University of Moratuwa
Department of Electronic and Telecommunication Engineering
EN2150 - Communication Network Engineering
Semester 4
Design of Local Area Network
Team Halo

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This report is submitted as a partial fulfillment of the module EN2150 - Communication Network Engineering

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1 Introduction

A backbone network is a centralized network infrastructure that provides connectivity between multiple local area networks (LANs) or wide area networks (WANs) in an institution which is designed for long term use. Many aspects should be taken into consideration when designing a backbone network for an institution.

2 The Approach to the Backbone Design of University of Moratuwa

As the first step of the backbone network design process for University of Moratuwa, an in-depth analysis was conducted on the existing network and the observations were recorded.

2.1 Features of the existing backbone network of University of Moratuwa

- The backbone network of University of Moratuwa has a ring topology.
- Mainly there are 2 server locations namely,
  1. Sumanadasa Building
  2. Center for Information Technology Services (CITeS)
- There are 9 nodes to access the network. They are in the following locations.
  1. Network Operating Center at CITeS
  2. Faculty of Information Technology
  3. Department of Electronic and Telecommunication Engineering
  4. Sumanadasa Building
  5. Department of Civil Engineering
  6. Department of Transport Management and Logistics Engineering
  7. Department of Material Science and Engineering
  8. Department of Mechanical Engineering
  9. Administration Building

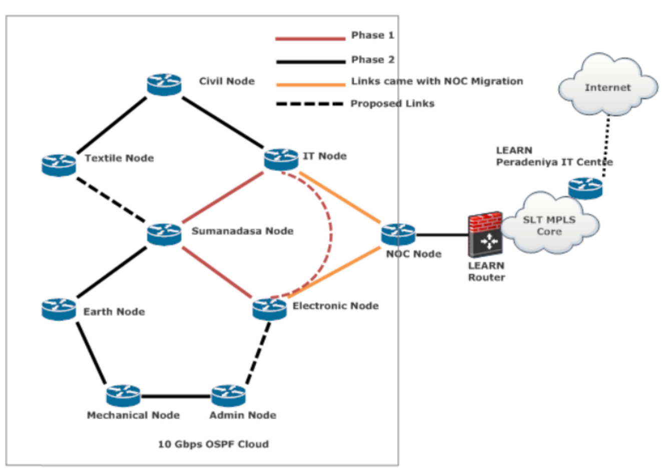

Figure 1: University of Moratuwa Core Network Architecture

- All the nodes are Layer 3 switches whcih are running over the Open Shortest Path First protocol which is a IP routing protocol used to distribute IP routing information throughout a single Autonomous System (AS) in an IP network.
- There are 25 access points have been installed based on the network traffic which can be extended up to 500 such points that can support 7000 clients.
- The current bandwidth of the backbone network is 1600 Mbps which is provided by 2 internet service providers: 1400 Mbps from Sri Lanka Telecom and 200 Mbps from Dialog.
- Daily inbound and outbound traffic of the network of University of Moratuwa is as follows.
  - Inbound refers to connections that are coming-in to a specific device from a remote location.

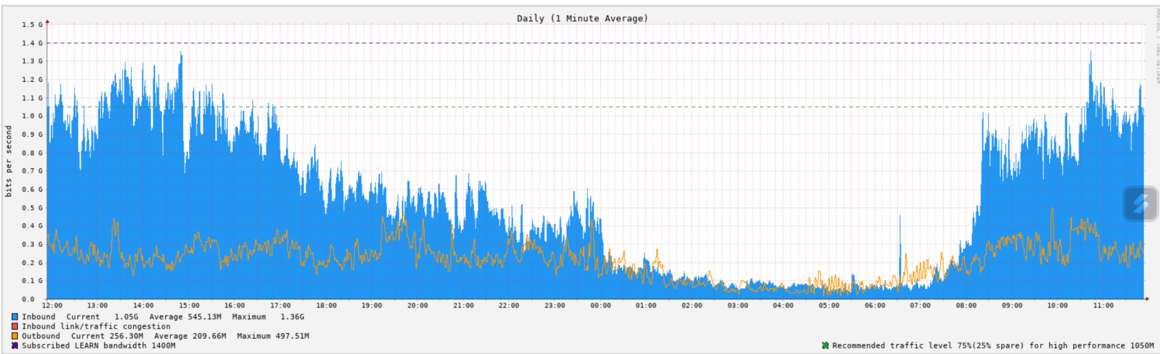

Figure 2: Daily Inbound Traffic

  - Outbound refers to the connections going-out to a specific device from a device or host.

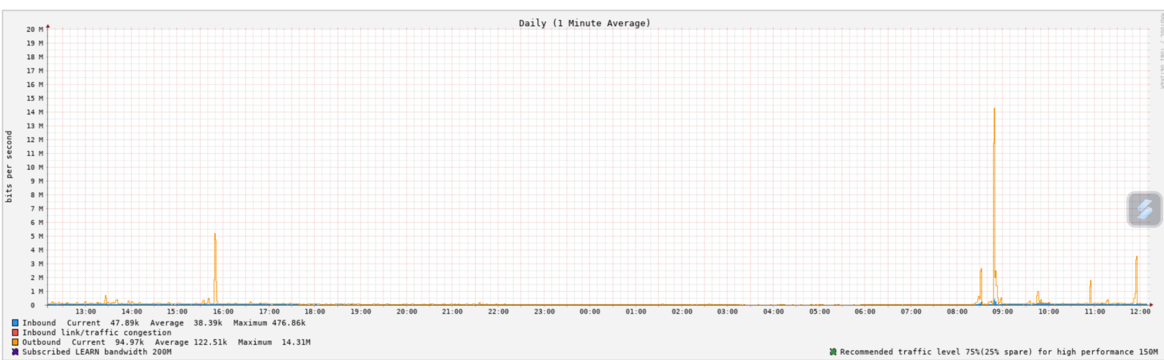

Figure 3: Daily Outbound Traffic

- The current bandwidth of the backbone network is 1600 Mbps which is provided by 2 internet service providers: 1400 Mbps from Sri Lanka Telecom and 200 Mbps from Dialog.
- University of Moratuwa is a member of Lanka Education and Research Network (LEARN).It subscribes 240 Mbps Internet bandwidth and 500 Mbps Local bandwidth through LEARN.

2.2 Features of the local area network of the department building of Department of Electronic and Telecommunication Engineering

- ENTC LAN is a flat network.
- No Virtual Local Area Network (VLAN) has been divided inside the network.
- LAN of ENTC department building is connected to the backbone network of University of Moratuwa through ENTC node which is a layer 3 switch.
- ENTC node switch can support a maximum data rate of 10 Gigabits per second.
- From the ENTC node switch, 10 Gigabits per second fibre cable is connected to the core switch of the ENTC LAN which is again a layer 3 switch.
- From the ENTC core switch , 8 fibre cables of speed 1 Gigabits per second has been connected to 8 24-Port Network Switches which are 2 layer in the following locations.
  1. Biomedical Engineering Laboratory.
  2. Computer Laboratory.
  3. Department Office.
  4. Digital Electronic Laboratory.
  5. Instructors' Room.
  6. Telecommunication Laboratory.
  7. Microwave Laboratory.
  8. Vision Laboratory.
- Copper UTP cables have been used to connect the following 24-Port network switches to the ENTC Core switch .
  - Switch inside the Premium Biomedical Engineering laboratory.
  - 2 switches inside the Network Room, Ground Floor.
- There are 14 wireless access points inside the building to access the LAN. Their locations and the switch which each one is connected are as follows.
  - From the 2 switches at the Network Room,
    * ENTC1.
    * 0.5 Student Area.
    * UAV Laboratory.
  - From the switches at the Biomedical Engineering Laboratory,
    * Biomedical Laboratory.
  - From the switch at the Computer Laboratory,
    * Computer Laboratory.
  - From the switch at the Department Office,
    * Near the lift of 1st floor.
    * Near the HOD Office.
  - From the switch at the Digital Electronic Laboratory,
    * Near the Digital Electronic Laboratory.
    * Inside the Analog Electronic Laboratory.
  - From the switch at the Department Office,
    * Near the Upper Common Student Area.
    * Near the Instructors' Room.

- From the switch at the Telecommunication Laboratory,
  - Inside the Telecommunication Laboratory.
- From the switch at the Vision Laboratory,
  - Near the Dialog Laboratory.
- From the switch at the Microwave Laboratory,
  - Inside the Microwave Laboratory.

The diagram indicating their locations is

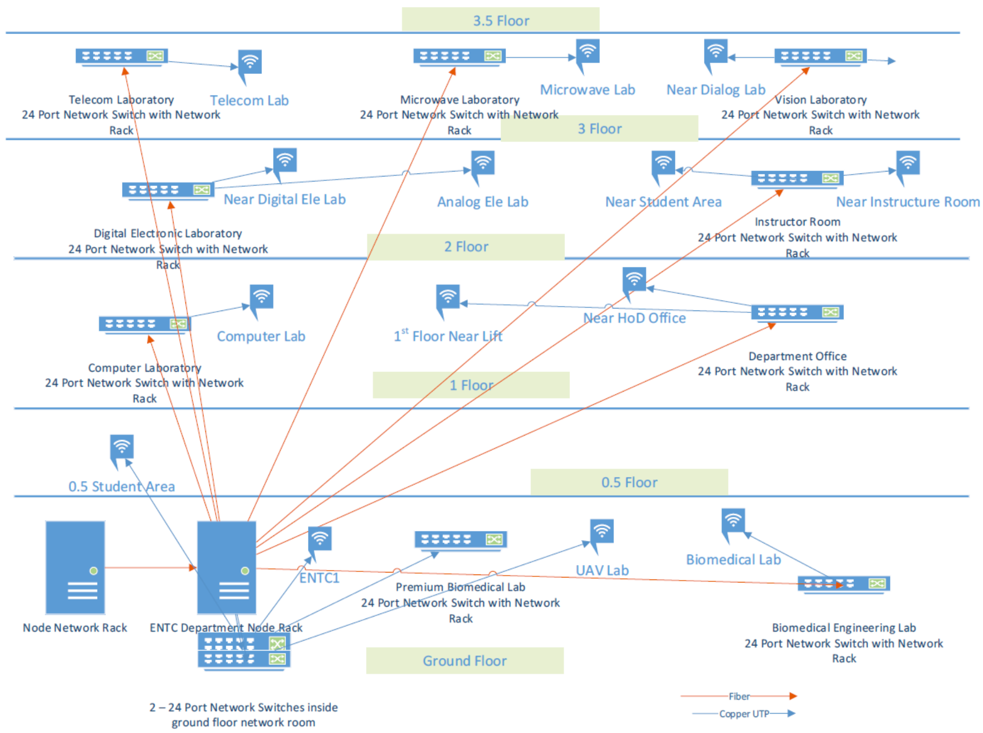

Figure 4: ENTC Network Architecture

2.3 Proposed Design for the Backbone Network of University of Moratuwa

- The topology suggested for the backbone network is ring topology. It has the following features which makes it suitable for the backbone network of University of Moratuwa.
  - Ring topology has a high data transmission rate because of single-direction data transmission which reduces collision.
  - Easy to troubleshoot problems among the devices.
  - Ring topology is a cost effective topology.
- According to the inbound and outbound traffic diagrams(Figure 2 and Figure 3) of the existing backbone network, 75 percent of the subscribed bandwidth is often used. According to the **Horizontal Factor Requirement of 10**, the effective ensured bandwidth of the current backbone link is 1 Gigabits per second. With the emerging aspects such as 4K, 8K video streaming, virtual reality, rising users for accessing Internet of Things applications, Software as a Service capabilities (Cloud Computing), a high bandwidth is expected. Bandwidth used by a person has increased overtime.To reduce the network traffic and share the network traffic among the main sever locations, 40 Gigabits per second fibre connection(Achieved by connecting 4 fibre cables of speed 10 Gigabits per second parallel with each other) is proposed to connect **Sumanadasa node** and **CITeS Node**.
- It is also recommended to use 40 Gigabits per second connections over the remaining nodes so that with the Horizontal Factor Requirement, a 4 Gigabits per second bandwidth is ensured among the nodes.
- Although there are 180 access points located inside the university premises to access the network, during the peak hours (Such as lunch break) it is observed that the latency increases and the speed of the network is becoming lower which makes hard for the users to access the network.Therefore, it is suggested to use more access points in those areas to reduce network traffic to provide a quality service.
- It is recommended to keep the main nodes as it is because it is sufficient to cover the entire university premises using those 9 nodes which is futureproof.
- It is further recommended to increase the number of access points so the congestion is distributed among the nodes.

3 Network diagram With all the Building Nodes and Bandwidth in each Link

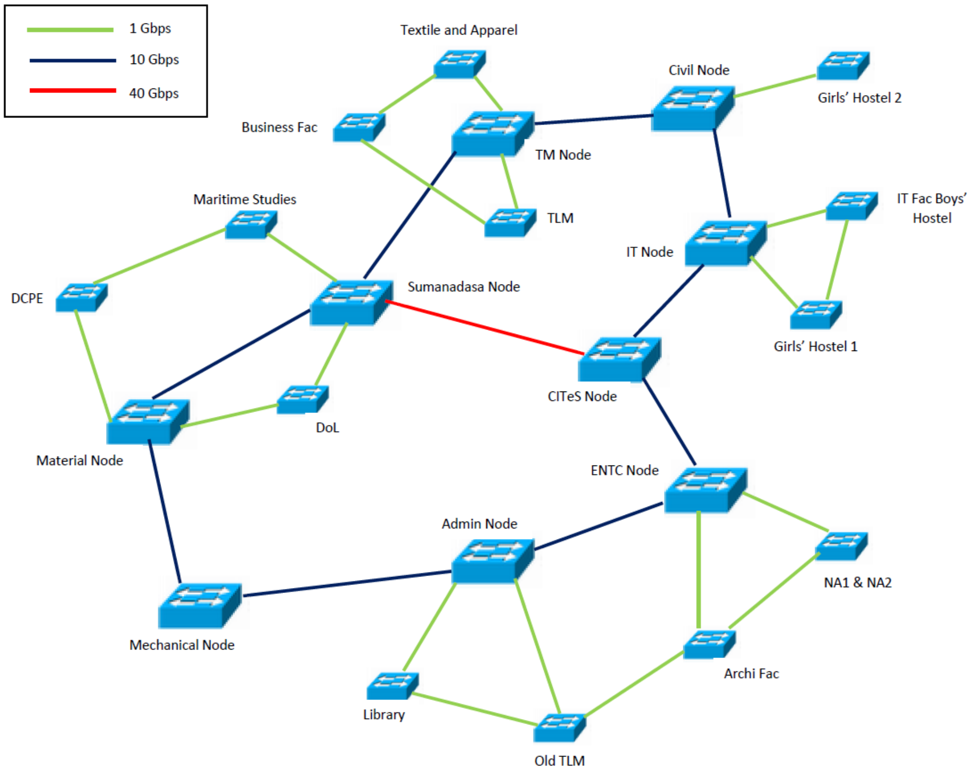

Figure 5: Proposed Backbone Network for University of Moratuwa

4 IP Addressing

4.1 For the Backbone Network

The proposed IP address for the backbone network is IPv4 Class C: 192.168.0.0/16. The IP address allocation for each subnet in the backbone (main 9 nodes with other sub-nodes) is done by allocating certain number of bits for the host side of the address based on the number of users in such a way that it fits for the future demand of the network with increasing user count in the university.

Building	**Estimated No. of Users**	**IP addressing**
CITES	200	192.168.0.0/24
Sumanadasa	800	192.168.1.0/22
Admin	200	192.168.5.0/24
ENTC	300	192.168.6.0/23
IT	900	192.168.8.0/22
Civil	300	192.168.12.0/23
Material	250	192.168.14.0/24
Mechanical	300	192.168.15.0/23
Library	800	192.168.17.0/22
TLM	250	192.168.21.0/24
Architecture	500	192.168.22.0/23
Business	200	192.168.24.0/24
Textile	150	192.168.25.0/25
Fashion Design	150	192.168.25.128/25
NA Building	100	192.168.26.0/25
Maritime Studies	50	192.168.26.128/26
Chemical	250	192.168.26.192/26
Language	100	192.168.27.0/25
Hostel	200	192.168.27.128/25
Girl's Hostel	200	192.168.28.0/25

4.2 For the ENTC LAN

The current local area network of the Department of Electronic / Telecommunication Engineering is a flat network. A flat network, also known as a non-segmented or non-segregated network, refers to a network architecture where all devices and endpoints are connected to a single broadcast domain or subnet. In a flat network, there are no logical divisions or separate subnetworks created using technologies like VLANs (Virtual Local Area Networks) or subnetting. Even though implementation of a flat network is comparitvely simple, it has several disadvantages as well which can be avoided either by using subnets or by using VLANS. The issues associated with having a flat network, without proper segmentation or network boundaries are as follows,

1. Security Risks
2. Broadcast Storms and Network Congestion
3. Limited Network Performance and Bandwidth Management
4. Lack of Scalability and Flexibility
5. Compliance and Regulatory Challenges
6. Difficulties in Network Administration

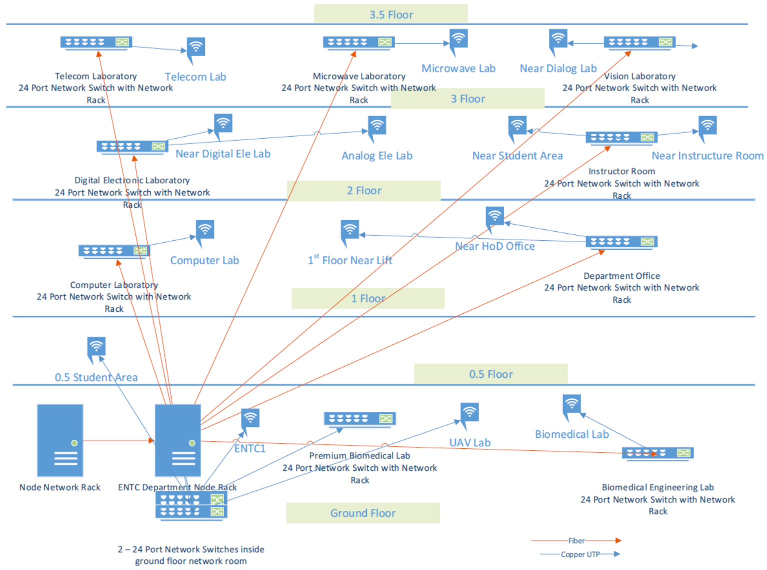

Figure 6: Current ENTC Network Architecture

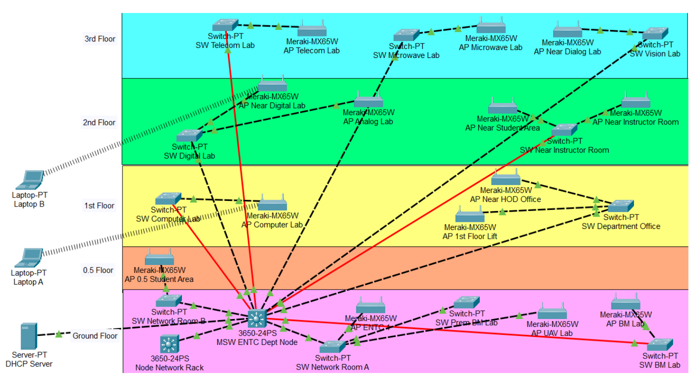

Figure 7: Implementation of current ENTC Network using Packet Tracer

However, as an improvement to the current design of the ENTC network, we suggest separating the ENTC LAN into several VLANs. We suggest separating the devices connected to each layer 2 switch into VLANS. Hence there are 11 such VLANs in the system we propose. Using a VLAN in the system will provide the following benefits,

1. Enhanced Network Security
2. Improved Performance and Bandwidth Management
3. Simplified Network Administration
4. Scalability and Flexibility
5. Broadcast Control

The proposed IP address scheme is shown below.

VLAN No.	**VLAN Name**	**IP Address**
VLAN 20	NETROOM_1	192.168.20.0/24
VLAN 21	NETROOM_2	192.168.21.0/24
VLAN 22	PREM_BM_LAB	192.168.22.0/24
VLAN 23	BM_LAB	192.168.23.0/24
VLAN 24	COMPUTER_LAB	192.168.24.0/24
VLAN 25	DEPT_OFFICE	192.168.25.0/24
VLAN 26	DIGITAL_LAB	192.168.26.0/24
VLAN 27	INSTRUCTOR_ROOM	192.168.27.0/24
VLAN 28	TELECOM_LAB	192.168.28.0/24
VLAN 29	MICROWAVE_LAB	192.168.29.0/24
VLAN 30	VISION_LAN	192.168.30.0/24

5 Active and Passive Components in the Backbone Network and Justifications

5.1 Active Components

Active components are the components which require power in the network to operate with in the network. In a typical backbone network, devices such as routers, switches and access points belong to this category.

5.1.1 Switches

- **HP 1920 24-Gigabit Port Layer 3 Switch**

  The HPE Office Connect 1920 Switch Series consists of advanced smart-managed fixed configuration Gigabit switches designed in an easy-to-administer solution. It has the following key features.

  - IEEE 802.1p/Q VLAN tagging - Delivers data to devices based on the priority and type of traffic; supports IEEE 802.1Q.
  - FTP, TFTP, and SFTP support - Offer different mechanisms for configuration updates; FTP allows bidirectional transfers over a TCP/IP network; trivial FTP (TFTP) is a simpler method using User Datagram Protocol (UDP);Secure File Transfer Protocol (SFTP) runs over an SSH tunnel to provide additional security
  - IEEE 802.3X Flow Control - A flow throttling mechanism to prevent packet losses in a congested node.
  - IEEE 802.3at Power over Ethernet (PoE+) - Supports the latest PoE+ capable devices such as IP phones, wireless access points, and security cameras, as well as any IEEE 802.3af compliant end device. Can provide up to 30 W per port.
  - Auto MDI/MDI-X - Adjust automatically for straight-through or crossover cables on all 10/100/1000 ports.
  - Cable diagnostics - an detect cable issues directly fro a remote web application.
  - Class of Service (CoS) - Sets the IEEE 802.1p priority tag based on IP address, IP Type of Service (ToS), Layer 3 protocol, TCP/UDP port number, source port, and DiffServ.

- **TRENDnet 24-Port Gigabit Managed Layer 2 Switch**

  - The 24-Port Gigabit Layer 2 Switch with 4 Shared Mini-GBIC Slots, model TL2-G244, provides a reliable foundation for a highly scalable managed network.
  - The TL2-G244 features a 48Gbps switch fabric, 802.1X authentication, SNMP v3, and Multiple Spanning Tree (MSTP) support
  - Gigabit Ethernet ports and Mini-GBIC slots provide high speed uplinks to backbone switching or servers. Configure the switch using the choice of Telnet, HyperTerminal, SNMP, or a Browser.
  - View statistics captured for 17 unique switching parameters.
  - Auto MDI/MDI-X - Adjust automatically for straight-through or crossover cables on all 10/100/1000 ports.
  - Additional management features such as port Trunking, IGMP snooping, Static and Dynamic VLAN, Load Balancing, RMON, QoS, and RSTP allow administrators to effectively manage departmental work groups.

5.1.2 Access Points

- **Cisco Catalyst 9105 Series Access Point**
  The Cisco Catalyst 9105 Series Access Points are next generation access points which have the following key features.

  – Wi-Fi 6 (802.11ax) - The IEEE 802.11ax emerging standard, also known as High-Efficiency Wireless (HEW) or Wi-Fi 6, builds on 802.11ac. It is compatible for more predictable performance for advanced applications such as 4K or 8K video, high-density, high-definition collaboration applications,and IoT.

  – Uplink/downlink OFDMA - OFDMA-based scheduling splits the bandwidth into smaller frequency allocations called Resource Units (RUs), which can be assigned to individual clients in both the downlink and uplink directions to reduce overhead and latency.

  – BSS coloring - Spatial reuse (also known as Basic Service Set [BSS] coloring) allows the access points and their clients to differentiate between BSSs, which permits more simultaneous transmissions.

5.2 Passive Components

Components which do not require power to operate in the network are passive components.

5.2.1 AMP 48 Port CAT6 Patch Panel

Rack-mounted CAT 6 component rated patch panel provides an excellent performance for network designs requiring maximum bandwidth and speed. It supports PoE++ (Power Over Ethernet) type 4; up to 100W on each port. It satisfies ANSI/TIA-568-B.2 category 6 connecting hardware requirements and includes both TIA-568A and TIA-568B color wiring diagrams. This particular patch panel was designed to provide 110 IDC termination reducing installation time and to fit all standard 19” racks and cabinets.

5.2.2 Duplex 50/125um OM3 10Gig Laser Optimized Multi-mode Patch Cable

- Fiber Cable Description - OM3 LC Fiber Patch Cable 50M — 10Gig, Corning, Laser Optimized Multimode Fiber (LOMMF), 50/125 optical fiber core/cladding. Aqua, 2.0mm outer diameter, zip-cord reinforced, jumper. Used in educational, corporate, military/defense, government, healthcare, finance, and commercial industries.

- Fiber Patch Cable Details - 50 Meter (164 feet), 1/10/40Gb Multimode, Zip-Cord Reinforced, Duplex (2 Fiber Strands), 1.25mm ceramic ferrule, LC-UPC to LC-UPC, Fiber Patch Cable/Jumper Cord.

- Core / Cladding - Corning 50µm (micron) diameter fiber core / 125µm diameter cladding (1 micron is 1 one-millionth/1 meter). The fiber optic core is surrounded by a transparent, low refraction, cladding material. Light is contained within the fiber core (total internal reflection) causing the fiber within the patch cord assembly to act as a waveguide. Light travels through the fiber bouncing off the boundary between core cladding.

- Optical Modality Details for OM3 Ethernet Over Multimode Fiber - 1500 / 2000 MHz-km Modal Bandwidth 850nm / 1300nm — Fast Ethernet 100Basw-FX 2000m — 1Gb (1000Mb) Ethernet 1000Base-SX 550m (Requires mode-conditioning patch cord) — 10Gb Ethernet 10GBase-SR 300m — 40Gb Ethernet 40GBase-SR4 100m (330m QSFP+ eSR4) — 100Gb Ethernet 100GBase-SR10 100m.

- Durable Construction, Commercial Grade, Cost Effective and Built to Last with 100 percent Lifetime Warranty on all fiber cables purchased from Fiber Cables Direct.

5.2.3 40GBASE-CSR4 Transceiver

Optcore's QSFP-40G-eSR4 is designed for use in 40 Gigabit Ethernet (40GbE) applications over multi-mode fiber. It complies with QSFP+ MSA and IEEE 802.3ba 40GBASE-CSR4 specifications. The QSFP+ CSR4 transceiver integrates four data lanes in each direction with each lane to give an aggregated 40 Gbps bandwidth. Each lane supports link lengths of 300m on OM3 multi-mode fiber or 400m on OM4 multi-mode fiber. The optical transmitter incorporates a 4-channel 850nm VCSEL laser, a 4-channel input buffer and laser driver, control and bias blocks. The optical receiver incorporates a 4-channel PIN photodiode, a 4-channel TIA array, a 4-channel output buffer and control blocks.

The QSFP-40G-eSR4-CSC QSFP+ transceiver is programmed and tested to be compatible with Cisco data center switches, routers, NICs and other optical transport devices for 40G Ethernet and high-performance computing networks It is an ideal equivalent to Cisco QSFP-40G-CSR4 40GBASE-CSR4 QSFP+ optics module at much lower price, which provides a reliable compatible 40G QSFP+ optics solution for system integrator, distributors and end users in data center networking infrastructure.

5.2.4 10GBase-LR Fiber Transciever

- 10GBase-LR SFP+: 10 Gigabit Ethernet Single mode SFP+ Module, 10 Gb/s, 1310nm wavelength, Duplex Dual LC, SMF, operates on Single-mode (OS2/OS3) LC/UPC fiber cable spans of up to 10km (6.2 mile) in length. 2 Pack.
- Wide Compatible: For Cisco SFP-10G-LR, Meraki MA-SFP-10GB-LR, Ubiquiti UniFi UF-SM-10G, Mikrotik, Netgear, D-Link, TP-Link and Other Open Equipment with 10G SFP+ Port.
- Hot-swappable: PLUG and PLAY, with Advanced DDM Function to monitor real-time parameters and state fiber links. SFP+ MSA and SFF-8431 Compliant, IEEE 802.3ae-compliant.
- Low Power Consumption: Less than 1.05watt Power Consumption, that can save costs wisely. Low EMI and advanced ESD protection. Each SFP module is individually done test before packing.
- After-sales service: Provides 24/7 Customer Service, 30 Days Free-returned, 3 Year Free Warranty and Lifetime Technology Support.

6 Bill of Quantities

6.1 ENTC Network

Component	Quantity	Unit Price (USD)	Cost (USD)
10GBase-LR Fiber Transciever	18	253	4554
Duplex 50/125um OM3 10Gig Laser Optimized Multimode Patch Cable	200m	13(per m)	2600
CISCO2911/K9 Layer 3 Switch	2	3550	7100
AMP 48 Port CAT6 Patch Panel	2	50	100
10 Gigabit Speed UTP LAN CAT6 cable	400m	0.8(per m)	320
Cisco Aironet 3700 Series Access Point	13	1645	21385
TRENDnet 24-Port Gigabit Layer 2 Switch	11	330	3630

Grand Total = $39689

6.2 Backbone Network

Component	Unit Price (USD)
40GBASE-CSR4 Transceiver	46
10GBase-LR Fiber Transciever	29
Duplex 50/125um OM3 10Gig Laser Optimized Multimode Patch Cable	13
HP 1920 24-Gigabit Port Layer 3 Switch	105
AMP 48 Port CAT6 Patch Panel	50
10 Gigabit Speed UTP LAN CAT6 cable	0.6
Cisco Catalyst 9105 Series Access Point	500
TRENDnet 24-Port Gigabit Layer 2 Switch	330

The length for the fibre and CAT6 cables were calculated based on the following information.

Cable	Length
CITeS - Sumandasa	143m
CITeS - ENTC	29m
CITeS - IT	75m
Sumanadasa - material	82m
Sumanadasa - TLM	207m
IT - Civil	120m
TLM - Civil	92m
Material - Mechanical	102m
ENTC - Admin	165m
Mechanical - Admin	130m

7 Simulation Results

Cisco Packet Tracer uses various packet types to simulate network traffic and communication. Some of the common packet types used in Cisco Packet Tracer include:

1. Ethernet Frames: Ethernet frames are used for local area network (LAN) communication. They encapsulate data and carry it across Ethernet connections. They contain source and destination MAC addresses, along with other control information.

2. IP Packets: IP (Internet Protocol) packets are fundamental units of data in IP-based networks. They carry data between different network devices and are responsible for addressing and routing information.

3. ARP (Address Resolution Protocol) Packets: ARP packets are used to resolve IP addresses to MAC addresses in a local network. They help in identifying the MAC address corresponding to a specific IP address.

4. ICMP (Internet Control Message Protocol) Packets: ICMP packets are used for network troubleshooting and error reporting. They carry error messages, such as "ping" requests and responses, to diagnose network connectivity issues.

5. UDP (User Datagram Protocol) Packets: UDP packets provide connectionless, lightweight transport for data transmission. They are used for applications that do not require reliable delivery, such as real-time streaming and DNS.

6. TCP (Transmission Control Protocol) Packets: TCP packets provide reliable, connection-oriented data transmission. They ensure that data is delivered correctly and in the correct order. TCP is commonly used for web browsing, email, file transfer, and other applications that require guaranteed delivery.

7. DNS (Domain Name System) Packets: DNS packets are used to resolve domain names to IP addresses. They carry queries and responses between DNS servers to facilitate name resolution.

We studied the local area network of the Department of Electronic and Telecommunication Engineering of University of Moratuwa and used Cisco Packet Tracer to Simulate it. The way we designed the ENTC local area network using Cisco Packet Tracer is shown below.

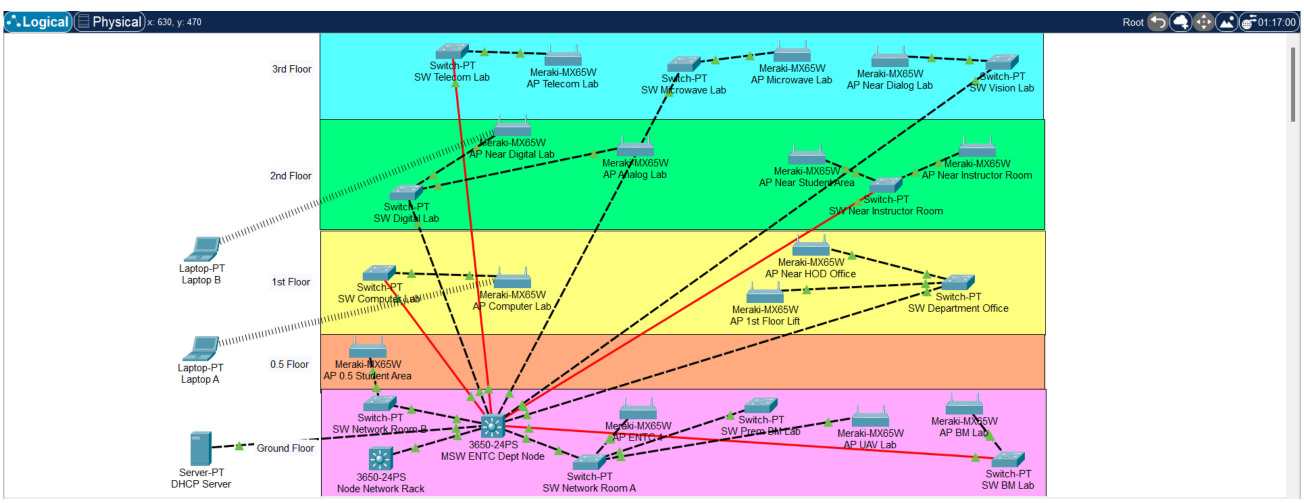

Figure 8: Implementation of ENTC Network using Packet Tracer

A DHCP server was used to automatically assign IP addresses to the devices in the network. Two computers (Laptop A and Laptop B) were connected wirelessly to access points in the network and it was possible to execute ping command and tracert command fromn one laptop to the other. The results are shown below.

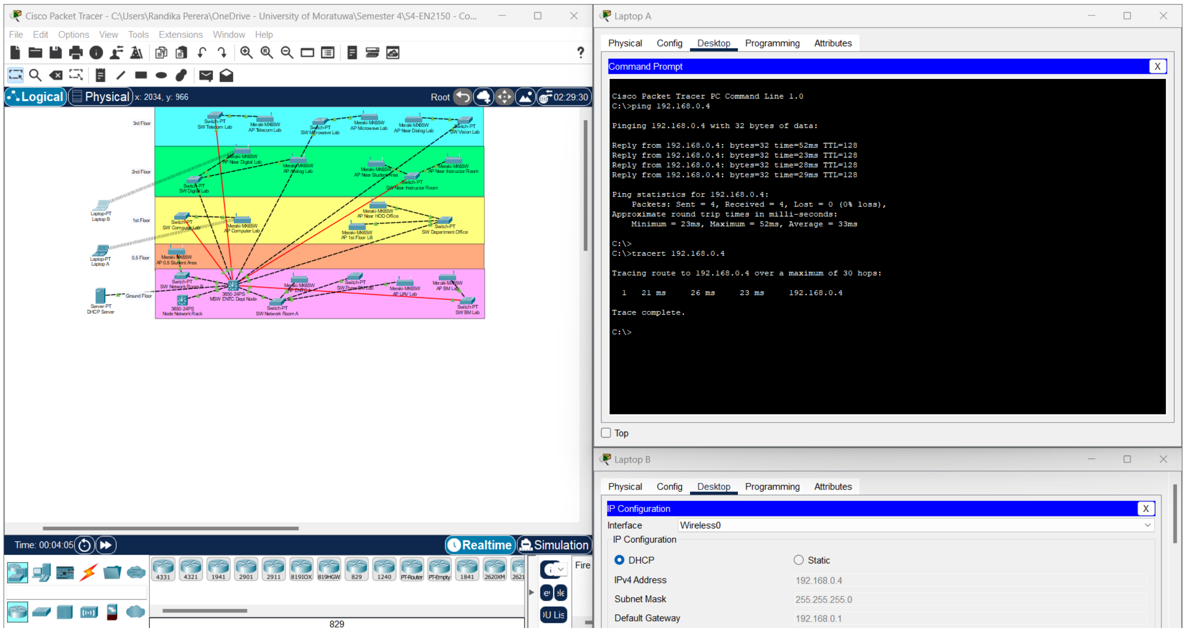

Figure 9: Ping and Tracert from Laptop A to Laptop B

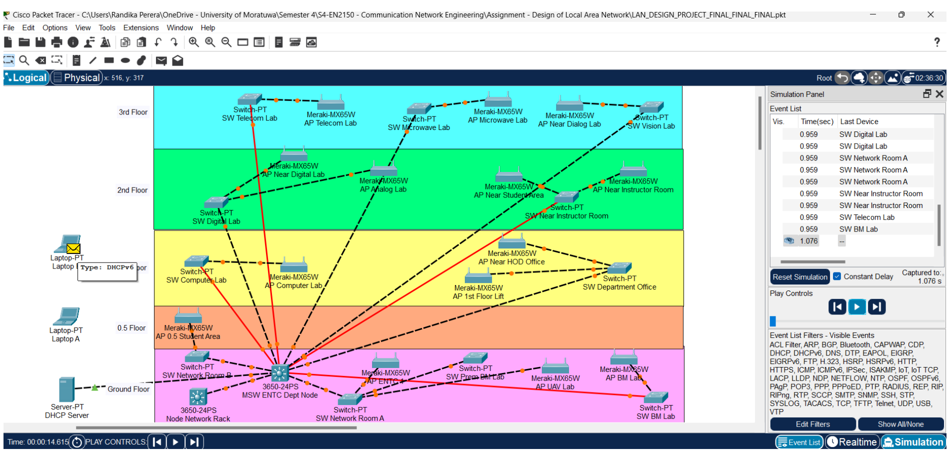

Figure 10: Transmission of DHCPv6 Packets

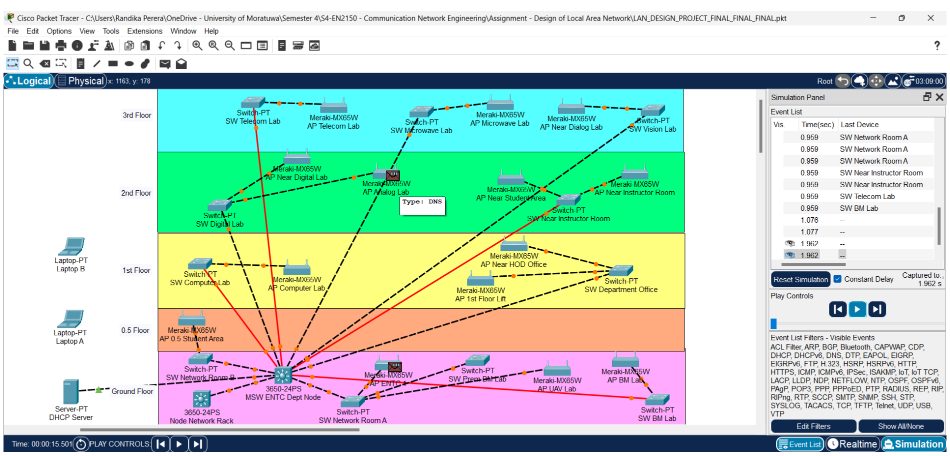

Figure 11: Transmission of DNS Packets

The proposed design for the backbone network of University of Moratuwa was designed and simulated using Cisco Packet Tracer. The results are shown below.

GitHub Repository for the Simulation Files and Videos

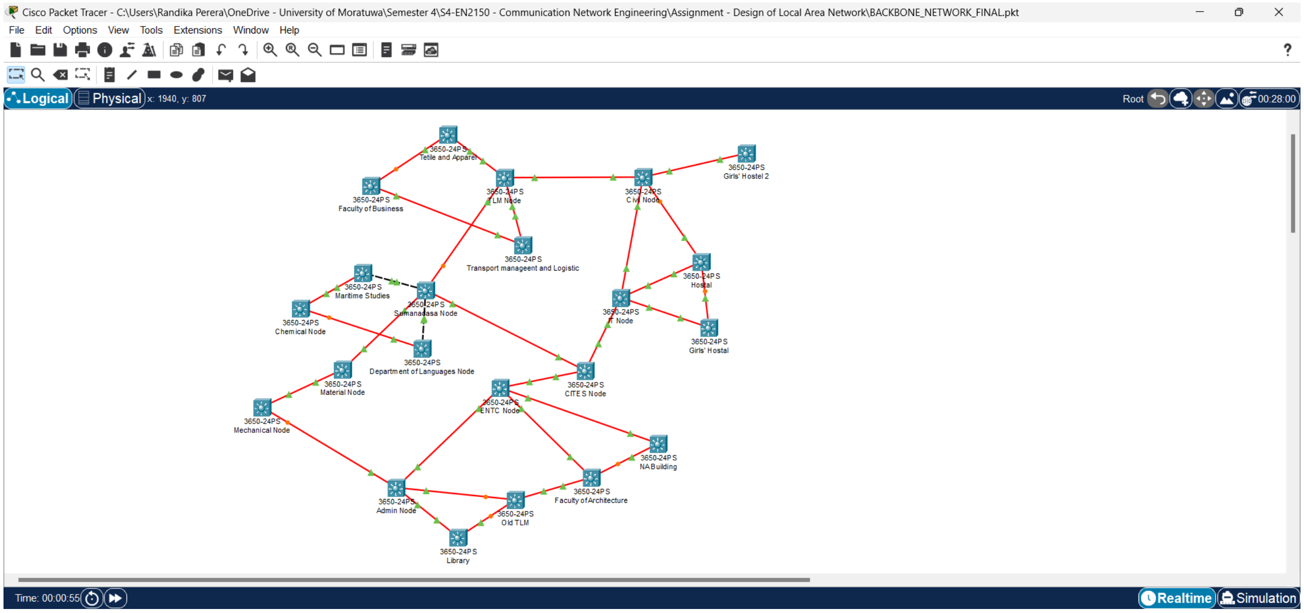

Figure 12: Logical View of Proposed Backbone Network

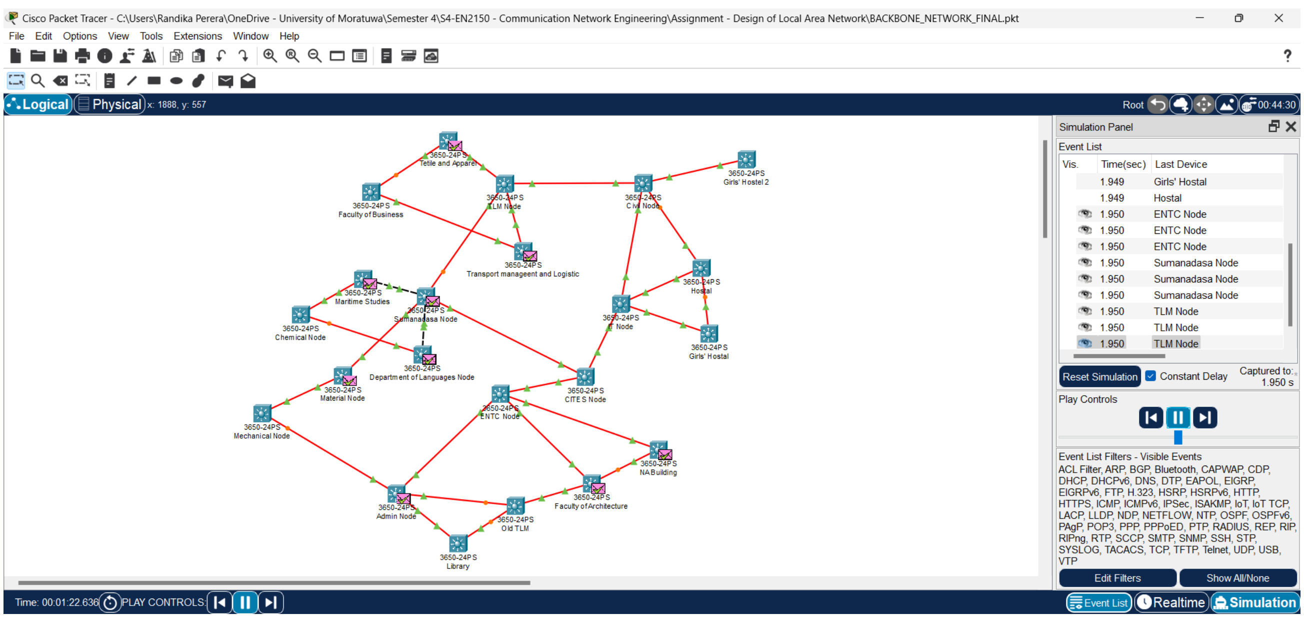

Figure 13: Simulation in Logical View

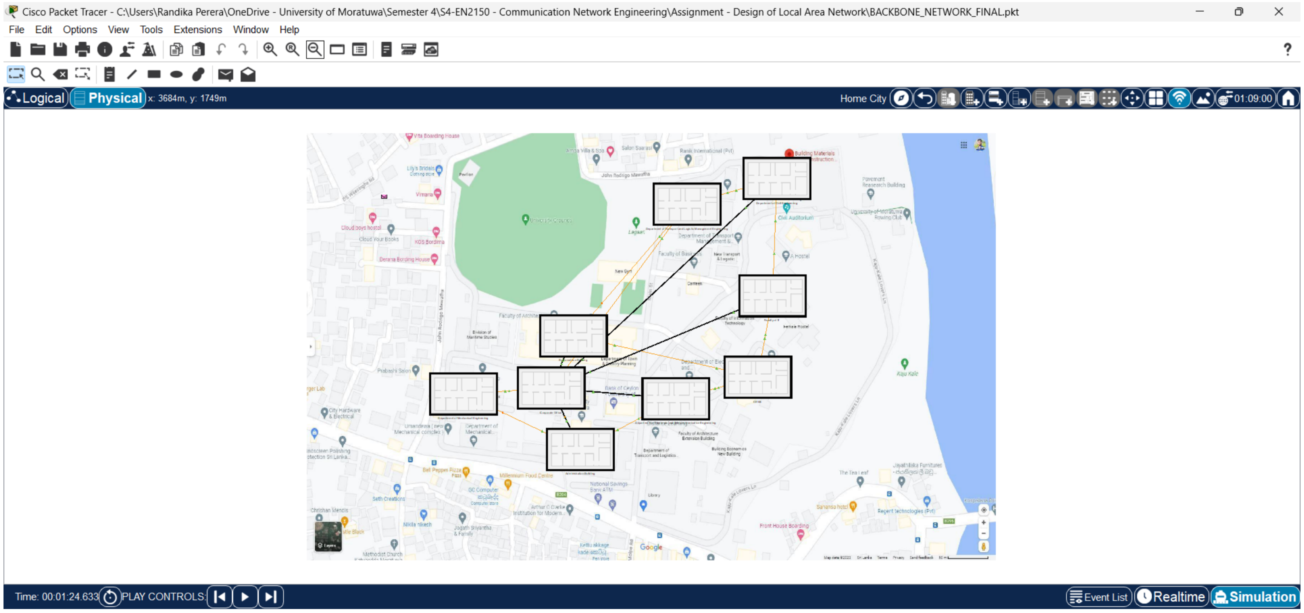

Figure 14: Physical View of Proposed Backbone Network

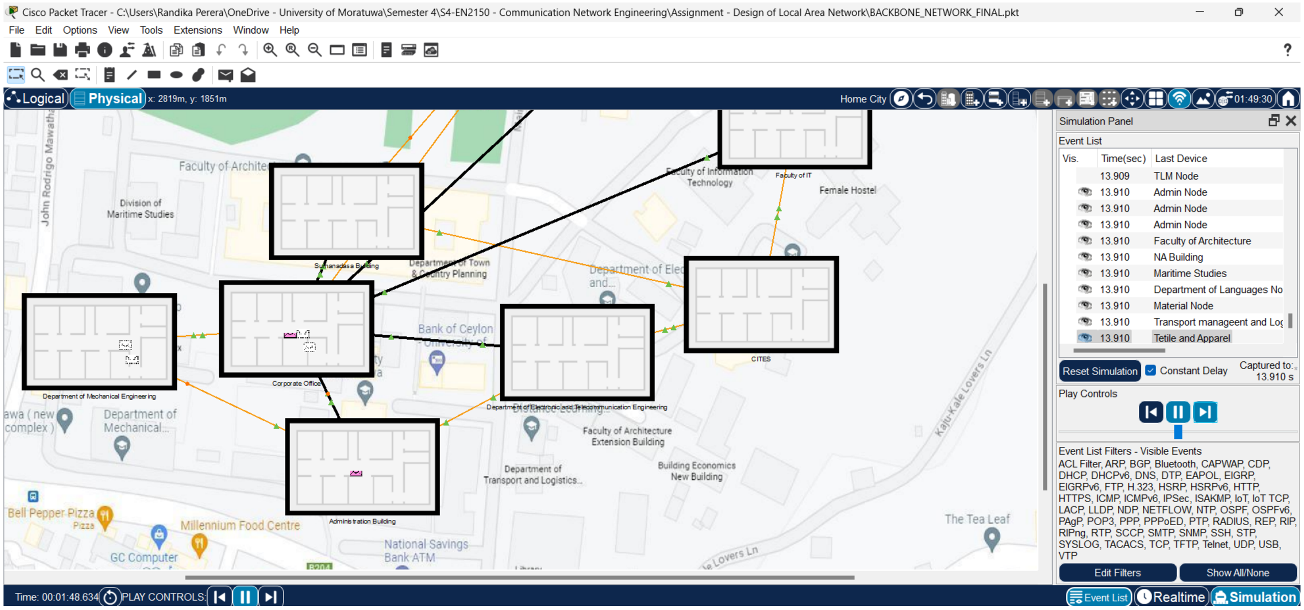

Figure 15: Simulation in Physical View

8 References

- Network Status Review University of Moratuwa
- Cisco Annual Internet Report
- Inbound Traffic of the Network of University of Moratuwa
- Outbound Traffic of the Network of University of Moratuwa
- Sri Lanka Internet Speed
- Single Mode vs. Multimode Fiber Optic Cables
- Ookla Insights Articles
- Manage the Backbone Network - CITeS
- Cisco Catalyst 9105 Series Access Points Data Sheet
- TRENDnet 24-Port Gigabit Managed Layer 2 Switch