Design of IoT-based System for Smart Temporary Waste Shelter

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Abstract—**Internet of Things (IoT) is a concept where all products can interact with each other to help human activities by utilizing the internet. The IoT system can help solve problems such as the schedule-based retrieval system at a temporary shelter in Indonesia. This paper creates a web-based geographic information system along with the IoT-based waste temporary shelter prototype. The prototype also integrated with an Arduino Microcontroller so that it can sort the waste automatically into three types of waste, then record data in the form of height and weight, and send the results of the data to the database so that the geographic information system can display the results of the data. Node-RED serves as an Application Programming Interface (API) that sends data from the server to the database belonging to a web-based geographic information system. The results of the performance analysis are that the prototype has sorted waste well, and the system also produced good QoS by ETSI standards from the Message Queuing Telemetry Transport (MQTT) server to the database, and from the end-user to the web. As for the QoE results for tools and systems have produced good results according to the ITU-T standard.**

Keywords: *internet of things, waste temporary shelter, node-red, arduino, qos, qoe*

Abstrak—***Internet of Things*** **(IoT) merupakan suatu konsep dimana segala produk yang dapat saling berinteraksi untuk membantu aktivitas manusia dengan memanfaatkan internet. Sistem IoT dapat membantu dalam menyelesaikan permasalahan seperti sistem pengambilan secara manual per hari pada Tempat Penampungan Sementara (TPS) di Indonesia. Paper ini membuat sebuah sistem informasi geografis beserta prototipe TPS berbasis IoT yang terintegrasi dengan Mikrokontroler Arduino, sehingga dapat memilah sampah secara otomatis menjadi tiga jenis sampah lalu mencatat data berupa ketinggian serta berat, dan mengirimkan hasil data tersebut menuju server agar sistem informasi geografis dapat menampilkan hasil data tersebut.** ***Node*****-RED berfungsi sebagai** ***Application Programming Interface*** **(API) melakukan pengiriman data dari server menuju database milik sistem informasi geografis berbasis web. Hasil dari analisis perfomansi dari segi alat adalah telah memilah sampah dengan baik dan dari segi sistem telah menghasilkan QoS yang baik sesuai dengan standar ETSI pada bagian server** ***Message Queuing Telemetry Transport*** **(MQTT) menuju database, dan end user menuju web. Adapun juga hasil QoE untuk alat dan sistem telah menghasilkan hasil yang baik sesuai dengan standar ITU-T.**

Kata kunci: *internet of things, tps, arduino, node-red, qos, qoe*

I. INTRODUCTION

Internet of Things (IoT) is a concept where all products can interact with one another to help human activities by utilizing the internet. In daily use, IoT is commonly found in different tools that help human activities in specific fields, such as GPS Tracking, Remote Temperature Sensor on a Smart Home, and so on that use the internet or network as the medium.

The main challenge in IoT is bridging the gap between the physical and the information world. The problem is how to process data from electronic equipment through an interface between the user and the device. The sensor collects raw data from real-time scenarios and converts it into machine format so that the data exchange process can run easily [1]. After that, the data process can be applied in an information system or a tool that helps human activities.

One of the essential sectors essential to manage the urban area is related to waste management system. The amount of waste, however, relates to the number of population. The growing number of population will affect the increase in the amount of waste. It can be seen from the population of Indonesia. Indonesian statistical data in 2019 [2] shows that in the year of 2010, the population in Indonesia amounted to 238,618.8 thousand people. Then, in the year of 2018, it grew to 275,015.3 thousand people.

Based on data on Bandung City Garbage Disposal Site in 2018 (updated in December 2019) [3] there were 159 Waste Temporary Shelters in Bandung city, with a total of 2312.66 m^3, while the total waste transported to the final processing site was only 1944 m^3. Currently, there is a scheduling system for garbage collection at each temporary shelter. The December 2019 data shows that it is less effective because the amount of waste entering

the temporary shelter was higher than the amount of waste released.

The questionnaire distributed during the community service held by the University of Ibn Khaldun Bogor in Leuwisadeng Village in 2020 [4] shows that only about 45 % of the residents of the village know the difference between the types of organic and non-organic waste. It means that there is a lack of community knowledge level related to the waste type.

If there is no innovation in the system, there will be a buildup of waste which will result in a full temporary shelter. If the temporary shelter is overfull, it will cause negative impacts such as health problems, lower environmental quality, degrading environmental aesthetics, and some obstructions to the country's development. Therefore, it is necessary to have an innovation in the time system for collecting waste at the waste temporary shelter. In addition, there is also a need for innovation that can make it easier for people to know where to dispose of their type of waste due to the lack of community knowledge about the waste type.

There have been many studies related to this issue, but with different aims and objectives. As in 2019, there was a study on Organic Sorting with Inductive and Capacitive Sensor Integrated with Infrared Sensors using the Raspberry Pi Model B [5], and a study on Prototype of Organic and Non-Organic Waste Sorting [6] using LDR sensors, inductive sensors, and infrared sensors integrated with Arduino. In 2020, there was a study on the Design of a Waste Height Monitoring System Using an Arduino Microcontroller and Web-Based Applications [7] by sending the results of height monitoring to the server with an Arduino integrated with Wemos D1 Mini Wi-Fi module. In 2021, there was a study on Improved Performance of Trash Detection and Human Target Detection Systems Using Robot Operating System [8].

This paper discusses a development of an IoT-based temporary waste shelter prototype using Arduino Mega based on those three previous studies. The prototype can automatically sort waste into three types of waste, namely metal, organic, and inorganic, by applying the inductive, infrared, and LDR sensors. The prototype can also monitor the height and the weight of the shelter using the ultrasonic and load cell sensors where the data is further sent to the database using an Arduino microcontroller integrated with an ESP8266 Wi-Fi module.

It is a form of solution to the waste problem in Indonesia. This paper also performs a performance analysis using Quality-of-Service (QoS) and Quality-of-Experience (QoE) parameters on the built prototype and systems to ascertain the proper of the prototype and systems.

II.   LITERATURE REVIEW

A. Quality-of-Service

The ability of a network to offer good service, i.e. by supplying large bandwidth while overcoming jitter and latency, is known as Quality-of-Service (QoS) [9]. Several factors can reduce QoS, such as attenuation, distortion, and noise. A QoS can be determined to be good or not by referring to the ETSI standard where the standard classifies the QoS parameters into several levels [10]. Table 1, 2, and 3 shows the standard of each QoS parameter according to the ETSI.. The QoS parameters include:
1. Throughput: The speed at which a network transferring data measured in bits per second (bps).
2. Packet Loss: Failure of the transmission of data packets to reach their destination.
3. Delay: The total time that a data packet passes from sender to receiver over the network.

B. Quality-of-Experience

Based on the ITU-T G.1011 standard in 2015 [11], The total acceptability of an application or service based on the user's subjective impression is known as Quality-of-Experience (QoE). QoE aims to measure whether users feel the quality of service or not by the results of QoS. Because QoE measurement includes the effect of the entire system during delivery, so it produces more accurate results compared to those of QoS. To determine the quality of QoE subjectively requires several methods including:
•   Mean Opinion Score (MOS) is a technique for assessing the quality of IP networks based on the ITU-T P.1501 standard [12]. The assessment of this method is based on the opinions of users testing the use of the application or service. Table 4 shows the classification of the MOS values.

Table 1. Throughput standard according to the ETSI [10]

Category	Throughput	Index
Bad	0–338 Kbps	0
Poor	338–700 Kbps	1
Fair	700–1200 Kbps	2
Good	1.2–2.1 Mbps	3
Excellent	>2.1 Mbps	4

Table 2. Packet Loss standard according to the ETSI [10]

Category	Packet Loss	Index
Poor	> 25 %	1
Medium	15 – 24 %	2
Good	3 – 14 %	3
Perfect	0 – 2 %	4

Table 3. Delay standard according to the ETSI [10]

Category	Delay	Index
Poor	> 450 ms	0
Medium	300 – 450 ms	1
Good	150 – 300 ms	2
Perfect	< 150 ms	4

Table 4. MOS classification [12]

Category	MOS
Outstanding	5
Great	4
Medium	3
Weak	2
Not Acceptable	1

III. DESIGN METHODOLOGY

A. System Design

The system design of this research shows in Fig.1, where the IoT-based waste temporary shelter prototype sends data via WiFi to the Message Queuing Telemetry Transport (MQTT) server using the MQTT protocol. The MQTT server, which also acts as a subscriber, receives the data from the prototype. Then, the server sends the data to the Google Firebase database using an API inside the Node-RED programming and the SARIBAN web displays the data from the database.

B. IoT-based Waste Temporary Shelter Prototype Design

IoT-based waste temporary shelter prototype is a new waste temporary shelter model that has the integration of IoT. The prototype can sort waste automatically with a d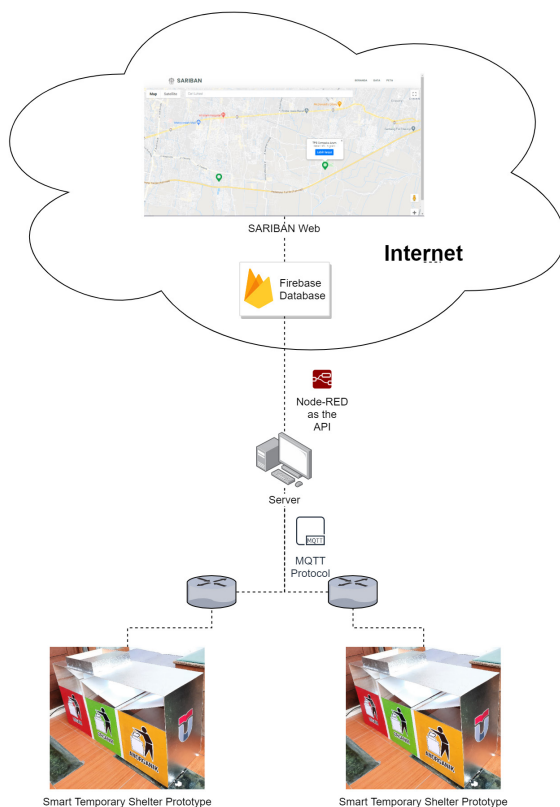igital infrared sensor to identify the presence of waste, a digital inductive sensor to identify metal waste, a digital LDR sensor to identify organic waste, and some servo motors to sort the waste. Fig. 2 shows the shape of the prototype, where the way it works is that when someone wants to dispose trash he/she only needs to put his/her trash one by one into the holes, then the prototype will sort the waste based on the result data from the sensor.

The flowchart of the proposed prototype shows on Fig. 3, where it uses an Arduino Mega microcontroller with an analog ultrasonic sensor as a height gauge, an analog weight sensor as a weight gauge for waste, and a Wi-Fi module as a means of communication with the server that it can connect to the geographic information system.

C. Geographic Information System Design

SARIBAN is a geographic information system for IoT-based prototypes of temporary shelters in Bandung. The name comes from a city janitor of the city of Bandung, Mr. Sariban, whose name was globally known in 2016 because of his voluntary cleaning service [13]. SARIBAN uses the PHP programming language with Bootstrap as the front-end framework and Laravel as the back-end framework. The map in SARIBAN displays a combination of map layers between the point layer of landmarks and the line layer of streets. Fig. 4 shows the data display page on SARIBAN, where SARIBAN displays the data of weight of the prototype, the height of the prototype, and the landmark point of the prototype location.

The flowchart of SARIBAN shows on Fig. 5, where SARIBAN constantly checks the data contained in the Google Firebase database and immediately displays its results.

IV. RESULTS AND ANALYSIS

A. Trash Prototype Accuracy Testing

Testing the accuracy of the prototype for the waste analyzes how accurate the prototype is in sorting waste into

Fig. 1. System design

Fig. 2. IoT-based waste temporary shelter prototype

three types of waste, namely metal, organic, and inorganic. The way to get this data is to dump an example of trash and repeat the experiment for every type of waste for 30 times. Table 5 shows the results of the test on accuracy of metal-type waste that the inductive sensor can sort all metal

waste with an average accuracy rate of 100%. It shows that the inductive sensor is suitable to become a sensor that sorts metal and non-metallic waste in the prototype.

Table 6 shows the results of the test on the accuracy of organic type waste that the LDR sensor can sort all organic
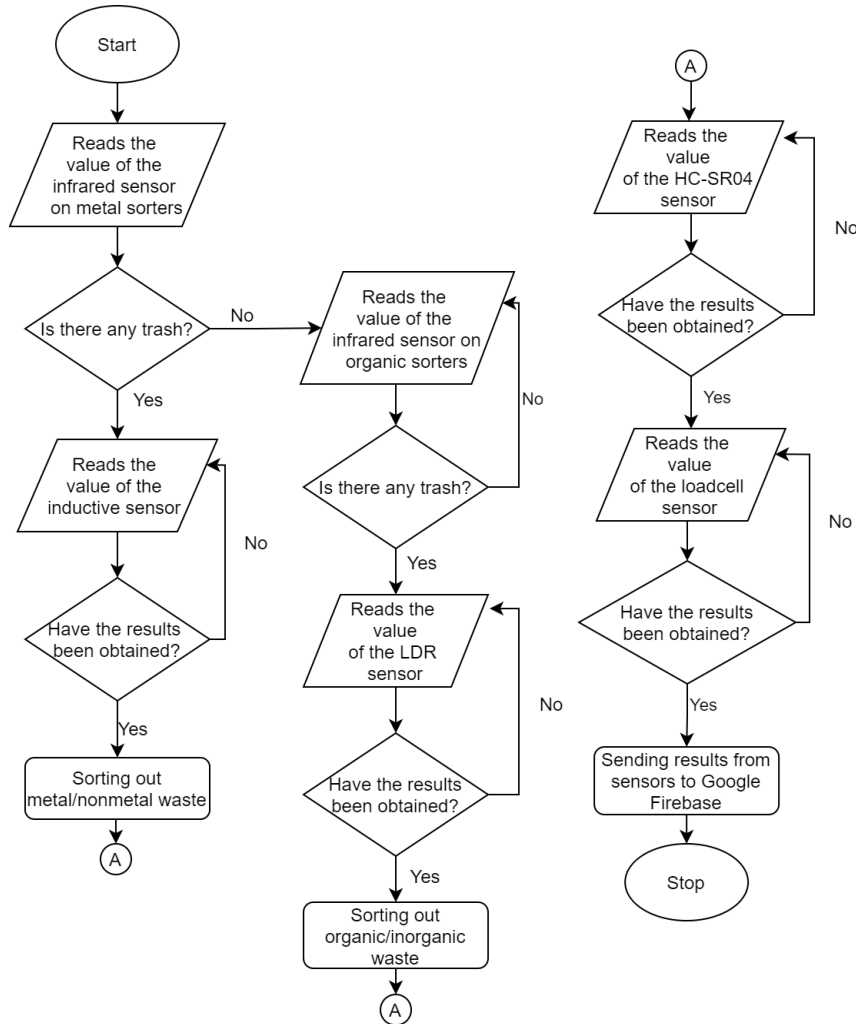

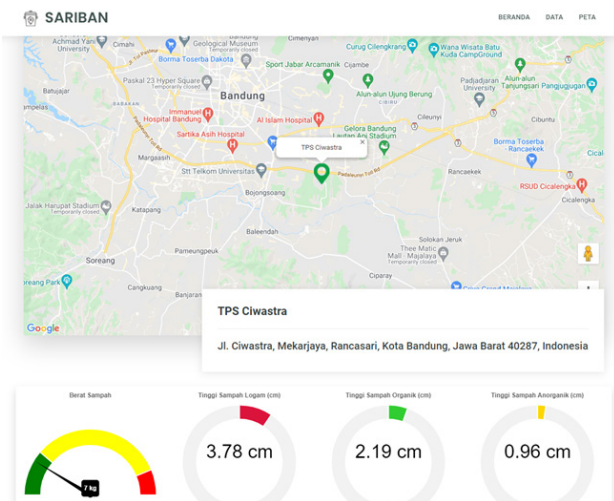Fig. 3. Flowchart of the prototype

Fig. 4. Data display page on SARIBAN

Fig. 5. Flowchart of SARIBAN

waste with an average accuracy rate of 84.15%. It shows that the LDR sensor is suitable to become a sensor that sorts organic waste in the prototype.

Table 7 shows the results of the test on the accuracy of inorganic type waste that the LDR sensor can sort all inorganic waste with an average accuracy rate of 85.8%. It shows that the LDR sensor is suitable to become a sensor that sorts either organic or inorganic waste in the prototype.

B. Network Testing Performance

Network Testing Performance with QoS tests how the network performance of the network traffic flow is, i.e. from the MQTT server to the database and from the end-user to the web-based GIS. The way to get this data is by capturing the network traffic using Wireshark 30 times with tenuous and busy conditions

The results of the testing with throughput parameters on the system show on Fig. 6 and 7. The average throughput resulted from the network traffic flow from the MQTT server to the database is 10.84 Mbps in the tenuous and

10.87 Mbps in the busy condition. Meanwhile, the average throughput resulted from the network traffic flow from the end-user to the web is 10.17 Mbps in the tenuous and 6.27 Mbps in the busy condition.

The QoS result under the throughput parameter from the network traffic flow from the MQTT server to the database increases by 0.28 % when getting many loads of traffic or in busy conditions. The cause of this increase could be due to the effect of the data transmission protocol or the absence of load traffic in the testing. Meanwhile, the QoS result of the network traffic flow from the end-user to the web decreases by 38.35 % when busy conditions. If we look at both average results of the two QoS, it can be seen that in the throughput parameter, the QoS results get an index value of 4 or the excellent category by the ETSI standards. Thus, the system has been made well when referring to the results of the throughput parameter.

Fig. 8 and 9 show the results of the testing with delay parameters on the system. The average delay results of the network traffic flow from the MQTT server to the database is 74.98 ms in the tenuous and 79.98 ms in the busy condition. Meanwhile, the average delay result of the network traffic flow from the end-user to the web is 1.01 ms in the tenuous and 1.64 ms in the busy condition.

The QoS result under the delay parameter of the network traffic flow from the MQTT server to the database increases by 6.67 % when getting many loads traffic or busy conditions. Meanwhile, the QoS results of the network traffic flow from the end-user to the web increases by 62.38 % when busy conditions. If we look at both average results of the two QoS, it can be seen that under

Table 5. Metal type waste accuracy testing results

	Example of Trash	Amount of Trash Entering the Container	Amount of Trash Not Entering the Container	Level of Accuracy
1	Drink Can	30	0	100 %
2	Used Battery	30	0	100 %
3	Scrap Iron	30	0	100 %

Table 6. Organic type waste accuracy testing results

	Example of Trash	Amount of Trash Entering the Container	Amount of Trash Not Entering the Container	Level of Accuracy
1	Fruit	25	5	83.3 %
2	Foliage	16	14	53.3 %
3	Cardboard	30	0	100 %
4	Wooden Sheets	30	0	100 %

Table 7. Inorganic type waste accuracy testing results

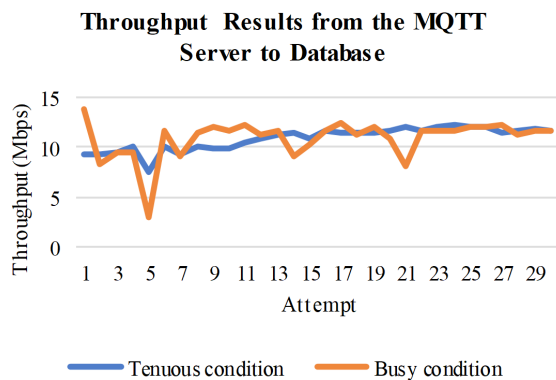|	Example of Trash	Amount of Trash Entering the Container	Amount of Trash Not Entering the Container	Level of Accuracy
1	Fruit	25	5	83.3 %
2	Foliage	16	14	53.3 %
3	Cardboard	30	0	100 %
4	Wooden Sheets	30	0	100 %

Fig. 6. Graph of throughput testing results from the server to database
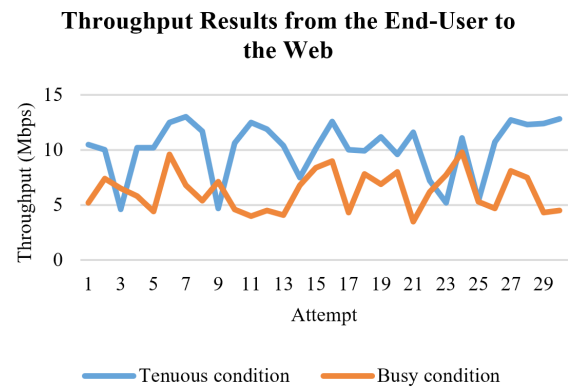

Fig. 7. Graph of throughput testing results from the end-user to the web

the delay parameter, the QoS results get index value of 4 or the perfect category by the ETSI standards. Thus, the system has been made well when referring to the results of the delay parameter.

Fig. 10 shows the results of the testing with packet loss parameters on the system. The packet loss results of the network traffic flow from the MQTT server to the database is 0 % in both tenuous and busy conditions, or there was no packet loss during the test. Meanwhile, the average packet loss result of the network traffic flow from the end-user to the web is 0.12 % in both conditions.

The QoS results under the packet loss parameter of the network traffic flow from the MQTT server to the database did not show any changes in both conditions because both conditions indicated no packet loss. The QoS results of the network traffic flow from the end-user to the web do not show any sign of changes either when looking at the two average results because both of them get an average of 0.12 %. The similar results could be due to the limits placed on the link from the web. However, if we look at both results of the two QoS, it can be seen that under the packet loss parameter, the QoS results get an index value of 4 or the perfect category. Thus, the system has been made well when referring to the results of the packet loss parameter.

C. Prototype and GIS Testing Performance

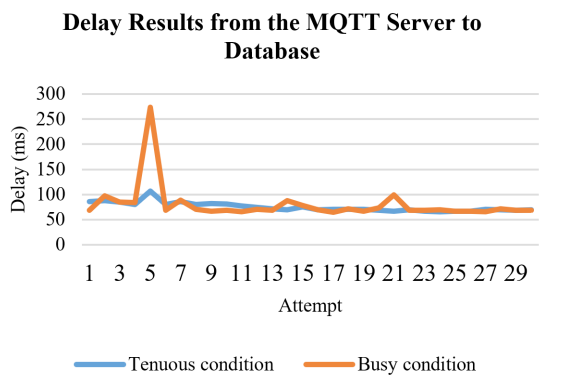Prototype and GIS testing performance with the QoE parameters tests whether the user has gained good experience while using both prototype and the GIS or not. The way to obtain the data for this parameter is by distributing questionnaires to respondents. This test involves 33 respondents, 25 of males and 8 of females. Table 8 shows the characteristics of the respondents based on age criteria. The average age of the respondents was 24 years old, with a mean value of 22.
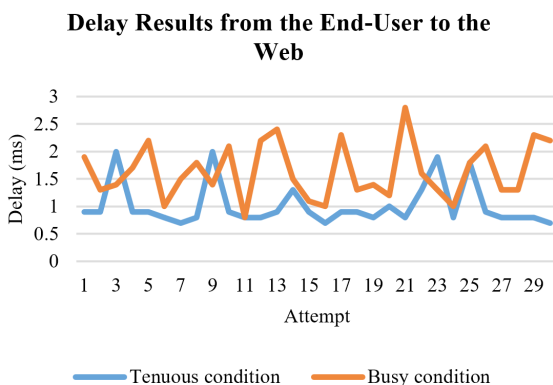
Table 9 shows the results of MOS measurements on several aspects of the prototype from all respondents. The lowest MOS value is 3.1 with a standard deviation of 0.75 in durability, while the highest value is 4.4 with a standard deviation of 0.65 in the aesthetic aspect. The factor that put MOS in the fair category in the durability aspect is the selection for the prototype case material that is still not water-resistant. The factor that put MOS in the fair category in the efficiency aspect, however, is the lenghty period of the prototype to separate the waste.

The QoE results on the prototype show that almost all aspects of the assessment scores are higher than four or in a good category with a relatively low standard deviation value. However, two of them need improvement, namely durability aspect and efficiency of which the scores are still lower than four, or in a fair category.

Table 10 shows the results of MOS measurements on several aspects of the SARIBAN (the GIS) gained from the

Table 8. The characteristics of the respondent

	Age (Years)	Gender	Count
1	Below 21	Men	2
		Woman	1
2	21	Men	8
		Woman	2
3	22	Men	9
		Woman	2
4	23	Men	3
		Woman	1
5	Above 23	Men	3
		Woman	2
	Total		33

Delay Results from the MQTT Server to Database

Fig. 8. Graph of delay testing results from the server to database

Delay Results from the End-User to the Web

Fig. 9. Graph of delay testing results from the end-user to the web

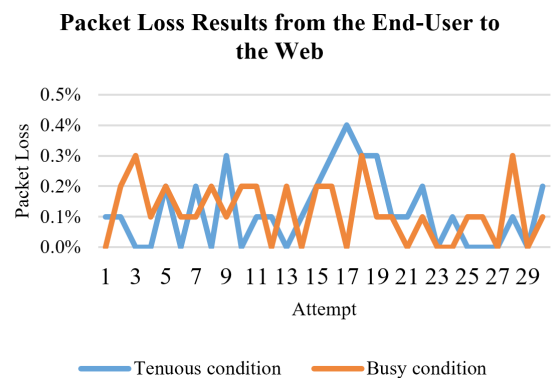**Packet Loss Results from the End-User to the Web**

Fig. 10. Graph of packet loss testing results from the end-user to the web

Table 9. MOS measurement results for the prototype

	Aspect	MOS Value	Deviation Standard
1	Durability	3.1	0.75
2	Functionality	4.3	0.7
3	Efficiency	3.7	0.86
4	Technical	4	0.85
5	Aesthetic	4.4	0.65
6	Safety	4.4	0.82

Table 10. MOS measurement results for the GIS

	Aspect	MOS Value	Deviation Standard
1	Homepage	4.1	0.6
2	Content	4	0.73
3	Context	4.1	0.71
4	Usability	4.3	0.7
5	Readability	4.2	0.56
6	Data Mobility	4.1	0.79
7	Accuracy	4.1	0.7
8	Platform	4.2	0.7

respondents. The lowest MOS value is 4 with a standard deviation of 0.73 in content, while the highest value is 4.3 with a standard deviation of 0.7 in the usability aspect. The QoE results on the SARIBAN system show that the assessment scores for all of the aspects are higher than four or in a good category with a relatively low standard deviation value.

If we look at both results of the two QoE, it can be seen that almost all aspects of the assessment get good scores with a relatively low standard deviation value. A low deviation value indicates that the sample value of each respondent gathers in a single value. Thus, the result score of the QoE is accurate because each respondent chooses almost the same score for every aspect.

V. CONCLUSION

This paper shows the results of the testing which include the performance testing of prototype accuracy, the performance testing using the QoS and QoE method for the geographic information system called SARIBAN, and the IoT-based waste temporary shelter prototype. The prototype can automatically sort waste and transmit data such as the height of each type of waste and the weight of the waste shelter to the database. SARIBAN will then display the results of the data stored from the database.

The QoS results of the network performance test found weaknesses in the throughput results of the network traffic flow from the MQTT server to the database which tend to increase or do not differ much from the tenuous condition when load traffic is given, presumably it is due to the lack of load traffic. However, in the QoS results of the network traffic flow from the end-user to the web, it is found that the packet loss results tend to have the same value in both conditions, presumably due to the packet acceptance limit contained in the link from the web.

The QoE results of the prototype performance test also found weaknesses in several aspects, namely in durability and efficiency of which the MOS is still in fair category. It could be due to the selection for the prototype case material that is not water-resistant and the lenghty waste sorting process.

Considering the conclusion of the analysis, there are some suggestions that can be taken for future studies. They may include the development of a water-resistant IoT-based waste temporary shelter that can sort waste fast and handle the process of disposing much waste at once rather than putting it one by one. Then, it is also suggested to try to implement a network system with the CoAP protocol using a cloud-based server. Further, it may also involve some calculation on the data measurement end-to-end from the waste temporary shelter to the database. And last but not least, it is suggested to use more handy features for the GIS such as analysis of data history of the waste temporary shelter.

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