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Quality of Service (QoS) Comparative Analysis of Wireless Network

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Abstract - Nowadays the education sector has changed due to the covid-19 pandemic, but the government has tried to reduce this impact by providing WiFi in some areas. This article seeks to compare the quality of the internet network in an area that offers WiFi to the surrounding population, particularly students as a support for DL (Distance Learning), simulation, and the ideal scenario. In order to determine the quality of a network, one needs to consider the QoS (Quality of Service) metrics, which include packet loss, throughput, latency, and jitter. Using Wireshark (network analyzer software), this research collects data on the item to be investigated; the obtained data will be analyzed to determine the QoS of the WiFi service under investigation. In addition, this research will do network modeling and simulation using the opnet modeler (network simulation software), which will be utilized to compare the observed items. While video conferencing was used to analyze latency and jitter during a 60-minute sample length assessment, 500 MB of data was used to evaluate throughput and packet loss.

Keywords: Quality of Service, packet loss, throughput, delay, jitter

I. INTRODUCTION

The COVID-19 pandemic has had a major impact on the education sector in Indonesia. Learning that could initially be carried out face-to-face has now switched to distance learning methods, this has resulted in students and teachers having difficulty implementing this. In the distance learning process (DL) [1] students and teachers need to prepare electronic devices such as smartphones or laptops and internet connections. The government is trying to overcome this problem by providing free Wireless Fidelity (WiFi) in several places.

Wi-Fi, the popular acronym for IEEE 802.11 Wireless Local Area Network (WLAN), has become a common tool for broadband Internet access in everyday life [2]. With the availability of WiFi, a large number of people will flock to that site, forcing the construction of Quality of Service in the network system to sustain the internet's quality, thereby facilitating the growth of distance learning.

QoS is the ability of a network to provide satisfactory service by assigning sufficient bandwidth to account for jitter and latency. The objective of Quality of Service is to prioritize specific types of traffic, such as those with a constant or fixed bandwidth, regulated latency, jitter, and decreased packet loss [3].

Years of study and development in packet networks by notable organizations such as Cisco, IIT Delhi, and the International Telecommunication Union (ITU-T) [4-7] have shifted their attention to Quality of Service. Numerous recent studies on service quality from a variety of sources, such as quality of service in the telecommunications industry especially IoT, as cited in [8], This paper present the result of an experimental study of QoS metrics measurement in LoRaWAN networks. Complete research on the QoS parameters of wireless networks and an evaluation of their performance based on real-time situations were published in [9]. Another study on QoS was undertaken in [10] to determine the extent of the ISP's QoS performance utilizing Samarinda's top cellular carriers. This study measured service quality attributes based on time to the mobile network using a MySQL application running on a mobile device. Based on research [11] to analyze Telkomsel's internet network in Soreang. This study examined service quality attributes based on upload, download, and streaming video using the Wireshark tool. This study also measured QoS as in previous studies, but updated the subject of previous studies who were cellular operators into WiFi, besides that this research carried out simulations of modeling WiFi networks according to the actual conditions to be measured, and added modeling of the WiMAX network to compare the quality QoS between WiFi in the original state, WiFi in the simulation, and WiMAX in the simulation.

The focus of this study is to compare the quality of the internet network in the area that provides WiFi for the surrounding community, especially students as a support for DL (Distance Learning), simulation, and optimal scenario. Parameters used in measuring network quality include throughput, packet loss, delay, and jitter.

II. RESEARCH METHODS

Research Design

Research preparation begins to determine the location and then proceed with preparing the things needed in the measurement at the location. What is needed at the measurement location is a laptop as a measurement tool and a Wireshark as a measurement instrument, hereinafter takes WiFi with QoS parameters, including throughput, packet loss, delay, and jitter. Followed by network modeling in the opnet modeler application according to the condition of the object under study and perform simulations on the network being modeled. After that, analyze the measurement results and compare the results between the object studied and the simulation results, if it has been obtained, it ends with the preparation of a report, this is shown in Figure 1. The data collection method used in this research is capturing data on the object to be studied using the Wireshark application [12] and modeling the measured network and then simulating it using the opnet modeler application [13].

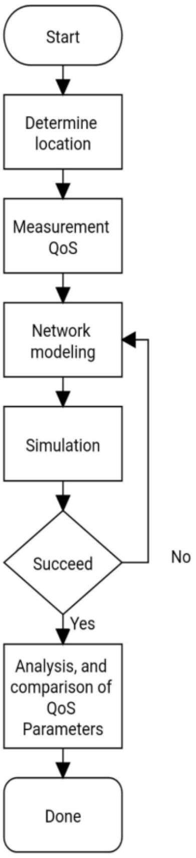

Figure 1. Research flow chart

Network Modeling

The red circle in Figure 2 represents the location where the router is measured, with a measuring distance of roughly 1 meter from the router. As described in the section on research method, measurements were conducted on a laptop running Windows 10 using Wireshark software version 3.4.4 and simulations were conducted using opnet modeler software version 14.5.

Figure 2. Measurement location condition

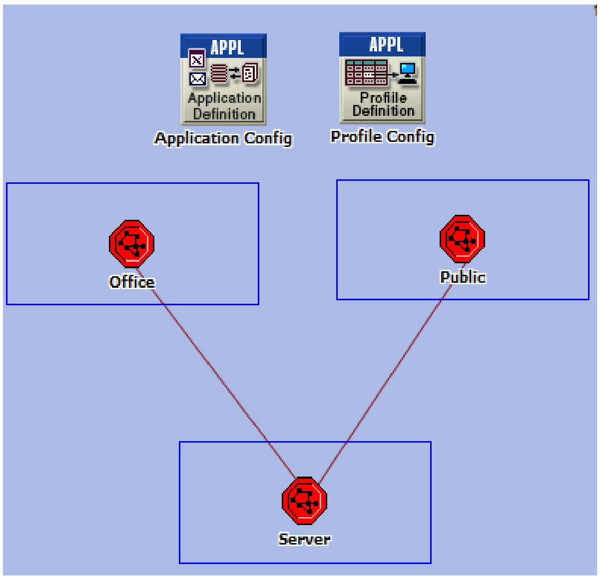

Figure 3. WiFi network model

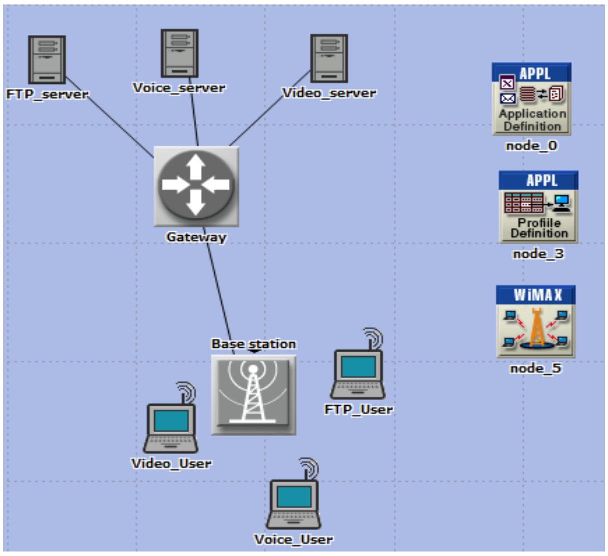

Figure 4. WiMAX network model

Table 1. List of devices used in the research

Name	Type	IP Address	Base Station	Number of Work Station
WiFi_1	Simulation	192.168.1.1	WiFi	20
WiFi_2	Simulation	192.168.1.12	WiFi	10
WiMAX	Simulation	192.168.1.2	WiMAX	3
Real_1	Real Condition	192.168.1.61	WiFi	20
Real_2	Real Condition	192.168.1.61	WiFi	10
Opt_1	Optimal Scenario	192.168.1.1	WiFi	20
Opt_2	Optimal Scenario	192.168.1.1	WiFi	10

Based on Table 1 network modeling in the simulation using the opnet modeler application is divided into 3 scenarios, in the first scenario the simulation is modeled as in Figure 3 initialized as (WiFi_1) with a WiFi base station, IP address 192.168.1.1, and the number of users is 20 devices. In the second scenario, the simulation is modeled as shown in Figure 3, initialized as (WiFi_2) with WiFi base station, IP address 192.168.1.12, and the number of users is

10. In the last scenario, the simulation is modeled as shown in Figure 4, initialized as (WiMAX) with WiMAX base station. , IP address 192.168.1.2, and the number of users is 3.

In the original network measurement, it is divided into 2 conditions, the first condition is initialized as (Real_1) with a WiFi base station, IP address is 192.168.61, and the number of users is 20. The second condition is initialized as (Real_2) with a WiFi base station, IP address 192.168.61, and a total of 10 users. Figure 2 depicts the measurement location

In the optimal scenario, it is divided into 2 conditions, the first condition is initialized as (Opt_1) with a WiFi base station, IP address is 192.168.1, and the number of users is 20. The second condition is initialized as (Opt_2) with a WiFi base station, IP address 192.168.1, and a total of 10 users.

WiFi

Wi-Fi is a technology that employs electronic equipment to exchange data wirelessly (through radio waves) over a computer network, including a high-speed Internet connection. According to the Wi-Fi Alliance, any wireless local area network (WLAN) product is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 specifications. WiFi is currently available in the home, office, and public settings, including public transportation [14].

WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) was established ten years ago with the intention of providing global high-speed mobile Internet access. Long Term Evolution (LTE) has basically replaced this application. WiMAX is not dead, however, and there are approximately 580 operators worldwide offering backhaul and rural access to high-speed broadband Internet access, typically in less developed regions. Figure 5 depicts the design of WiMAX.

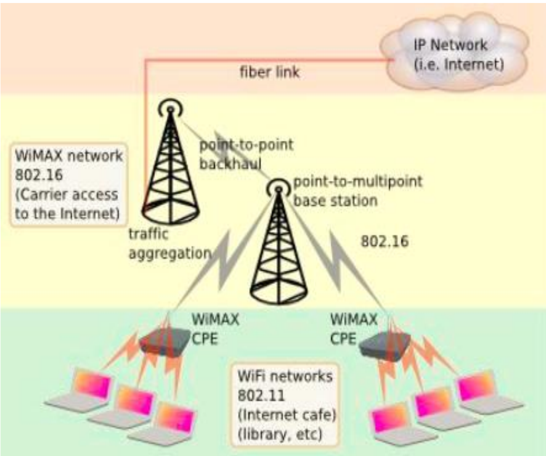

Figure 5. Application Scenarios of WiMAX [20]

Quality of Service

Quality of Service (QoS) is a network mechanism that evaluates whether applications or services can operate in accordance with predetermined criteria. Various characteristics, including packet loss, delay, throughput, jitter, and latency factors, might indicate the performance of an Internet access network [15-16]. Table 2 displays QoS categories

Table 2. Percentage and Value of QoS [17]

Value	QoS (%)	Index
3,8 – 4	95 – 100	Extremely Satisfying
3 – 3,79	75 – 94,75	Satisfactory
2 – 2,99	50 – 74,75	Less Satisfying
1 -1,99	25 – 49,75	Poor

a) Throughput

Throughput is the real bandwidth measured over a specific period of time and under specific network conditions that are used to move files of a specific size [19]. Table 3 displays throughput categories.

Table 3. Throughput categories [18]

Category	Throughput (%)	Index
Very Good	100	4
Good	75	3
Moderate	50	2
Poor	<25	1

Equation of calculation Throughput :

$$\text{Throughput} = \frac{\text{Data packet received}}{\text{Observation time}} \quad (1)$$

b) Packet loss

Packet loss refers to the number of packets lost during the transmission process to the destination. If packet loss exceeds a certain threshold, performance degrades significantly, and the system becomes unusable if packet loss is excessive [19]. Table 4 demonstrates the numerous types of packet loss.

Table 4. Packet loss categories [17]

Categories	Packet loss (%)	Index
Very Good	0	4
Good	3	3
Moderate	15	2
Poor	25	1

Equation of calculation Packet loss :

$$\text{Packetloss} = \frac{(\text{Packets sent} - \text{packets received})\text{x}100\ \%}{\text{Data packets sent}} \quad (2)$$

c) Delay

Delay is the time it takes for data to get from its source to its destination (latency). Physical medium distance, congestion, and extended processing times can all contribute to delay [18]. Table 5 outlines the numerous forms of delays.

Table 5. Delay (Latency) categories [17]

Categories	Large Delay (ms)	Index
Very Good	<150 ms	4
Good	150 ms to 300 ms	3
Moderate	300 ms to 450 ms	2
Poor	>450ms	1

Equation of calculation Delay (Latency) :

$$\text{Delay} = \frac{\text{Total Delay}}{\text{Total packets received}} \quad (3)$$

d) Jitter

The variation in the arrival time of subsequent packets is known as jitter [19]. delays Jitter can be caused by queuing routers and switches. Table 6 shows the jitter classifications.

Table 6. Jitter category [17]

Categories	Jitter (ms)	Index
Very Good	0 ms	4
Good	0 ms to 75 ms	3
Moderate	75 ms to 125 ms	2
Poor	125 ms to 225 ms	1

Equation of calculation Jitter :

$$\text{Jitter} = \frac{\text{Total variation of Delay}}{\text{Total received packets}} \quad (4)$$

e) Bandwidth

Bandwidth is the width of the data channel that the data being sent traverses. It is possible to configure the Quality of Service such that the user does not consume the bandwidth allocated by the supplier. In the realm of electrical engineering, bandwidth refers to the overall distance or range between the highest and lowest signals in bandwidth transmission.

Wireshark

Wireshark is an application that serves as a network analyzer by collecting data packets on the network using the Network Interface Card (NIC). Wireshark is a free utility that complements the existing Network Analyzer. And the appearance of Wireshark itself is fairly user-friendly because it employs a graphical user interface (GUI) (Graphical User Interface). Figure 6 depicts Wireshark interface.

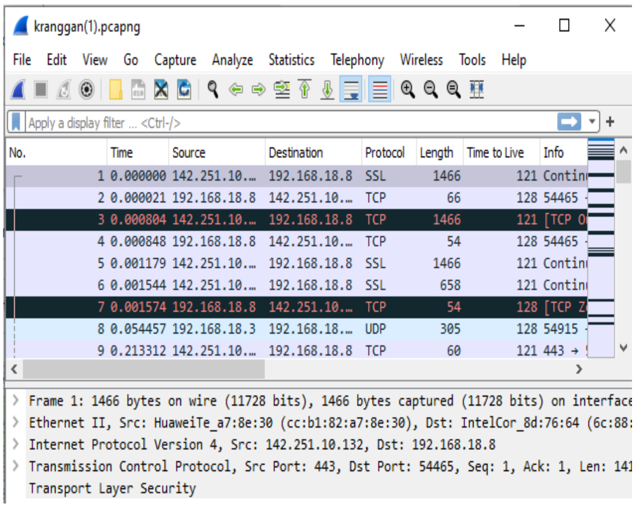

Figure 6. Wireshark interface

Opnet Modeler

OPNET Technologies Inc. created OPNET Modeler, a network simulator. OPNET Modeler accelerates the R&D network, decreases time-to-market, and enhances product quality. By utilizing simulation, network designers can cut expenses associated with research and optimize product quality. The most modern technology OPNET Modeler offers a platform for building protocols and cutting-edge technology. OPNET Modeler provides a platform for building protocols and technologies, as well as testing and illustrating actual scenarios prior to their production. Figure 7 illustrates the OpenNet Modeler.

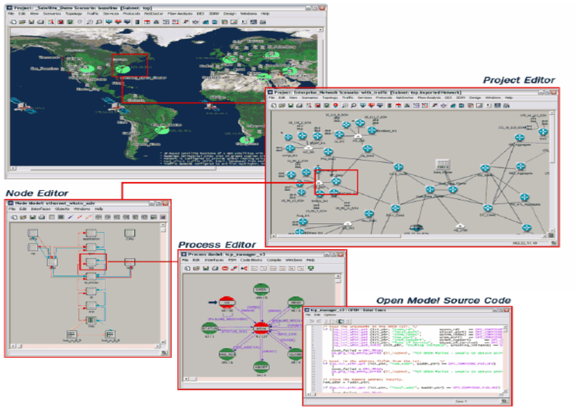

Figure 7. Opnet modeler [21]

III. Results and Discussion

Measurement Scenario

In the measurement scenario, it begins by measuring the QoS parameters at a predetermined location using the Wireshark application, then for the sample that has been determined according to Table 7, followed by making a network simulation according to the original state using the opnet modeler application, and after the data has been obtained, a graph will be created as a comparison between each parameter that has been measured, and it will also be compared with the optimal scenario.

Table 7. Sample measurements

Sample	Size	Resolution	Duration
File transfer	500 MB	-	60 min
Video conference	300 MB	480x360	60 min

Measurement Method

Based on Figure 9, the measurement procedure begins with the identification of the location to be tested, followed by the use of a laptop as the measurement medium and Wireshark as the measuring instrument. The QoS characteristics that are measured include throughput, packet loss, delay, and jitter. After gathering measurement data for the Table 7 measurement sample, the findings will be compared to simulation results and optimal conditions. To classify the measured WiFi quality, it will be compared to the features in Table 2. The measurement data acquired from the Wireshark application are depicted in Figure 8.

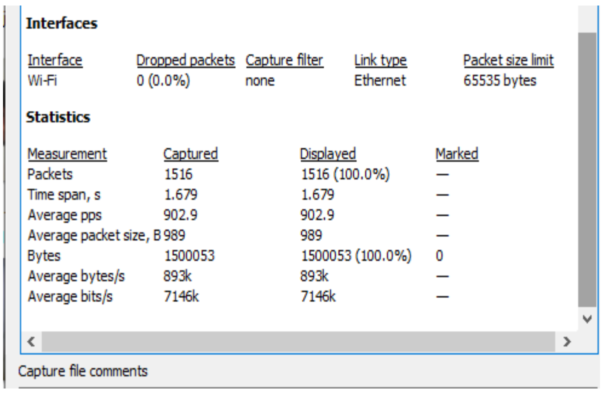

Figure 8. Display of data obtained by Wireshark

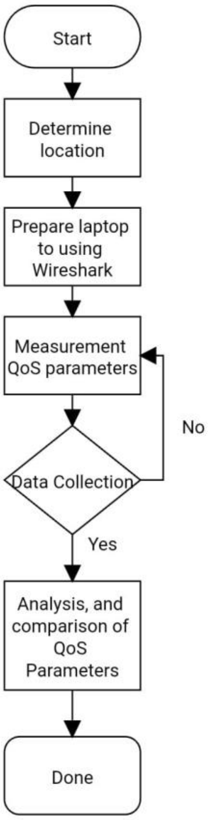

Figure 9. Measurement method flowchart

Simulation Method

As depicted in Figure 11, the simulation method begins by preparing a device in the form of a laptop and an opnet modeler as the simulation instrument, followed by network modeling based on the network under study, and then configuring parameters such as bandwidth, connection type, and the number of devices. In addition, organize the samples according to Table 7 to reflect the actual conditions of measurement. In this simulation, throughput, latency, jitter, and packet loss are monitored as QoS characteristics. Figure 10 depicts the outcomes of the opnet modeler's simulation.

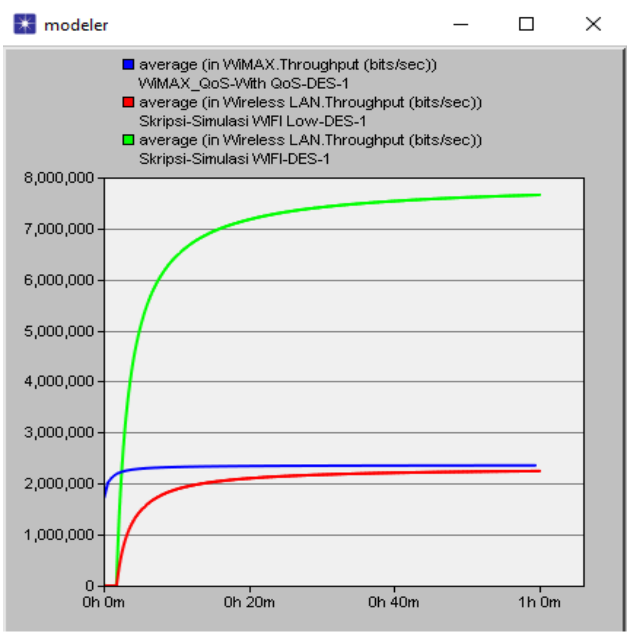

Figure 10. Display of data obtained by Opnet modeler

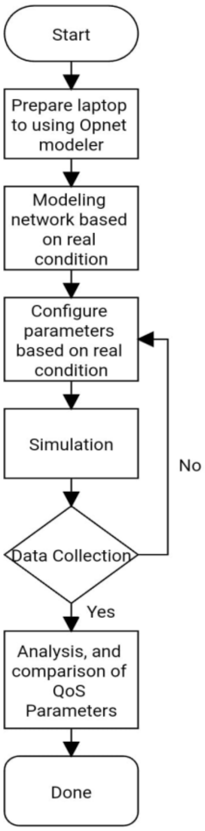

Figure 11. Simulation method flowchart

Throughput

Based on the graph in Figure 12 the results of measuring the throughput when compared with the TIPHON standard which refers to Table 3, throughput was obtained in the WiFi simulation in the first scenario with a value of 82 % belonging to the very good category, and the lowest throughput was obtained on the results of direct measurement of the second condition with a value of 51 % belonging to the moderate category. Table 8 displays the cumulative throughput results.

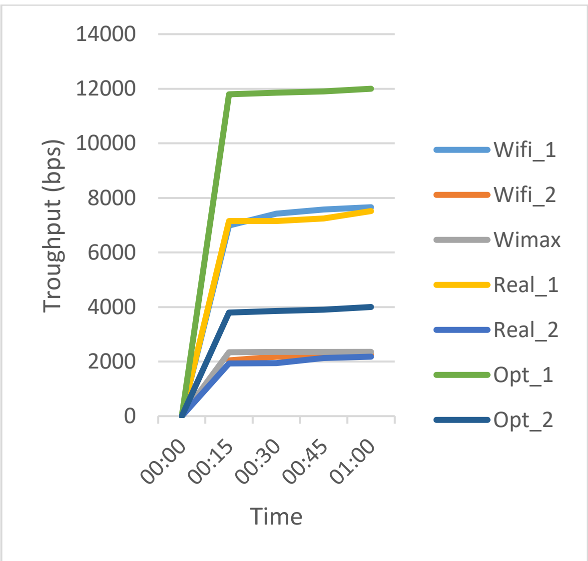

Figure 12. Graph comparison on WiFi and WiMAX throughput between simulations and measurement.

Table 8. Throughput

Name	Type	Throughput (%)	Index
WiFi_1	Simulation	82	4
WiFi_2	Simulation	54	2
WiMAX	Simulation	58	2
Real_1	Real Condition	72	2
Real_2	Real Condition	51	2
Opt_1	Optimal Scenario	100	4
Opt_2	Optimal Scenario	100	4

Packet loss

Based on a graph in Figure 13 that depicts the results of measuring packet loss relative to the TIPHON standard referenced in Table 4, the highest packet loss was obtained in the direct measurement of the first condition with a value of 6,15 % belonging to the good category, and the lowest packet loss was obtained in the simulation of the first to the third scenario with a packet loss of 0 % belonging to the very good category. Table 9 displays the cumulative packet loss results.

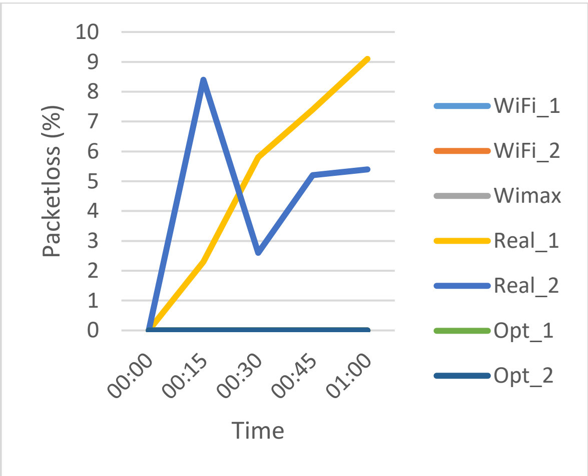

Figure 13. Graph comparison on WiFi and WiMAX packet loss between simulations and measurement

Table 9. Packetloss

Name	Type	Packetloss (%)	Index
WiFi_1	Simulation	0	4
WiFi_2	Simulation	0	4
WiMAX	Simulation	0	4
Real_1	Real Condition	6,15	4
Real_2	Real Condition	5,4	4
Opt_1	Optimal Scenario	0	4
Opt_2	Optimal Scenario	0	4

Delay

Based on the graph in Figure 14 the measurement results of the delay when compared with the TIPHON standard which refers to Table 5, the delay was obtained in the WiMAX simulation with a value of 217 ms belonging to the good category, and the lowest delay was obtained in the second scenario WiFi simulation with a value of 0,02 ms classified as a very good category. Table 10 displays the cumulative delay results.

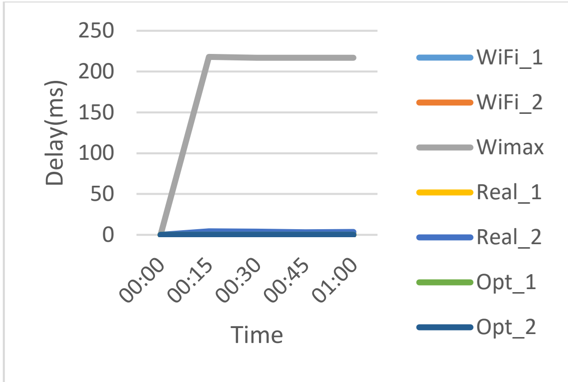

Figure 14. Graph comparison on WiFi and WiMAX delay between simulations and measurement

Table 10. Delay

Name	Type	Delay (ms)	Index
WiFi_1	Simulation	0,57	4
WiFi_2	Simulation	0,02	4
WiMAX	Simulation	217	3
Real_1	Real Condition	1.1	4
Real_2	Real Condition	3,8	4
Opt_1	Optimal Scenario	0	4
Opt_2	Optimal Scenario	0	4

Jitter

On the basis of the graph in Figure 15, the results of measuring the jitter when compared to the TIPHON standard referenced in Table 6, jitter was obtained in the direct measurement of the first condition with a value of 0.048 ms in the very good category, and the lowest jitter was obtained in the second scenario WiFi simulation with a value of 0.0000002 ms, which also belongs to the very good category. Table 11 displays the cumulative jitter results.

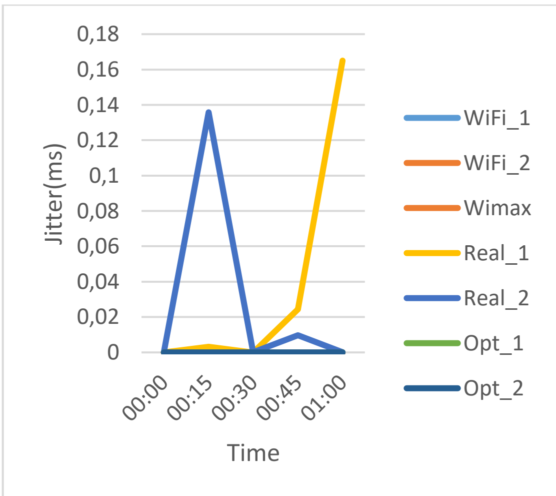

Figure 15. Graph comparison on WiFi and WiMAX jitter between simulations and measurement

Table 11. Jitter

Name	Type	Jitter (ms)	Index
WiFi_1	Simulation	0,000006	4
WiFi_2	Simulation	0,000002	4
WiMAX	Simulation	0,000002	4
Real_1	Real Condition	0,048	4
Real_2	Real Condition	0,036	4
Opt_1	Optimal Scenario	0	4
Opt_2	Optimal Scenario	0	4

Quality of Service

Based on the results Quality of Service analysis in Table 12 with parameters throughput, packet loss, delay, and jitter when compared with TIPHON which refers to in Table 2, the WiFi simulation obtains a satisfactory category with an average index value of 3,75.

Table 12. QoS Measurement Results through

No	Quality of Service (QoS)	Description	
		Index	Category
1	Throughput	3	Good
2	Packet loss	4	Very Good
3	Delay	4	Very Good
4	Jitter	4	Good
Average Index		3,75	Satisfactory

Based on the results of the Quality of Service analysis in Table 13 with the parameters of throughput, packet loss, delay, and jitter when compared to TIPHON which refers to in Table 2, the WiFi service provided obtains a satisfactory category with an average index value between 3,5.

Table 13. Results of Direct QoS Measurement

No	Quality of Service (QoS)	Description	
		Index	Category
1	Throughput	2	Moderate
2	Packetloss	4	Very Good
3	Delay	4	Very Good
4	Jitter	4	Good
Average Index		3,5	Satisfactory

Comparison

In this study, there are 3 simulation scenarios consisting of WiFi_1, WiFi_2, and WiMAX, while the direct measurement consists of Real_1 and Real_2 measurements, and 2 optimal scenarios consist of Opt_1 and Opt_2. Based on the QoS parameter data that has been obtained, the comparison between the simulation results and direct measurements has several differences, including. Throughput, there is a 10% discrepancy between the WiFi 1 simulation and the Real 1 measurement for this parameter, followed by a 3% difference between the WiFi 2 simulation and the Real 2 measurement for this parameter. Packet loss, there is a 6.15 percent discrepancy between the WiFi 1 simulation and the Real 1 measurement for this parameter, followed by a 5.4 percent difference between the WiFi 2 simulation and the Real 2 measurement. Delay, there is a 0.57 ms discrepancy between the WiFi 1 simulation and the Real 1 measurement for this parameter, followed by a 3.6 ms difference between the WiFi 2 simulation and the Real 2 measurement for this parameter. Jitter, there is a difference of 0,047994 ms between the WiFi 1 simulation and the Real 1 measurement for this parameter, followed by a difference of 0,035998 ms between the WiFi 2 simulation and the Real 2 measurement for this parameter. In all cases where simulation results and direct measurements have been compared, it has been determined that simulation results are superior to direct measurements. This is due to the fact that disturbances that can affect network quality, such as distance, obstructions, and weather conditions, are ignored in simulations.

IV. CONCLUSION

According to the results of the conducted research, it can be inferred that there are distinctions between direct measurement and simulation in which simulation QoS measurement results are superior to direct measurements. parameter throughput, the direct measurement results obtained an average index of 2 classified as moderate; on packet loss, the direct measurement results obtained an average index of 4 classified as very good; on delay, the direct measurement results obtained an average index of 4 classified as very good; and on jitter, the direct measurement results obtained an average index of 3.5 classified as good. Using an average index score of 3.50, the WiFi service supplied is categorized as satisfactory.

On the basis of the results of the conducted research, it can be suggested that the government is expected to increase the WiFi services have quality can be better even though there are many users. It is expected that the WiFi service will be controlled according to the Quality of Service so that the service quality is more stable among service users.

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