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Real-time Wi-Fi network performance evaluation

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ABSTRACT

The most critical parameters that indicate the Wi-Fi network are throughput, delay, latency, and packet loss since they provide significant benefits, especially to the end-user. This research aims to investigate Wi-Fi performance in an indoor environment for light-of-sight (LOS) and non-light-of-sight (NLOS) conditions. The effect of the surrounding obstacles and distance has also been reported in the paper. The parameters measured are packet loss, the packet sent, the packet received, throughput, and latency. Site measurement is done to obtain real-time and optimum results. The measured parameters are then validated using the EMCO ping monitor 8 software. The comparison results between the measurement and the simulation are well presented in this paper. Additionally, the measurement distance is done up to 30 meters and the results are reported in the paper as well. The results indicate that the throughput value decreases with an increasing distance, where the lowest throughput value is 24.64 Mbps and the highest throughput value is 70.83 Mbps. Next, the maximum latency value from the measurement is 79 ms, while the lowest latency value is 56.09 ms. Finally, this research verified that obstacles and distances are among the contributing factors affecting the throughput and latency performance of the Wi-Fi network.

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1. INTRODUCTION

This paper aims to evaluate the surrounding effects on Wi-Fi performance in an indoor environment. The evolution in wireless technology has been given the biggest impact on modern communication systems. The understanding of radio frequency (RF) propagation in RF planning is very important because ideal 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, and navigation. However, there are a few factors that will degrade the performance of the wireless signal such as distance, interference, and obstacles [2].

Wi-Fi uses the industrial, science, and medical (ISM) 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. The levels of power are also modest, 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 [3]. 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 [4]. 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 2.4 GHz or 5 GHz Wi-Fi is required, as with older systems [5].

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 [6]. The 5 GHz spectrum can carry up to 1,300 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 [7].

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 [8]. From [9], [10], a study was submitted to investigate the performance of received signal strength indicators (RSSI) that measure the received power level from radio-frequency devices such as base station sectors, access points, or routers. The research found that the factors that affect the low RSSI value at the receiver are the range of wireless signal and the coverage area between transmitter and receiver that induce path loss and attenuation. The RSSI value is low when the path loss is high. A high signal-to-noise ratio (SNR) channel yields high RSSI at the receiver [11], [12].

Penetration losses are defined as the amount of signal power measured in decibels [13]. This loss known as the signal passes through a material (which could be a wall, floor, or window). These losses occur due to the reflection caused by the wave attempting to traverse the obstacle, as well as the substance itself performing further absorption [14], [15]. Tables 1 and 2 respectively show the value of the path loss degradation due to specific surroundings materials that are used in the measurement and simulation calculation [13].

Table 1. The 2.4 GHz path loss [13]

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

Table 2. The 5 GHz path loss [13]

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

2. RESEARCH METHOD

The research location for the light-of-sight (LOS) environment is located in the lobby of the Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK) building (as shown in Figure 1), where there is no barrier between the router and the laptop. Even from a greater distance, it is possible to make out the shape of the router. A minimum of ten meters and maybe up to twenty-five meters between the laptop and the router. For the purpose of carrying out the measurement, an EMCO ping monitor 8 program and a Wi-Fi scanner were utilized. The EMCO ping monitor 8 is utilized in order to ascertain the amount of packets transmitted, received, and lost in a time span of thirty minutes for each scenario [16]. In addition to that, this software calculates the amount of latency, measured in milliseconds, for each individual circumstance. The Wi-Fi scanner tool is utilized for the purpose of determining the throughput of the wireless network under all circumstances. The research space for the non-light-of-sight (NLOS) environment may be found on the third level (as shown in Figure 2), and it is enclosed by a brick wall and a door made of wood on all sides. The router is hidden, and the distance between it and the laptop can be up to 12 meters at any one time (as shown in Figures 3(a) and (b)).

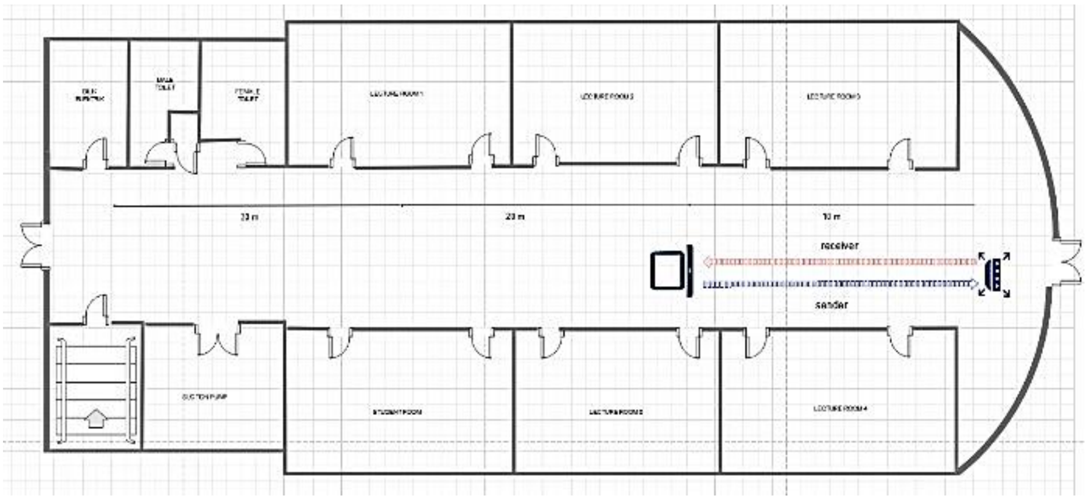

Figure 1. The lobby floor plan used for the LOS environment

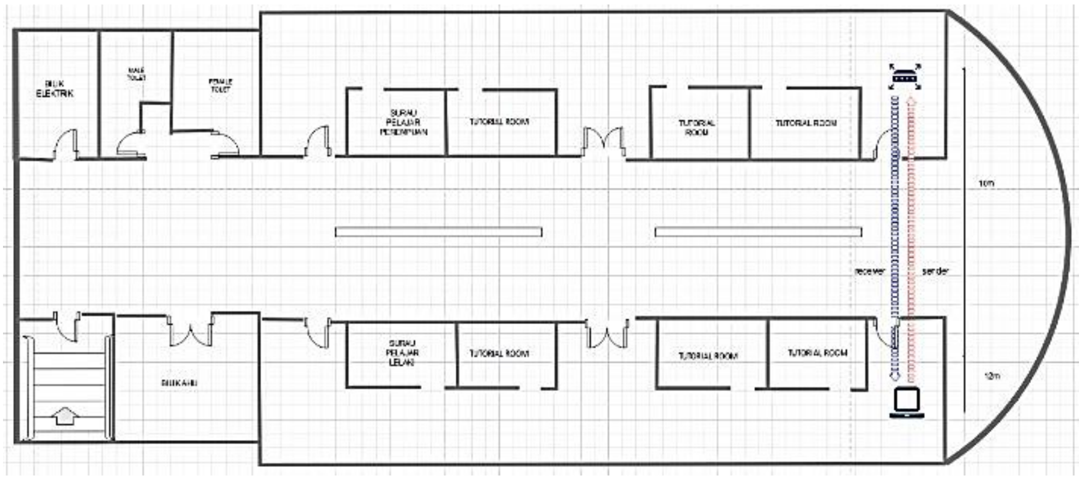

Figure 2. The third level floor plan used for the NLOS environment

(a) (b)

Figure 3. Site measurement for (a) the LOS environment and (b) the NLOS environment

3. RESULTS AND DISCUSSION

Four scenarios had been set up in this research based on different distances and surroundings. The distance starts at 10 meters and up to 30 meters. The surroundings for each measurement are different in terms of (LOS) and NLOS conditions [17].

3.1. Scenario 1 (LOS, 10 m)

In this scenario, the distance between the router and the laptop is set to 10 meters with the LOS environment. Figure 4 shows the packet loss, the packet sent, and the packet received that is obtained from the measurement, while Figure 5 shows the result from the simulation. The number of packet losses from both graphs is equally the same. From the measurement result the highest packet loss is 1.8% (11 packet loss) where the received packet is 598 while the packet sent is 609. Next, for the simulation result, the highest packet loss is 1% (10 packet loss) where the received packet is 599 while the packet sent is 609.

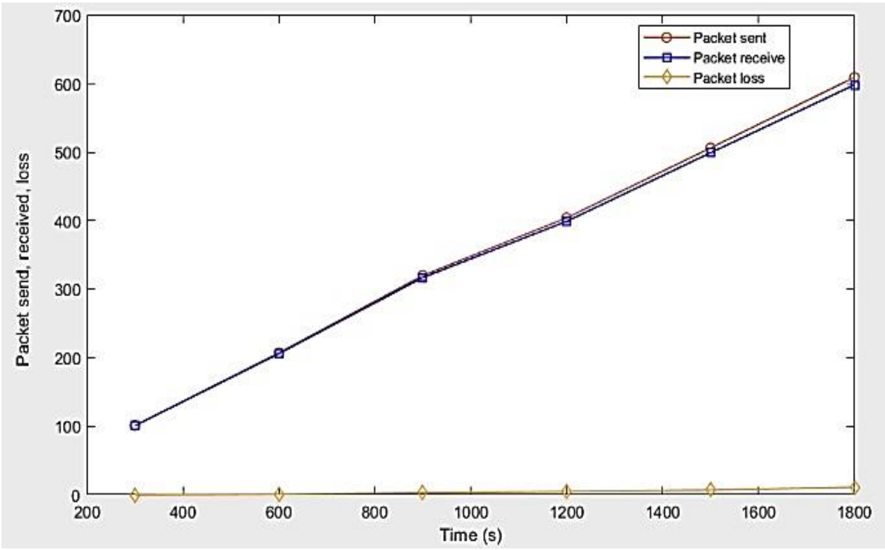

Figure 4. Packet loss from the measurement result

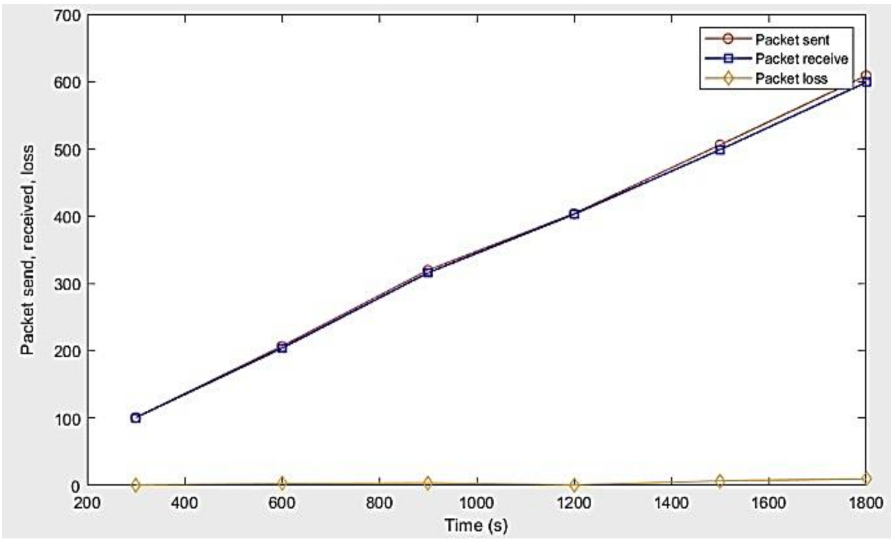

Figure 5. Packet loss from the simulation result

Figure 6 demonstrates 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 1,800 seconds, the throughput value is 70.83 Mbps for a 10 meter distance.

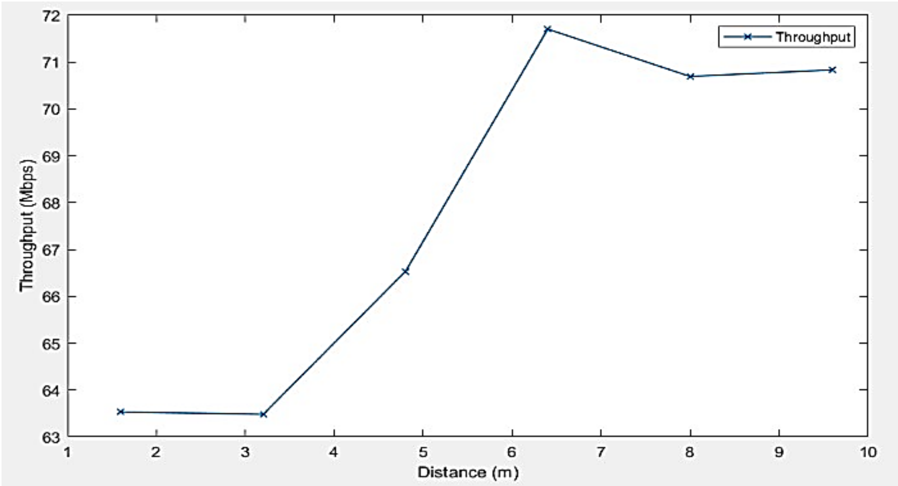

Figure 6. Throughput from the measurement result

Figure 7 explains the latency results obtained from the measurement while Figure 8 latency results are 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 10 meter distance. For the simulation result, the highest latency value is 35.23 ms while the measurement result is 55 ms.

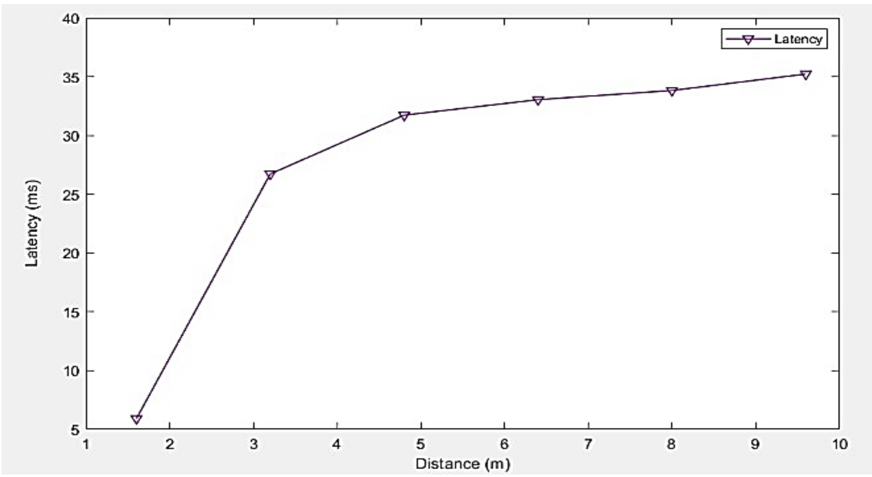

Figure 7. Latency from the simulation result

3.2. Scenario 2 (LOS, 20 m)

The distance is now increased up to 20 meters, LOS with the same condition as in the previous scenario. Figure 9 shows the packet loss, the packet sent, and the packet received obtained from the measurement, while Figure 10 shows the result from the simulation. The number of packets received at 600 seconds at simulation results shows the decreasing amount of packets 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 also of distances [18]. It summarized that the amount of packet loss is increasing with increasing distance.

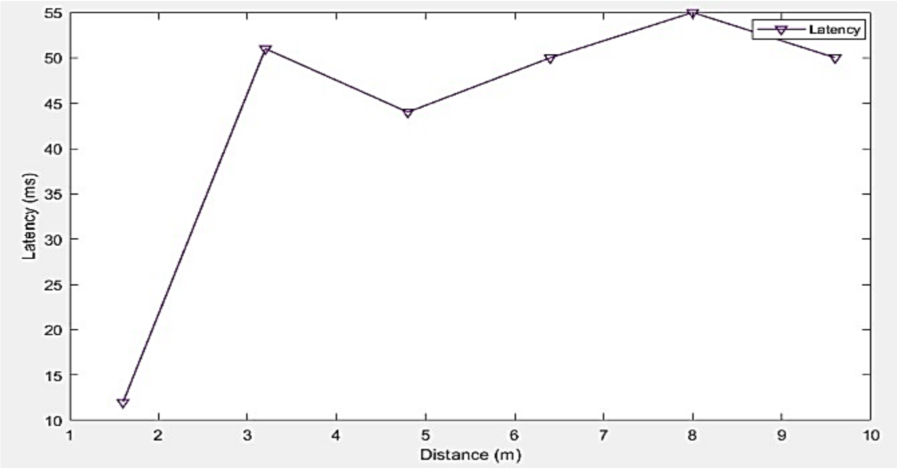

Figure 8. Latency from the measurement result

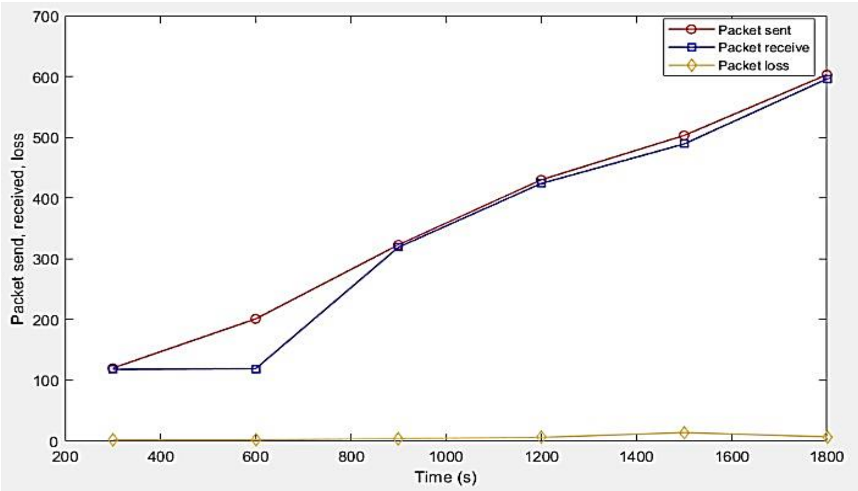

Figure 9. Packet loss from the measurement result

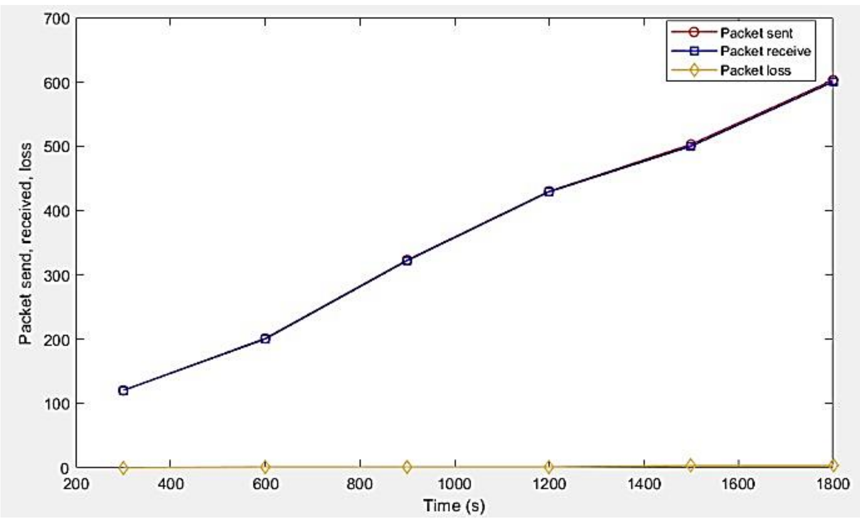

Figure 10. Packet loss from the simulation result

Figure 11 shows the throughput from the measurement result. At 1,800 seconds, the throughput value is 63 Mbps lower than the throughput in scenario 1. This proved that when the distance increases, 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 [19].

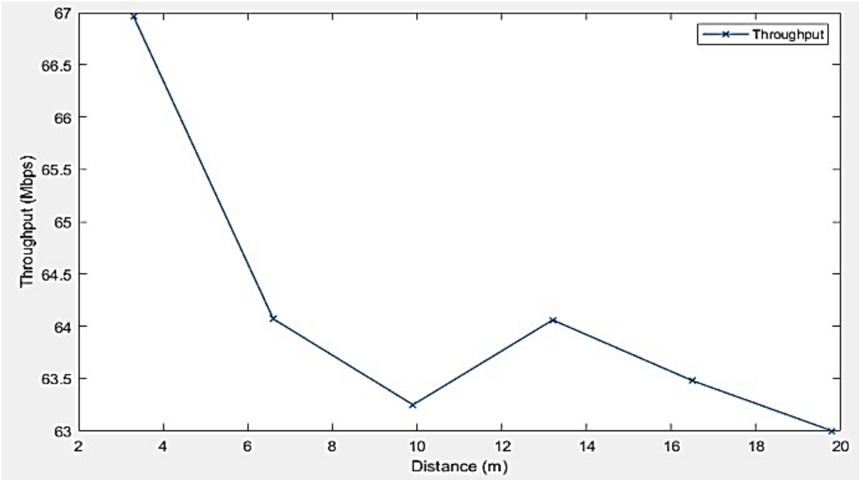

Figure 11. Throughput from the measurement result

Figure 12 explains the latency results obtained from the measurement while Figure 13 results are obtained from the simulation. The highest latency for measurement results is 56.09 ms while for simulation is 60 ms. This trend indicates that the latency is beginning to increase as the distance is increased by the last 6 m. This is because the 20 meter distance between the user and server affects the latency results.

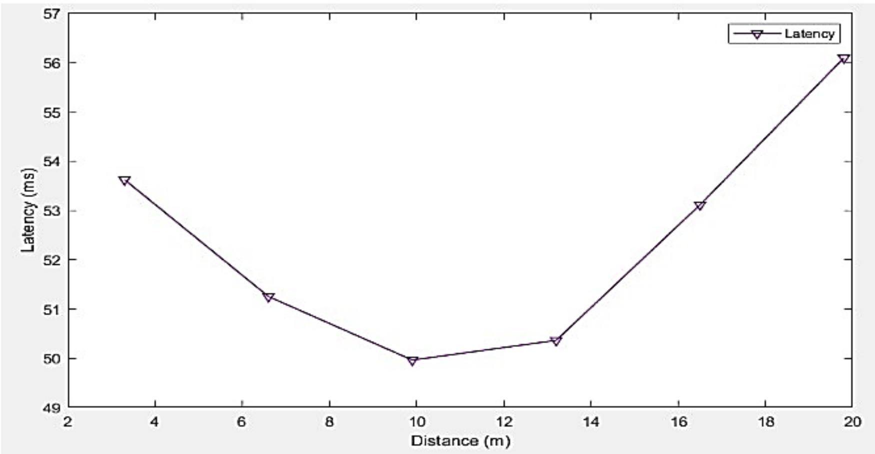

Figure 12. Latency from the measurement result

3.3. Scenario 3 (NLOS, 10 m)

In this scenario, the distance is 10 meters however with NLOS conditions. Figure 14 shows the packet loss, the packet sent, and the packet received result obtained from the measurement, while Figure 15 shows the result from the simulation. The number of packet losses from both graphs is equally the same and almost the same as in scenario 1 results. From the measurement result, the highest packet loss is 0.19% (1 packet loss) where the received packet is 509 while the packet sent is 510. Next, for the simulation result, the highest packet loss is 0% (4 packet loss) where the received packet is 420 while the packet sent is 416.

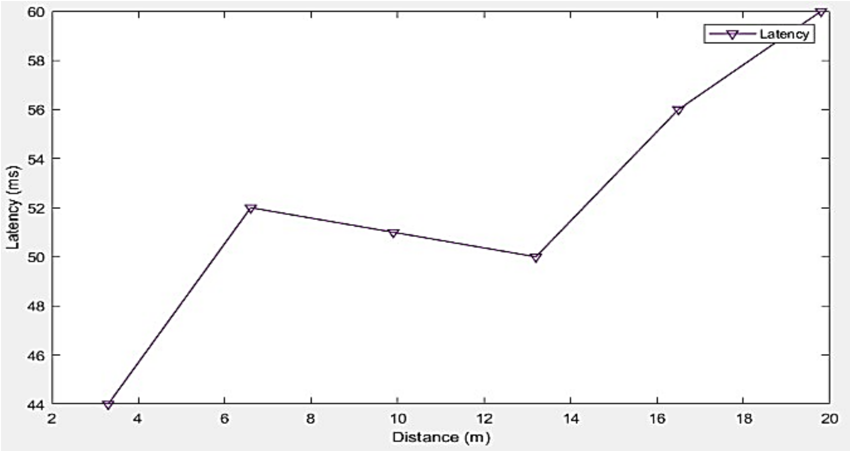

Figure 13. Latency from the simulation result

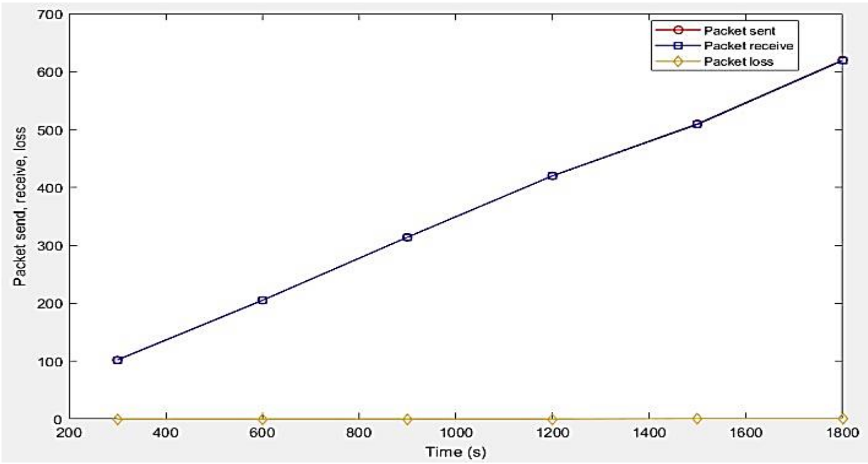

Figure 14. Packet loss from the measurement result

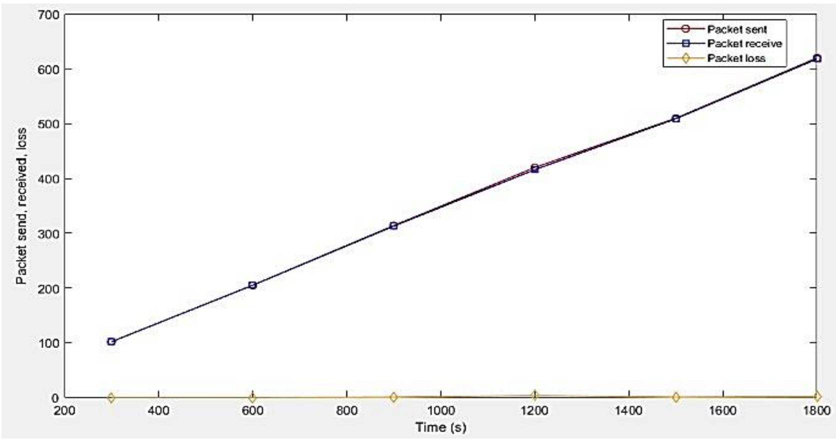

Figure 15. Packet loss from the simulation result

Figure 16 explains the throughput results obtained from the measurement. It shows that the throughput received is not stable all along the simulation time. This happened due to many factors such as network coverage, interference from other wireless devices, and barriers. At 1,800 seconds, the throughput value is 33.75 Mbps for a 10 meter distance. The throughput value for NLOS is lower than the throughput value in the LOS conditions that are due to the obstacle that caused the signal drop.

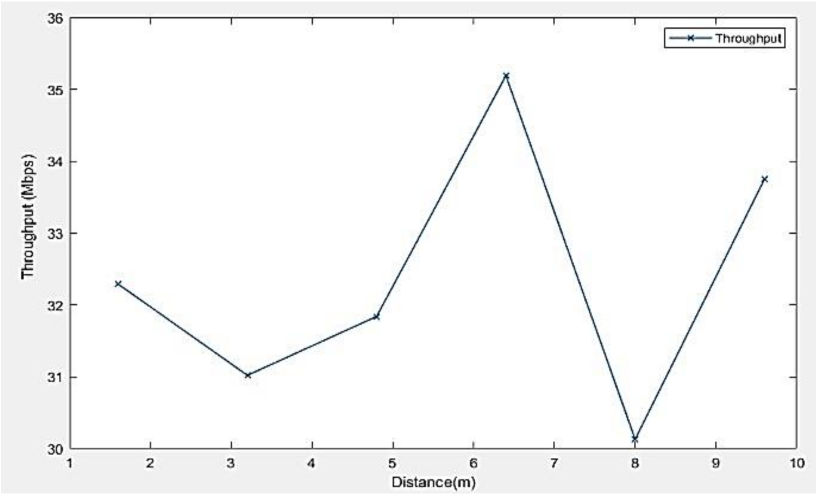

Figure 16. Throughput from the measurement result

3.4. Scenario 4 (NLOS, 12 m)

As to validate the effects of the distances on the Wi-Fi network performance, the condition for this scenario is to remain as the NLOS while the distance is increased up to more than 10 meters. However, the achievable maximum distance is only up to 12 meters. There is no signal received beyond the 12 meters distance. The results are explained in Figures 17 and 18. The number of packet losses from both graphs is equally the same. From the measurement result, the highest packet loss is 2.12% (13 packet loss) where the received packet is 598 and the packet sent is 611. Next, for the simulation result, the highest packet loss is 0% (4 packet loss) where the received packet is 506 while the packet sent is 510. The packet loss from the measurement result is higher than in the LOS scenario. It shows that the amount of packet loss is increased with increasing distance.

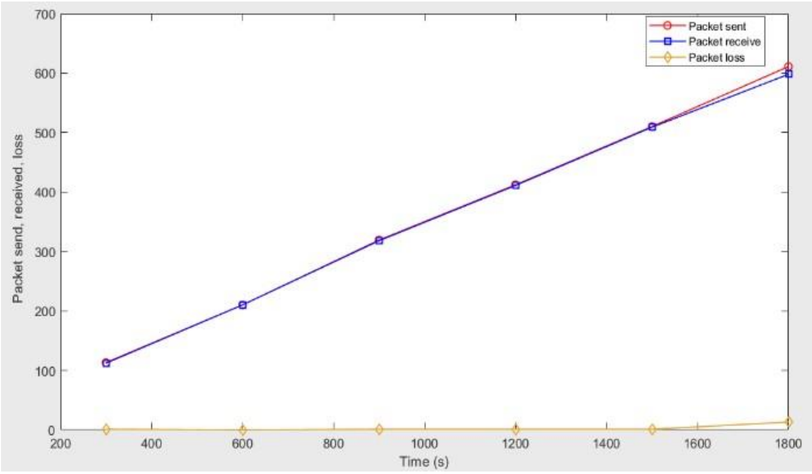

Figure 17. Packet loss from the measurement result

Figure 19 explains the latency results obtained from the measurement while Figure 18 shows the latency results obtained from the simulation. This trend indicates that the latency is beginning to increase as the distance is increased by the last 5 m. 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 serverare separated by a 12 meter distance. For measurement results, the highest latency value is 79 ms while for simulation result is 93 ms. The latency value for NLOS is higher than the latency value for LOS. This is due to the obstacles that contribute to propagation loss in the transmission line.

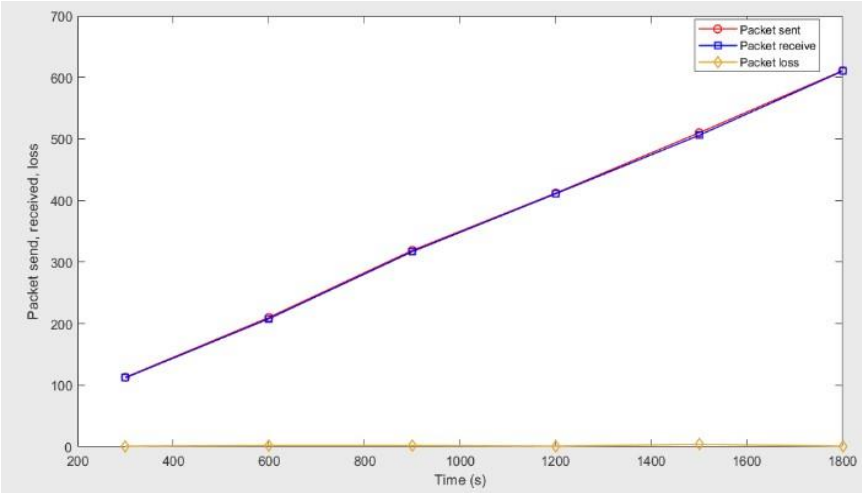

Figure 18. Packet loss from the simulation result

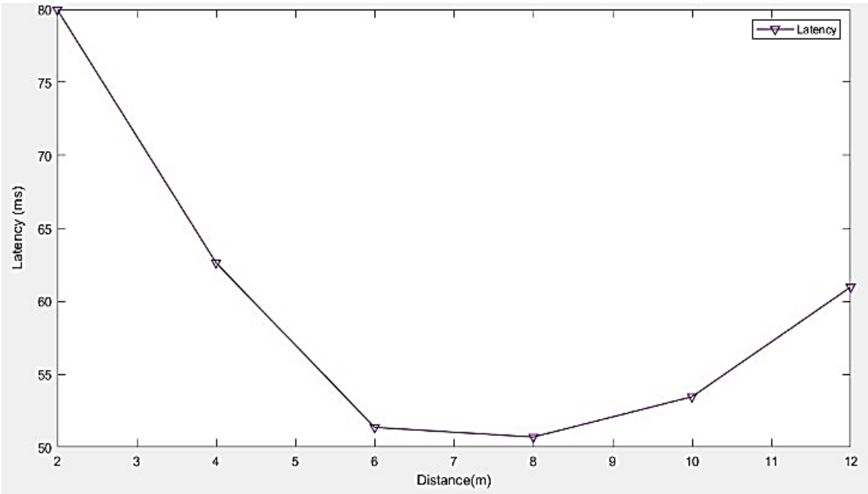

Figure 19. Latency from the measurement result

Figure 20 represented the throughput value of the 10 meter distance for LOS and NLOS from the measurement result. 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 [20] 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 [21]. One of the variables that contribute to dropping is an overloaded router.

Figure 21 explains 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, the latency for the NLOS environment is much higher compared to the LOS environment.

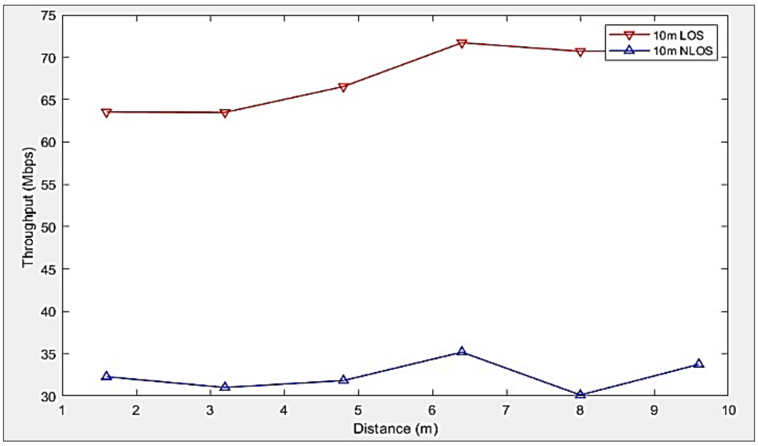

Figure 20. Comparison of the throughput result between LOS and NLOS environment

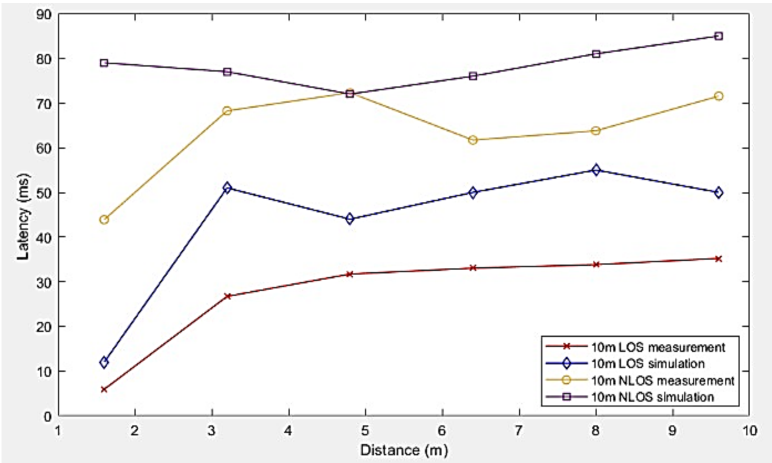

Figure 21. Comparison of the latency result between LOS and NLOS environment

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 3 dB path loss and 8 dB 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 [22]. Besides that, the latency result is also affected by the distance between the user and the server. As shown in Figure 21, the latency will start to increase as the distance is larger. The high latency value affects the throughput value in Wi-Fi performance thus causing the delay in loading the application such as web browsing, transferring files, and others [23]. The surroundings environment plays an important role in the Wi-Fi network performance since it will affect the successful achievable data packet rates. On top of that, to reduce the latency value, the placement of the router is very important to make sure that a good performance in the Wi-Fi network [24].

4. CONCLUSION

This research has succeeded and met its objective to investigate the Wi-Fi network performance in an indoor environment for LOS and NLOS conditions, in terms of throughput, packet loss, and latency. Based on the results for the NLOS scenarios, it can be concluded that the obstacles in the indoor environment affect the throughput and latency performance. The throughput value in NLOS surrounding is lower than in LOS, while the latency is higher in NLOS compared to LOS. Wi-Fi performance suffers when latency is too high, resulting in sluggish loading times for common activities like web surfing and file transfers. The Wi-Fi network's performance is influenced by the surrounding environment, which can affect the data packet rates that can be achieved successfully. Additionally, the location of the router is critical for optimal Wi-Fi network performance and lowering latency.

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