INVESTIGATION AND ANALYSIS OF NETWORK PERFORMANCE FOR AN INDOOR ENVIRONMENT USING MATLAB

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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2022

DECLARATION

I declare that this report entitled "Investigation and Analysis of Network Performance for an Indoor Environment using MATLAB" is the result of my own work except for quotes as cited in the references.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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DEDICATION

Special Dedicated to my beloved family, my supervisor and all my friends

ABSTRACT

Wi-Fi performance plays a bigger role in a wireless network. Numerous parameters affect the operation of Wi-Fi in a network, including throughput, delay, latency, and packet loss. Wi-Fi performance metrics provide significant benefits to the user in terms of Wi-Fi performance. Because fire stations have a low-quality of Wi-Fi network. Thus, this project aims to investigate the Wi-Fi performance in an indoor environment for LOS and NLOS condition. This project also aims to analyse the Wi-Fi performance in terms of throughput, packet loss for LOS and NLOS indoor environment. The parameters being measured in this project include packet loss, a packet sent, a packet received, throughput, and latency. These parameters are being measured using EMCO Ping Monitor 8 and the results are being validated using Ping. The parameter is determined in 2 different environments which is LOS, and LOS. Additionally, the measurement is made from a 10-meter to a 30-meter distance. The results indicate that the throughput value decreases with increasing distance where the lowest throughput value is 24.64 Mbps and the higher throughput value 70.83 Mbps. Next, the maximum latency value from measurement is 79ms while the lowest latency value is 56.09ms. Finally, this study established that the obstacle is a factor affecting the throughput and latency performance of the Wi-Fi network.

ABSTRAK

Prestasi Wi-Fi memainkan peranan yang besar dalam rangkaian wayarles. Banyak parameter mempengaruhi pengendalian Wi-Fi dalam rangkaian, termasuk throughput, latency dan kehilangan paket. Metrik prestasi Wi-Fi memberikan manfaat kepada pengguna dari segi prestasi Wi-Fi. Kerana balai bomba mempunyai rangkaian Wi-Fi berkualiti rendah. Oleh itu, projek ini bertujuan menyiasat prestasi Wi-Fi di dalam kawasan bagi LOS dan NLOS dan menganalisis prestasi isyarat Wi-Fi dari segi throughput, latency dan kehilangan paket bagi persekitaran LOS dan NLOS. Parameter yang diukur dalam projek ini termasuk kehilangan paket, paket dihantar, paket diterima, throughput dan latency. Parameter ini diukur menggunakan EMCO Ping Monitor 8 dan keputusan disahkan menggunakan Ping. Parameter ditentukan dalam 2 persekitaran berbeza iaitu LOS dan LOS. Selain itu, ukuran dibuat dari jarak 10m hingga 30m. Keputusan menunjukkan bahawa nilai throughput menurun dengan jarak yang semakin meningkat, nilai throughput terendah ialah 24.64 Mbps manakala nilai throughput yang lebih tinggi 70.83 Mbps. Nilai latency maksimum daripada pengukuran ialah 79ms, manakala nilai latency terendah ialah 56.09ms. Akhir sekali, kajian ini membuktikan bahawa halangan adalah faktor yang mempengaruhi throughput dan latency dalam rangkaian Wi-Fi.

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LIST OF SYMBOLS AND ABBREVIATIONS

BER	:	Bit Error Rate
IP	:	Internet Protocol
ISM	:	Industrial, Scientific, and Medical
LAN	:	Local Area Network
RF	:	Radio Frequency
QoS	:	Quality of Service
Wi-Fi	:	Wireless Fidelity
BER	:	Bit Error Rate
ms	:	Milliseconds
Mbps	:	Megabits Per Second
m	:	Meter
GHz	:	Gigahertz
MIMO	:	Multiple Input Multiple Output
OFDM	:	Orthogonal Frequency- Division Multiplexing
CCK	:	Complimentary Code Keying
USB	:	Universal Serial Bus
SNR	:	Signal-To-Noise-Ratio

CHAPTER 1

INTRODUCTION

1.1 Introduction

Network performance can be defined as a measurement of the quality of a network received by users. There are different ways to measure the performance of a network, depending on the surroundings and design of the network. The characteristics that can be used in measuring the stability of a network are throughput, latency, bandwidth, and packet loss.

This chapter starts with an explanation about network performance measurement, which is the current challenges that will contribute to the problem statement in this project. The next part is the objectives of this project that is supposed to overcome the problem mention in the problem statement. Later, the process of flow for this project is described in the project scope. Finally, the thesis outline section briefly explains the structure of this thesis.

1.2 Background

The evolution in wireless technology has been given the biggest impact on modern communication systems. The understanding of radiofrequency (RF) propagation in RF planning is very important because nonideal environments are needed for wireless systems to propagate the signals. Radio waves are the form of electromagnetic radiation where they are affected by the phenomenon of reflection, refraction, diffraction, absorption, polarization, and scattering [1]. The application of radio waves is a television, standard broadcasts radio, shortwave radio, navigation. However, there are a few factors that will degrade the performance of the wireless signal such as distance, interference, and obstacles [1].

Usually, Wireless Fidelity (Wi-Fi) uses the ISM, industrial, science and medical bands of 2.4 and 5 GHz; because the bands do not require a license, it also implies that they are open to other users too. Levels of power are also modest. They are typically about 100 or 200 mW, even if the maximum levels depend on the location of the device. Certain canal systems permit maximum power of a watt or more [2].

Public Wi-Fi access points are usually utilized for providing local Internet access to items such as smartphones or other devices, sometimes without needing to spend more expensive mobile data. They often are also positioned in buildings with insufficient cellphone signals. Often home Wi-Fi systems employ Ethernet routers: both the Wi-Fi connection and the Ethernet connection for desktop computers, printing, and the like, together with all-important firewall connectivity to the Internet. It transcribes IP addresses as an Ethernet router to give the capacity of the firewall.

While the two primary bands, 2.4 GHz, and 5 GHz are connected via Wi-Fi, a lot of Ethernet and Wi-Fi routers offer dual-band Wi-Fi connection, with Wi-Fi access at 2.4 GHz and 5GHz. This allows for the best Wi-Fi connectivity irrespective of band utilization and interference.

A range of Wi-Fi channels will normally be available. Generally, the optimal channel for use will be selected in the Wi-Fi access point or wireless router. If a double band Wi-Fi is offered by the access point or router, the band will be selected as well. These days, the Wi-Fi access port or router usually operates with this selection, without user action so that 2.4 GHz or 5 GHz Wi-Fi is required, as with older system.

This project investigates the performance of Wi-Fi signal focused on a fire station in Melaka. The effect of the surrounding area which is LOS environment and NLOS environment in wireless network is used to analyse the packet loss, throughput, and latency. This network performance is obtained from the measurement and simulation method.

1.3 Problem Statement

Wireless communication is one of the fields which has made the most progress in the past decades due to the digitization of human life [3]. However, a few factors will degrade the performance of the wireless signal, such as distance, interference, and obstacles. This project will investigate the performance of a Wi-Fi network focused on a fire station environment. Several effects at the fire station environment could degrade the network performance such as metals from the fire engine, radio communication devices interferences and distances. Therefore, the effect of the surrounding area will be used to analyses the throughput, latency, and packet loss. This analysis will be plotted in MATLAB.

1.4 Objective

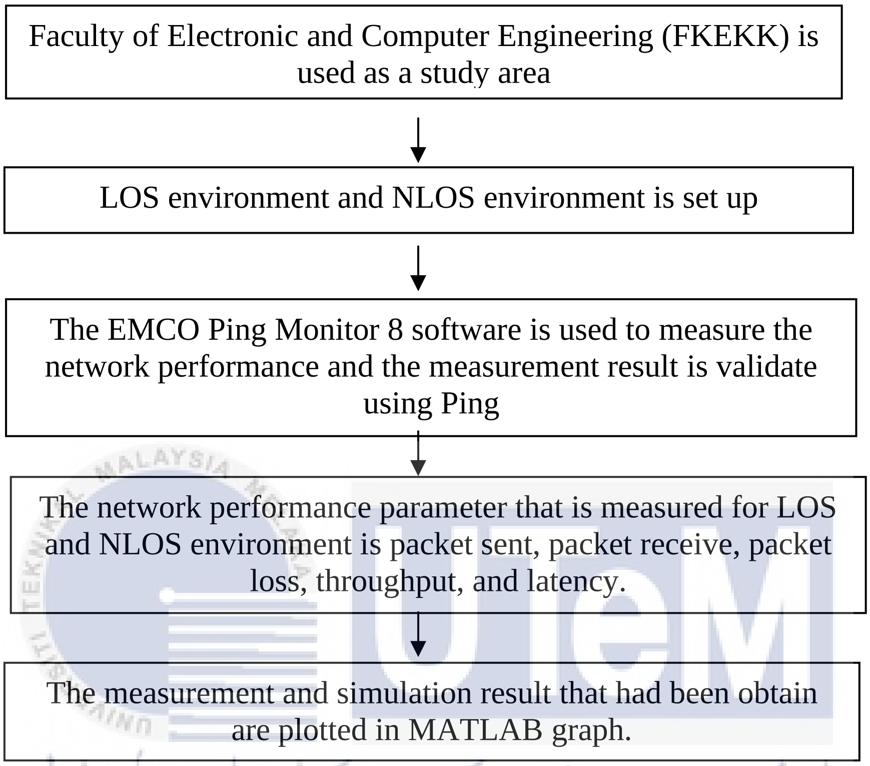
The objective of this project is to:

1. To investigate the Wi-Fi network performance in an indoor environment for LOS and NLOS conditions.
2. To analyse the Wi-Fi signal performance in terms of throughput, packet loss and latency for LOS and NLOS indoor environments.

1.5 Scope of the Project

This project begins by establishing a study area at the Faculty of Electronics and Computer Engineering (FKEKK) to measure network performance in both the LOS and NLOS environments. The lobby serves as the LOS environment study area. The third floor is used for the NLOS environment; this study place was obstructed by a wooden door and brick wall. The measuring technique is used to determine the network performance, followed by simulation. The network performance is measured using the EMCO Ping Monitor 8 software, and the measurement result is validated using Ping. A packet sent, a packet received, packet loss, throughput, and latency are the network performance parameters that are monitored in LOS and NLOS environments. The resulting measurement and simulation data are presented in a

MATLAB graph. This graph illustrates the network performance characteristics of LOS and NLOS situations in terms of throughput, latency, and packet loss.



1.6 Thesis Outline

There are five chapters in this thesis. The explanation on the overall project is briefly described on each chapter.

Chapter 1 This chapter focuses on this project's background problem statement, followed by the objective and scope identified. Finally, the proposed solution will be discussed.

Chapter 2 This chapter is related to the literature review's reading material. The content focused on this project includes Wi-Fi network, the standards and other materials that related. The information obtained from this literature review will be used to assist the implementation of the next process.

Chapter 3 This chapter shows the method used in this project. A flow chart is presented to give the general idea on how this project works. The results will be illustrated by using a graph that obtained from the MATLAB.

Chapter 4 This chapter summaries the findings from each stage of the methodology. Additionally, the outcomes are analysed and discussed.

Chapter 5 This chapter discuss about the conclusion that can be made from the analysis for future research to improve. Finally, recommendations for additional research have been made.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

This chapter is related to the literature review reading material. The content focused on this project includes the Wi-Fi network, the standards and other materials that related. The information obtained from this literature review will be used to assist the implementation of the next process.

2.2 Wi-Fi

The latest technologies of the Wi-Fi router are Wi-Fi 6 that is created to increase the network capacity and improve the Wi-Fi signal performance. Wireless communication via Wi-Fi has become an integral component of modern life. All cellphones feature Wi-Fi technology as a fundamental component, allowing for low-cost connectivity. Additionally, Wi-Fi is used by desktops, laptops, tablets, cameras, and a wide variety of other devices. This wireless network had a wide variety of locations, including residences, offices, shopping centers, airports, and coffee shops. This technology has become a primary mode of communication for many devices, and with the growth of home automation, even more, gadgets are adopting it. Wi-Fi, along with Ethernet, is a primary mode of communication for all types of local area networks. This wireless network is a critical data carrier in the home, office, and many other sectors. Common standards are required to enable different items equipped with wireless technology to communicate with one another.

A frequency band is used to transmit wireless data between devices. These bands are radio waves that carry the data to 2.4 GHz or 5 GHz. The main difference between 2.4 GHz and 5 GHz bands is the range and the bandwidth. The 2.4 GHz band has a longer coverage but sends data at a slower rate while the 5GHz frequency has less coverage but transmits data more quickly.

The 2.4 GHz frequency spectrum covers a wider range and offers a wider field than the 5 GHz band but lower data speeds. Rather than that, the 5 GHz frequency offers a lower coverage area but a faster data rate than the 2.4 GHz band. For example, the 2.4 GHz band normally allows up to 450 Mbps or 600 Mbps, however, the associated congestion might lead to stopped connections and decreased speeds depending on the device type.

The 5 GHz spectrum can carry up to 1300 Mbps instead. It tends to be less overcrowded than the 2.4 GHz band, as there are fewer devices and more channels to use than the 2.4 GHz. The maximum speed that the access point supplies would rely on the wireless technology 802.11b, 802.11g, 802.11n or 802.11ac [4].

When the 2.4 GHz band is compared to 5 GHz, the latter provides a poorer coverage. Thus, its capacity to penetrate solid objects such as walls declines with the frequency increases because the 5 GHz band was meant mostly for outdoor use. However, the greater the frequency, the more quickly the data is sent. The 5GHz spectrum, therefore, carries more data and sends it more quickly.

The third thing to check for is possible interference with the frequency range of the Wi-Fi network. Interference can substantially slow down a network and decrease its reach. For example, for the 2.4 GHz band, wireless telephones and microwave ovens are the two most visible sources of wireless network interference. For the 5 GHz band, however, the most prevalent sources of interference are cordless phones, radars, digital satellite, and perimeter sensors.

On the other hand, the shorter waves of the 5 GHz range make it less capable of crossing walls and solid objects. This is due to the features of electromagnetic waves: at high frequencies (5 GHz), waves attenuate stronger. Thus, certain impediments such as walls, floor, ceiling, doors, and others easily affect the signal.

Overall, the 5 GHz Wi-Fi frequency is less interfered with by devices other than Wi-Fi connections using 2.4 GHz. This is due to many interferences with other devices or applications on network which will slow the connection down. For a better signal coverage, 2.4 GHz frequency is more suitable to use.

2.2.1 History of Wi-Fi

Wi-Fi history is extensive and interesting. In 1971, Hawaiian Islands were connected by ALOHAnet to a wireless UHF network. Early precursors to Ethernet were ALOHAnet and the ALOHA Protocol and then IEEE 802.11 technologies, respectively. Vic Hayes is commonly considered to be the "wireless internet father." He began this job in 1974 when he joined NCR Corp., now part of Agere Systems, a manufacturer of semiconductor components. The 1985 US Federal Communications Commission ruling unleashed the unlicensed ISM band that are 2.4 GHz frequencies. These frequency ranges are the same for equipment such as microwave ovens and are interfered with. In 1991, NCR Corporation devised the forerunner of 802.11, designed for use in the cashier system, along with AT&T Corporation.

WaveLAN was the first wireless products. They are the ones with which Wi-Fi is invented. Together with Terence Percival, Graham Daniels, Diet Ostry, and John Deane the Australian radio astronomer John O' Sulliva developed a key patent for the use of the Wi-Fi system in the context of a research project of the Commonwealth Scientific and Industrial Research Organization (CSIRO), "a failed experiment to detect mini-black holes of atomic particle size." In 1992 and 1996, CSIRO patents were granted for a subsequent technology used in Wi-Fi signal. The initial version of the protocol 802.11 was introduced in 1997 with up to 2 Mbit/s connection speeds. This was modified with 802.11b in 1999 to allow 11 Mbit/s link speed, which was popular.

Figure 2.1: Wi-Fi Internet Alliance logo [5]

The establishment of the Wi-Fi Alliance, together with the 5 GHz band regulation in some countries, assisted the 802.11a to come into being. This new standard allowed speeds of up to 54 Mbps with the new OFDM technology, thanks to its new possibility. When they found out how useful it would be to adapt OFDM to the ISM band, 802.11g was ratified in 2003 by using the CCK technique to ensure 802.11b compatibility. In 2007 the 802.11n was started by bringing innovative MIMO and Channel Bonding (for boosting bandwidth available and hence data rates up to 600 Mbps) technology that allowed backwards compatibilities with prior standards. However, the new 802.11n was launched with the novel BW technology. Years later, extending the 802.11n interface concepts, an 802.11ac for 5 GHz band was launched, the bandwidth and data rates were increased, MIMO techniques were improved to MU-MIMO; beamforming was also implemented. Finally, the future points on 802.11ax (HEW) as an ambition, among other things, to extend the 802.11ac by increasing speed x4 by broader channels and allowing even 8K videos to be streamed [5].

2.2.2 Wi-Fi Standard

Wi-Fi is available in IEEE 802.11b, IEEE 802.11a, IEEE 802.11g and IEEE802.11n according to the time and the speed. It is popular to employ IEEE802.11b and IEEE802.11g [7]. The most used Wi-Fi standard is IEEE802.11b and is the older wireless network criterion. The bandwidth is maximal 11 Mbps. The bandwidth can be reduced to 5.5 Mbps, 2 Mbps and 1 Mbps when the signal is weak, or interferences occurs. Bandwidth automatic conditioning ensures network stability and reliability. IEEE 802.11a has more than IEEE802.11b performance. It functions in the 5 GHz range and has an excellent ability to prevent interference. However, IEEE 802.11b and IEEE 802.11g cannot be compatible.

IEEE 802.11a is therefore hardly used under contemporary Wi-Fi standards. In July 2003, IEEE Working Group 802.11 formally accepted the IEEE 802.11g standard [17] to resolve the inconsistent difficulties between IEEE 802.11a and IEEE 802.11b. It may be IEEE 802.11b compatible. Thus IEEE 802.11g applications are greater than IEEE 802.11a. The latest Wi-Fi standard is IEEE 802.11n, ratified in 2009. It has a 300 Mbps standard and transmission velocity of up to 600 Mbps [10]. In addition to improving wireless transmission quality, the IEEE 802.11n standard combined MIMO and OFDM [11] technology significantly increase transmission speed.

Table 2.1: Wi-Fi Standard [8]

IEEE Standard	Speed (Mbps)	Frequency (GHz)
802.11	1 - 2	2.4
802.11a	6 - 54	5
802.11b	1 - 11	2.4
802.11g	6 - 54	2.4
802.11n	72 - 600	2.4 / 5
802.11ac	433 - 6933	5
802.11ax	600 - 9608	2.4 / 5

2.2.3 Frequency Band in Wi-Fi

There are 14 channels defined for usage by Wi-Fi installations and devices in the 2.4 GHz ISM band. Not all the Wi-Fi channels are legal in all countries, 11 channels are approved by the FCC and utilized in what is sometimes considered the North American domain, while 13 are allowed in Europe, where channels have been specified by ETSI. The WLAN / Wi-Fi channels are spaced 5 MHz, 802.11 Wi-Fi standards require a bandwidth of 22 MHz, and channels are on a 5 MHz incremental step. The 20/ 22 MHz bandwidth and channel separation of 5 MHz means that neighboring channels overlap, and communications on neighboring channels will interfere with one other. The 22 MHz Wi-Fi channel bandwidth holds for all standards even though 802.11b Wireless LAN standard can operate at a variety of rates: 1, 2, 5.5, or 11 Mbps and the newer 802.11g standard can run at rates up to 54 Mbps [9]. The changes exist in the RF modulation technique employed; however, the WLAN channels are the same across all the appropriate 802.11 specifications.

When utilizing 802.11 to provide Wi-Fi networks and connection for offices, installing Wi-Fi access points, or for any WLAN applications, it is vital to ensure that parameters such as the channels are correctly tuned to ensure the desired performance is reached. On most Wi-Fi routers these days, this is configured automatically, but for some larger applications, it is required to set the channels manually or at least under central supervision. Wi-Fi routers often use two bands to offer dual-band Wi-Fi, the 2.4G Hz band is one of the critical bands, and it is most usually utilized alongside the 5 GHz Wi-Fi band.

Table 2.2: 2.4 GHz Wi-Fi channel frequency for IEEE 802.11 [9]

Channel Number	Lowest Frequency (MHz)	Upper Frequency (MHz)	Lowest Frequency (MHz)
1	2401	2412	2423
2	2406	2417	2428
3	2411	2422	2433
4	2416	2427	2438
5	2421	2432	2443
6	2426	2437	2448
7	2431	2442	2453
8	2436	2447	2458
9	2441	2452	2463
10	2446	2457	2468
11	2451	2462	2473
12	2456	2467	2478
13	2461	2472	2483
14	2473	2484	2495

As the 2.4 GHz band becomes increasingly saturated, many users decide to adopt the ISM Band 5 GHz for their wireless LANs. This not only produces a greater spectrum, but it is less commonly utilized for other equipment, such as microwave ovens. The best microwave ovens work about 2.4 GHz because the food peaks absorb radiation. As a result, 5GHz Wi-Fi usually has less interference. Many Wi-Fi routers offer Wi-Fi with dual band for smartphones and other electronic devices for Wi-Fi access. The use of 5 GHz band frequencies often offers faster Wi-Fi network speeds.

2.2.4 Network Type

Local area network is a form of network that usually referred to as a LAN network. A Wi-Fi access point (AP) is connected to a local area network to enable both wireless and wired connections, frequently with several Wi-Fi hotspots. The infrastructure application is intended for use in office environments or as a "hotspot." The office may even operate entirely wirelessly and rely solely on a WLAN. A wired backbone network connected to a server is still necessary. The wireless network is then divided into cells, each of which is serviced by a base station or AP that serves as the cell controller. Each AP may have a range of up to 300 meters, depending on the surroundings and the AP position.

Typically, a LAN-based network will provide both cable and wireless connectivity. This is the most common type of network in homes, in which a router with its own firewall connects to the Internet, and wireless connectivity is supplied by a Wi-Fi access point built into the router. Additionally, Ethernet and frequently USB connections are provided for wired access.

The other sort of Wi-Fi network that can be employed is an ad hoc network [9]. These are created when a collection of computers and peripherals are combined. They may be required when a group of people gather and need to share data or when they need to use a printer without using wire connections. In this scenario, users communicate exclusively with one another and not with a wider wired network. As a result, no Wi-Fi AP is required, and specific algorithms within the protocols enable one of the peripherals to assume the position of master and control the Wi-Fi network, with the others functioning as slaves. This form of network is frequently used to connect between devices such as game consoles.

2.2.5 Penetration Loss

Penetration Losses are defined as the amount of signal power that measured in decibels. This lost known as the signal passes through a material (which could be a wall, floor, or window). These losses occur due to the reflection that caused by the wave attempting to traverse the obstacle, as well as the substance itself performs further absorption. These losses are calculated as follows: significant for total route loss, as receivers require a minimum RSSI or SNR to operate properly. The appropriate data rate forgiving these losses may be crucial in environments with varying degrees of complexity.

Table 2.3: 2.4GHz Path loss [10]

Material	Path loss (dB)
Glass window (non-tinted)	2
Wooden door	3
Cubicles	3-5
Dry wall	4
Marble	5
Brick wall	8
Concrete wall	10-15

Table 2.4: 5GHz Path loss [10]

Material	Path loss (dB)
PVC plate	0.6
Gypsum plate	0.7
Plywood	0.9
Gypsum wall	3.0
Rough chipboard	2.0
Veneer board	2.0
Glass plate	2.5
6.2cm Soundproof door	3.6
Double-glazed window	11.7
Concrete block wall	11.7

2.2.6 Line of sight

Line of sight (LOS) is one of the propagation types that transmit and receive data when the transmit and receive stations are in direct line of sight of one another. LOS communication is achievable when no obstacle exists between the transmitter and receiver. Because Wi-Fi network signals travel in all directions, they may be reflected, diffraction, or scattering, although propagation loss has no effect on network measurements such as NLOS environment. Due to the lower attenuation in LOS communication, it provides a better signal and a higher throughput than NLOS [11].

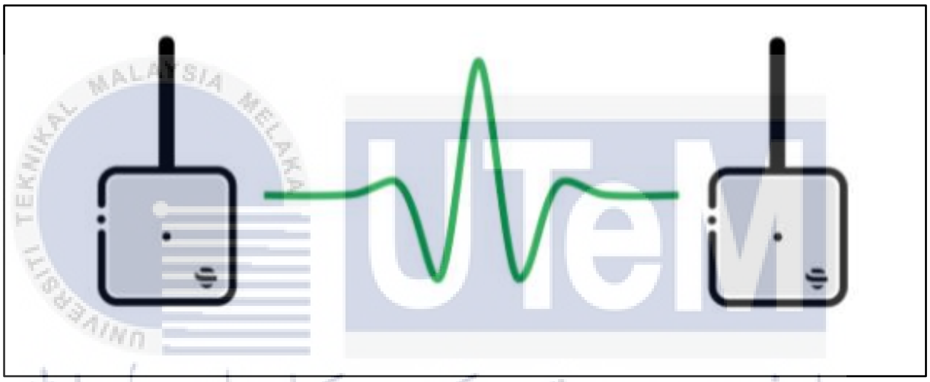


Figure 2.2: Line of sight [11]

2.2.7 Non-line of sight

In non-line of sight (NLOS) communication, the performance of higher frequencies is worse with reliable distances reducing even faster. Most pathways are barred by objects and buildings. Whenever penetrating obstacles, the radio waves amplitude is decreased. The surface of the obstacle affects the signal reflection and scattering effect in an NLOS environment, which has a significant impact on measurements [13]. The dielectric characteristics and signal frequency have a considerable influence on two effects. Thus, as the radio frequency increases, the rate of attenuation increases [14].

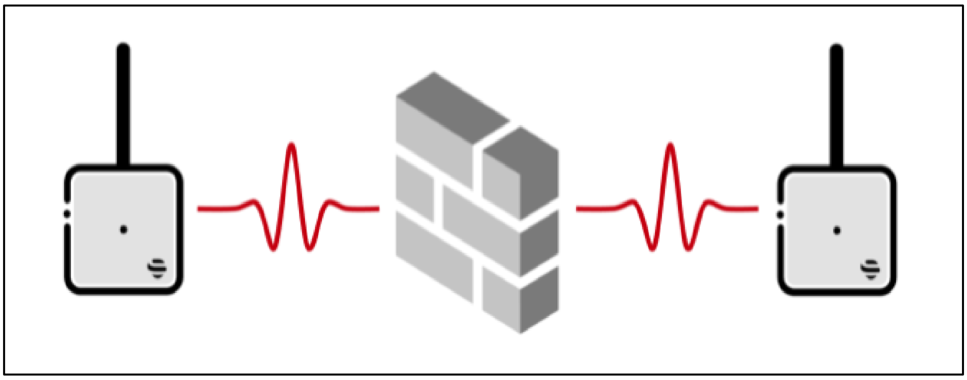


Figure 2.3: Non line of sight [12]

2.2.8 Advantage and Disadvantage of Wi-Fi

Wi-Fi network has a long-distance transmission where the standard radius of 802.11n is up to around 1000m [4]. This wireless network also has a fast speed of transmission. Its pace of transmission is rapid. The speed of 600Mbps is suitable for personal and social needs. Other services compatibility. In and above the second layer of Wi-Fi technology, the Ethernet is fully compatible. Next, Wi-Fi is convenient for network building. Every wireless network adaptor device may be easily entered into the network. It is therefore particularly suitable for mobile applications and has a wide market. Wi-Fi network is saved to use because IEEE802.11 had real transmission power which is approximately 60-70mW. In contrast, cell phone transmission power is approximately 200mW to 1W.

The disadvantage of Wi-Fi is wireless networks can choose to use another option of encryption technology available to combat this problem. Some of the more widely used encryption techniques, on the other hand, are known to have flaws that a determined adversary can exploit. The average range of a standard 802.11g network with standard equipment is tens of meters [15]. Although adequate for a standard house, it will fall short in a larger structure. Repeaters or additional access points will need to be purchased to extend the range. The costs of these things will easily add up. The wireless networking signals are susceptible to a wide range of interference as well as dynamic propagation effects outside the network administrator's control. Lastly, many wireless networks (typically 1-54 Mbps) are far slower than even the slowest wired networks (100Mbps up to several Gbps). However, in certain situations, the throughput of a wired network may be needed.

Table 2.5: Advantage and disadvantage of Wi-Fi network [16]

Advantage of Wi-Fi	Disadvantage of Wi-Fi
Long distance transmission	Can choose to use another option of encryption technology
Fast transmission speed	Distance is limited
Compatibility with other speed	Wide range of interference
Convenient to form the network	Limited speed of network
Safe to used	

2.3 Network Performance

It is necessary to measure a variety of different performance measures to assess the network overall performance. Connectivity, latency, loss rate in packets, bandwidth and performance are the most common parameters.

2.3.1 Latency

Latency during networking is the time a packet needs to reach the destination host from the source host [17]. Network delay is sometimes known as latency. The overall network-to-end latency is a result of multiple separate delays which is processing delay, transmission delay and propagation delay and queuing delay. The term "latency" is frequently used to refer to the monitoring of TCP and UDP traffic. Latency is a critical indicator of a bad network connection and poor performance. The cutoff point changes according to circumstance. For example, a latency of up to 100 milliseconds may be acceptable for general data, but normally no more than 50 milliseconds are acceptable for real-time applications.

$$Latency = Propagation\ time + transmission\ time + queining\ time + processing\ delay \quad (1)$$

$$Propagation\ time = \frac{Distance}{Propagation\ speed} \quad (2)$$

$$Transmission\ time = \frac{Message\ size}{Bandwidth} \quad (3)$$

2.3.2 Packet loss

Packet loss is a metric that indicates congestion, insufficient bandwidth, and interference in both wireless and wired systems. It is a term that refers to a data packet that are transferred from one computer to another but are unable to reach their intended destination. Packet loss is quantified acceptable packet loss benchmarks vary by data type. For example, while a packet loss rate of up to 3% is acceptable for normal data transfer, a packet loss rate of 1% to 2% is nearly intolerable for a clear and comprehensible audio discussion while using Voice over Wireless Local Area Network (VoWLAN) [18].

$$Packet\ loss = \frac{Packet\ sent - Packet\ received}{Packet\ sent} \times 100\ \% \quad (4)$$

$$Loss\ rate = \frac{Packet\ lost}{Sum\ of\ packet\ lost} \quad (5)$$

2.3.3 Jitter

Jitter monitors the consistency of the transfer rate of the network and shows the fluctuation in a delay period [18]. While TCP connections are extremely tolerant of jitter, and because they account for the vast bulk of network traffic, jitter is frequently overlooked. However, applications that require real-time processing, such as video and sound, require extremely minimal jitter. When jitter is present, it has a major impact on the performance of these applications. Additionally, due to radio frequency and interference difficulties, wireless networks are far more prone to jitter than wired networks. While jitter up to 100 msec may be acceptable for general data, jitter more than 20 msec might pose significant problems for real-time data.

$$Jitter = \frac{Variation\ delay}{Packet\ received} \quad (6)$$

2.3.4 Throughput and Bandwidth

Throughput is the amount of data transferred from one point to another along a network path [18]. Bandwidth means the amount of data that is expected to be carried by a network path or that is expected to be passed from one point to the next in a network during a defined period. Both bandwidth and performance can be assessed with reference to Kbps, Mbps or Gbps and the variances between the two can be used to determine wireless network performance.

$$Throughput = \frac{Total\ packet\ (bit)}{Total\ time\ delivery\ (s)} \tag{7}$$

2.3.5 Bit rate

Bit rate is known as the number of bits that conveyed per unit of time. Bit rate is usually measured in bits per second. It is a standard metric of data speed for computer modems and transmission carriers in data communications. Based on Table 2.1, each of the IEE 802.11 protocols has a different data rate. The bit rate can be seen as the upload speed and download speed. In mobile communication, two frequent technologies are used which is uplink and downlink where the uplink bit rate helps with the upload while the downlink bit rate helps with the download.

$$Bit\ rate = 2\ \times BW \times log_2 L \tag{8}$$

$$L = Number\ of\ signal\ levels\ used\ to\ represent\ the\ data, BW\ = Bandwith$$

2.3.6 Received signal strength indicators (RSSI)

RSSI is an approximated measure of the power level received by an RF client device from an access point or router. At greater distances, the signal weakens and wireless communication speeds decline, resulting in lower overall data throughput. These parameters also measured the signal strength in wireless network**.** Path loss and the environment have an impact on the RSSI value[16]. A mobile receiver RSSI value is indicated by a negative sign, and its unit is dBm. Table 2.6 and table 2.7 below shows the RSSI range value for 2G, 3G and 4G in communication system.

$$RSSI = P_t - P_L(d) \qquad (9)$$

$$P_t = Transmission\ power, P_L(d) = Path\ loss\ for\ a\ reference\ distance$$

$$RSSI = Received\ signal\ strength\ indicator$$

Table 2.6: RSSI value range for 2G and 3G [19]

RSSI value	Signal Strength	Description
>= -70 dBm	Excellent	Strong signal with maximum data speed
-70 dBm to -85 dBm	Good	Strong signal with good data speed
-86 dBm to -100 dBm	Fair	Fair but useful, fast, and reliable data speed may be attained, but marginal data with drop-out is possible
< -100 dBm	Poor	Performance is drop drastically
-100 dBm	No Signal	Disconnection

Table 2.7: RSSI value range for 4G [19]

RSSI value	Signal Strength	Description
>= -65 dBm	Excellent	Strong signal with maximum data speed
-65 dBm to -75 dBm	Good	Strong signal with good data speed
-75 dBm to -85 dBm	Fair	Fair but useful, fast, and reliable data speed may be attained, but marginal data with drop-out is possible
-85 dBm to -95 dBm	Poor	Performance is drop drastically
<= -95dBm	No Signal	Disconnection

2.4 Previous Research

From this journal [20], an analysis of the Wi-Fi using localization through Cramer-Rao lower bound (CRLB) found that the localization performance dependent to the number of APs and RSS gradient which had been conducted using Wi-Fi fingerprint-based localization in a real environment. In [21], the Brute Force method had been successfully used to improve the Wi-Fi signal quality thus reduced the positioning by only using 2 APs with at least 78% signal quality in each place. Next, journal [22], from the experiment the 5 GHz Wi-Fi are more feasible for indoor rather than 2.4 GHz Wi-Fi where the noise and interference effects in 2.4 GHz Wi-Fi reduce the accuracy of this signal. Then, the author used Wireshark, Fixed Daily Measurement Interval (FDMI) and Quality of Services (QoS) are the method to measure the Wi-Fi network performance [23]. The QoS analysis consist of delay, throughput, and packet loss. However, there is lowest delay value that had been measured due to the bad weather in the measurement day where affect the process of transmitting data this reduce the quality delivery of the data.

From [19], a study was submitted to investigate the performance of received signal strength indicators (RSSI) that measure the received power level from radio frequency device such as base station sector, access point or router. They found that the factors that affect the low RSSI value at the receiver is the range of wireless signal and coverage area between transmitter and receiver that induce path loss and attenuation. The RSSI value is low when the path loss is high. High SNR channel yields high RSSI at the receiver.

In [24], the author tried to monitor the state of a HetNet using received signal strength indicator (RSSI), throughput, and delay metrics. From the experiments, if a cell is placed randomly by the users, the UEs are transmitting at a high rate relative to the achievable on LTE uplink. The best metric for network selection access and switching is RSSI. Thus, the uses of throughput and delay metrics does not efficient and effective as compared to HetNet's resources.

From [25] the authors proposed about the evaluation performance of vertical handover between Wi-Fi and 3G network. From the analysis of FTP traffic that had been done, we found that the Wi-Fi network had a high average throughput, low average delay and low average jitter rate than 3G network. Next, MATLAB software is used to analyse the performance of Wi-Fi network [26]. PER ratio and SNR value is analysed from changing the Doppler frequency shift, AWGN and flat fading. An empirical throughput comparison study was conducted in an indoor environment between 802.11a/b/g standards [22]. There have been reports of signal strength within the coverage area of the various WLAN versions, average bandwidth, and medium-throughput measures.

From [28], a study was submitted with a throughput and delay analysis was reported. The author used monitoring tool to monitor the real time network for indoor environment. From these experiments, the result of throughput is approximately about 649,030 to 54,920 bytes/second compared to the theoretical maximum of 11 Mbps, this result is due to the numerous factors such as network such as network traffic, interference from another device and others. A WLAN performance for indoor environment by using MATLAB is proposed [8]. Based on the SIR analysis, the signal strength is good when its near to transmitter while had interference when far from the transmitter. In[29], network throughput, jitter, and delay performance of 1EEE 802.11ax is analysed. From investigation, the author found that if packet loss is greater than zero, the average end-to-end transmission time increases and when the packet loss is equal to 100% thus the throughput value decrease to zero.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the methodology included in this project in detail. The chapter started by illustrated a flow chart that presented to give the general idea on how this project works. The results will be analyzed and displayed by using the MATLAB software.

3.2 Methodology Flowchart

The methodology flowchart for this project is illustrated in Figure 3.1. This project began with a literature search on the Google Scholar, IEEE, and Scopus websites, locating research publications on Wi-Fi performance, throughput, and latency analysis, and QoS parameters. A different environment is created in terms of LOS and NLOS. The LOS environment was designed so that the user can directly see the router, whereas the NLOS environment was designed so that the user cannot see the router due to a physical barrier or obstruction. The Wi-Fi performance parameters packet transmit, received packet, packet loss, throughput, and latency are measured using the EMCO Ping Monitor 8 software in both LOS and NLOS environments. Following that, a simulation is run to test the software output by utilizing Ping in both contexts.

Later, MATLAB code was used to plot the measurement results and validation results, which include a packet sent, a packet received, packet loss, throughput, and latency. The study is continued by analyzing the results and discussing the relationship between throughput and latency of the Wi-Fi performance. Finally, a conclusion to the project and recommendations for future work will be provided in the final phase.

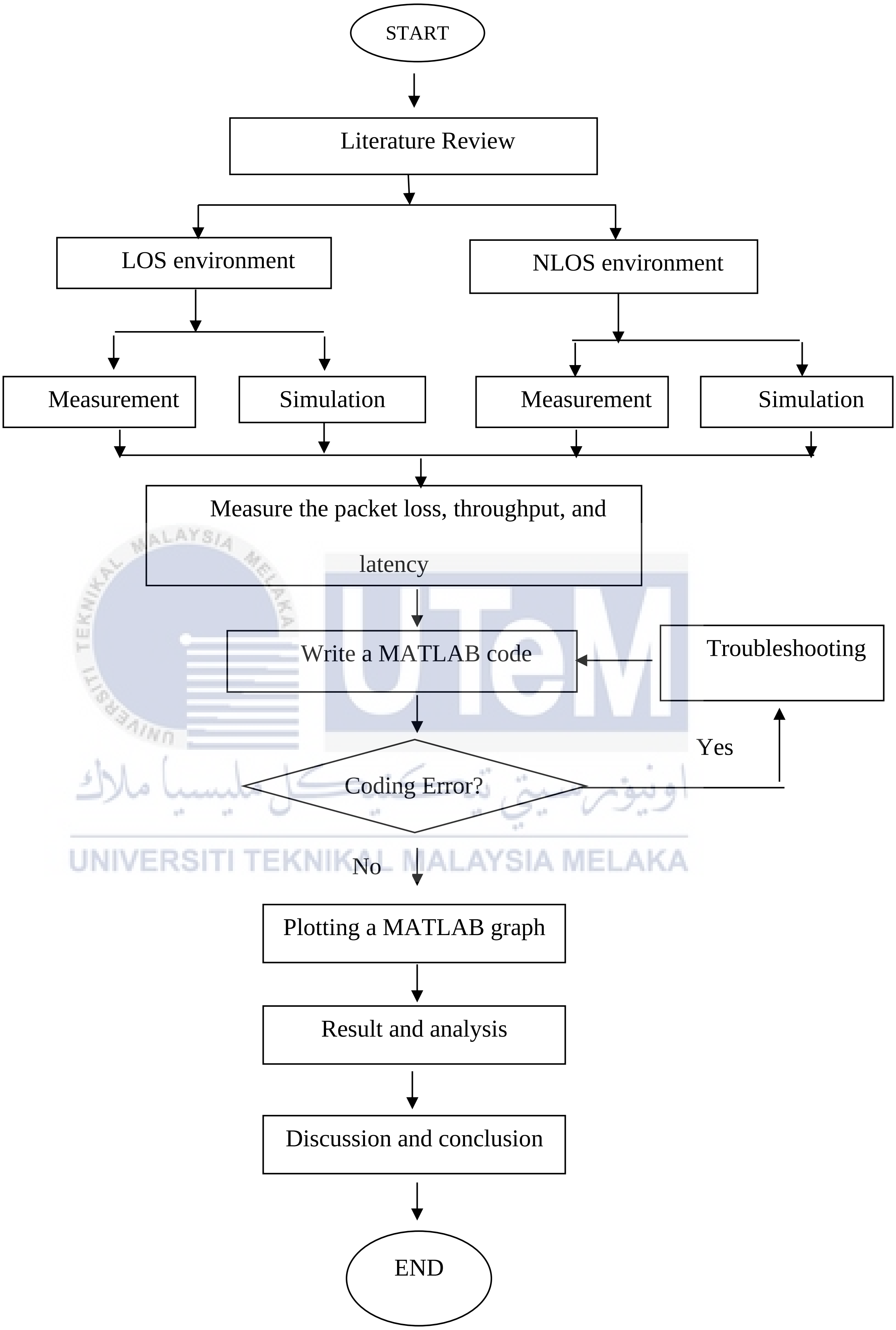


Figure 3.1: Process flowchart

3.2.1 Literature Review

This project started by finding the literature review from Google Scholar, Scopus, and IEEE website. The journal and research paper will be used as a reference for this project. The research paper that related to wireless network, network performance in LOS and NLOS environment, analysis of throughput and latency using MATLAB and many more.

3.2.2 LOS environment

The study area for the LOS environment is located in the FKEKK lobby, where there is no obstruction between the router and the laptop. Even with the distance increases, the router is visible. The router and laptop are separated by 10m up to 30m.

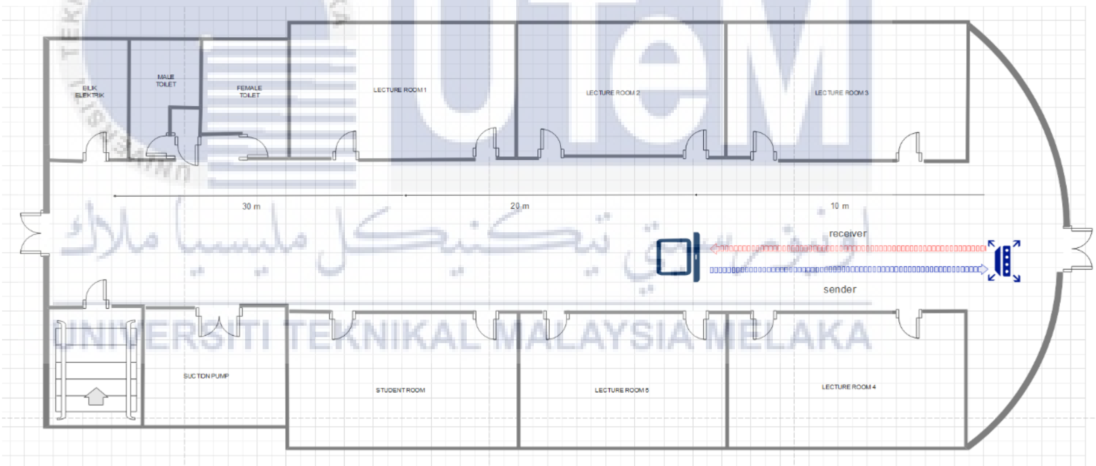


Figure 3.2: The floor plan for the lobby that are used for LOS environments

The study area for the NLOS environment is placed on the third level, and it is bounded by a brick wall and a wooden door. The router is hidden, and the distance between it and the laptop is between 10m and 12m.

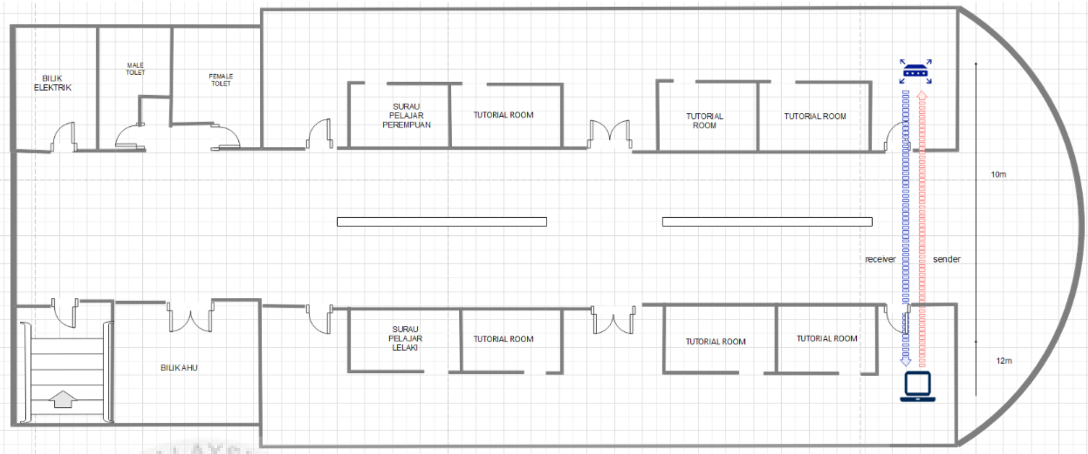


Figure 3.3: The floor plan for the third floor that are used for NLOS environments

3.2.3 Measurement

EMCO Ping Monitor 8 software and a Wi-Fi scanner were used to conduct the measurement. The EMCO Ping Monitor 8 is used to determine the number of packets delivered, received, and loss in 30 minutes for each scenario. Additionally, this software determined the latency in milliseconds for each situation. The Wi-Fi scanner tool is used to determine the wireless network throughput in all conditions.

Figure 3.4: The measurement method for LOS environments

Figure 3.5: The measurement method of NLOS environment

Figure 3.6: The measurement process that had been done to measure the Wi-Fi performance

3.2.4 Simulation

Ping is used to validating the wireless network measurement results. Ping was used to determining the number of packets sent, received, and lost in each scenario over 30 minutes. Additionally, this software analysed the wireless networks latency. Therefore, the differences between them can clearly be noticed.

3.2.5 Measure the packet loss, throughput, and latency

The Wi-Fi performance is measured by measuring the throughput, latency, packet loss with software. Throughput is amount of data transferred from one point to another along a network path while packet loss is measure of the amount of data that failed to reach the targeted destination. Latency measures the time it takes for some data to get to its destination across the network.

3.2.6 Plotting a MATLAB graph

The MATLAB is used to plot a graph from the measurement and validation results. A MATLAB code is written to represent the results for packet sent, packet received, packet loss, throughput, and latency. For packet loss, received and sent the graph is plotted versus time which is 30 minute or 1800 seconds, while the throughput and latency is plotted versus distance from 10-meter up to 30-meter.

3.2.7 Results and Analysis

The results that had been plotted in a graph from the measurement and validation is analyse. The analysis is done for packet loss, packet received, packet sent, latency and throughput for all scenarios.

3.2.8 Discussion and Conclusion

A discussion will be made to discuss the relationship between throughput and latency of the Wi-Fi performance. Finally, a conclusion to the project and recommendations for future work will be provided in the final phase

3.3 MATLAB

MATLAB [23] is a high-performance technical computing language. It integrates the environment for computing, visualization, and programming. MATLAB is also a modern language programming environment with advanced data structures. MATLAB is integrated editing and debugging and object-oriented programming support tools. Those factors make MATLAB an excellent educational and research tool. MATLAB offers numerous advantages over standard computer languages for technical issues resolution. MATLAB is a system whose interactive system is the basic data element is an array that requires no dimensions. The package of software has been sold commercially since 1984 and is presently considered the most common tool worldwide in universities and industries [30].

Figure 3.7: MATLAB Logo [31]

It contains sophisticated integrated routines allowing for a wide range of calculations. It is also straightforward to utilize graphic commands that immediately display the results available. Specific applications are grouped in toolbox packages. There are signal processing toolboxes, symbolic computing, control theory, simulation, optimization and many more domains of applied science and engineering.

The MATLAB code is used to plot a graph from the measurement and validation results. A MATLAB code is written to represent the results for packet sent, packet received, packet loss, throughput, and latency. For packet loss, received and sent the graph is plotted versus time which is 30 minute or 1800 seconds, while the throughput and latency is plotted versus distance from 10-meter up to 30-meter.

3.4 EMCO Ping Monitor 8

The tool is designed to ping network hosts automatically and discover outages and connection quality issues. It detects the up/down status of monitored hosts via ICMP pings and estimates the real-time connection quality of those hosts based on packet loss, latency, and jitter metrics. The application records information about each ping and provides extensive statistics for any server over a specified period, including a list of outages, uptime percentage, average latency, and latency deviation.

Figure 3.8: EMCO Ping Monitor 8 logo [32]

In this project, the EMCO Ping Monitor 8 is used to measure the packet loss, packet received, packet sent, throughput and latency in the network. Every parameter is measured for all scenarios. Later, the measurements results are plotted in MATLAB.

3.5 Ping

In computer network administration, a Ping is simple Internet software that allows a user to test and verify that a certain destination IP address exists and is able of accepting requests. The name was concocted to correspond to the phrase used by submariners to describe the sound of a returning sonar pulse.

Ping is also used diagnostically to verify the operation of the host machine to which the user is attempting to connect. Ping is compatible with any operating system (OS) that supports networking, including the majority of embedded network administration software.

For this project, Ping is used to validate the results that is obtained from the measurement. Ping is used to obtain the results for the packet loss, packet received, packet sent and latency in the network.

3.6 Wi-Fi Scanner

Wi-Fi Scanner allows the user to quickly find visible wireless networks and their associated data. The tool provides information on the network's name (SSID), signal strength (RSSI) and quality, MAC address (BSSID), channel, maximum and achievable data rates, and security, among other things. Wi-Fi Scanner is beneficial for determining the signal strength distribution for their wireless network at home or for determining the ideal location for their access point. In this project, the Wi-Fi scanner is used to measure the throughput in the wireless network for every scenario in Mbps.

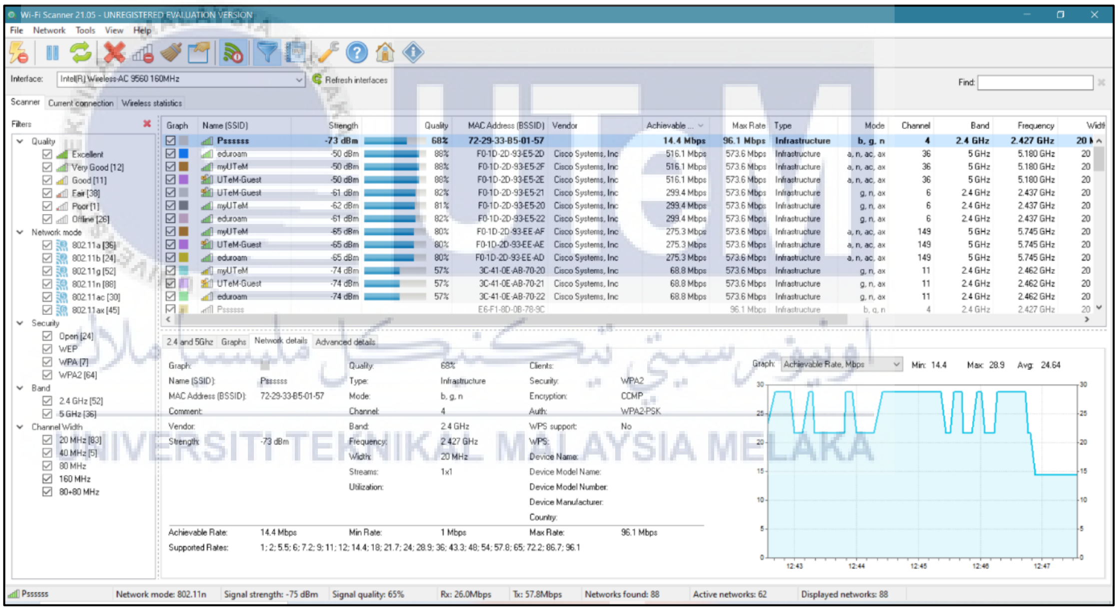


Figure 3.9: The network detail in Wi-Fi scanner

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter summaries the findings from measurement and simulation for this project. 5 scenarios have been set up in this project based on different distances and surroundings. For the measurement result, the distance is being measured first, starting with a 10-meter distance and up to 30 meters. On top of that, the surroundings for each measurement are different in terms of Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions.

The measurement had been done using the EMCO Ping Monitor 8. To validate the results obtained from the measurement, Ping is used as well. Therefore, the differences between them can be noticed. The parameters that are being measured in this project are packet sent, the packet received, packet loss, throughput, and latency. The 5 scenarios are scenario 1 (LOS, 10m distance), scenario 2 (LOS, 20m distance), scenario 3(LOS, 30m distance), scenario 4 (NLOS, 10m distance) and scenario 5 (NLOS, 12m distance).

4.2 Scenario 1 (LOS, 10m)

The first scenario that had been measured is a line-of-sight environment with a 10-meter distance between the router and the laptop. In this scenario, there is no obstacle between the router and the laptop. The parameter that was measured is packet loss, throughput, and latency by using EMCO Ping Monitor 8 and Ping. Thus, a graph is plotted in MATLAB for measurement and simulation results for all parameters.

a) Packet loss, sent, received

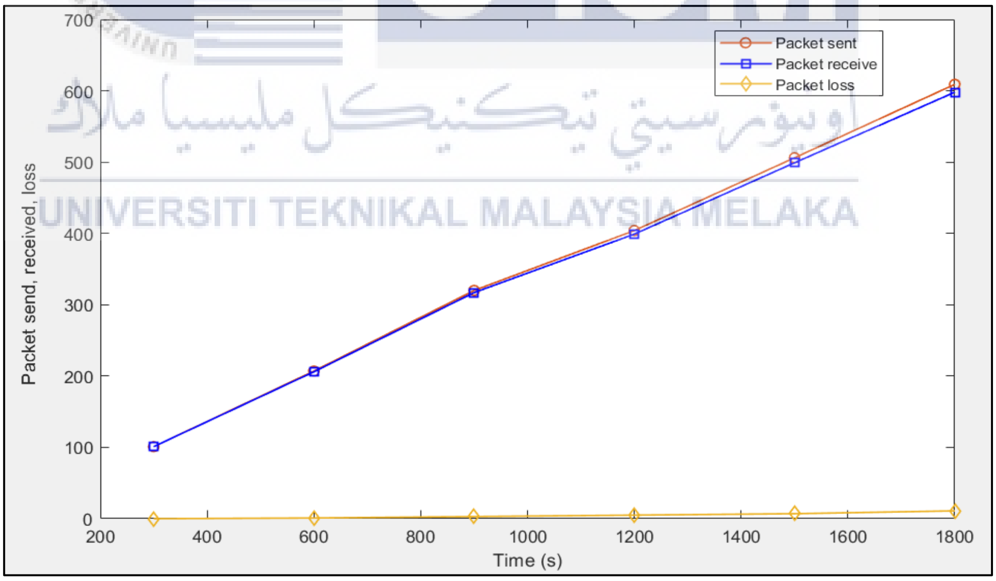


Figure 4.1: Packet loss from the measurement result

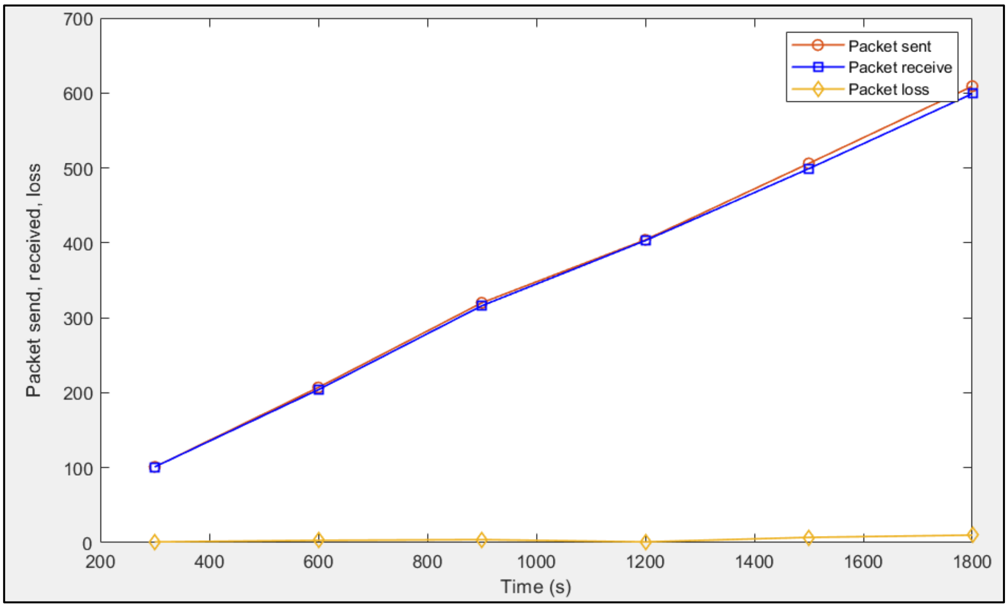


Figure 4.2: Packet loss from the simulation result

Figure 4.1 shows the packet loss, packet sent, and packet received result that is obtained from the measurement, while Figure 4.2 shows the result from the simulation. The number of packet loss from both graphs are equally the same. From measurement result, the highest packet loss is 1.8 % (11 packet loss) where the received packet is 598 while the send packet is 609. Next, for the simulation result the highest packet loss is 1 % (10 packet loss) where the received packet is 599 while the send packet is 609.

b) Throughput

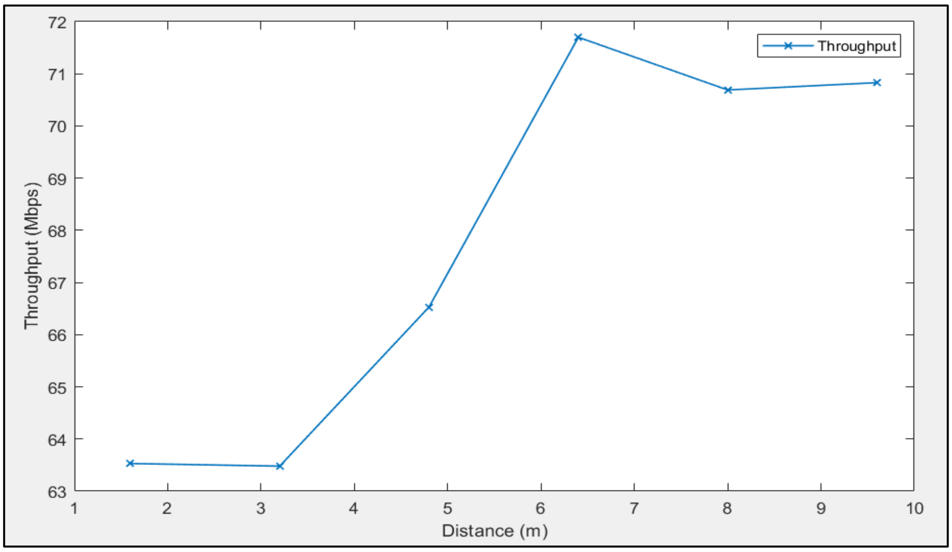


Figure 4.3: Throughput from the measurement result

Figure 4.3 explains the throughput results obtained from the measurement. It shows that the throughput is starting to decrease while increasing the distance. This happened due to many factors such as network coverage, interference from other wireless devices and barriers. At 1800 seconds, the throughput value is 70.83 Mbps for 10-meter distance.

c) Latency

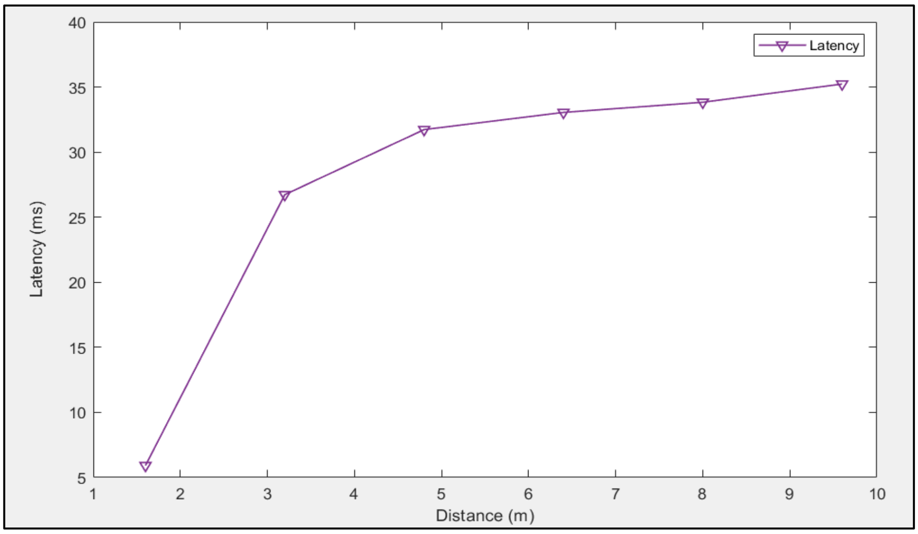


Figure 4.4: Latency from the measurement result

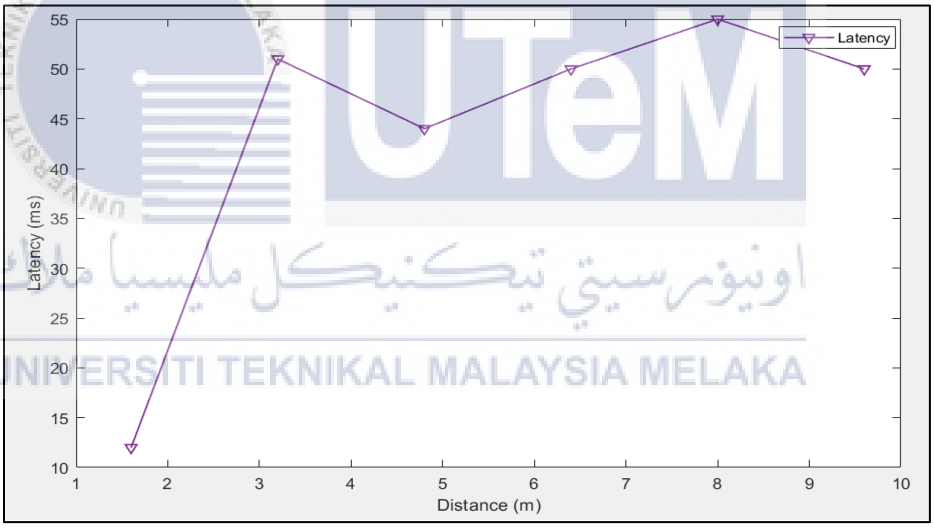


Figure 4.5: Latency from the simulation result

Figure 4.4 explains the latency results obtained from the measurement while Figure 4.5 latency results is obtained from simulation. It shows that the latency is starting to increase while increasing the distance. This is because the distance between the user and server affects the latency results where the user and the server are separated by a ten-meter distance. For measurement result, the highest latency value is 35.23ms while for simulation result is 55ms.

4.3 Scenario 2 (LOS, 20m)

Next, a 20-meter distance between the router and the laptop for a line-of-sight environment is measured. In this scenario, there is no obstacle between the router and the laptop. The parameter that was measured is packet loss, throughput, and latency by using EMCO Ping Monitor 8 and Ping. Thus, a graph is plotted in MATLAB for measurement and simulation results for all parameters.

a) Packet loss, sent, received

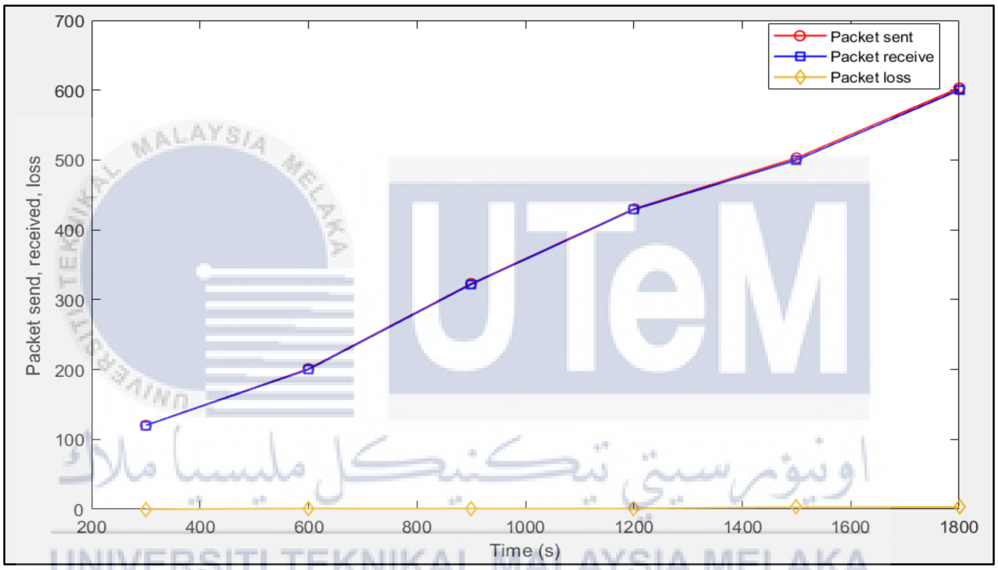


Figure 4.6: Packet loss from the measurement result

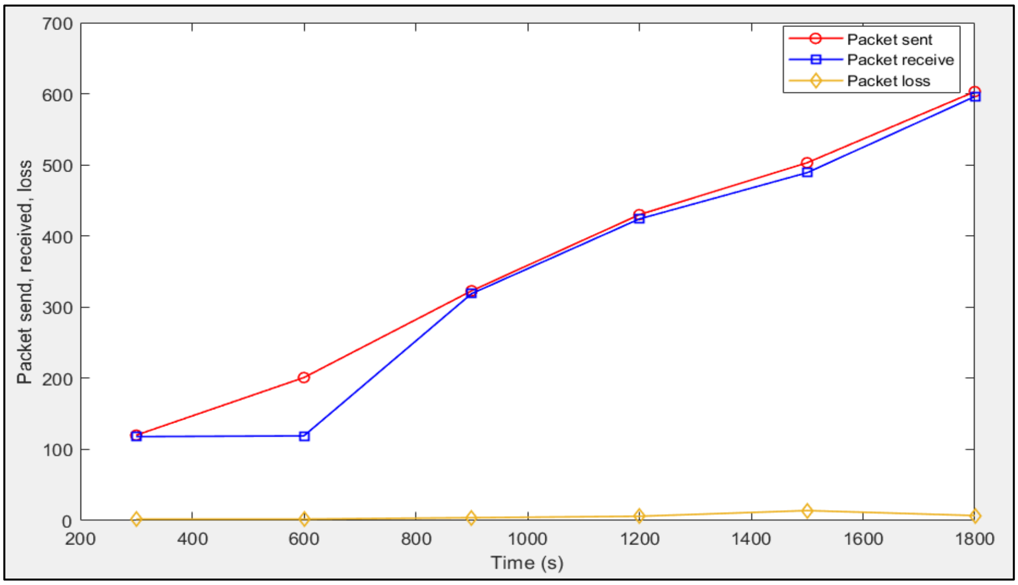


Figure 4.7: Packet loss from the simulation result

Figure 4.6 shows the packet loss, packet sent, and packet received result that is obtained from the measurement, while Figure 4.7 shows the result from the simulation. The number of packets received at 600 seconds at simulation results shows the decreasing amount of packet that had been received compared to scenario 1. This packet loss could be the result of network congestion. The high packet loss may affect the throughput result. This packet loss is also caused by low signal strength at the destination, which can be caused by natural or artificial interference, system noise, hardware failure and others [33]. It summarized that the amount of packet loss is increasing with increasing distance.

b) Throughput

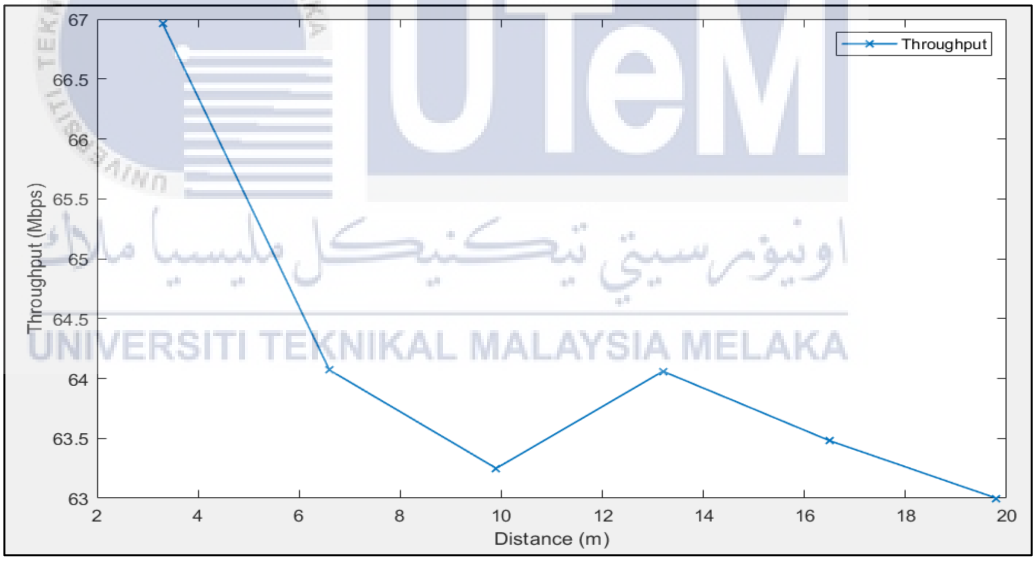


Figure 4.8: Throughput from the measurement result

Figure 4.8 shows the throughput from the measurement result. At 1800 seconds, the throughput value is 63 Mbps lower the throughput at scenario 1. This proved that when the distance increasing, the throughput is dropping. It is because of the network coverage, network traffic, and interference from other wireless devices. The low throughput value may be caused by the large packet loss [33].

c) Latency

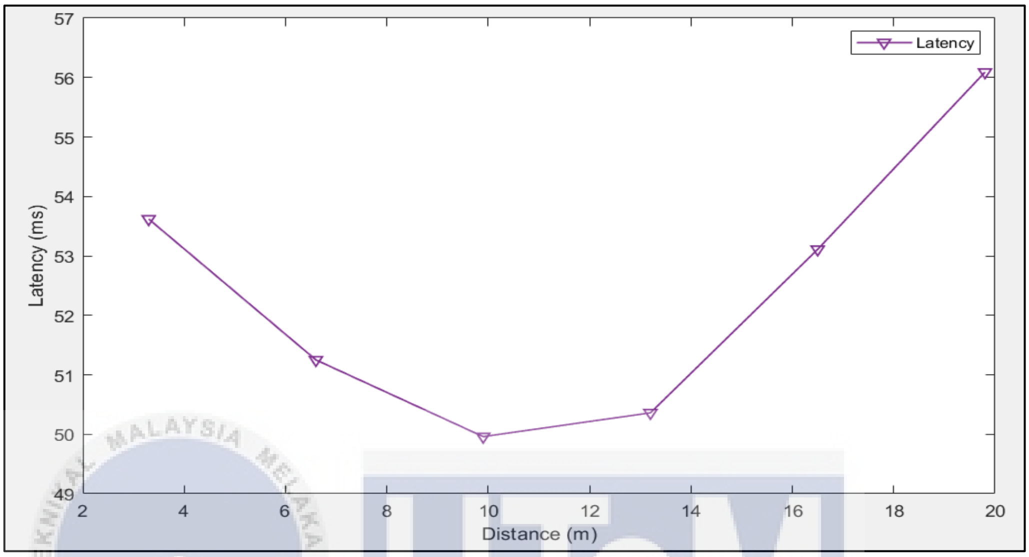


Figure 4.9: Latency from the measurement result

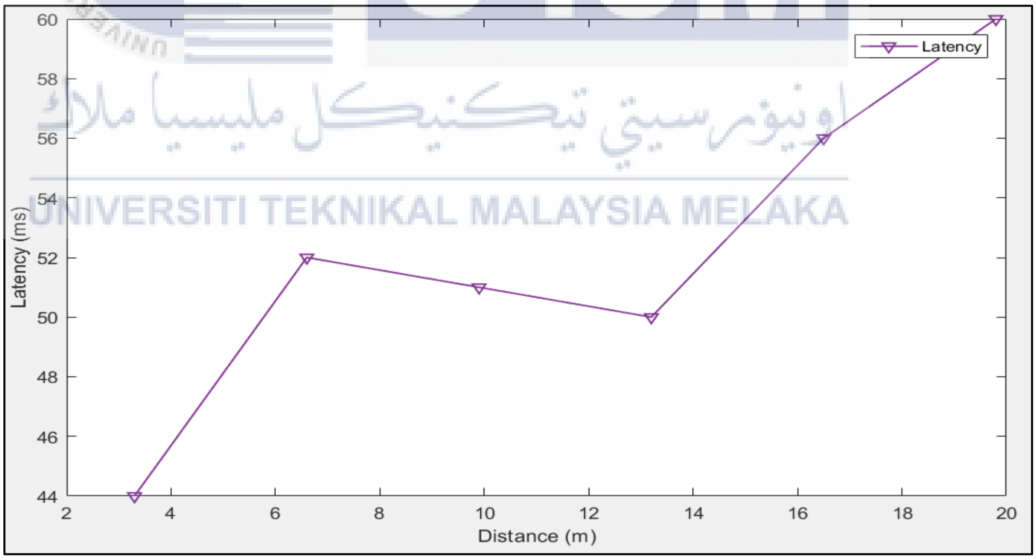


Figure 4.10: Latency from the simulation result

Figure 4.9 explains the latency results obtained from the measurement while Figure 4.10 latency results is obtained from simulation. The highest latency for measurement result is 56.09ms while for simulation is 60ms. This trend indicates that the latency is beginning to increase as the distance is increased by the last 6m. This is because the 20-metre distance between the user and server affects the latency results. The latency value obtained from the measurement result is one of the difficulties in measuring latency when end hosts perform the test and network devices act as passive participants. [34].

4.4 Scenario 3 (LOS, 30m)

Afterwards, a 30-meter distance between the router and the laptop for a line-of-sight environment is measured. In this scenario, there is no obstacle between the router and the laptop. The parameter that was measured is packet loss, throughput, and latency by using EMCO Ping Monitor 8 and Ping. Thus, a graph is plotted in MATLAB for measurement and simulation results for all parameters.

a) Packet loss, sent, received

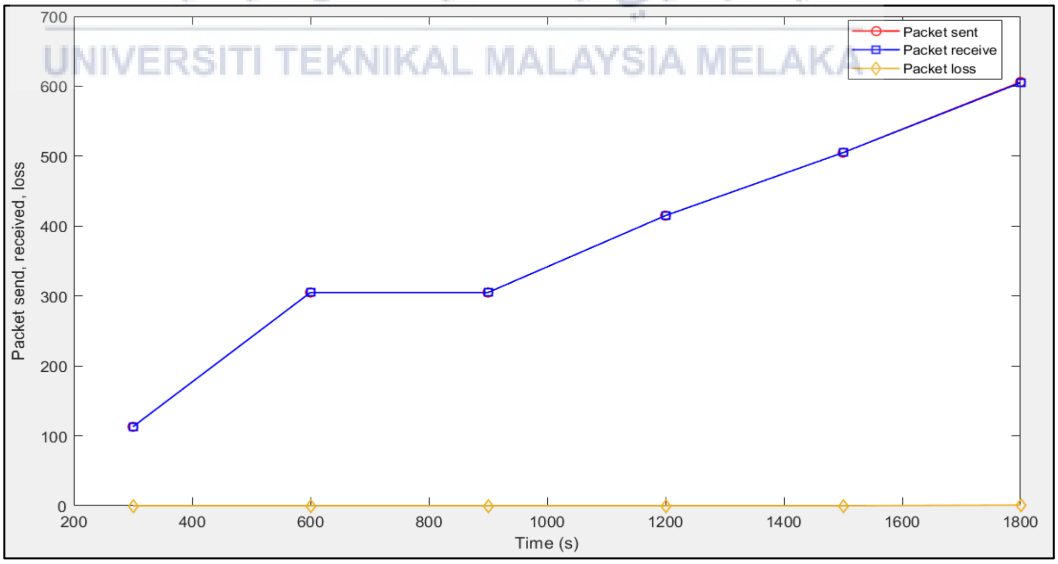


Figure 4.11: Packet loss from the measurement result

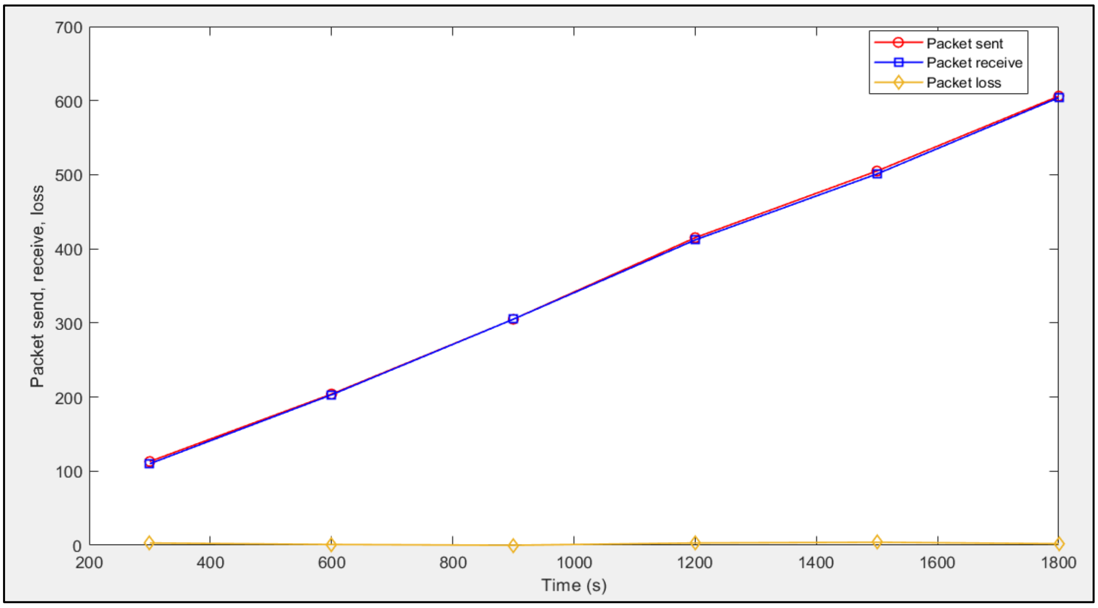


Figure 4.12: Packet loss from the simulation result

Figure 4.11 shows the packet loss, packet sent, and packet received result that is obtained from the measurement, while Figure 4.12 shows the result from the simulation. The number of packet loss from both graphs are equally the same. From measurement result, the highest packet loss is 0.16 % (1 packet loss) where the received packet is 605 while the send packet is 606. Next, for the simulation result the highest packet loss is 2 % (3 packet loss) where the received packet is 110 and the packet send is 113.

b) Throughput

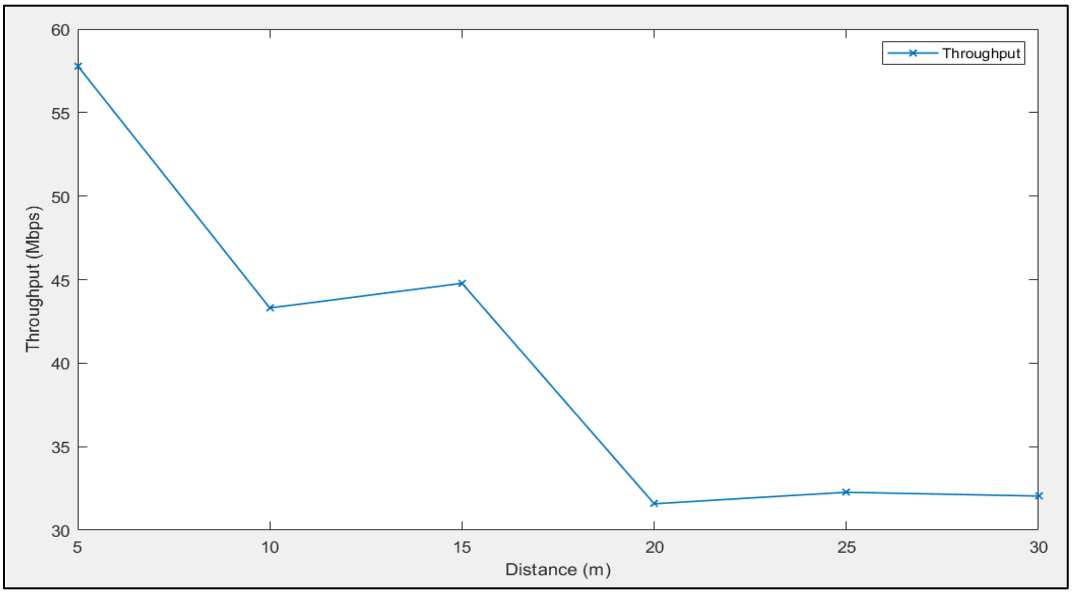


Figure 4.13: Throughput from the measurement result

Figure 4.13 illustrate the throughput results obtained from the measurement. The throughput value is 32.04 Mbps in 1800 second. Thus, we can conclude that the 30-meter distance affect the throughput value because the longer the distance, the throughput value will be decrease due to signal drop.

c) Latency

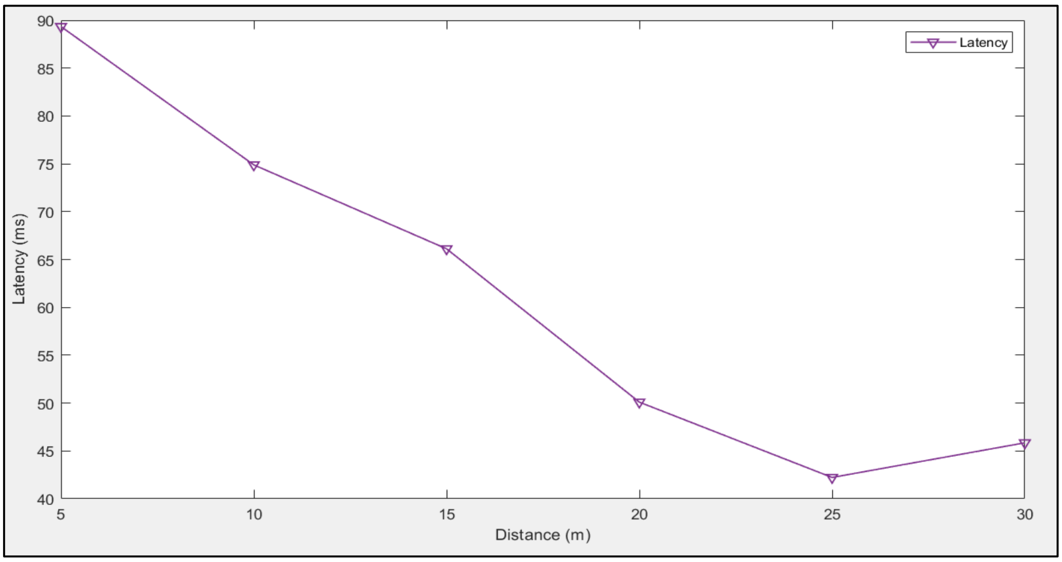


Figure 4.14: Latency from the measurement result

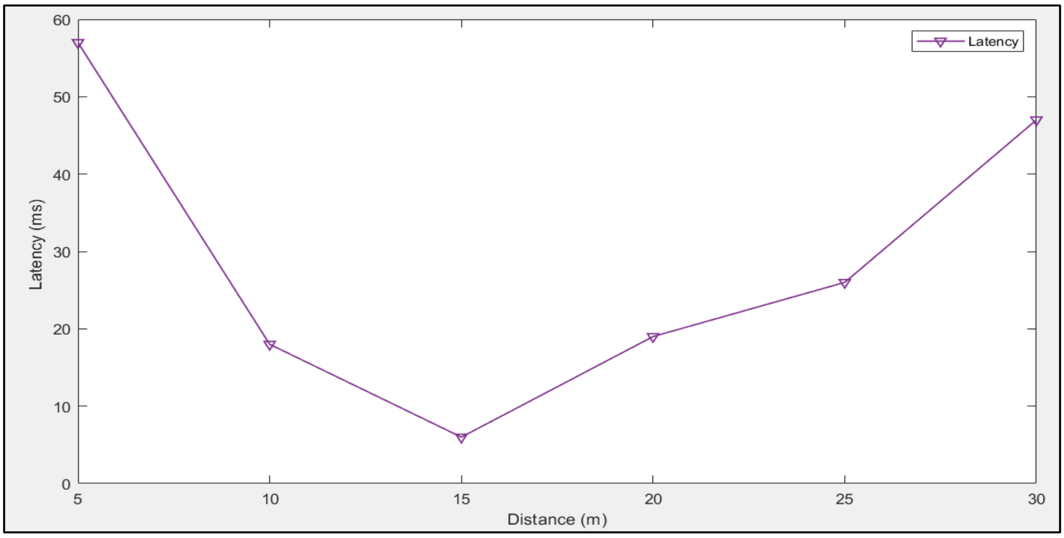


Figure 4.15: Latency from the simulation result

Figure 4.14 illustrate the latency results obtained from the measurement while Figure 4.15 latency results is obtained from simulation. The highest latency for measurement result is 89ms while for simulation is 57ms. This shows that the latency is starting to increase while increasing the distance. This is because the 30-metre distance between the user and server affects the latency results.

4.5 Scenario 4 (NLOS, 10m)

This analysis is continued for non-line of sight with a 10-meter distance between the router and the laptop. In this scenario, there is an obstacle between the router and the laptop. The parameter that was measured is packet loss, throughput, and latency by using EMCO Ping Monitor 8 and Ping. Thus, a graph is plotted in MATLAB for measurement and simulation results for all parameters.

a) Packet loss, sent, received

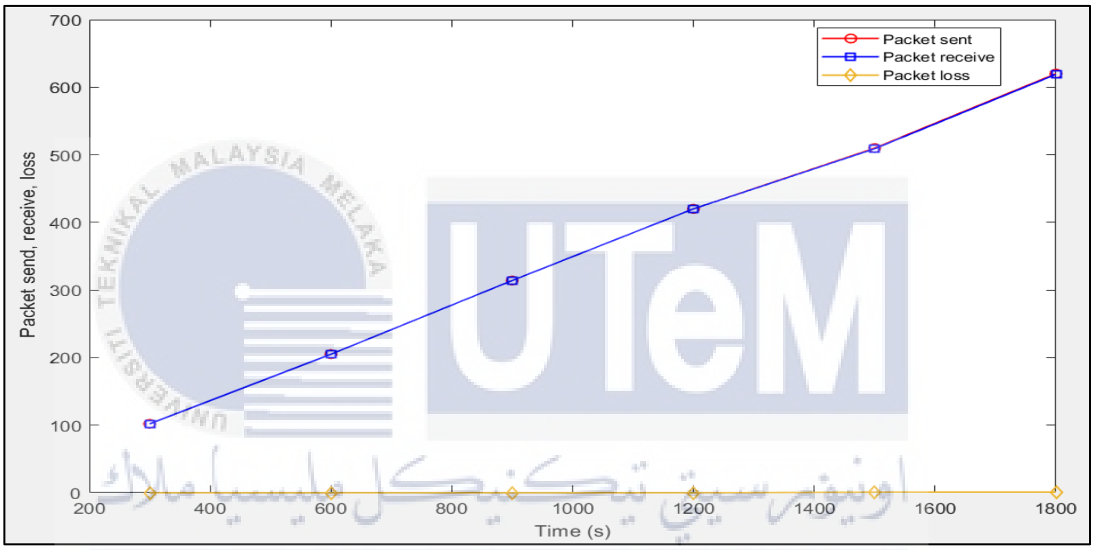


Figure 4.16: Packet loss from the measurement result

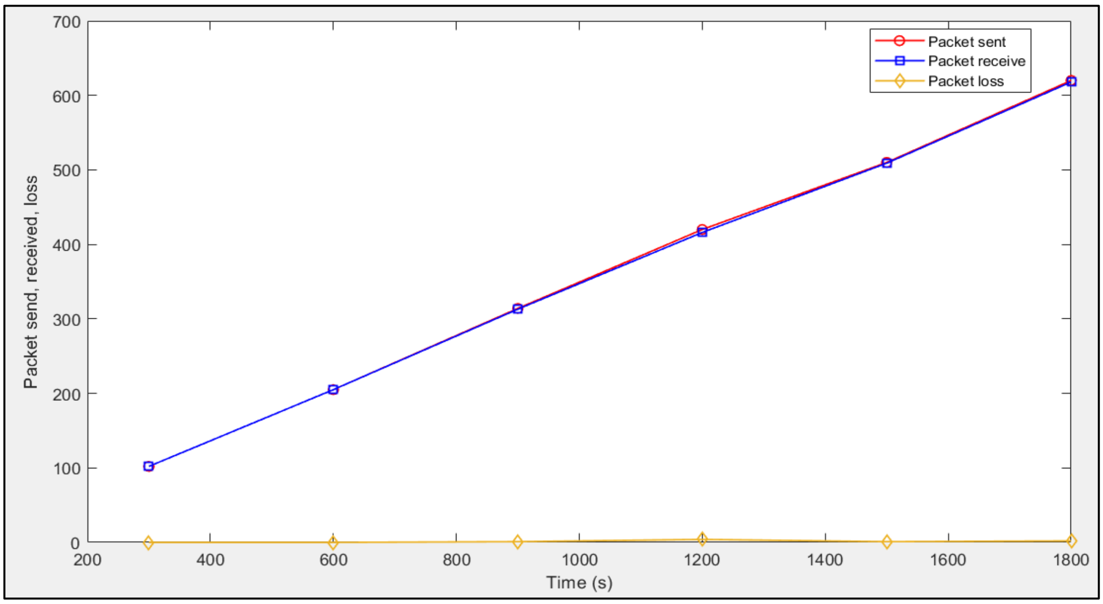


Figure 4.17: Packet loss from the simulation result

Figure 4.16 shows the packet loss, packet sent, and packet received result that is obtained from the measurement, while Figure 4.17 shows the result from the simulation. The number of packet loss from both graphs are equally the same. From measurement result, the highest packet loss is 0.19 % (1 packet loss) where the received packet is 509 while the send packet is 510. Next, for the simulation result the highest packet loss is 0 % (4 packet loss) where the received packet is 420 while the send packet is 416. There is not much difference between results obtained at previous scenario.

b) Throughput

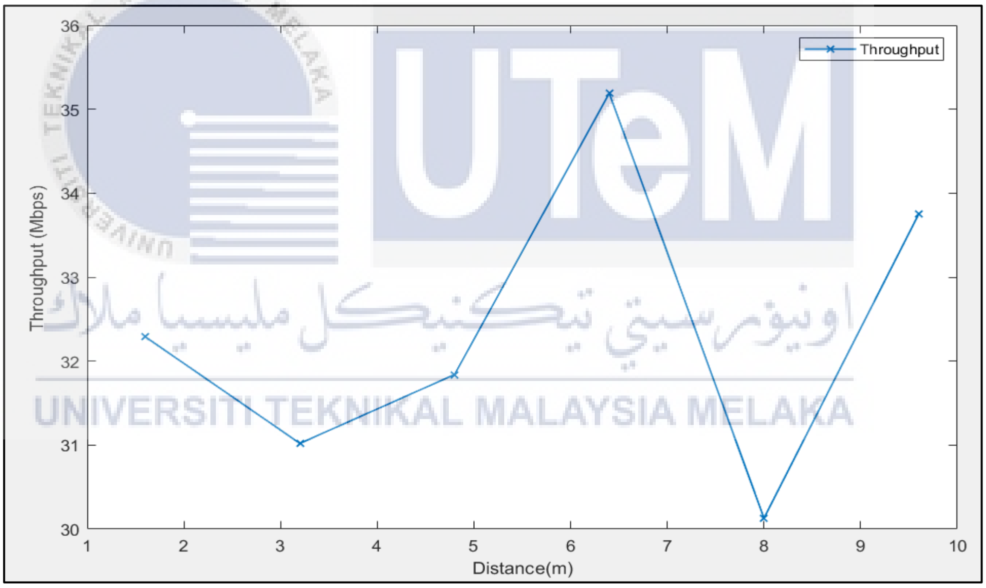


Figure 4.18: Throughput from the measurement result

Figure 4.18 explains the throughput results obtained from the measurement. It shows that the throughput is starting to decrease while increasing the distance. This happened due to many factors such as network coverage, interference from other wireless devices and barriers. At 1800 seconds, the throughput value is 33.75 Mbps for 10-meter distance. The throughput value for NLOS is lower than throughput value in LOS. This is due to obstacle that cause the signal drop.

c) Latency

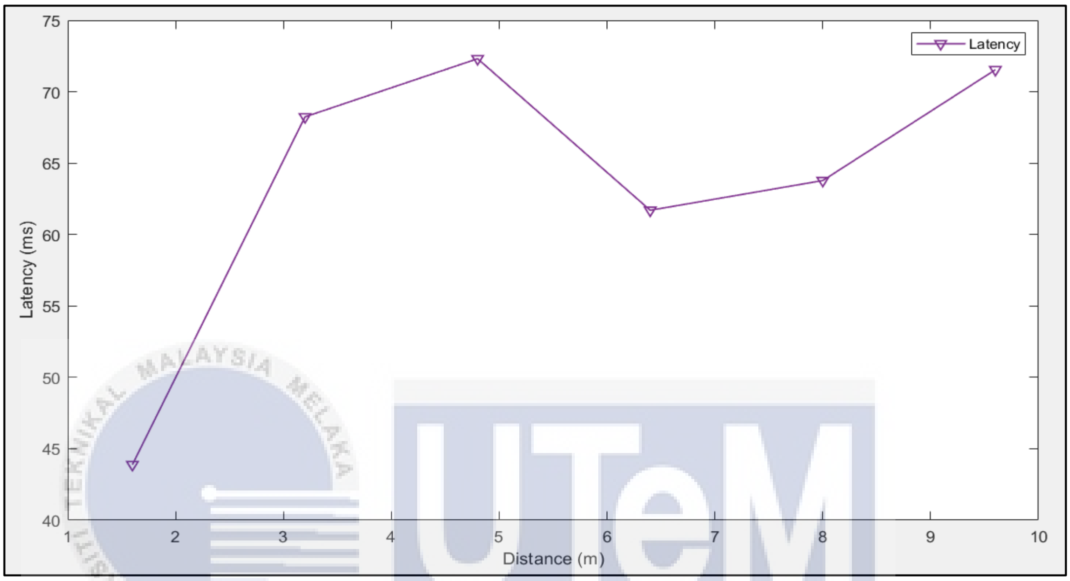


Figure 4.19: Latency from the measurement result

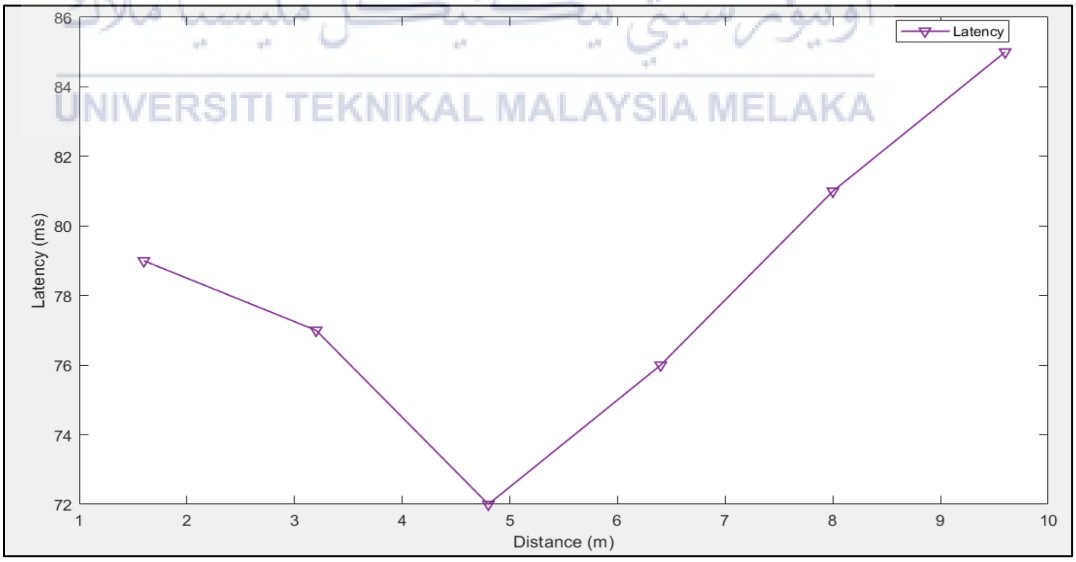


Figure 4.20: Latency from the simulation result

Figure 4.19 explains the latency results obtained from the measurement while Figure 4.20 latency results is obtained from simulation. It shows that the latency is starting to increase while increasing the distance. This is because the distance between the user and server affects the latency results where the user and the server are separated by a ten-meter distance. For measurement result, the highest latency value is 72ms while for simulation result is 85ms. The latency value for NLOS is higher than the latency value for LOS. This is due to the NLOS surrounding that had obstacle that contribute to propagation loss in transmission line.

4.6 Scenario 5 (NLOS, 12m)

Finally, a 12-meter distance between the router and the laptop for a non-line-of-sight environment is measured. In this scenario, there is an obstacle between the router and the laptop. The parameter that was measured is packet loss, throughput, and latency by using EMCO Ping Monitor 8 and Ping. Thus, a graph is plotted in MATLAB for measurement and simulation results for all parameters.

a) Packet loss, sent, received

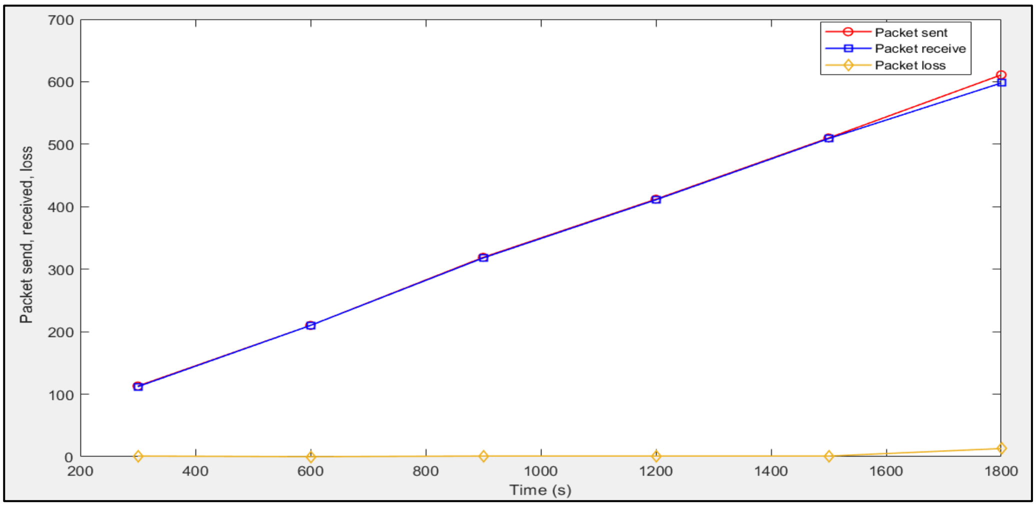


Figure 4.21: Packet loss from the measurement result

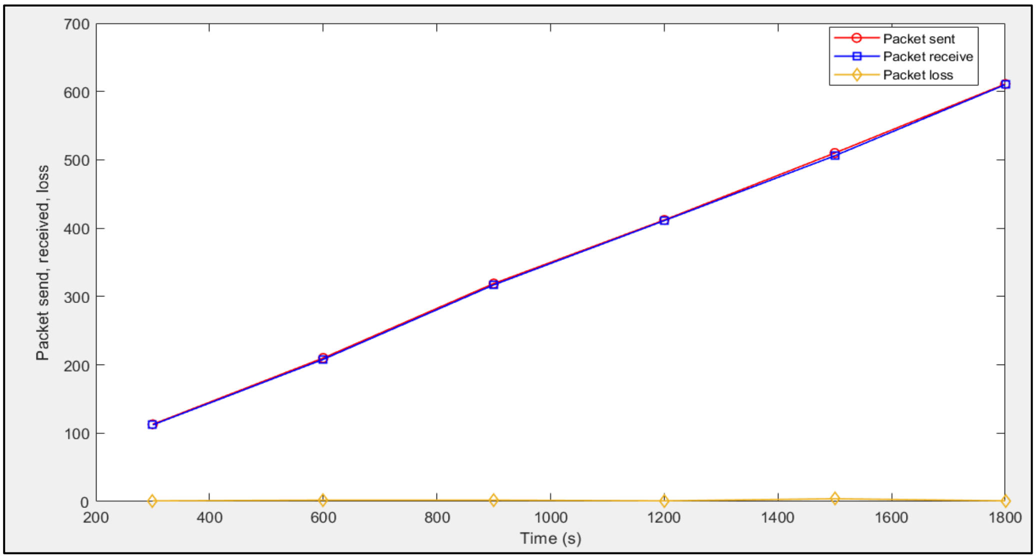


Figure 4.22: Packet loss from the simulation result

Figure 4.21 shows the packet loss, packet sent, and packet received result that is obtained from the measurement, while Figure 4.22 shows the result from the simulation. The number of packet loss from both graphs are equally the same. From measurement result, the highest packet loss is 2.12 % (13 packet loss) where the received packet is 598 and the packet send is 611. Next, for the simulation result the highest packet loss is 0 % (4 packet loss) where the received packet is 506 while the send packet is 510. The packet loss from measurement result is higher than LOS scenario. The amount of packet loss is increased with increasing distance.

b) Throughput

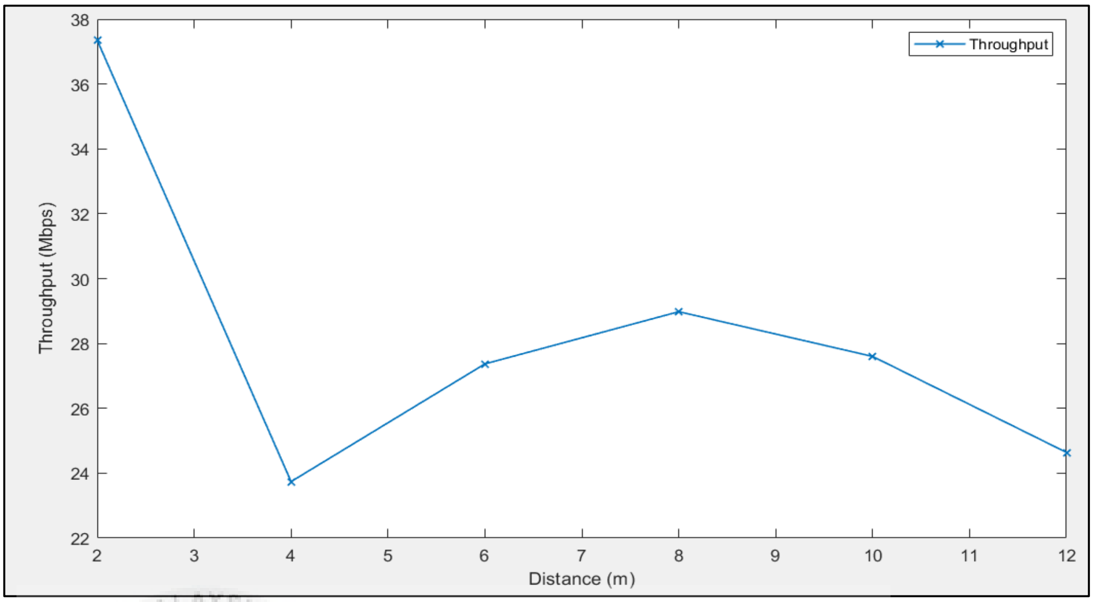


Figure 4.23: Throughput from the measurement result

Figure 4.23 illustrate the throughput results obtained from the measurement. It shows that the throughput is starting to decrease while increasing the distance. At 1800 seconds, the throughput value is 24.64 Mbps for 12-meter distance. The throughput value for NLOS is lower than throughput value in LOS. This is due to obstacle that cause the signal drop. The longer the distance, the amount of throughput that drop during transmission is high.

c) Latency

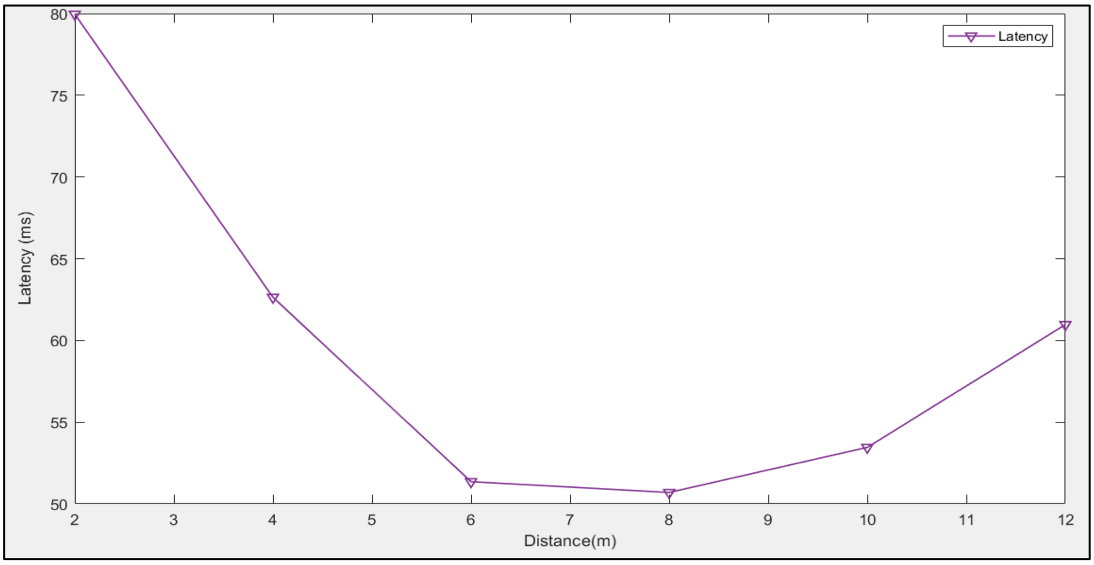


Figure 4.24: Latency from the measurement result

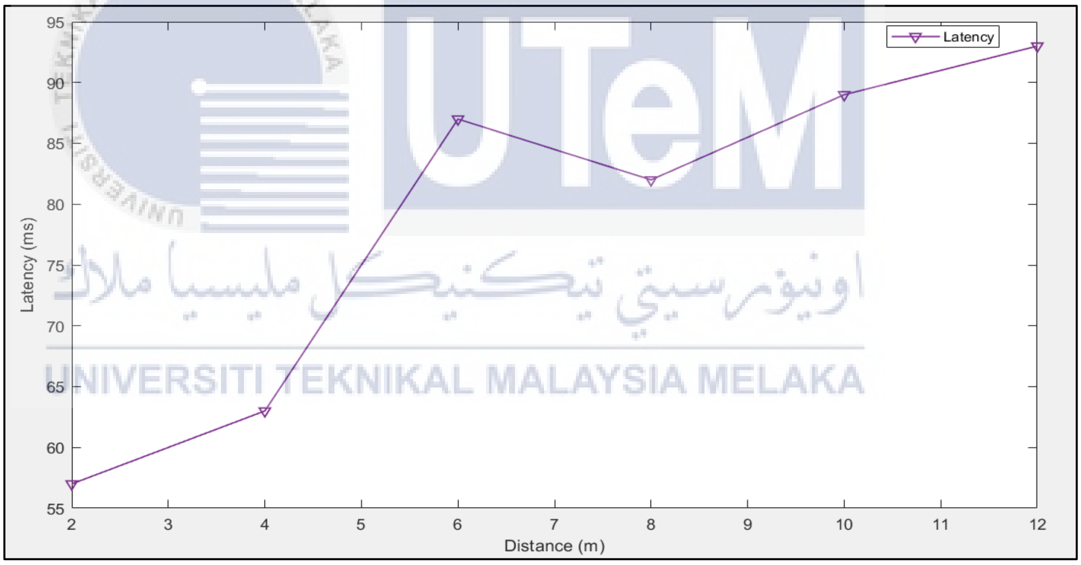


Figure 4.25: Latency from the simulation result

Figure 4.24 explains the latency results obtained from the measurement while Figure 4.25 latency results is obtained from simulation. This trend indicates that the latency is beginning to increase as the distance is increased by the last 5m. It shows that the latency is starting to increase while increasing the distance. This is because the distance between the user and server affects the latency results where the user and the server are separated by a 12-meter distance. For measurement result, the highest latency value is 79ms while for simulation result is 93ms. The latency value for NLOS is higher than the latency value for LOS. This is due to the NLOS surrounding has obstacle that contribute to propagation loss in transmission line.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

In this chapter, a conclusion will be made to discuss the comparison of the throughput and latency for LOS and NLOS in a 10-meter distance. After completing the analysis in this chapter, the results were summarized for future research to improve. Finally, recommendations for additional research have been made.

5.2 Comparison of the throughput result between LOS and NLOS for 10-meter distance

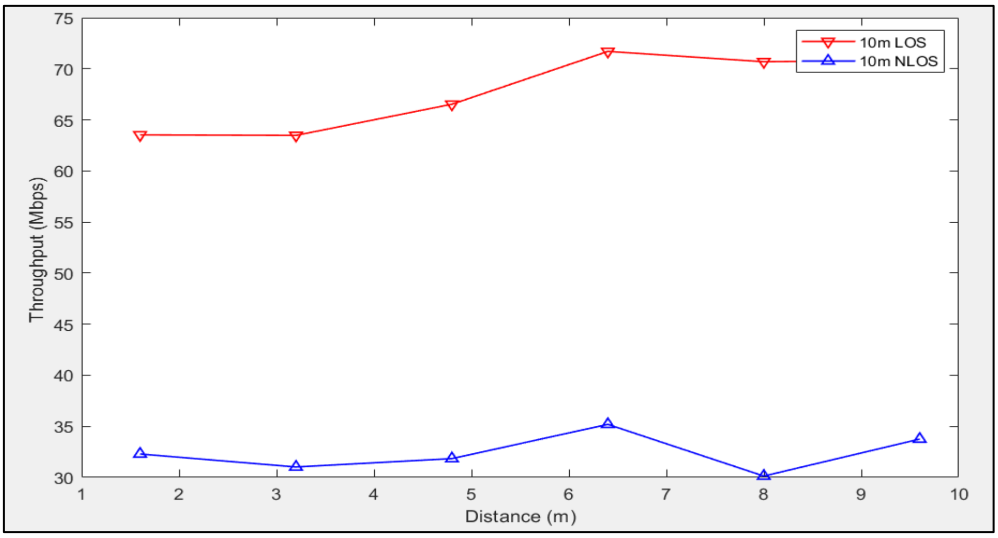


Figure 5.1: Comparison of the throughput from the measurement result

Figure 5.1 represented the throughput value of 10-meter distance for LOS and NLOS. It can be observed that the throughput value for both environments are stable because there is not much difference between the highest and lowest reading. This occurs because the throughput for Wi-Fi performance performs in a good condition in a 10-meter distance or less. However, based on the two different environments, the throughput result for LOS is higher than the NLOS. This conclusion satisfied the statement from [10] that the throughput value in LOS is higher than the throughput value in NLOS. This is because in LOS surrounding there is no obstacle thus the propagation loss that occurs during transmission is low.

The lowest throughput value in NLOS could be due to packet loss as well. Another aspect that contributes to packet loss is natural or artificial interference. A packet loss can occur when a router receives packets and decides not to distribute them [32]. One of the variables that contribute to dropping is an overloaded router.

5.3 Comparison of the latency result between LOS and NLOS for 10-meter distance

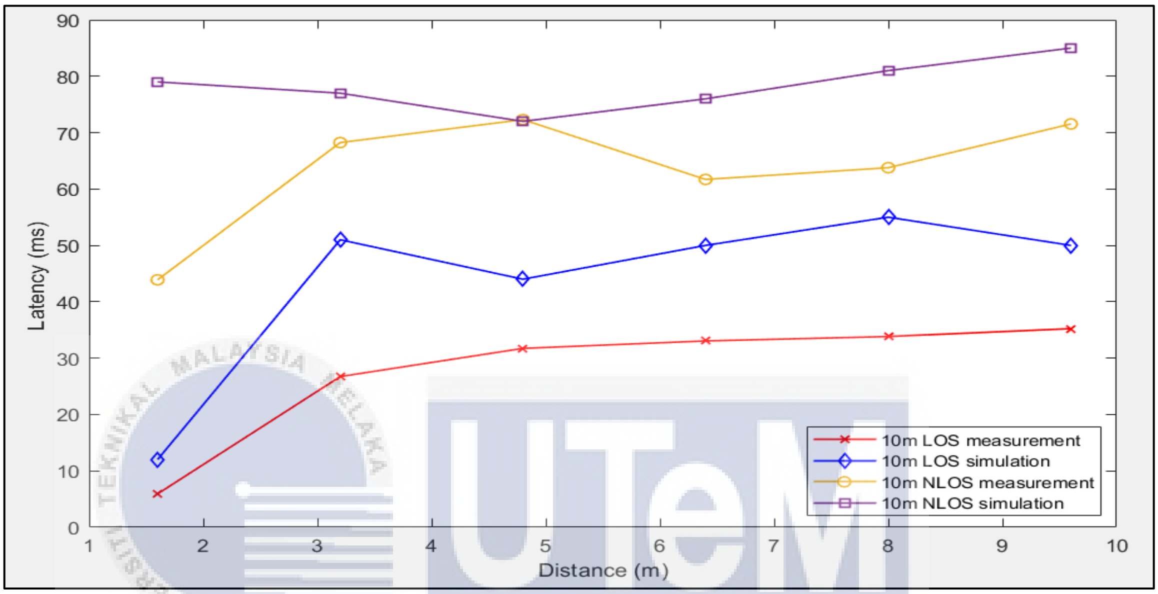


Figure 5.2: Comparison of the latency from the measurement and simulation results

Figure 5.2 explain the latency value for four different scenarios for LOS and NLOS. The red line indicates the latency value from the measurement result for LOS while the blue line indicates the latency value from the simulation result for LOS. Next, a yellow line indicates the latency value from the measurement result for NLOS and finally, the purple line indicates the latency value from simulation results for NLOS. Based on the result that is obtained the latency for the NLOS environment is much higher compared to the LOS environment.

This is because the study area was built with an NLOS and there is a physical obstacle in the form of a wooden door that has caused 3dB path loss and 8dB for the brick wall, while the fire door has caused 14 dB path loss. The physical barrier may result in wireless network penetration loss and signal loss. This study indicates that the latency value in NLOS is larger than the throughput value in LOS, as stated in [10].

Besides that, the latency result is also affected by the distance between the user and the server. As shown in Figure 5.2, for all four conditions, the latency will start to increase as the distance is larger. The reason for this is that the distance between the transmitter and receiver affects the latency value. This factor is called propagation delay where the propagation delay is the time taken for a signal to travel over a network from sender to receiver and the signal is travel at the speed of light. There are a four component that that cause latency which is processing delay, propagation delay, transmission delay and queuing delay.

5.4 Conclusion

This project has succeeded and meet its objective to investigate the Wi-Fi network performance in an indoor environment for LOS and NLOS conditions. This project also success to analyse the Wi-Fi signal performance in terms of throughput, packet loss and latency for LOS and NLOS indoor environments. From the analysis at Figure 5.1 and 5.2 for the NLOS surroundings can conclude that the obstacle in indoor environment affect the throughput and latency performance for NLOS condition. The throughput value in NLOS surrounding is lower than in LOS, while the latency is higher in NLOS compared to LOS. The high latency value affects the throughput value in Wi-Fi performance thus cause the delay in loading the application such as web browsing. For example, the high latency and low throughput in Wi-Fi router affect the communication at fire station because there are a lot of wireless devices thus the high latency cause delay in communication. Besides, the obstacle in fire station also causes a high propagation loss that increased the latency value and cause the signal to drop. To reduce the latency and throughput value, the placement of the router is very important to make sure that a good performance in Wi-Fi network.

5.5 Future Works

To obtain a good reading for throughput and latency, a suitable software with high accuracy can be used to obtain a good result with high accuracy. In future, the placement of router can be implemented to improve the Wi-Fi performance in fire stations.

5.6 Project Limitation

The limitation in this project is the network performance parameter that are being measured is limited where this project only measure packet loss, latency, and throughput. to Covid-19 situation, the measurement cannot be performed at the fire station area thus the experiment is done at the study area which is Faculty of Electronic and Computer Engineering (FKEKK) at first floor and third floor. This surrounding area is different compared to the fire station that had a different physical obstacle. However, the measurement has been done by considering the thickness of the fire door, the thickness of the wall and the surrounding environment.

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