setup of secure authentication measures and firewall protections, to take control over network access and ensure data security. Regular monitoring and maintenance, aided by a network monitoring system, can track traffic, identify bottlenecks, and facilitate bandwidth shaping to prioritise essential traffic across the faculty. This structured approach allows effective bandwidth allocation, providing all students and faculty with smooth, reliable access.

Backup systems, such as cloud storage and uninterruptible power supplies (UPS) for network devices, also support operational continuity. Although implementing UPS for every device involves upfront costs, it prevents data loss and network disruptions during power outages. The QoS setup in routers for video conferencing rooms also ensures steady connections by adjusting resources dynamically based on network demand. The overall operational plan is, therefore, practical and sustainable for the faculty's educational and administrative needs.

5.0 Choosing The Appropriate LAN Devices

5.1 LAN Devices

5.1.1 Router

In a network, a router is a device that links several devices such as computers, phones and tablets to the internet and to one another. It ensures that information delivered from one device reaches its destination.

5.1.1.1 Wired Router

A wired router is a device that uses Ethernet connections to link PCs and other devices to the internet. It provides a quick and stable connection since data passes straight via the cable, which makes it perfect for settings in workspaces. All linked devices must be plugged in using cables because wired routers do not use Wi-Fi like wireless routers do.

Table 2.1: Comparison of Wired Routers

Wired Router	Cisco RV345 Dual WAN [5]	TP-Link ER 7206 [6]	Ubiquiti EdgeRouter ER-4 [7]
Price	RM 1400.00	RM 1099.00	RM 1304.00
WAN Ports	2 WAN ports for load balancing	Multi-Gigabit WAN ports	4 Gigabit Ethernet ports
VPN Support	IPsec, L2TP over IPsec, Cisco VPN	IPsec, PPTP, L2TP, OpenVPN	Full VPN support, including IPsec
Firewall Security	Advanced Firewall	Advanced Firewall	Advanced Firewall
Network Management	-	Centralized via Omada SDN	Robust management interface

Cisco RV345 Dual WAN Gigabit VPN Router is the best option due to its dual WAN ports, 16 LAN ports, robust VPN and security features, so it is ideal for handling large numbers of users

and providing secure connections. Although it is priced higher at RM1400.00, its functionality and performance make it well suited for lab demands.

5.1.1.2 Wireless Router

A wireless router in a university allows students and staff to access the internet without the use of wire. It provides multiple connections across several devices, offering access to learning platforms, internet resources and communication tools in classrooms, libraries and other locations.

Table 2.2: Comparison of Wireless Routers

Wireless Router	Netgear Nighthawk AX12 (RAX200) [8]	TP-Link Archer AX73 (AX5400) [9]	Asus ROG Rapture GT-AX11000 [10]
Price	RM 3099.00	RM 499.00	RM 2436.00
Wi-Fi Type	Tri-band Wi-Fi 6	Dual-band Wi-Fi 6	Tri-band Wi-Fi 6
Speed	Up to 10.8 Gbps	Up to 5400 Mbps	Up to 11000 Mbps
Streams	8-stream support	6-stream support	Not specified
LAN Ports	Not specified	Not specified	8 Gigabit Ethernet ports
Special Features	Not specified	Multiple antennas for extensive coverage	Gaming acceleration, customizable QoS

TP-Link Archer AX73 (AX5400) is the best budget option for this project. At RM 499.00, it offers good speed (up to 5400 Mbps) and coverage with dual-band Wi-Fi 6. The Netgear Nighthawk AX12 and Asus ROG Rapture GT-AX11000 offer faster speeds, but they are much more expensive. As a conclusion, **TP-Link Archer AX73** provides great value for project needs at a lower cost.

5.1.2 Switches

Switches are the essential components for any network. They link several devices on the same network, including servers, printers, wireless access points, and PCs, within a building or campus.

5.1.2.1 Access Switches

Access switches are used to control local traffic and link endpoints to the network.

Table 2.3: Comparison of Access Switches

Access Switch	CiscoWS-C2960X-48 TS-LL Catalyst 2960-X [11]	HPE 2930F [12]	C9200-48T-A - Cisco Switch Catalyst 9200 [13]
Price	RM 9955.43	RM 21800.00	RM 18,039.88
Ports	48 x Ethernet 10/100/1000 Gigabit ports	(24) RJ-45 autosensing 10/100/1000 ports (4) SFP+ 1/10GbE ports	48 ports data
Forwarding Bandwidth	100Gbps	-	261.9 Mpps
Switching Bandwidth	100Gbps	128 Gbps	176 Gbps
RAM	256MB	1GB	4GB
Flash Memory	64MB		4GB

The **Cisco C9200-48T-A Catalyst 9200** is the ideal choice due to its outstanding performance. Of the available alternatives, it provides the maximum forwarding rate (261.9 Mpps) and switching bandwidth (176 Gbps). Additionally, it comes with 4GB of RAM and 4GB of flash memory, which ensures efficient operation of advanced network functions. Although the price is slightly higher than CiscoWS-C2960X-48TS-LL Catalyst 2960-X, it justifies the cost with its enhanced capabilities.

5.1.2.2 Core Switches

Core switches connect all access switches, which provide high-speed interconnectivity. They act as the foundation for creating high-performance, high-availability networks by supporting a variety of network protocols and services.

Table 2.4: Comparison of Core Switches

Access Switch	C9500-24X-E - Cisco Switch Catalyst 9500 [14]	Aruba Networking CX 6400 [15]
Price	RM44140.09	RM 56135.00
Ports	16-port 10G switch	10 I/O module slots, maximum
Switching Bandwidth	960 Gbps	28 Tbps

RAM	16 GB	16 GB
Flash Memory	16 GB	32 GB

Of the two options, the **Aruba Networking CX 6400** is the preferable one. Its 28 Tbps switching bandwidth is a lot more than the Cisco C9500-24X-E Catalyst 9500's. While both core switches have 16 GB of RAM, Aruba offers 32 GB of flash memory along with 10 I/O module slots for more expandability. This makes it perfect for high-performance, large-scale networks requiring scalability and flexibility.

5.1.3 Cables

Communications cables are used to interconnect, connect and transfer data and information between computers, routers, switches and storage area networks. It establishes multiple physical connections that enable direct communication between devices.

5.1.3.1 Fiber Optic Cables

A fiber optic cable is a network cable with glass fiber wires wrapped in an insulated casing. It connects switches located on separate floors.

Table 2.5: Comparison of Fiber Optic Cables

Fiber Optic Cables	RS PRO 4-way TB [16]	FS OM4LCDX [17]	RS PRO 12-way TB Fibre Optic Cable [18]
Price	RM 1894.55	RM 20.00	RM 2340.00
Length (m)	200	1	100
Propagation Mode	OM4 Multi Mode	OM4 Multi Mode	OM4 Multi Mode
Number of Core	4	2	12
Maximum Operating Temperature	+70°C	+70℃	+70℃
Minimum Bend Radius	15 D	20 D	15D

RS PRO 12-way TB Fibre Optic Cable is the best option among these. It has the highest number of cores, providing higher capacity for scalability. Besides, it provides reasonable value at RM 23.40 per meter given its features, especially for multi-core connections.

5.1.3.2 Ethernet Cables

Ethernet cables are used to connect devices to the internet and to a local network. They connect to the Ethernet ports of various devices.

Cat 6a cables are suitable to be used in high-performance areas to ensure reliable connections for labs and hybrid classrooms.

Table 2.6: Comparison of Ethernet Cables

Ethernet Cable	RJ 45 2996AS-1GY [19]	ETHERLINE Cat. 6A Y [20]	RS PRO Shielded Cat6a Cable [21]
Price	RM 32.86	RM 46.23	RM 79.28
LAN Category	Cat6a	Cat6a	Cat6a
Length (m)	1	1	3
Speed	10Gbps	10Gbps (Industrial Ethernet)	10Gbps
AWG	26	22	26

RJ 45 2996AS-1GY is the best budget option. It has the lowest price but similar specifications with others, delivering excellent 10Gbps performance. Its Cat6a rating ensures high-speed, reliable connections for hybrid classrooms and labs.

5.1.4 Wireless Access point

Wireless Access Point is the networking device that allows wireless-capable end devices such as PCs, laptops of staff and students in UTM to connect to the wired network. The router chosen as stated above does not have a built-in wireless access point. To include WiFi functionality to the **Cisco RV345 Dual WAN Gigabit VPN Router,** an access point is needed.

Table 2.7: Comparison of Wireless Access Point

Access Points	Ubiquiti UniFi U7 Pro Max [28]	TP-Link Omada EAP783 [29]
Price	RM1700	RM5899
Wi-Fi Standard	802.11a/b/g/n/ac/ax/be (WiFi 6/6E, WiFi 7)	Wi-Fi 7 (802.11be), Wi-Fi 6 (802.11ax)
Speed (Data Rate)	2.4 GHz: 688 Mbps (BW40) 5 GHz: 8.6 Gbps (BW240) 6 GHz: 5.7 Gbps (BW320)	2.4 GHz: 1376 Mbps 5 GHz: 8640 Mbps (BW160) 6GHz: 11520 Mbps (BW320)

Coverage Area	1750 ft^2	2150 ft^2
Number of Supported Devices	500+	760+
Power Options	PoE+	PoE++
Security Features	Wireless Security WPA-PSK, WPA-Enterprise (WPA/WPA2/WPA3/PPSK)	WPA3
Multi-SSID Support	BSSID 8 per radio	up to 24 SSIDs
Management Options (Local/Cloud)	Local (Ethernet)	Centralized Cloud Management

Although the Omada EAP783 has a higher speed, and wider coverage, the wireless access point is only used in the general purpose lab. Thus, the **Ubiquiti UniFi U7 Pro Max**, would be more cost effective.

5.1.5 Patch Panel

A patch panel is the hardware device used in networking to manage and organize multiple cables in a centralized location. Patch panel provides an interface for the cables to be connected, arranged or disconnected easily without affecting the whole system.

Table 2.8: Comparison of Patch Panel

Patch Panel	QuickNet™ Shielded Patch Panel [30]	Leviton OPT-X™ UHDX Fiber Panels [31]
Price	RM930.31	RM 470.40
Number of Ports	48 Ports	72 Fiber Ports
Cable Compatibility	Cat5e, Cat6	Fiber Optic
Installation Method	1U Rack Mount	1U or 2U Rack Mount
Connector Type	RJ45 (Keystone Coupler)	LC, MPO/MTP Fiber

For Ethernet-based networks that use the Cat6 cabling as stated above, **QuickNet™ Shielded Patch Panel** are selected. It is cost effective and uses RJ45 (Keystone Coupler), allowing flexibility in port configurations and easy cable replacements.

5.1.6 Firewall

Firewall is a network security system that monitors and controls incoming and outgoing network traffic based on predetermined security rules. This helps block malicious traffic, unauthorized access attempts, and other threats that could compromise the network.

Table 2.9: Comparison of Firewall

	Fortinet FortiGate 200F [32]	Cisco Firepower 1010 [34]	Palo Alto Networks PA-820 [35]
Price	RM 18,444.88 [33]	RM 3,841.00	RM 27,316.13
IPS Throughput	5 Gbps	900 Mbps	1.3 Gbps
Threat Protection Throughput	3 Gbps	890 Mbps	790/840 Mbps
Maximum Concurrent Session	3,000,000	100,000	128,000
New Session Per Second	280,000	6,000	8,600

Based on the comparison, the **Fortinet FortiGate 200F** seems to be the best option for our case. Although it may be more expensive compared to the Cisco Firepower 1010, it has a higher throughput and can accommodate more sessions.

5.2 Budget Estimation

Table 2.10: Comparison of Budget Estimation

Item	Quantity	Unit Price (RM)	Total Price (RM)
Cisco RV345 Dual WAN Gigabit VPN Router (Wired Router)	2	1400.00	2800.00
TP-Link Archer AX73 (Wireless Router)	5	499.00	2495.00
Cisco C9200-48T-A Catalyst 9200 (Access Switch)	8	18,039.88	144319.04
Aruba Networking CX 6400 (Core Switch)	1	56135.00	56135.00
S PRO 12-way TB Fibre Optic Cable (100m)	3	2340.00	7020.00
RJ 45 2996AS-1GY (1m) (Cat 6a)	766	32.86	25170.76
Ubiquiti UniFi U7 Pro Max (Wireless Access Point)	2	1700.00	3400.00
Fortinet FortiGate 200F (Firewall)	1	18,444.88	18444.88
		Total	259784.68

5.3 Reflection

1. Are you surprised by the prices? How were you surprised?
   Yes. For some of the devices, we may expect it to be expensive but it turns out to be a little bit cheaper than expected while others may cost a fortune.

2. Have you ever considered cost as a factor for choosing networking devices?
   Yes. It is obvious that the devices that have a better specification would be more expensive. Thus, we need to trade-off with the price and specification of the devices.

3. What are the major differences between the same devices from different brands? For example, Cisco and Huawei Routers.
   The pricing and the specifications offered. Despite some of them having similar specifications, the price may vary.

6.0 Making the Connections - LAN and WAN

6.1 Network Devices Arrangement

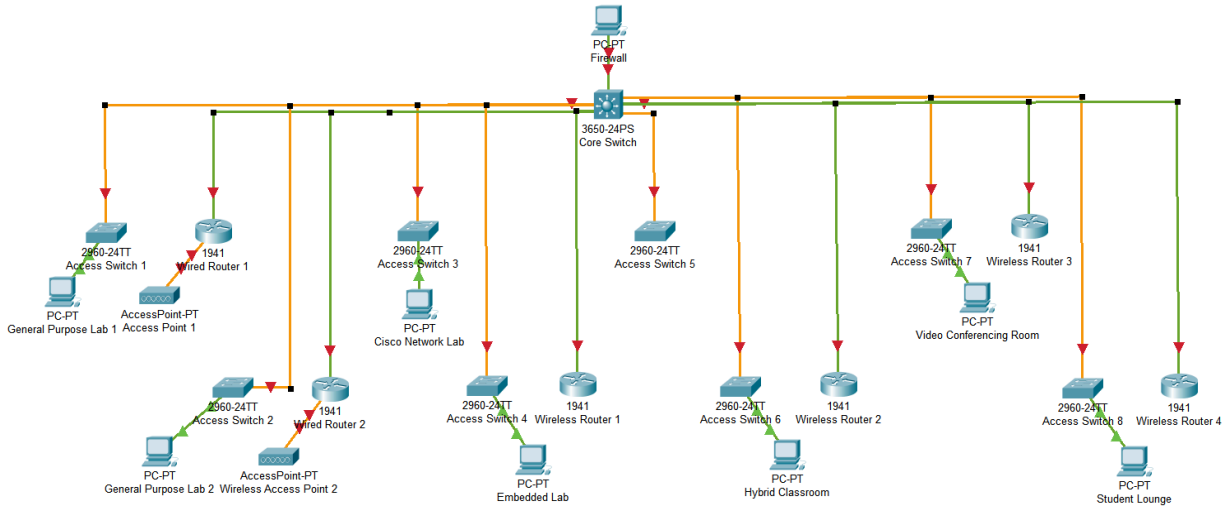

Figure 2.1: Network Device Arrangement

6.2 Ground Floor Plan

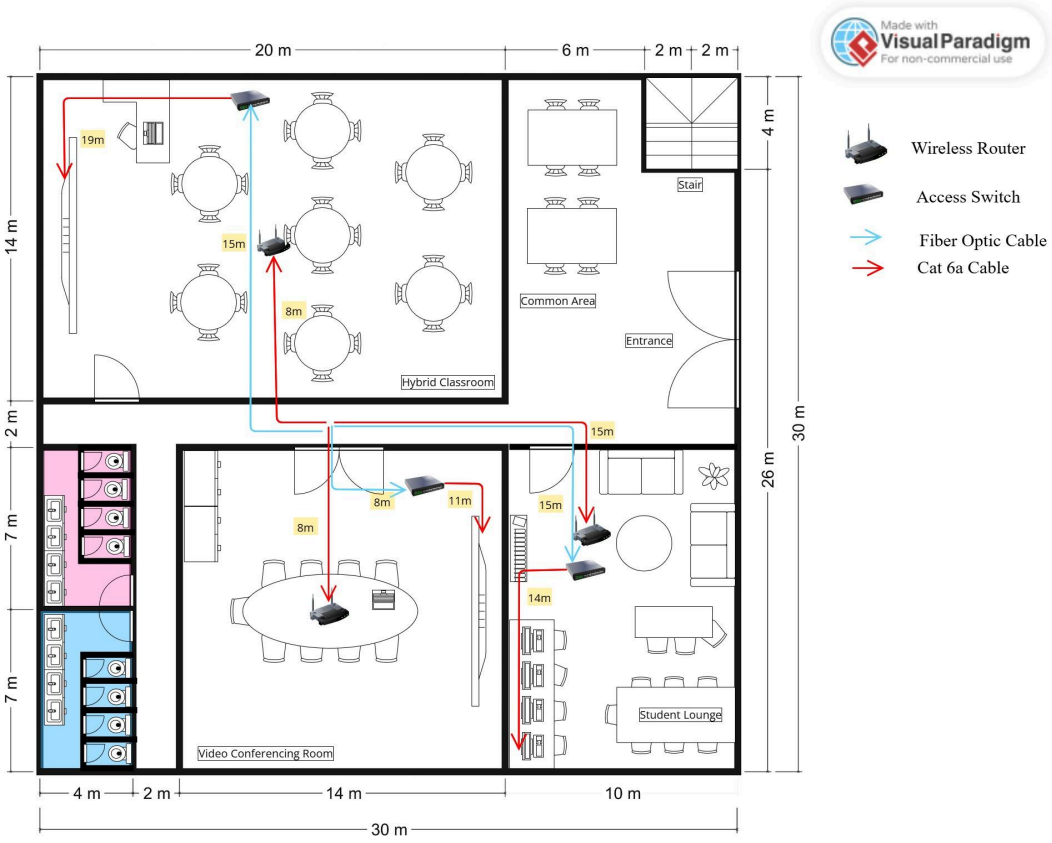

Figure 2.2: Network Device Arrangement in Ground Floor Plan

6.3 First Floor Plan

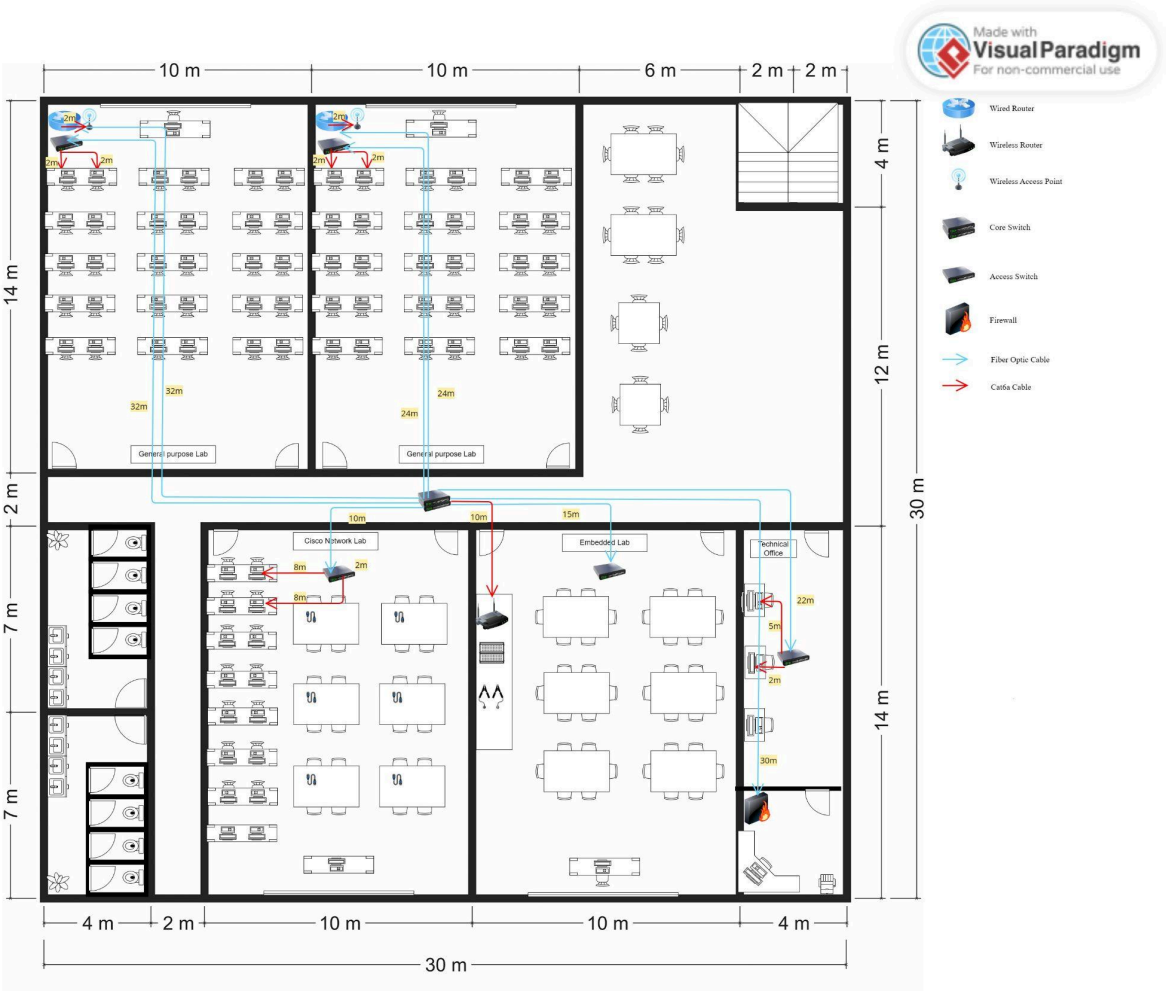

Figure 2.3: Network Device Arrangement in First Floor Plan

There are nine connections. One general connection connecting to the Internet service provider, firewall and the core switch. There is then one connection for each room, with 3 connections on the ground floor and 5 connections on the first floor.

CAT6 cables and RS PRO 12-way TB Fibre Optic Cable are used as patch cords. There is an estimated amount of 106 patch cords.
For switches, Cisco C9200-48T-A Catalyst 9200 would be used. It has 48 ports of data. There are a total of 8 switches.

The estimated length of cable needed is 1007 m by considering the height of a floor is 4m.

The calculations are shown in the table below.

Figure 3.1: Calculation of Cable Needed

Description	Patch Cords	Length (m)
General Connection		
- Firewall to core switch (Fiber Optic Cable)	1	30
Hybrid Classroom		
- Core switch to wireless router (CAT6)	1	8
- Core switch to access switch (Fiber Optic Cable)	1	15
- Access switch to smart TV (CAT6)	1	19
Video Conferencing Room		
- Core switch to wireless router (CAT6)	1	8
- Core switch to access switch (Fiber Optic Cable)	1	8
- Access switch to smart TV (CAT6)	1	11
Student Lounge		
- Core switch to wireless router (CAT6)	1	15
- Core switch to access switch (Fiber Optic Cable)	1	15
- Access switch to PC (CAT6)	4	14
General Purpose lab 1		
- Core switch to router (Fiber Optic Cable)	1	32
- Router to access point (CAT6)	1	2
- Core switch to access switch (Fiber Optic Cable)	1	32
- Access switch to PCs (CAT6)	31	216
General Purpose lab 2		
- Core switch to router (Fiber Optic Cable)	1	32
- Router to access point (CAT6)	1	2
- Core switch to access switch (Fiber Optic Cable)	1	32
- Access switch to PCs (CAT6)	31	216
Cisco Network Lab		
- Core switch to access switch (Fiber Optic Cable)	1	10
- Access switch to PCs (CAT6)	17	228
Embedded Lab		
- Core switch to wireless router (CAT6)	1	15
- Core switch to access switch (Fiber Optic Cable)	1	10
Technical Office		
- Core switch to access switch (Fiber Optic Cable)	1	22
- Core switch to PCs (CAT6)	4	12
Total	106	1004
Fiber Optics	11	238
CAT6	95	766

7.0 IP Addressing Scheme

Network Address: 10.48.0.0

Subnet Mask: /12 = 255.240.0.0

Subnet Mask in Binary

11111111.11110000.00000000.00000000 = 255.240.0.0

Available IP Address Range: 10.48.0.0 - 10.63.255.255

Available IP Address Range in Binary

00001010.00110000.00000000.00000000 = 10.48.0.0

00001010.00111111.11111111.11111111 = 10.63.255.255

Each lab would have a subnet. Besides, the video conferencing room, hybrid classroom, student lounge and the technician office will each have a subnet.

Table 4.1: Subnet Calculation

Area	Required IPs	Subnet Size (2^n) $2^n > IPs + 2$	Subnet Mask	Network Address	Broadcast Address	Usable IP Range
General Purpose Lab 1	30 workstation + 1 lecturer's workstation + 1 wireless access point + 1 router = 33 IPs	$2^n > 33 + 2$ $2^6 > 33 + 2$	$/32 - 6 = /26$ 11111111.11111111.11111111.11000000 = 255.255.255.192	10.48.0.0/26	00001010.00110000.00000000.00111111 = 10.48.0.63	10.48.0.0 - 10.48.0.62

General Purpose Lab 2	30 workstation + 1 lecturer's workstation + 1 wireless access point + 1 router = 33 IPs	$2^n > 33 + 2$ $2^6 > 33 + 2$	/32 − 6 = /26 11111111.11111111.11111111.11000000 = 255.255.255.192	10.48.0.64/26	00001010.00110000.00000000.01111111 = 10.48.0.127	10.48.0.64 - 10.48.0.126
Cisco Network Lab	30 workstation + 1 lecturer's workstation = 31 IPs	$2^n > 31 + 2$ $2^6 > 31 + 2$	/32 − 6 = /26 11111111.11111111.11111111.11000000 = 255.255.255.192	10.48.0.128/26	00001010.00110000.00000000.10111111 = 10.48.0.191	10.48.0.128 - 10.48.0.190
Embedded Lab	30 workstation + 1 lecturer's workstation + 1 router = 32 IPs	$2^n > 32 + 2$ $2^6 > 32 + 2$	/32 − 6 = /26 11111111.11111111.11111111.11000000 = 255.255.255.192	10.48.0.192/26	00001010.00110000.00000000.11111111 = 10.48.0.255	10.48.0.192 - 10.48.0.254
Technician Office	4 workstation = 4 IPs	$2^n > 4 + 2$ $2^3 > 4 + 2$	/32 − 3 = /29 11111111.11111111.11111111.11111000 = 255.255.255.248	10.48.1.0/29	00001010.00110000.00000001.00000111 = 10.48.1.7	10.48.1.1 - 10.48.1.6
Video Conferencing Room	1 smart TV + 1 workstation + 1 router = 3 IPs	$2^n > 3 + 2$ $2^3 > 3 + 2$	/32 − 3 = /29 11111111.11111111.11111111.11111000 = 255.255.255.248	10.48.1.8/29	00001010.00110000.00000001.00001111 = 10.48.1.15	10.48.1.9 - 10.48.1.14
Student Lounge	4 workstations + 1 router = 5 IPs	$2^n > 5 + 2$ $2^3 > 5 + 2$	/32 − 3 = /29 11111111.11111111.11111111.11111000 = 255.255.255.248	10.48.1.16/29	00001010.00110000.00000001.00010111 = 10.48.1.23	10.48.1.17 - 10.48.1.22

Hybrid Classroom	1 smart TV + 1 workstation + 1 router = 3 IPs	$2^n > 3 + 2$ $2^3 > 3 + 2$	/32 − 3 = /29 11111111.11111111.11111111.11111000 = 255.255.255.248	10.48.1.24/29	00001010.00110000.00000001.00011111 = 10.48.1.31	10.48.1.25 - 10.48.1.30

8.0 Reflection

We collaborated effectively on every task as a team. For the floor plan, we designed the floor layout with the needs of the building. In the research phase, we looked into networking devices and backup solutions to ensure network reliability. When choosing LAN devices, we helped each other select the best options. Next, we updated the floor plans to include the LAN devices. Lastly, we assigned IP addresses to different rooms and PCs. Overall, we learned how important preparation, communication and cooperation are to complete the project successfully.

9.0 Conclusion

Across the 12 week time, our team has successfully fulfilled the objective of the project, to design a networking solution that fits N28B's building plan within budget allocated, ensured that there is sufficient scalability to cope with a 15% increase in users over the following four years and also provided a internetworking device connection with reliable performance to the client, Faculty of Computing, UTM. In task 1, the floor plan of the new N28b building was sketched with a good functionality of each room and suitable space planning. In task 2, research was done on some requirements and other aspects to consider on a network plan. In task 3, our team surveyed the market price of LAN and network devices. We were surprised by the prices of the high ended device that are not as costly as we expected it to be. Looking into task 4, we planned the placement of the networking devices we chose and drew about the connections across all devices. Lastly, in task 5, we assigned IP addresses and allocated subnets wisely to maximise the efficiency. We were able to understand the theory in lectures and apply it in practical terms.

The project couldn't be successful without the strong team working, effective planning and the unremitting research on the topic. All the tasks will be equivalently distributed among our team members, and we collaborate in real-time on the platform Google Docs. During the tasks, all of us are aware of each other's progress. If there's any problem encountered, we will update each other using the 'comment' function of Google Docs. This mode of collaboration allows us to complete tasks in a breeze.

However, our team is aware of some issues while progressing through the project. Firstly, the contents of each task are limited by the boundary of our current knowledge, as we cannot imagine the things we haven't learned. This has caused us the problem of applying changes to the previous tasks after learning that it was wrong or not suitable. For example, the number of networking devices deployed written in task 4 is different from what we had thought initially in task 2. Nevertheless, the process of realisation of our own weakness has taught us numerous lessons that we won't forget.

For future projects, it is possible to have improvements by thoroughly planning all the tasks beforehand with a timeline, for example by using gantt chart. We should also look through the whole project description, understand the requirements and achievables of the project before we start the project. We should also crosscheck the work with the works of the other members to maintain the integrity and correctness of all information specified.

In conclusion, this project has been a valuable learning experience and a step forward in achieving our goals. By leveraging our strengths and addressing areas for improvement, let us hope that we will be able to achieve greater success in our future projects.

10.0 Team Member and Responsibilities

Group Members:

1. Goe Jie Ying
2. Lam Yoke Yu
3. Tan Yi Ya
4. Teh Ru Qian

Members	Responsibilities
Goe Jie Ying	● Place all labs on the same floor for accessibility and efficiency ● Formed question 5 - 7 ● Chooses switches, cables for the building ● Draw network device arrangement of the workspace ● Assign IP for Cisco Network Lab, Embedded Lab and Technical Office
Lam Yoke Yu	● Breaks down and explain the task initially ● Formed question 8 - 10 ● Chooses firewall for the building ● Do calculations for the wiring connecting each LAN devices ● Assign IP for General Purpose Lab
Tan Yi Ya	● Sketch and draft floor plan, determine room size and locations ● Formed question 4 and 6, wrote feasibility ● Chooses wireless access point, patch panel for the building ● Complete the placement of LAN devices and wiring for first floor ● Assign IP for Hybrid Classroom
Teh Ru Qian	● Designing the internals of rooms of ground floor ● Formed question 1 -3 ● Chooses router for the building ● Complete the placement of LAN devices and wiring for ground floor ● Assign IP for Video Conferencing Room and Student Lounge

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12.0 Appendices

12.1 Appendices A: Meeting Minutes

Task 1 Meeting Minutes

DATE/TIME		31 Oct 2024 6.00pm	
LOCATION		Online	
AGENDA		Discussion for Task 1	
MEETING MC		Goe Jie Ying	
ATTENDANCE			
NAME		**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying		6.00 pm	-
Lam Yoke Yu		6.00 pm	-
Tan Yi Ya		6.00 pm	-
Teh Ru Qian		6.00 pm	-
MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE & DATE**
1	Floor Plan & Design	Yoke Yu - Suggest the size of hybrid classroom and video conferencing room Ru Qian - Suggest a common area Yi Ya: ● Draft the floor plan on a tablet, then finalize it on a laptop. ● Recommend floor sizes and optimal restroom locations. Jie Ying: ● Place all labs on the same floor for accessibility and efficiency. Yoke Yu: ● Suggest dimensions for a hybrid classroom and a video conferencing room. Ru Qian: ● Design a common area with seating and tables for relaxation	All

		and collaboration.	
2	Software Used	Yi Ya - Use Freeform to sketch draft, then used Visual Paradigm Ru Qian - Use Visual Paradigm	Yi Ya 31/10 Ru Qian 31/10
3	Next Meeting	2/11 - Progress Checking	All
4	Meeting Ended	6.40 pm	All

Task 2 Meeting Minutes

DATE/TIME	3 Nov 2024 7.00pm	
LOCATION	M19, Kolej Tun Dr. Ismail	
AGENDA	Discussion for Task 2	
MEETING MC	Lam Yoke Yu	
ATTENDANCE		
NAME	**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying	7.00 pm	-
Lam Yoke Yu	7.00 pm	-
Tan Yi Ya	7.00 pm	-
Teh Ru Qian	7.00 pm	-

MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE & DATE**
1	Discuss the questions.	- Discuss the kinds of questions to be asked.	All 4/11/2024
2	Search the questions online.	- Use the keywords related to our task and search in the browser.	All 13/11/2024

3	Next Meeting	8/11 - Progress Checking	All
4	Meeting Ended	9.00 pm	All

Task 3 Meeting Minutes

DATE/TIME		12 Nov 2024 9.00pm	
LOCATION		Physical, Family Mart	
AGENDA		Discussion for Task 3	
MEETING MC		Teh Ru Qian	
ATTENDANCE			
NAME		**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying		9.00 pm	-
Lam Yoke Yu		9.00 pm	-
Tan Yi Ya		9.00 pm	-
Teh Ru Qian		9.00 pm	-
MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE & DATE**
1	Discuss the devices	- Discuss devices and quantity	All 13/11/2024
2	Do research about the devices	- Find out the devices through internet - Search for prices on internet using shopee and lazada - Find the specifications of devices	All 13/11/2024
3	Next Meeting	9/11 - Progress Checking	All
4	Meeting Ended	10.15 pm	All

Task 4 Meeting Minutes

DATE/TIME		10/12/2024	
LOCATION		Student Lounge, N28	
AGENDA		Discussion on Placement of LAN devices	
MEETING MC		Teh Ru Qian	
ATTENDANCE			
NAME		**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying		9:45pm	-
Lam Yoke Yu		9:45pm	-
Tan Yi Ya		9:45pm	-
Teh Ru Qian		9:45pm	-
MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE & DATE**
1	Placement of networking devices	All ● Discuss on the placement and arrangement of the networking devices Yi Ya ● Draft the placement of networking devices on tablet	All 10/12
2	Task Distribution	Ru Qian ● Use Visual Paradigm for the floor plan of the first floor Yi Ya ● Use Visual Paradigm for the floor plan of ground floor Jie Ying ● Use Cisco Packet Tracer for the networking devices connection Yoke Yu ● Calculated the needed cables and estimated length	All 10/12
3	Next Meeting	13/12 - Progress Checking	All
4	Meeting Ended	10:35 pm	All

Task 5 Meeting Minutes

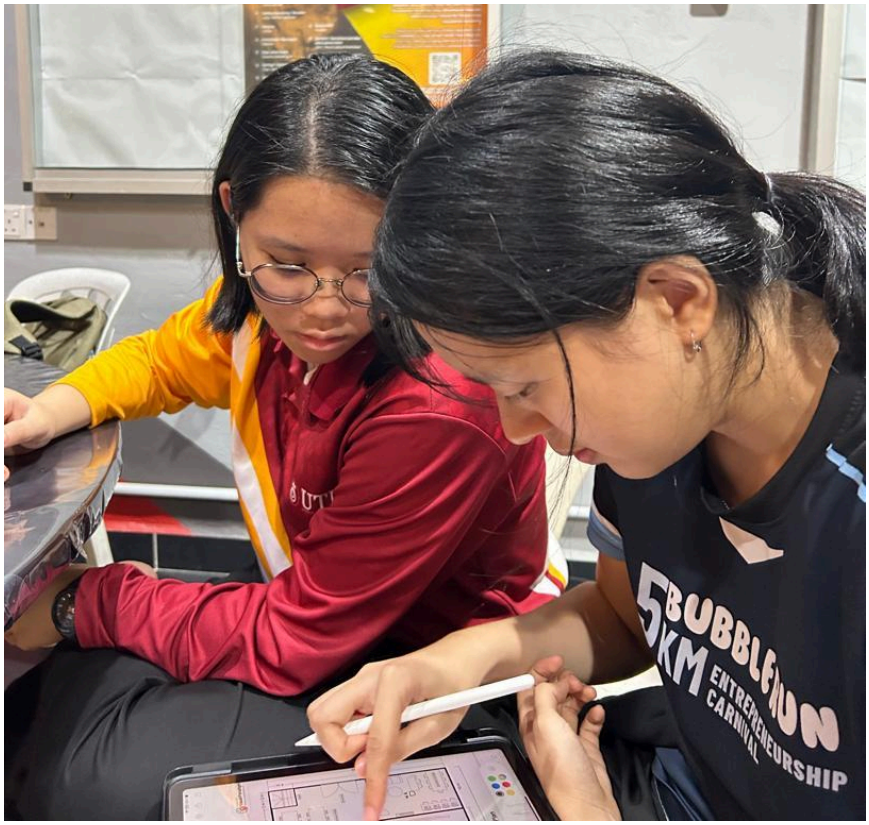
DATE/TIME		23/12/2024 9:00a.m.	
LOCATION		Online @google meet	
AGENDA		Discussion on IP Addressing Scheme	
MEETING MC		Tan Yi Ya	
ATTENDANCE			
NAME		**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying		9:00a.m.	-
Lam Yoke Yu		9:00a.m.	-
Tan Yi Ya		9:00a.m.	-
Teh Ru Qian		9:00a.m.	-
MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE & DATE**
1	IP Addressing Scheme	All ● Discuss on the best division of network for all lab	All, 23/12
2	Discussion Subnet Allocation	All ● Discussed individual subnets for labs, offices, and meeting rooms.	All, 23/12
3	Task Distribution	Ru Qian ● IP Assignation for Video Conferencing Room and Student Lounge Yi Ya ● IP Assignation for Hybrid Classroom Jie Ying ● IP Assignation for Cisco Network Lab, Embedded Lab and Technical Office Yoke Yu	All, 23/12

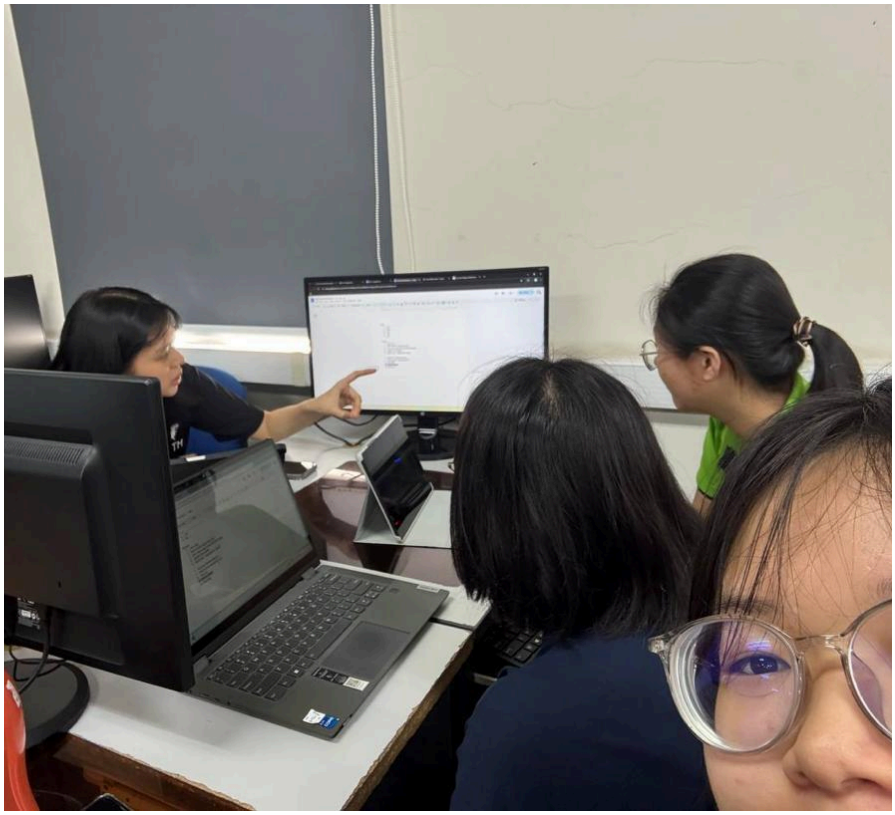
		• IP Assignation for General Purpose Lab	
4	Next Meeting	26/12 - Progress Checking	All, 26/12
5	End of Meeting	10:50 a.m.	All, 23/12

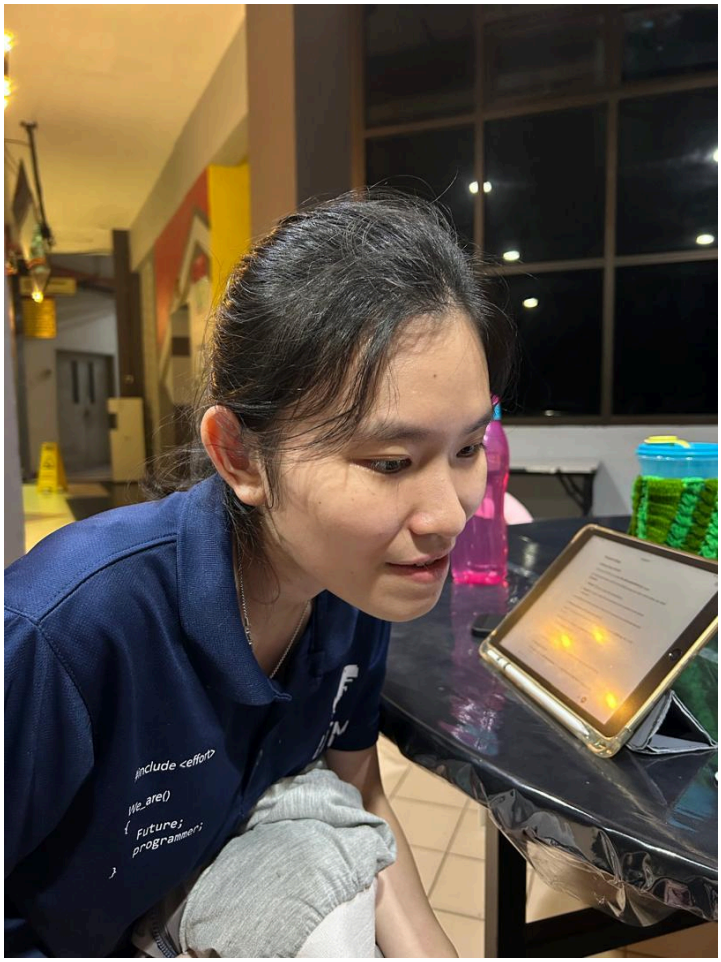
12.2 Appendices B: Financial Budget

Item	Quantity	Unit Price (RM)	Total Price (RM)
Cisco RV345 Dual WAN Gigabit VPN Router (Wired Router)	2	1400.00	2800.00
TP-Link Archer AX73 (Wireless Router)	5	499.00	2495.00
Cisco C9200-48T-A Catalyst 9200 (Access Switch)	8	18,039.88	144319.04
Aruba Networking CX 6400 (Core Switch)	1	56135.00	56135.00
S PRO 12-way TB Fibre Optic Cable (100m)	3	2340.00	7020.00
RJ 45 2996AS-1GY (1m) (Cat 6a)	766	32.86	25170.76
Ubiquiti UniFi U7 Pro Max (Wireless Access Point)	2	1700.00	3400.00
Fortinet FortiGate 200F (Firewall)	1	18,444.88	18444.88
		Total	259784.68
		Budget Left	2200000 - 259784.68 = 1940215.32

12.3 Appendices C: Pictures of our team






#include <effort>
We_are()
{
Future;
programmer;
}

Meeting Minutes

DATE/TIME		31/12/2024 10:00a.m.	
LOCATION		MPK9, N28 (Physically)	
AGENDA		Discussion on Task 6	
MEETING MC		Goe Jie Ying	
ATTENDANCE			
NAME		**TIME**	**REASON FOR ABSENCE**
Goe Jie Ying		10:00a.m.	-
Lam Yoke Yu		10:00a.m.	-
Tan Yi Ya		10:00a.m.	-
Teh Ru Qian		10:00a.m.	-
MINUTES			
NO.	**ITEM DISCUSSED**	**IDEA/SUGGESTIONS AND PERSON GIVING IT**	**PERSON IN CHARGE**
1	Project Outline	All ● Discussed the Outline and Dividing it into Clearer Parts	Jie Ying - suggest the part division for introduction and background to have clearer overview of the project Yi Ya - suggest to discuss our main and final requirement for the project, thus the compilation process afterwards would go through smoothly
2	Discussion about Task submitted before	All ● Reviewed the changes in our tasks and updated to the latest version	Yoke Yu - suggest some more suitable devices according to the network plan we did Ru Qian - check the floor plan to ensure all the wiring in

			correct arrangement
3	Task Distribution	Ru Qian ● Compile and check Task 4-6 Yi Ya ● Review the whole project and give suitable conclusion Jie Ying ● Introduce the project and overview the background Yoke Yu ● Compilation and checking for task 1-3	All
4	Next Meeting	5/1 - Progress Checking	All
5	End of Meeting	10:50 a.m.	All