Evaluation of QOS Measurements of Arduino Promini and Esp32 Based on LoRaWAN Nutritions of Plants

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Abstract—**This study proposed a system that compares the ESP32Lr-201 board with the Arduino Pro Mini board to determine which is more effective to use. Both of these sensors are based on the Internet of Things (IoT) and use Low Power Wide Area Networks (LPWAN) Long Range (LoRa) as the communication medium. In this study, the LoRa transmission parameters used the frequency of 922.4 MHz, the bandwidth was 125 kHz, a spreading factor was 10, and a code rate was 5. This research compared QoS consisting of delay, throughput, packet loss, Signal Noise Ratio (SNR), and Received Signal Strength Indicator (RSSI) on both the ESP32Lr-201 board and the Arduino Pro Mini board. Board and change the analog value use the YL-38 Analog-Digital Converter (ADC) sensor. The datasheet in this study helped facilitate calibration and data conversion in the manufacture of digital NPK sensors. These sensors later facilitated the data collection of nitrogen (N), phosphorus (P), and potassium (K) contained in the soil to control soil and soil levels. This way, fertilization can be more effective. The DHT 11 sensor in the Application and Technology Platform as your Reliable Solution (ANTARES) Shield has added a feature to monitor temperature and humidity in the room. The study's data collection was carried out at 5 points and their distance from the gate of Sentral Telepon Otomat (STO) Tarungga Bandung, Indonesia, ranges from 1.1 Km to 8.4 Km. From the extensive measurement, it was found that the ESP 32 was more effective than the Arduino Pro Mini in terms of Quality of Service (QoS).**

Index Terms—**LoRa, Internet of Things, ANTARES LR-ESP201, Arduino Pro Mini NPK Sensor.**

I. Introduction

INDONESIA is a large agricultural country. Most of its population works in the agricultural sector; therefore, agriculture plays an important role in the Indonesian economy. Agriculture is one of the pillars of the country's economy, especially in areas with great agricultural potential. Agriculture is expected to increase the regional income, especially in rural communities that are still below the poverty line, because it can be relied upon to recover the national economy [1].

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Kangkung or *kale* (*Ipomoea reptans*) is widely grown and favored in Indonesia due to its affordable price and good taste. Kale is also rich in vitamins and minerals. It contains 89.7 water salts, 3.0 protein salts, 0.3 fatty salts, 5.4 carbonate salts, 29 mg iron, 32 mg vitamin C, 6300 IU vitamins A, and 0.07 mg of vitamin B [2].

Kale can grow well in the yards or rice fields. Kale can also grow well in both highlands and lowlands of our country. In addition, land Kale can be grown in areas with hot and humid climates and grow well on soils rich in organic matter and sufficient nutrients. However, kale cultivation requires fertilizer to optimize its growth and yields [3]. Plants need fertilizer just as humans need food. Besides external fertilization, the soil provides nutrients and minerals suitable for plants. However, the supply of nutrients in the soil decreases in the long term, resulting in an imbalance between fast nutrient absorption and slow nutrient formation. Therefore, fertilization is a must in the agricultural system [3].

The use of fertilizers needs to be considered in an effort to fertilize efficiently. One of the ways is by knowing the amount of nutrients needed by the plants so the dose of the fertilizer can be determined. One of the measures with agronomic efficiency is to compare how much the increase in production is achieved from each amount of N (15-30 kg), P (15-40 kg), and K (8-40 kg) fertilizers added to the soil. It is intended that the fertilizers used are as recommended and provide economically profitable results. Thus, the expected impact of fertilization is increasing yield per unit area and using fertilizers efficiently. The use of fertilizers with normal limits on kale is when N = 0.01%-10%, P = 0.25%-0.5% and K = 2%-3% [4].

The Central Bureau of Statistics (2018) reported that the national production of kale in 2015-2019 continued to increase. The production value in 2015 was 305,080 tons, and the following year it was 297,130 tons. In 2017, the value decreased to 276,970 tons and increased in 2018 to 289,563 tons, and in 2019 it was 279,563 tons, 295,556 tons. This shows that kale production in Indonesia can be increased when it is viewed from the national production value [5].

In the field of agriculture in Indonesia, horticulture is one of the important sectors. The Centre for Agricultural Data and Information Systems of the Ministry of Agriculture of the Republic of Indonesia (2016) reports that there are 2.9 million farmers in the horticulture sector [6].

To help to improve the quality and quantity of kale yields, a system was designed in order to compare two different boards with IoT-based sensors using LPWAN LoRa, which functions to measure the level of nitrogen (N), phosphorus (P), potassium (K). All are contained in the soil so that soil content control and fertilization can be more effective.

Based on the data above, LoRa was chosen as a communication medium because there are many advantages of LoRa technology, such as wide area network solution that promises long-distance coverage with very low power consumption and safer security, with thousands of node devices that can be connected in the network, so it is very suitable for the Internet of Things [7].

II. RELATED WORKS

This study [8] explained that the monitoring and controlling NPK levels in the soil had been carried out quite well. Analysis such as SNR, RSSI, Delay, and packet loss using ESP 32 microcontroller. By using ESP 32 LoRa, monitoring and controlling chilli plants can run well. However, there is no comparison and testing of the Arduino Pro Mini microcontroller for monitoring NPK levels in the soil.

Researcher [9] explains about LoRa, which is implemented for IoT applications in various systems by collecting data from various sensors around the environment. LoRa is a wireless communication system with a long-distance communication distance of 10-15 Km outdoors and very low distance consumption, suitable for remote monitoring systems. With this data, it is hoped to help in the research work.

Research [10] explains the use of this microcontroller using a Wireless Fidelity (Wi-Fi) module to communicate between the end node and ANTARES. This research has been running well and successfully by monitoring and controlling automatic watering by getting the throughput and delay values of the tools that have been made. With the Arduino Pro Mini, monitoring NPK levels in the soil can provide the most effective QoS value answers.

Researchers [11] aim to create a Smart Home Gardening Management System (SHGMS), which consists of indoor and outdoor gardens and smart home plant pots to plant plants that keep the house fresh and pollution-free. This paper describes planting that is carried out on narrow land in urban areas, using Arduino Uno board as a microcontroller, DHT 11, and YL 69 as end nodes whose transmission uses Wi-Fi as a communication medium.

Study [12] explains the manufacture of tools using the ESP 8266 board with three end nodes such as 2 PC-28 soil moisture and L29 motor driver as data input. Furthermore, the data that enters the end node will be sent using Wi-Fi media to the firebase database to accommodate the data, and then it can be monitored using a smartphone with Android OS.

The use of sensors and NPK nodes as microcontrollers to measure nitrogen (N), phosphorus (P), and potassium (K) levels in plantations and uses a mesh topology to provide real-time connection information has been studied from [13]. Comparing the accuracy of measurement data and using an analog NPK tool from (Plant Doctor) which is more than 90% accurate. Using the Xiaomi 5000 mAh mobile power bank to test the durability of the device and system. The device and system can normally work for 30 hours without any problems. In addition, the accuracy of the data can be uploaded to the database.

Research [14] has conducted an analysis of mobility at IEEE 802.11Ah standards to introduce traffic patterns. The study has worked on various scenarios to prop patterns of traffic. We found that the study had not experimented on shipping from sensors about nutrition. The study of evaluating vehicle and LTE communication mobility using Gauss-Markov has been carried out by [15]. All traffic from vehicles to LTE is done by hybrid communication. Moreover, the development of offloading from LTE to IEEE 802.11ah standards has also been studied by [16].

Transmission congestion management in the power market requires coordination of controllable resources has been analyzed by [17]. A bi-level optimal dispatch model is proposed with distribution companies as the main body participating in transmission congestion. Multi-objective solution method is proposed to realize effective scheduling of resources in the Power Distribution Companies (PDC).

Researchers [18] describe the proposed IoT soil testing system to measurements and observations parameter of soil. This method is a color sensor to monitor temperature, humidity, soil moisture, pH, and NPK nutrients. The information recognized by the sensors is saved in the cloud drive, and suitable plants are created based on the development recommendations. The module of WiFi included with the Arduino is employed to show data tests. In addition, researchers [19] also proved that access networks for big data need minimum dispersion to overcome high bit error rate (BER).

III. RESEARCH METHOD

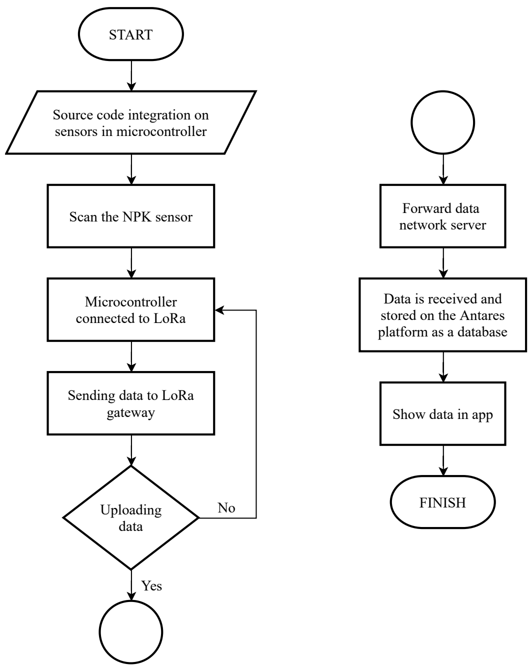

Fig. 1. Flowchart System.

Fig. 1 shows the process that starts from initiating a system that uses NPK sensors as end nodes, followed by 2 ESP 32 LR 201 microcontrollers and an Arduino Pro Mini microcontroller connected to the LoRa network. The Internet of Things application will occur when data uploading on the LoRa network has been successfully carried out. An android application has been prepared and integrated with the ANTARES platform to monitor data from end nodes in a different place.

A. Inverting Amplifier

Fig. 2 shows that OpAmp or Operational amplifier is an electronic component that returns a Direct Current (DC) or Alternating Current (AC) signal. YL 38 is used for inverting or inverting amplifiers. This module consists of transistors, resistors, and capacitors arranged in an Integrated Circuit (Integrated Circuit) [20].

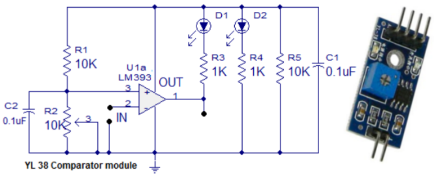

Fig. 2. Illustration for YL 38.

B. Design of NPK Sensor

Algorithm 1 Mapping of NPK Sensor

```
function ASIC(maptegangan)
    vaql ← analogRead(NPKa)
    ubh ← map(vaql, 4095, 0, 0, 4095)
    val ← map(ubh, 0, 4094, 1, 300)
end function
if ubh ≤ 150 then                          ▷ val ← 0
    Nx ← 0
    Kx ← 0
else                                       ▷ deklarasi sesuai datasheet
    Nx ← map(val, 1, 300, 51, 200)
    Px ← map(val, 1, 300, 4, 14)
    Kx ← map(val, 1, 300, 51, 185)
end if
if val ≥ 1 && val ≤ 50 then                ▷ deklarasi status npk
    soilstatus ← "POOR"
else if val > 50 && val ≤ 200 then
    soilstatus ← "IDEAL"
else
    soilstatus ← "TOO MUCH"
end if
```

Algorithm 1 describes the pseudocode that used in the program. Before determining the analog to digital converter (ADC), calibration is carried out first to obtain the minimum and maximum voltage values from the NPK sensor. The LR-ESP201 microcontroller has a 12-bit ADC, which means 2^{12} and is worth 4096 [21]. Because it starts from 0, then the ADC becomes 0-4095; also for Arduino Pro Mini, it has a 10-bit ADC, which means 2^{10} and is worth 1024, due to it starts from 0, then the ADC becomes 0-1023, each ADC value is adjusted to 0 - 3.3V.

Table I shows the datasheet value of the NPK sensor is displayed. The value range is too little to too much. For nitrogen (N), the values range from 50 to 200 ppm; for phosphorus (P), the values are at 4 to 14 ppm, and while for potassium (K) are in 50 to 200 ppm [22]. The numbers 1 to 300 are yielded through the calculation of a classification of the NPK sensor itself.

TABLE I
DATASHEET OF NPK SENSOR

	Too Little	Ideal Range	Too Much
Nitrogen	50 ppm	50-200 ppm	200 ppm
Phosphorous	4 ppm	4-14 ppm	14 ppm
Potash	50 ppm	50-200 ppm	200ppm

C. IoT Based LoRa

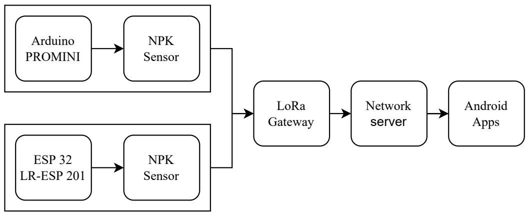

Fig. 3. System Design for IoT-LoRa.

The communication media above uses LoRa or (Long Range). LoRa is low power and low-bitrate long-range wireless communication technology established by Semtech in 2012. LoRa is promoted as an infrastructure solution for the Internet of Things [23]. At the same time, LoRaWAN is a standard LoRa communication system to facilitate communication between nodes, gateways, and network servers even though they are different [10].

The LoRa physical layer protocol operates below the sub-GHz frequency in the 433-MHz, 868-915, and 923-MHz frequency bands in accordance with the regulations of each country or region. In Indonesia, this regulation will be supervised by the Ministry of Communication and Information and follow the LoRa frequency standard set by the LoRa Alliance for the Asian region, namely the frequency 923-925 MHz (AS923) [10].

Fig. 3 shows end-nodes consisting of 2 different microcontrollers, each microcontroller has one end-node connected to each other, namely N, P, and K sensors. This system oversees collecting data that will be transferred to the LoRa Gateway. After processing in the microcontroller (Arduino Pro Mini LoRa and ESP32 LR 201). LoRa Gateway is a central medium for exchanging data from the microcontroller in the LoRa network; it will create a star-to-star topology. A network server is required to connect the LoRa Gateway to the database and platform. The application platform will serve as a media database to monitor real-time data from end nodes in the online system, one of the Internet of Things platforms used is the ANTARES platform. In addition, an Android application is used as a data user interface so users can understand it easily.

D. Hardware and Components

Table II describes the sensors and equipment for the device. There are six components that have different functions. The author has made holes for two board mounts to make it easier to replace the board for data retrieval. The author's

TABLE II
HARDWARE AND COMPONENTS.

Software	Function
ANTARES LR-ESP201 Board	Microcontroller as a whole system access.
Arduino Pro Mini LoRa	Microcontroller as a whole system access.
Sensor NPK	Used to detect the NPK condition.
LCD 16x2	To display the NPK condition.
Shield ANTARES	To terminalize the cable on the device
Power Supply	Energy source for the device

TABLE III
HARDWARE AND COMPONENTS.

No	Spesifikasi	Arduino Pro Mini	ESP 32 LR 201
1	Operating Voltage	3V and 5V	3V and 5V
2	Input Voltage	5V-12V	5V-12V
3	Pin Digital I/O	14 pin	12 pin
4	Pins Input Analog	8 pin	5 pin
5	Frequency Band	915-925MHz	915 MHZ-925 MHZ
6	Devboard	RFM95 and Atmega 328 chips with Arduino Pro Mini 3.3V. bootloader	Chip ESP32 Tensilica LX6 dual-core processor

first board uses the ESP 32 LR 201. This microcontroller features a built-in Wi-Fi with dual-mode Bluetooth. Meanwhile, ANTARES LR-ESP201 is a Development Board developed by ANTARES Telkom DDS IoT Platform based on ESP32 and has also embedded the RFM95 LoRa Transceiver module to transmit data via LoRa radio access to the Gateway, which has been integrated with the ANTARES platform [24]. The author's second board uses Arduino Pro Mini. Arduino Pro Mini is also a microcontroller board with RFM95 LoRa and Atmega328 chips for data transmission via LoRa radio access to the Gateway, which is already integrated with the ANTARES platform [25]. The power supply is made in series for all sensors or end nodes in this test. A power supply means an electrical device that can provide electrical energy for electric power or other electronic devices [26]. This study uses an NPK sensor; this sensor detects the presence of nutrients such as (N), phosphorus (P), and metal elements (K) using a photoelectric sensor. Sensors are needed to determine the proportion of other internal substances that will be added to the soil to increase the yield of these nutrients [27]. The LCD, DHT 11, YL-38, and LoRa antennas have been arranged in an acrylic box that the authors have made. As for the comparison table of the ESP32 board with the Arduino Pro Mini in Table III.

TABLE IV
HARDWARE AND COMPONENTS.

No	Arduino Pro Mini	ESP 32 LR 201
1	Arduino IDE	A software to configure and command Arduino as a microcontroller
2	ANTARES Database	Used to store realtime data and historical data
3	MIT App Inventor	Opensource platform to create Android Application

E. Software and Application.

Table III shows the software and platforms that can accommodate the interface through dataset to software. The first application that we use is the Arduino IDE, an application developed by Arduino to create/write programs, then compiled and flashed to a microcontroller chip, such as Arduino (atmega, atxmega, etc.), WEMOS (esp8266, esp32) [28]. ANTARES is a Horizontal IoT Platform developed by Telkom Media and Digital. In addition to being flexible and accessible, ANTARES can also meet regulations related to data storage in Indonesia set by the Ministry of Communication and Information Technology (Kominfo). MIT App Inventor is a website/app for designing and building fully functional mobile apps. This app is available for the opened general on Google Play Store. The project of open source that able be installed and execute on independent servers is App Inventor. In addition, MIT App Inventor provides user-friendly and easy-to-setup code blocks. MIT App Inventor is widely used for users in application platform. App Inventor develops subscribers using two different creator. The first creator is the Developer. That is employed to set on and off screen contains. The second creator is the Block Editor, where the user have to program the application's behavior by combining blocks [29].

IV. RESULT AND DISCUSSION

This chapter discusses the tool functionality testing and LoRa Network Testing using the Lora Tarungga gateway.

A. Integration Testing on End Nodes (Sensors)

This test is carried out to determine whether the end nodes (sensors) used can work appropriately according to the desired function or not. The results can be seen in Table V.

B. Monitoring Testing

This sensor testing is done by looking at the ground status and the value between the analog NPK sensor and the digital NPK sensor used in this research. If the status and value generated from the two sensors are the same or close, the sensor test can be said successful. The following are the test and data results from the resulting analog NPK sensor.

Fig. 4 shows the results of data collection with an analog NPK sensor. The following is the test and data from the digital NPK sensor in this research.

TABLE V
DEVICE TESTING.

No	Component	Function
1	ESP 32 LR 201 can transmit data, can run commands and code that has been made on Arduino Ide.	succeed
2	Arduino Pro Mini can transmit data, can run commands and code that has been made on Arduino Ide.	succeed
3	The NPK sensor can detect and transmit N, P and K values in kale to the ANTARES platform.	succeed
4	LCD 20 X 4 can display the Status of the ground, the value of N, P, K, H and T.	succeed
5	The DHT 11 sensor can detect room and ambient temperature.	succeed
6	The power supply can work optimally, by providing power to the microcontroller and sensors in this research.	succeed
7	Monitoring the growth of kale for 14 days.	succeed

Fig. 4. NPK Analog.

Fig. 5 shows the data collection results using a digital NPK sensor with the same results as an analog NPK sensor. It can be concluded that the NPK sensor test was successful.

TABLE VI
SENSOR TESTING.

Soil Sample	N (ppm)	P (ppm)	K (ppm)	Digital status	Analog status
Bali sand	0	0	0	Poor	Poor
Plant Land	134	9	126	Ideal	Ideal
Malang Sand	161	11	150	Too much	Too much

Table VI describes three different soil experiments; the digital NPK sensor can display the same data as the Analog NPK value. The results in the accuracy or similarity of data from the two sensors being the same and successful.

Fig. 5. LoRa Network Architecture.

C. Testing the growth of kale

In this test, we also observed the growth of kale for 14 days. This test used ideal soil as measured by analog and digital NPK tools.

Fig. 6. Process of Kale Growth.

Fig. 6 shows the results of the growth of kale for 14 days. In the first picture, the height of the kale plant at 3 days age has reached 3 cm, and the leaves are not grown yet. On the fifth day, the kale plant height was 5 cm, and the leaves had appeared. On the ninth day, this plant has reached 11 cm high from the ground, with the stems have strengthened, and the leaves are quite dense. On the 14th day, this plant has reached 28 cm in good condition with tall and dense stems and leaves. Due to the age of harvesting kale being 25 days, it needs 11 more days to harvest this plant [30].

D. Testing Of Sending And Receiving Data

```
21:10:55.413 → ADC NPK Value : 1005
21:10:55.413 → S:TOO MUCH, N : 197, P : 13, K : 182, H : 88.00, T : 31.80,~
21:10:55.413 → {ANTARES} Data: S:TOO MUCH, N : 197, P : 13, K : 182, H : 88.00, T : 31.80,~
21:10:55.413 → Fport: 5 Ch: 6 Freq: -19200
```

Fig. 7. Data on Serial Monitor.

Fig. 7 shows Arduino IDE's results on a serial monitor to the ANTARES platform at 21.10.55. On Arduino, the idea of sending data is done every 30 seconds for 20 minutes.


```
2021-06-08 21:10:56    /Antares-cse/cin-IBFaJ3w8SaquMGnn  {
    "type" : "uplink",
    "port" : 5,
    "data" : "S:TOO MUCH, N : 197, P : 13, K : 182, H : 88.00, T : 31.80,~",
    "counter" : 3,
}
```


Fig. 8. Data in ANTARES.

Fig. 8 shows the receiving data sent by Arduino Ide to the ANTARES platform. Any data sent or received from the serial monitor to the ANTARES platform and the android application is only 1-second lag. The data received on the ANTARES platform is at 21.10.56 in Western Indonesian Time, which means the delivery is declared successful.

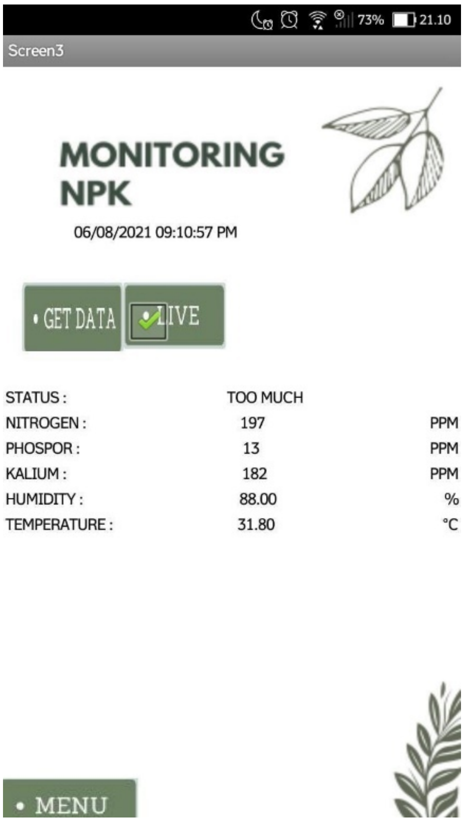

Fig. 9. Data in Android Application.

Fig. 9 shows the data results differently from Fig. 10, which is 21.10.57 due to human error. This test is considered successful if the data is displayed on the serial monitor, ANTARES platform, and the same application is at 21:10 in Western Indonesian Time. It was concluded that the test of sending and retrieving data was successful.

E. LoRa Network Quality Testing

This network test determines the quality of the network delivery system used. This test uses delay, packet loss, and throughput parameters with Telecommunications and Internet Protocol Harmonization Over Network (TIPHON) standards. The author uses the Quality of Services (QoS) standard from TIPHON issued by the European Telecommunications Standards Institute (ETSI) [31]. The testing of SNR and RSSI. Data is taken from ANTARES with a public network and then analyzed from the data obtained. The ANTARES database provides information about data, gateway, delay, SNR, and RSSI on the platform. In this research, 5 points are tested to determine delay, throughput, packet loss, SNR, and RSSI, as shown in Fig. 11.

Fig. 10 shows point A is at the Borma Fashion Point, located on a Buah Batu street with a 1.1 Km distance from the gateway. Point B or point 2 is at the Asia-Afrika monument, 2.58 Km from the gateway. Point C is at Zeboot Cisangkuy Fried Rice which is 3.4 Km from the gateway. Point D or point 4 is at Sukabirus Residence, which is 5.4 Km from the gateway, and the last point at point E is at Borma Rencong Banjaran with the furthest distance, namely 8.4 Km from the gateway. This test is carried out every 30 seconds every 20 minutes for each location.

TABLE VII
DELAY CATEGORY BY TIPHON.

Category	Delay Value (ms)
Very Good	$<$ 150 ms
Good	150 ms - 300 ms
Medium	300 ms – 450 ms
Poor	$> 450ms$

F. Delay

This delay test is carried out for 30 seconds 20 minutes for each point; this test runs 2 boards at once to find out and determine which board is better. This test uses a bandwidth of 125 kHz, Code Rate 4/5, SF 10, and uses the TIPHON standardization. The greater the resulting delay value indicates, the lower the network quality. Here is the test delay for each point and its analysis.

Fig. 11 and Fig. 12 show the delay results from 2 microcontrollers at Borma Fashion Buah Batu, which is 1.1 Km from the gateway for ESP and Pro Mini, respectively. Each board managed to collect 39 packets from 40 packets for 20 minutes. For ESP 32 LR-201, gets an average delay of 0.003 s when converted to ms is 3 ms, while Arduino Pro Mini gets an average delay of 0.005 s when converted to ms is 5 ms. As shown in Table III, the value of both microcontrollers is included in the very good category. So it can be concluded that LoRa delivery at the Borma Fashion location or point A, which is 1.1 Km away, gets a very good delay category according to TIPHON.

Fig. 13 and Fig. 14 show the delay results from 2 microcontrollers at the Tugu Asia Africa location, 2.58 Km from the gateway for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets from 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 40 packets out of 40 packets for 20 minutes. ESP 32 LR-201 and Arduino Pro Mini get an average delay of 0.005 s when converted to ms is 5 ms. As shown in Table III, the value of both microcontrollers is included in the very good category. So it can be concluded that LoRa delivery at the Tugu Asia Africa location or point B, which is 2.58 km away, gets a very good delay category according to TIPHON.

Fig. 15 and Fig. 16 show the delay results from 2 microcontrollers at the location of Nasi Goreng Zebot Cisangkuy, which is 3.4 Km from the gateway for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201, get an average delay of 0.013 s when converted to ms is 13 ms, while Arduino Pro Mini gets an average delay of 0.009 s when converted to ms is 9 ms. As shown in Table III, the value of both microcontrollers is included in the very good category. So it can be concluded that the delivery of LoRa at the Borma Fashion location or point C, which is 3.4 Km away, gets a very good delay category according to TIPHON.

Fig. 17 and Fig. 18 show the delay results from 2 microcontrollers at the Sukabirus Residence location, 5.4 Km from the gateway. Each board managed to collect 39 packets from 40 packets for 20 minutes. For ESP 32 LR-201, get an

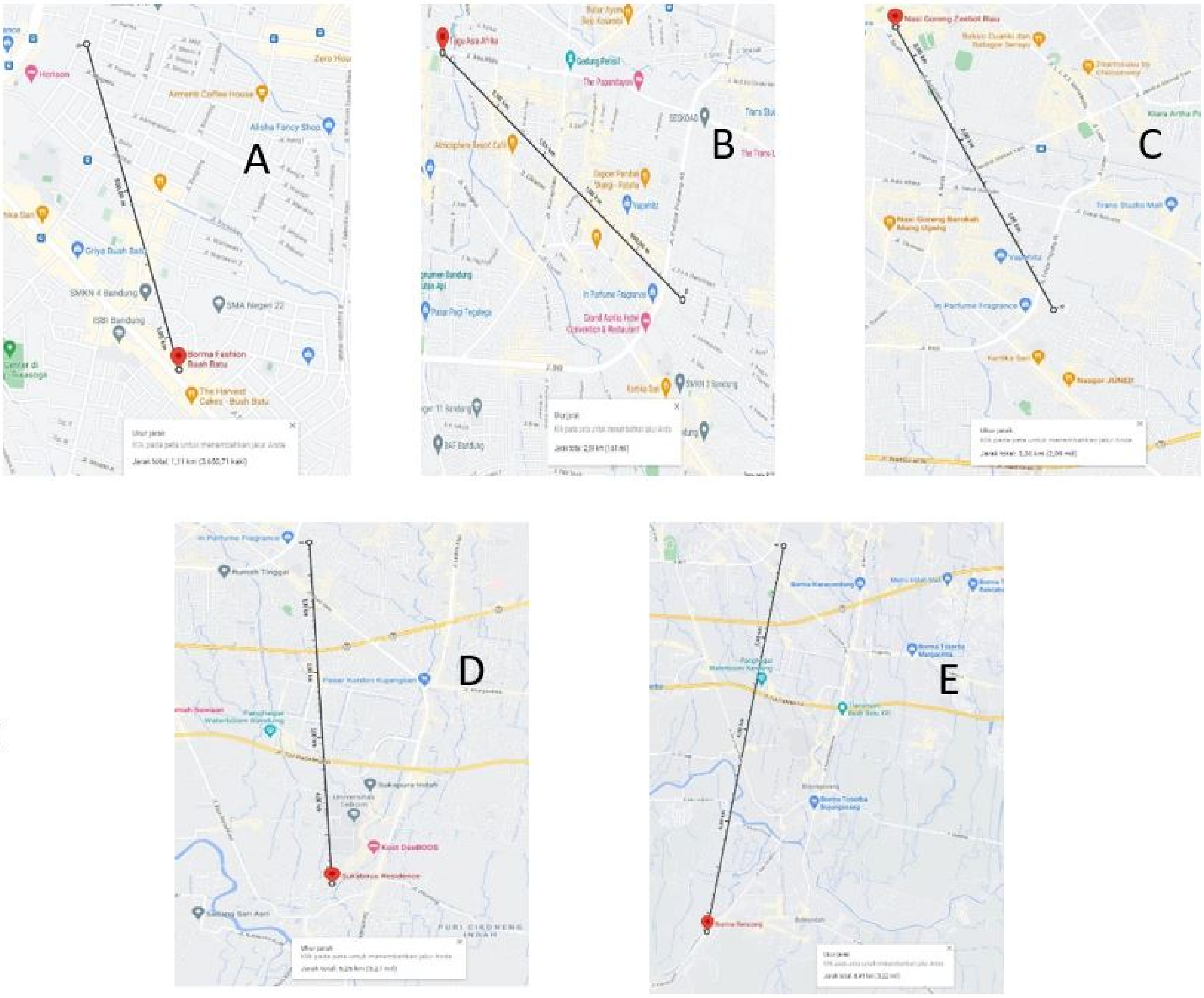

Fig. 10. 5 Points of Data Retrieval.

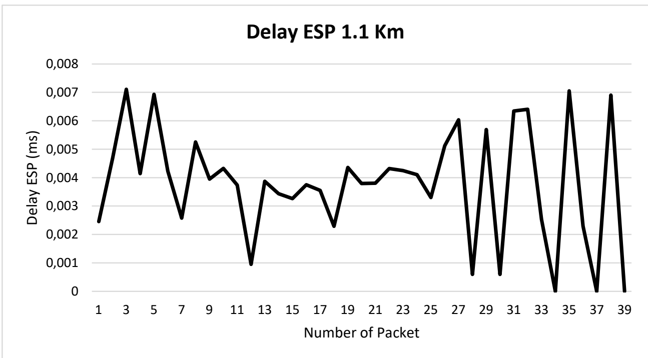

Fig. 11. Delay ESP for Distance 1.1 Km.

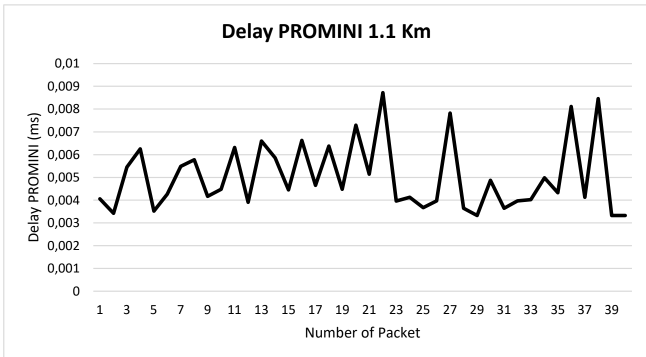

Fig. 12. Delay Pro Mini for Distance 1.1 Km.

average delay of 0.013 s when converted to ms is 13 ms, while Arduino Pro Mini gets an average delay of 0.024 s when converted to ms is 24 ms. As shown in Table III, the value of both microcontrollers is included in the very good category. So it can be concluded that the delivery of LoRa at the Sukabirus Residence or point D, which is 5.4 Km away, gets a delay in the very good category according to TIPHON.

Fig. 19 and Fig. 20 show the delay results from 2 microcontrollers at the Borma Rencong Banjaran, which is 8.4 Km from the gateway. The ESP 32 board managed to collect 39 packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201, get an average delay of 0.033 s when converted to ms is 33 ms, while Arduino Pro Mini gets an average delay of 0.124 s when converted to ms is 124 ms. As shown in III, the value of both microcontrollers is included in the very good category. So it can be concluded

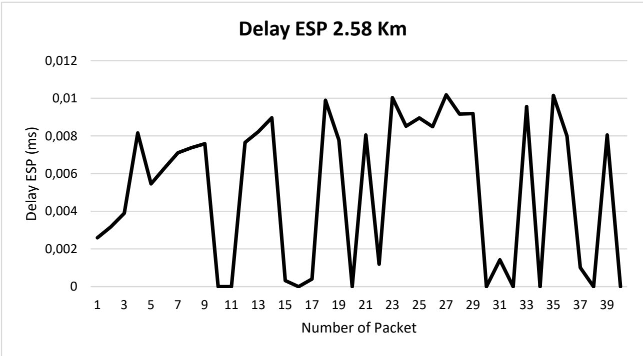

Fig. 13. Delay ESP for Distance 2.85 Km.

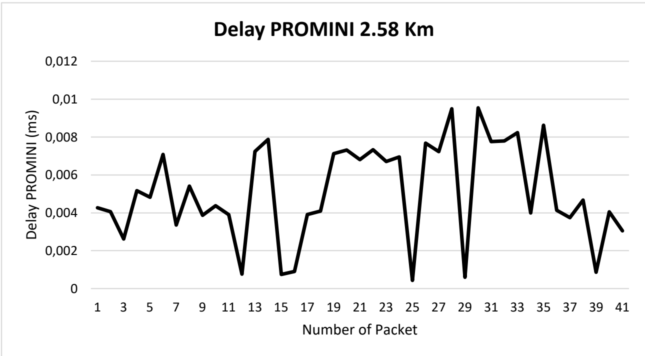

Fig. 14. Delay Pro Mini for Distance 2.58 Km.

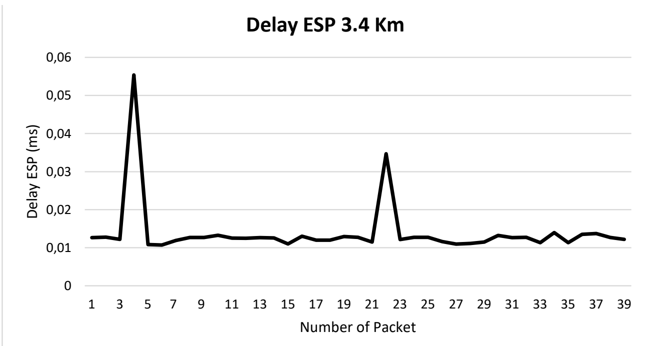

Fig. 15. Delay ESP for Distance 3.4 Km.

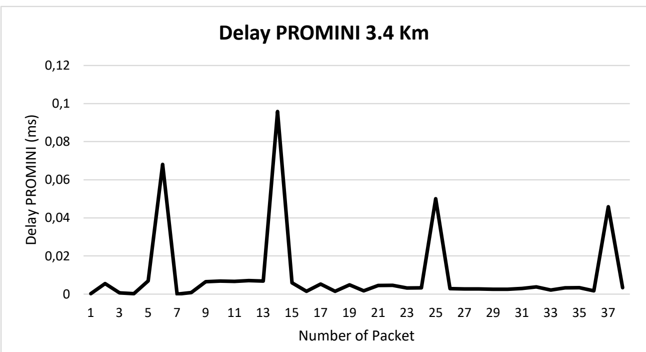

Fig. 16. Delay Pro Mini for Distance 3.4 Km.

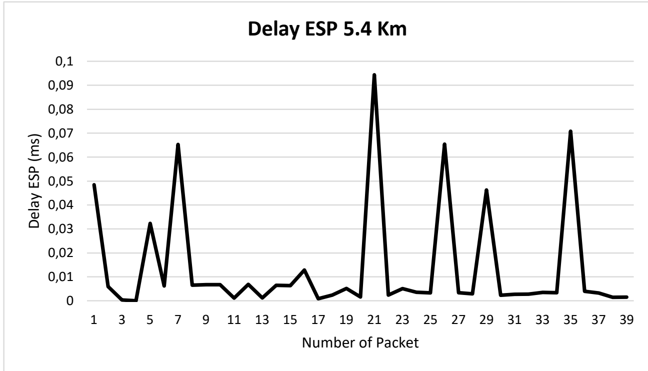

Fig. 17. Delay ESP for Distance 5.4 Km.

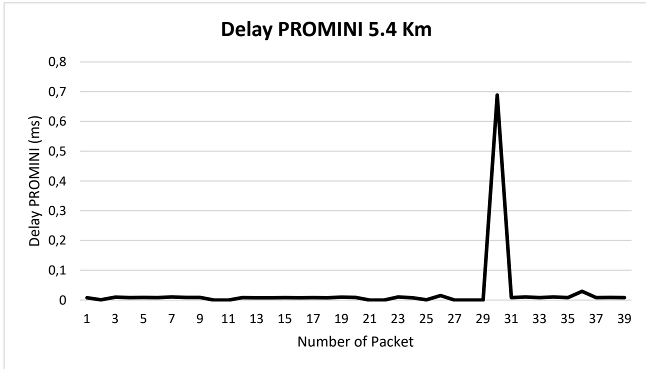

Fig. 18. Delay Pro Mini for Distance 5.4 Km.

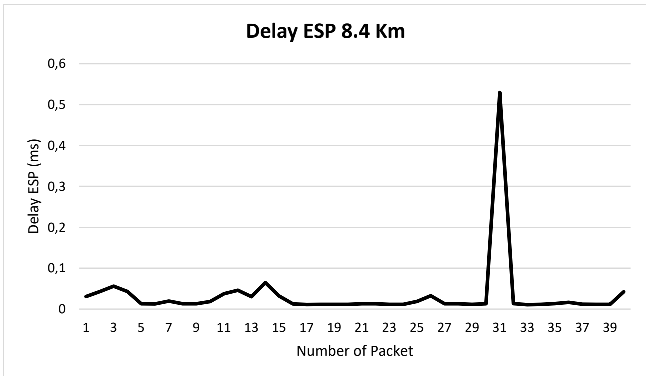

Fig. 19. Delay ESP for Distance 8.4 Km.

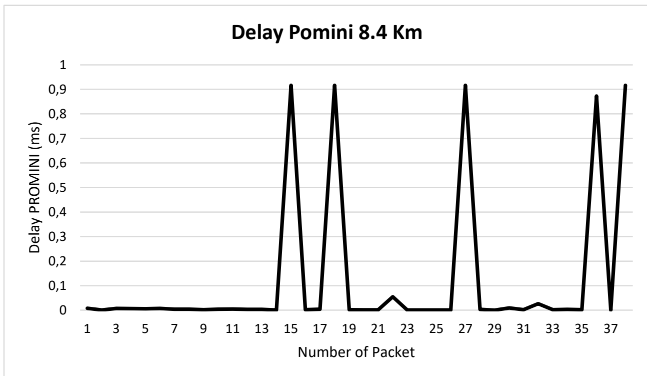

Fig. 20. Delay Pro Mini for Distance 8.4 Km.

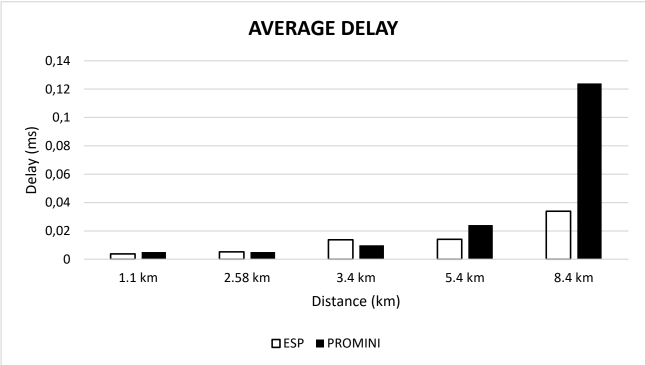

Fig. 21. Average Delay Esp and Pro Mini Distance 8.4 Km.

that the delivery of LoRa at the Borma Rencong Banjaran location or point E, which is 8.4 Km away, gets a very good delay category according to TIPHON.

Fig. 21 shows the average delay value from point 1 to point 5. The data above shows that the average delay value is getting more significant due to the increasing distance at each point. The smallest delay value is 1.1 Km on the ESP 32 board with an average of 0.003 or 3 ms. The average value of the largest delay is at a distance of 8.4 Km on the Arduino Pro Mini microcontroller with an average value of 0.124 or 124 ms. According to the TIPHON standard, 124 ms is a very good delay value because it is less than 150 ms. This causes the ESP 32 LR 201 board to be superior in data transmission because the average delay value of the ESP 32 board excels at 3 location points out of 5 location points.

G. Throughput Test

TABLE VIII
CATEGORY OF THROUGHPUT IN TIPHON.

Category	Packet Loss Value (%)
Very Good	100
Good	75
Medium	50
Poor	< 25

Throughput testing in this study, network data retrieval was carried out for 20 minutes for each location with a delay of 30 seconds for each transmission. This means that the amount of data sent to ANTARES is 40. To determine the category using TIPHON. For throughput, the greater amount of data received, the better the network quality.

For Table IX shows the number of packets received by 2 boards and the throughput value and category according to TIPHON. It can be analyzed that the throughput value of the two boards is below the standard of the THIPON standard because both boards are below 25 bps. Not only that, this study's test is done every 30 seconds, while the TIPHON standard requires testing to be done in real-time with millisecond intervals which LoRa technology cannot fulfill. It was concluded that the number of packets from 5 ESP 32 points was superior, with 195 packets from 200 packets with a throughput value of 15.86 bps, while Pro Mini with 192 packets from 200 with a throughput value of 15.61

TABLE IX
THROUGHPUT.

Location	Packet received from ESP	Throughput (bps)	Packet recevied from ProMini	Throughput (bps)
Borma Buah Batu	39	15.86	39	15.86
Tugu Asia Afrika	39	15.86	40	16.26
Nasi Goreng Cisangkuy	39	15.86	37	15.04
Sukabirus Residence	39	15.86	39	15.86
Borma Banjaran	39	15.86	37	15.04
Number of Data	195	15.86	192	15.61

bps. It can be concluded that the throughput value of ESP 32 is superior with a difference of 0.25 bps with 195 packets from 200 packets in 5 points.

H. Packet Loss Testing

TABLE X
CATEGORY OF PACKET LOSS IN TIPHON.

Category	Packet Loss Value(%)
Very Good	0
Good	3
Medium	15
Poor	25

Packet loss testing in this study took network data for 20 minutes for each location with a delay of 30 seconds for each transmission. It means that the number of information sent to ANTARES is 40. To determine the category using TIPHON. For packet loss, the higher the percentage of packet loss, the network quality decreases, as seen in Table XI for the amount of data received by 2 boards and packet loss values. It can be analysed that the value of packet loss in the ESP 32 board remains stable at 39 packets from 40 with a packet loss percentage of 2.5%, while the Arduino Pro Mini varies, for a distance of 2.58 Km at Tugu Asia Africa, the packet that was received was perfect in 40 packets with 0% value of packet loss. It was concluded that the number of packets from 5 ESP 32 points was superior, with 195 packets from 200 packets with a packet loss percentage of 2.5%, while Pro Mini with 192 packets from 200 packets with a packet loss percentage of 4%. It can be concluded that the percentage

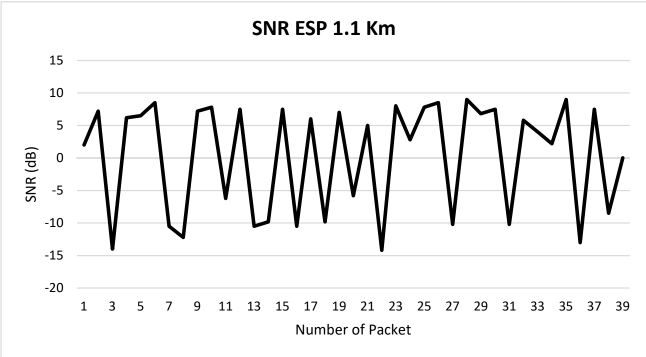

Fig. 22. SNR ESP for Distance 1.1 Km.

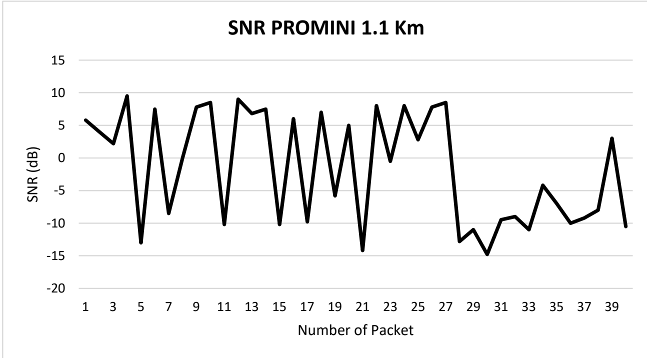

Fig. 23. SNR Pro Mini for Distance 1.1 Km.

of Pro Mini is greater than Esp 32. This causes ESP 32 to excel with a difference of 1.5% from Pro Mini.

TABLE XI
PACKET LOSS.

Location	Packet received from ESP	Packet loss(%)	Packet recevied from ProMini	Packet loss(%)
Borma Buah Batu	39	2.5	39	2.5
Tugu Asia Afrika	39	2.5	40	0
Nasi Goreng Cisangkuy	39	2.5	37	7.5
Sukabirus Residence	39	2.5	39	2.5
Borma Banjaran	39	2.5	37	7.5
Number of Data	195	2.5	192	4

I. SNR

This SNR test is done every 30 seconds for 20 minutes for each point; this test runs 2 boards at once to find out and determine which board is better. This test uses a bandwidth of 125 kHz, Code Rate 4/5, SF 10. Due to this test using SF10, the SNR value can match the maximum value of -12.5 dB. The greater the value of the SNR, the higher the network quality. The following is for testing the SNR for each point and its analysis.

Fig. 22 and Fig. 23 show the SNR results from 2 microcontrollers at Borma Fashion Buah Batu, which is 1.1 Km from the gateway for ESP and Pro Mini, respectively. Each board managed to collect 39 packets from 40 packets for 20 minutes. ESP 32 LR-201 gets an average SNR of 0.305 dB; this value is outstanding and included in the spreading factor 10 because this value is less than -12.5 dB. Meanwhile, Arduino Pro Mini gets an average SNR of -1.612 dB; this value is outstanding and included in the spreading factor of 10 because this value is greater than -12.5 dB. So it can be concluded that LoRa delivery at the Borma Fashion location or point A, which is 1.1 Km away, gets an SNR in a very good category.

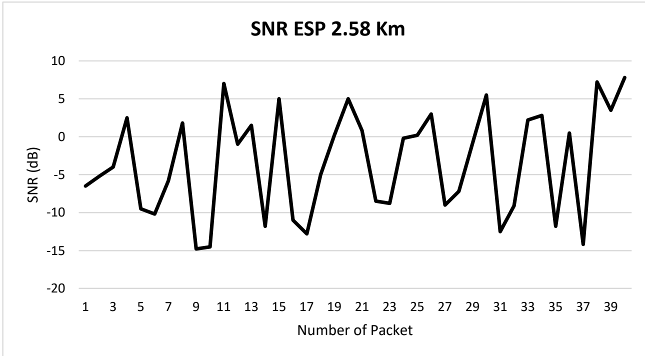

Fig. 24. SNR ESP for Distance 2.58 Km.

Fig. 24 and Fig. 25 show the SNR results from 2 microcontrollers at the Tugu Asia Africa location, 2.58 Km from the gateway, respectively, for ESP and Pro Mini. The ESP 32 board managed to collect 39 packets from 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 40 packets out of 40 packets for 20 minutes. ESP 32 LR-201 gets an average SNR of -5.49 dB; this value is outstanding and included in the spreading factor 10 because this value is less than -12.5 dB. Meanwhile, Arduino Pro Mini gets an average SNR of -2.22 dB; this value is outstanding and included in the spreading factor of 10 because this value is greater than -12.5 dB. So, it can be concluded that LoRa

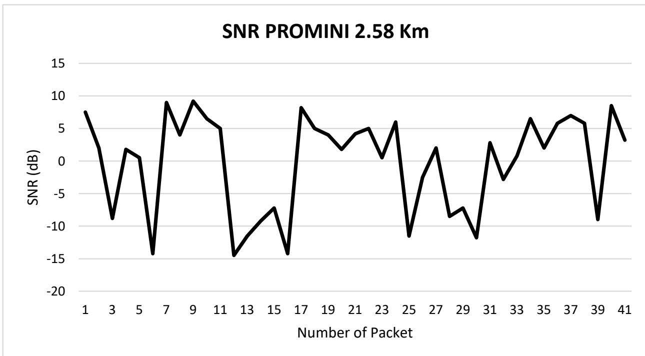

Fig. 25. SNR Pro Mini for Distance 2.58 Km.

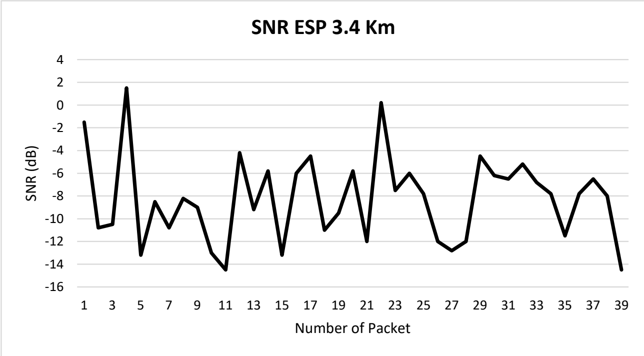

Fig. 26. SNR ESP for Distance 3.4 Km.

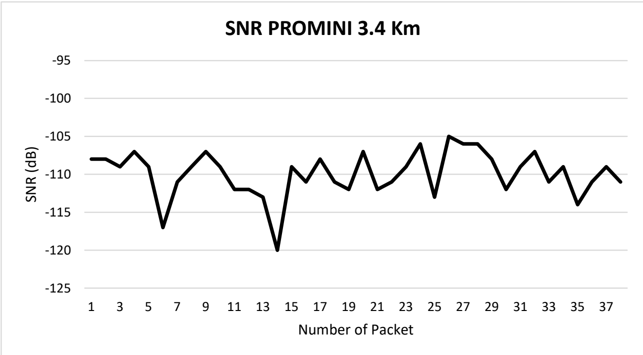

Fig. 27. SNR Pro Mini for Distance 3.4 Km.

delivery at the Tugu Asia Africa location or point B, which is 2.58 km away, gets an SNR in the very good category.

Fig. 26 and Fig. 27 show the SNR results from 2 microcontrollers at the location of Nasi Goreng Zebot Cisangkuy, which is 3.4 Km from the gateway, for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201 gets an average SNR of -8.470 dB; this value is outstanding and included in the spreading factor 10 because this value is less than -12.5 dB. Meanwhile, Arduino Pro Mini gets an average SNR of -6.431 dB; this value is outstanding and included in the spreading factor of 10 because this value is greater than -12.5 dB. So it can be concluded that LoRa delivery at Zebot Cisangkuy Fried Rice or point C, which is 3.4 Km away, gets an SNR in the good category.

Fig. 28 and Fig. 29 show the SNR results from 2 microcontrollers at the Sukabirus Residence location, 5.4 Km from the gateway. Each board managed to collect 39 packets from 40 packets for 20 minutes. For ESP 32 LR- 201 gets an average SNR of -7.712 dB; this value is very good and included in the spreading factor of 10 because this value is less than -12.5 dB. Meanwhile, Arduino Pro Mini gets an average SNR of -5.948 dB; this value is very good and included in the spreading factor of 10 because this value is greater than -12.5 dB. So it can be concluded that LoRa delivery at the Sukabirus residence location or point D, which is 5.4 Km away, gets an SNR in the good category.

Fig. 30 and Fig. 31 show the SNR results from 2 microcontrollers at the Borma Rencong Banjaran location, 8.4 Km from the gateway. The ESP 32 board managed to collect 39

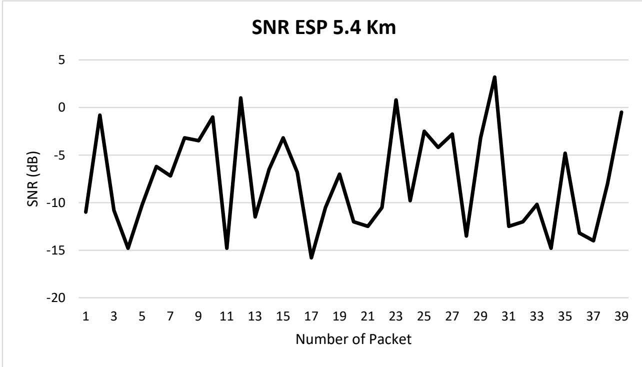

Fig. 28. SNR ESP for Distance 5.4 Km.

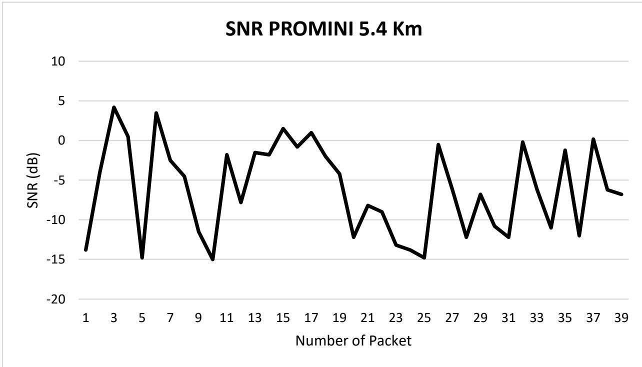

Fig. 29. SNR Pro Mini for Distance 5.4 Km.

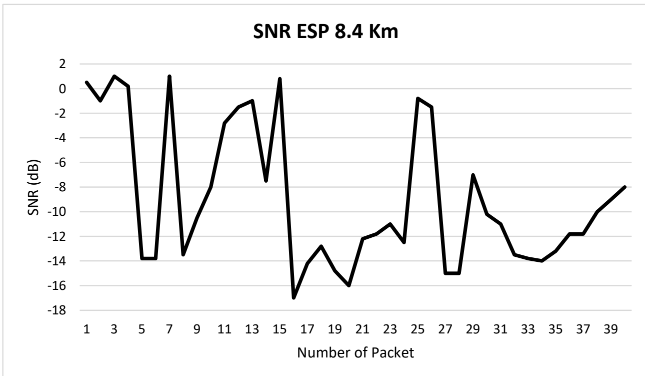

Fig. 30. SNR ESP for Distance 8.4 Km.

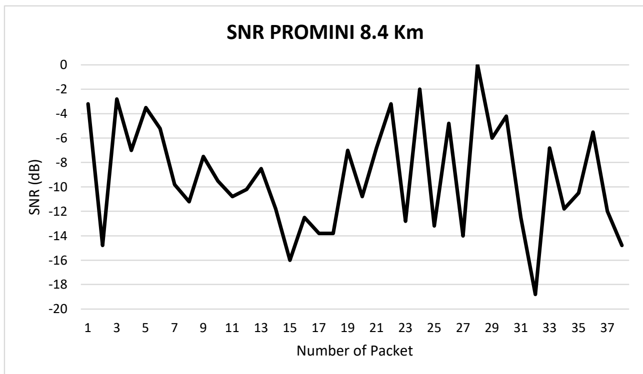

Fig. 31. SNR Pro Mini for Distance 8.4 Km.

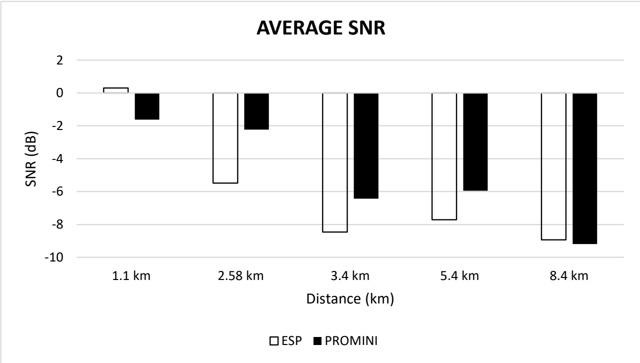

Fig. 32. Average SNR Esp and Pro Mini.

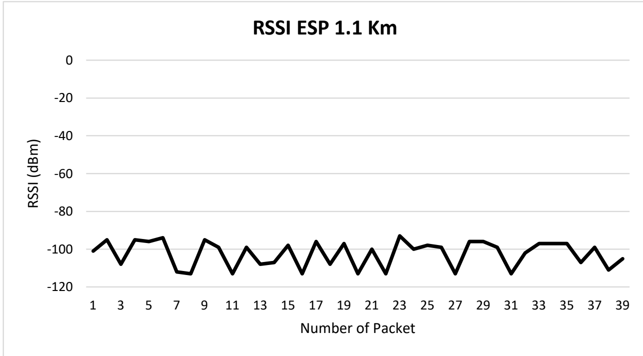

Fig. 33. RSSI ESP for Distance 1.1 Km.

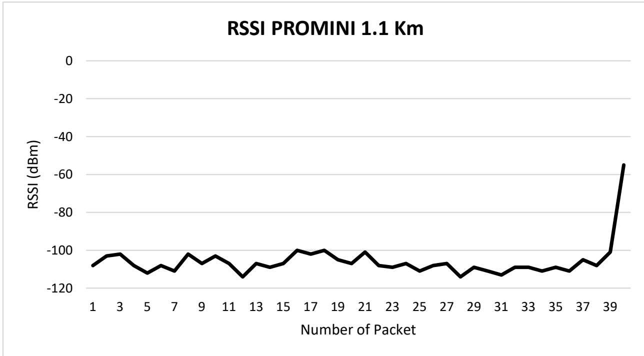

Fig. 34. RSSI Pro Mini for Distance 1.1 Km.

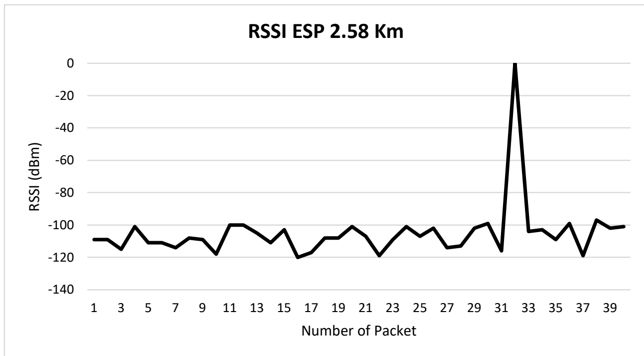

Fig. 35. RSSI ESP for Distance 2.58 Km.

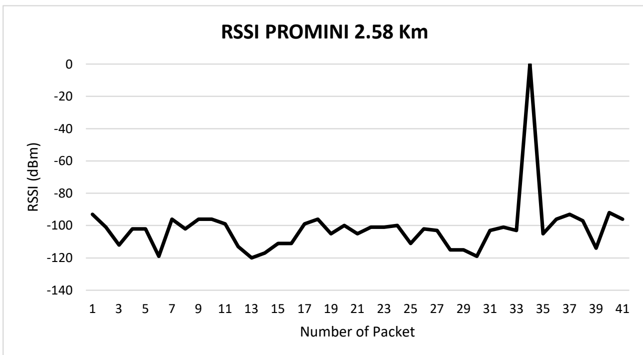

Fig. 36. RSSI Pro Mini for Distance 2.58 Km.

packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201 gets an average SNR of -8.945 dB; this value is very good and included in the spreading factor 10 because this value is less than -12.5 dB. Meanwhile, Arduino Pro Mini gets an average SNR of -9.194 dB; this value is very good and included in the spreading factor of 10 because this value is greater than -12.5 dB. So it can be concluded that LoRa delivery at the Borma Rencong Banjaran location or point E, which is 8.4 Km away, gets an SNR in the good category.

Fig. 32 shows the average value of SNR from point 1 to point 5. The average value of the largest SNR is at 1.1 Km on the ESP 32 board with an average of 0.305 dB. The average value of the largest SNR is at a distance of 8.4 Km on the Arduino Pro Mini microcontroller with an average value of -9.914 dB. The average value of SNR is -9.914 dB, including the SNR value, which is in the speeding factor of 10 because it is greater than -12.5 dB. It can be concluded that the 5 points of location are still included in the speeding factor of 10, namely with an average value of -12.5 dB. The Arduino Pro Mini board excels at 3 from 5 location points because the average SNR value is greater than the ESP 32 board.

J. RSSI

This RSSI test is done every 30 seconds for 20 minutes for each point; this test runs 2 boards at once to find out and determine which board is better. This test uses a bandwidth of 125 kHz, Code Rate 4/5, SF 10. The RSSI value can depend on field conditions and distance; if the distance and location are further away and there are many obstacles, the RSSI value will decrease. RSSI value can be said to be good if the average value of RSSI is less than -120 dBm.

Fig. 33 and Fig. 34 show RSSI results from 2 microcontrollers at the location of Borma Fashion Buah Batu, which is 1.1 Km from the gateway for ESP and Pro Mini, respectively. Each board managed to collect 39 packets from 40 packets for 20 minutes. For ESP 32 LR-201 gets an average RSSI value of -102.43 dBm; this value is very good because this value is less than -120 dBm. While the Arduino Pro Mini gets an average RSSI value of -105.95 dBm, this value is very good because this value is less than -120 dBm. So that it can be concluded that LoRa delivery at the Borma Fashion location or point A, which is 1.1 Km away, gets the RSSI average value in the very good category.

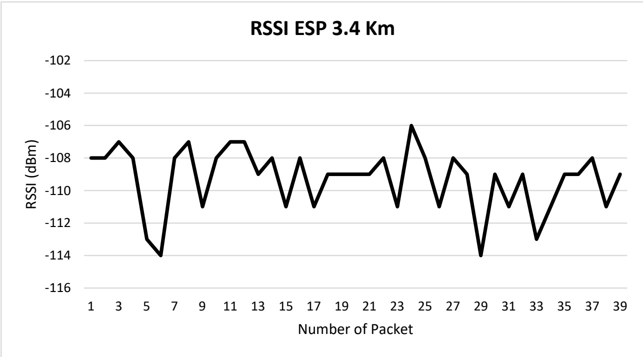

Fig. 37. RSSI ESP for Distance 3.4 Km.

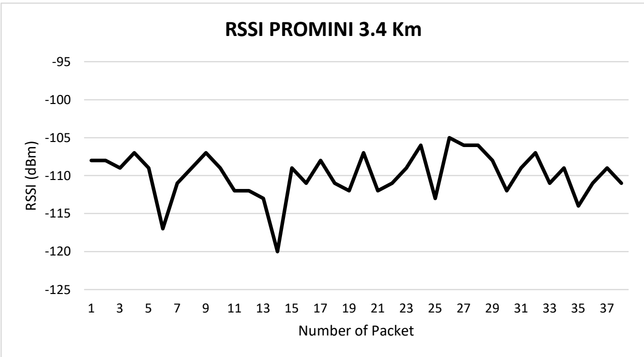

Fig. 38. RSSI Pro Mini for Distance 3.4 Km.

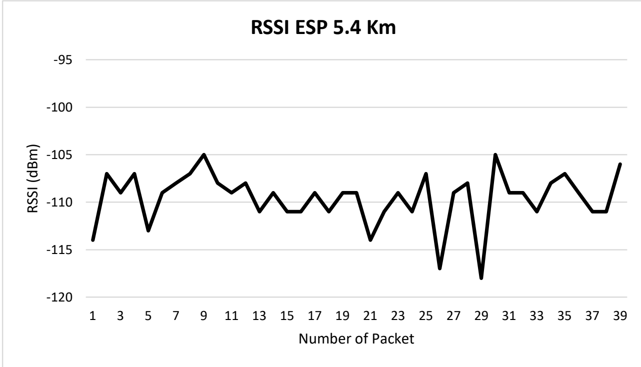

Fig. 39. RSSI ESP for Distance 5.4 Km.

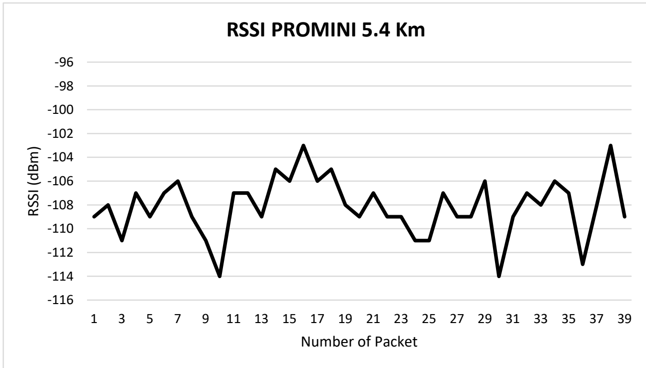

Fig. 40. RSSI Pro Mini for Distance 5.4 Km.

Fig. 35 and Fig. 36 show RSSI results from 2 microcontrollers at the Tugu Asia Africa location, 2.58 Km from the gateway for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets from 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 40 packets out of 40 packets for 20 minutes. For ESP 32 LR-201 gets an average RSSI value of -105.3 dBm; this value is very good because this value is less than -120 dBm. While the Arduino Pro Mini gets an average RSSI value of -101.51 dBm, this value is very good because this value is less than -120 dBm. So it can be concluded that LoRa delivery at the Tugu Asia Africa location or point B, which is 2.58 km away, gets an average RSSI value in the very good category.

Fig. 37 and Fig. 38 show RSSI results from 2 microcontrollers at the location of Nasi Goreng Zebot Cisangkuy, which is 3.4 Km from the gateway for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201 gets an average RSSI value of -109.29 dBm; this value is very good because this value is less than -120 dBm. While the Arduino Pro Mini gets an average RSSI value of -109.94 dBm, this value is very good because this value is less than -120 dBm. So it can be concluded that LoRa delivery at Zebot Cisangkuy Fried Rice or point C, which is 3.4 Km away, gets an average RSSI value in the very good category.

Fig. 40 and Fig. 40 show RSSI results from 2 microcontrollers at the Sukabirus residence location, 5.4 Km from the gateway for ESP and Pro Mini, respectively. Each board managed to collect 39 packets from 40 packets for 20 minutes. For ESP 32 LR-201 gets an average RSSI value of -109.58 dBm; this value is very good because this value is less than -120 dBm. While the Arduino Pro Mini gets an average RSSI value of -108.17 dBm, this value is very good because this value is less than -120 dBm. So it can be concluded that the delivery of LoRa at the Sukabirus Residence or point D, which is 5.4 Km away, gets an average RSSI value in the very good category.

Fig. 41 and Fig. 42 show RSSI results from 2 microcontrollers at Borma Rencong Banjaran, which is 8.4 Km from the gateway for ESP and Pro Mini, respectively. The ESP 32 board managed to collect 39 packets out of 40 packets for 20 minutes, while Arduino Pro Mini managed to collect 37 out of 40 packets for 20 minutes. For ESP 32 LR-201 gets an average RSSI value of -109.93 dBm; this value is very good because this value is less than - 120 dBm. While the Arduino Pro Mini gets an average RSSI value of -108.86 dBm, this

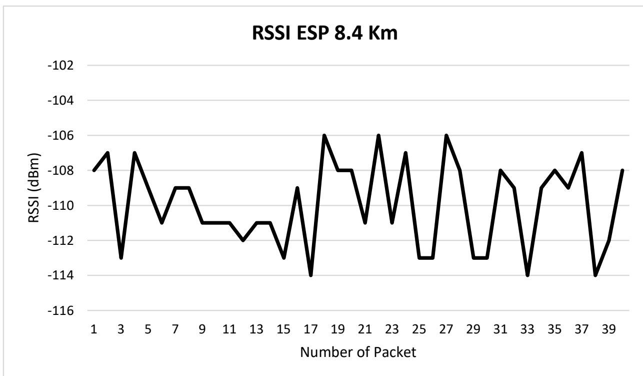

Fig. 41. RSSI ESP for Distance 8.4 Km.

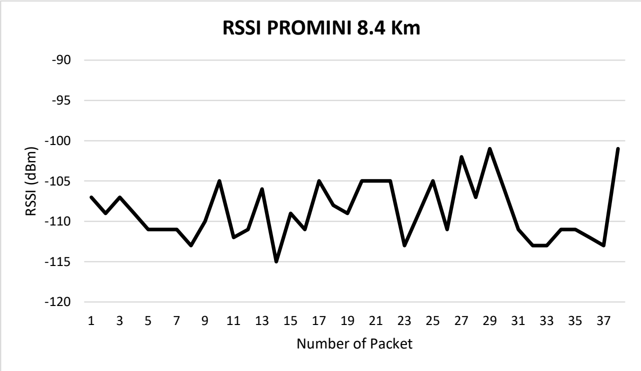

Fig. 42. RSSI Pro Mini for Distance 8.4 Km.

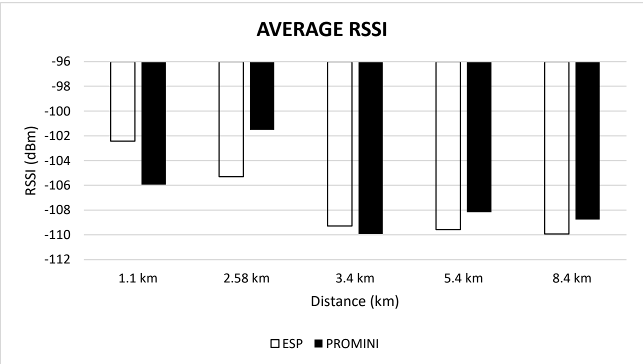

Fig. 43. Average RSSI Esp and Pro Mini.

value is very good because this value is less than -120 dBm. So it can be concluded that LoRa delivery at Borma Rencong Banjaran or point E, which is 8.4 Km away, gets an average RSSI value in the very good category.

Fig. 43 shows the average RSSI value from point 1 to point 5. The largest RSSI average value is at 1.1 Km on the ESP 32 board with an average of -102.43 dBm. The largest RSSI average value is at a distance of 8.4 Km on the ESP 32 microcontroller with an average value of -109.93 dBm. The average RSSI value is -109.93 dBm, including a very good RSSI value because the average value is less than -120 dBm. The Arduino Pro Mini board excels at 3 out of 5 location points because the average RSSI value is greater than the ESP 32 board.

V. Conclusion

Based on the system design, testing, and analysis results, we proved that the calibration of 2 boards on the 3 ground tests between the digital NPK sensor and the analog NPK sensor has more than 95%. It can be concluded that the Esp32 board and Arduino Pro Mini board capabilities on the digital NPK sensor are running well. To detect temperature and humidity on the ESP 32 board and the Arduino Pro Mini board, it runs 100% according to the command. It can be concluded that the temperature and humidity detector is successful. All hardware and software run as expected to test the integration of ESP 32 board and Arduino Pro Mini board on hardware and software.

For sending and receiving data, these 2 boards also run according to their functions; the ESP 32 microcontroller and Arduino Pro Mini can send data to ANTARES and display the same data in real-time in the Android application. We also tested the delay on the ESP 32 board and the Arduino Pro Mini board using a bandwidth of 125 kHz and a Code Rate of 4.5 locations, the average value is in the very good category according to TIPHON. The best delay value is at the location of 1.1 Km from the LoRa BTS with an average value of 0.003 or 3 ms, and the worst delay value is at the location of 8.5 Km from the LoRa BTS location with an average value of 0.124 or 124 ms. The quality of the resulting delay is also bad. For the delay comparison, the ESP 32 LR 201 board is superior in data transmission because the average delay value of the ESP 32 board is superior at 3 location points out of 5 location points.

For throughput testing on ESP 32 and Arduino Pro Mini boards with TIPHON standardization, it can be concluded that the throughput value of the two boards is below the TIPHON standard because both boards are below 25 bps. Because the test is done every 30 seconds, the TIPHON standard requires testing in real-time with millisecond intervals that LoRa technology cannot fulfill. It was concluded that the number of packets from 5 ESP 32 points was superior, with 195 packets from 200 packets with a throughput value of 15.86 bps, while Pro Mini with 192 packets from 200 with a throughput value of 15.61 bps. It can be concluded that for superior ESP 32 throughput value.

For packet loss testing, the number of packets received by 2 boards in all locations and packet loss values along with categories according to TIPHON. It can be concluded that the packet loss value of the ESP 32 board remains stable at 39 packets from 40 with a packet loss percentage of 2.5%, while the Arduino Pro Mini varies, for a distance of 2.58 Km at Tugu Asia Africa, the packet that was received was perfect in 40 packets with 0% value of packet loss. It was concluded that the number of packets from 5 ESP 32 points was superior, with 195 packets from 200 packets with a packet loss percentage of 2.5%, while Pro Mini with 192 packets from 200 packets with a packet loss percentage of 4%. It can be concluded that the percentage of Pro Mini is greater than Esp 32. This causes ESP 32 to excel with a difference of 1.5% from Pro Mini.

For testing the SNR of the ESP 32 board and the Arduino Pro Mini board using a Spreading Factor of 10 from 5 location points, it shows the average SNR value is decreasing due to the increasing distance at each point which results in greater noise. The average value of the largest SNR is at 1.1 Km on the ESP 32 board with an average of 0.305 dB. The average value of the largest SNR is at a distance of 8.4 Km on the Arduino Pro Mini microcontroller with an average value of -9.914 dB. The average value of SNR is -9.914 dB, including the SNR value, which is in the speeding factor 10 because it is less than -12.5 dB. It can be concluded that at 5 points, the location is still included in the speeding factor of 10, namely with an average value of -12.5 dB. The Arduino Pro Mini board excels at 3 out of 5 location points because the average SNR value is greater than the ESP 32 board.

For the RSSI test, the data obtained from the Esp 32 board and the Arduino Pro Mini board show that the average RSSI value decreases due to the increasing distance at each point, resulting in greater noise. The largest RSSI average value is at 1.1 Km on the ESP 32 board with an average of -102.43 dBm. The largest RSSI value is at a distance of 8.4 Km on the ESP 32 microcontroller with an average value of -109.93 dBm. The average RSSI value is -109.93 dBm, including a very good RSSI value because the average value is less than -120 dBm. The Arduino Pro Mini board excels at 3 location points from 5 location points because the average RSSI value on this board is greater than the ESP 32 board.

To test the comparison of the Esp 32 board and the Arduino Pro Mini board in terms of QoS (Quality of Service), consisting of throughput, delay, packet loss, SNR, and RSSI. Out of 5 tests, ESP 32 excels in throughput, delay, and packet loss tests. While Arduino Pro Mini excels in SNR and RSSI testing, it can be concluded that the ESP 32 board is more effective to use in further research.

References

[1] A. Wildan, T. H. Santoso, and S. H. Kusuma, “Income in sukorambi village sub-district of sukorambi, district of jember,” *Jurnal Agribest Vol*, vol. 2, no. 02, pp. 79–91, 2018.

[2] H. Y. Wibowo and S. Sitawati, “Respon tanaman kangkung darat (ipomoea reptans poir) dengan interval penyiraman pada pipa vertikal,” *PLANTROPICA: Journal of Agricultural Science*, vol. 2, no. 2, pp. 148–154, 2018.

[3] I. Irawati and Z. Salamah, “Pertumbuhan tanaman kangkung darat (ipomoea reptans poir.) dengan pemberian pupuk organik berbahan dasar kotoran kelinci,” *Jurnal bioedukatika*, vol. 1, no. 1, pp. 3–14, 2013.

[4] Y. S. Rambe, “Pengaruh mindset dan inovasi terhadap keberhasilan usaha pakaian di jalan halat medan,” 2017.

[5] B. P. Statistik, “Produksi tomat menurut provinsi,2014-2018,” *BPS*, vol. 2018.

[6] L. Aminulloh, W. T. Sesulihatien, and D. Pramadihanto, “Feature extraction of tomato growth model using greenhouse monitoring system,” in *2019 International Electronics Symposium (IES)*. IEEE, 2019, pp. 370–375.

[7] I. Samuel, A. Soyemi, A. Awelewa, and A. Adekitan, “Artificial neural network based load flow analysis for power system networks,” *IAENG International Journal of Computer Science*, vol. 48, no. 4, pp. 1135–1142, 2021.

[8] Lora, “Implementasi sistem monitoring dan controlling unsur hara implementation of monitoring and controlling system of nutriesnts and soil moisture in chili plants based on iot using,” pp. 1–8.

[9] P. Luna, S. Gutiérrez, and R. Espinosa, “Design and implementation of a node geolocation system for fire monitoring through lorawan,” in *2020 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC)*, vol. 4. IEEE, 2020, pp. 1–6.

[10] A. F. P. Of, “Kedelai berbasis internet of things prototype of automatic fertilizer control system in soybean plant based on internet of.”

[11] S. Sharma, A. Sharma, T. Goel, R. Deoli, and S. Mohan, “Smart home gardening management system: A cloud-based internet-of-things (iot) application in vanet,” in *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. IEEE, 2020, pp. 1–5.

[12] M. S. Hadi, P. A. Nugraha, I. M. Wirawan, I. A. E. Zaeni, M. A. Mizar, and M. Irvan, “Iot based smart garden irrigation system,” in *2020 4th International Conference on Vocational Education and Training (ICOVET)*. IEEE, 2020, pp. 361–365.

[13] D. Perdana, R. Putra, and G. Bisono, “Analysis of soil substance measurement system based on internet of things (iot) with star topology network,” *International Journal of Simulation: Systems Science & Technology*, 2019.

[14] R. N. Muktiarto, D. Perdana, and R. M. Negara, “Performance analysis of mobility impact on ieee 802.11 ah standard with traffic pattern scheme,” *International Journal of Communication Networks and Information Security*, vol. 10, no. 1, pp. 139–147, 2018.

[15] D. Perdana, R. Munadi, and R. C. Manurung, “Performance evaluation of gauss-markov mobility model in hybrid lte-vanet networks,” *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 15, no. 2, pp. 606–621, 2017.

[16] M. A. P. Putra, D. Perdana, and R. M. Negara, “Performance analysis of data traffic offload scheme on long term evolution (lte) and ieee 802.11 ah,” *Telkomnika*, vol. 15, no. 4, pp. 1659–1665, 2017.

[17] P. Du, Z. Chen, Z. Zhang, and Q. Zhao, “A congestion mitigation model of transmission network considering the participation of distribution companies in power market,” *IAENG International Journal of Applied Mathematics*, vol. 51, no. 4, pp. 1017–1026, 2021.

[18] F. Siva, “Smart fertilizer recommendation through npk analysis using artificial neural networks,” Ph.D. dissertation, Strathmore University, 2019.

[19] B. Pamukti, D. Perdana, and M. R. Kirom, “Thermal effect analysis of arrayed waveguide grating in ng-pon2 network.” *Engineering Letters*, vol. 26, no. 2, pp. 216–223, 2018.

[20] P. Devipriya, M. S. Kumar, and C. Nanthakumar, “Automatic plant irrigation using solar panel.”

[21] M. Muliadi, A. Imran, and M. Rasul, “Pengembangan tempat sampah pintar menggunakan esp32,” *Jurnal Media Elektrik*, vol. 17, no. 2, pp. 73–79, 2020.

[22] N. Tasneem, M. A. Hasan, S. B. Akther, and M. M. Khan, “An automatic soil testing machine for accurate fertilization,” in *2021 IEEE World AI IoT Congress (AIIoT)*. IEEE, 2021, pp. 0325–0331.

[23] A. Augustin, J. Yi, T. Clausen, and W. M. Townsley, “A study of lora: Long range & low power networks for the internet of things,” *Sensors*, vol. 16, no. 9, p. 1466, 2016.

[24] A. C. Journal, “Plant disease diagnosis,” *PLANT Dis. DIAGNOSIS,*, vol. IX, no. 2231, pp. 14–41, 2020.

[25] M. A. Khan and K. Salah, “Iot security: Review, blockchain solutions, and open challenges,” *Future generation computer systems*, vol. 82, pp. 395–411, 2018.

[26] Taylor, “Power supply,” *Recycl. Today,*, vol. 45, no. 10, pp. 48–54, 2007.

[27] J. Fenila Naomi, R. Theepavishal, K. Madhuaravindh, and V. Tharuneshwar, “Soil quality analysis and an efficient irrigation system using agro-sensors,” *International Journal of Engineering and Advanced Technology (IJEAT)*, vol. 8, no. 5, pp. 703–706, 2019.

[28] H. Pudugosula, “Automatic smart and safety monitoring system for kitchen using internet of things,” in *2019 International Conference on Intelligent Computing and Control Systems (ICCS)*. IEEE, 2019, pp. 1174–1177.

[29] B. Z. Barkana and W. McDonough, “Ap computer science principles: Designing the hour. ly app in mit app inventor,” in *2019 IEEE Long Island Systems, Applications and Technology Conference (LISAT)*. IEEE, 2019, pp. 1–6.

[30] I. S. NINGROEM, F. Sulaiman, and Z. P. Negara, “Budidaya tanaman kangkung darat (ipomoea reptans poir.) secara terapung pada dua dimensi ukuran polybag berbeda dan penambahan pupuk kotoran kambing,” Ph.D. dissertation, Sriwijaya University, 2020.

[31] S. W. Pamungkas, E. Pramono *et al.*, “Analisis quality of service (qos) pada jaringan hotspot sma negeri xyz,” *E-JURNAL JUSITI: Jurnal Sistem Informasi dan Teknologi Informasi*, vol. 7, no. 2, pp. 142–152, 2018.

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