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Developing of Automatic Fertilizer Control System in Soybean Plant Based on Internet of Things and LoRa Networks

Doan Perdana, Wahyu Rizal Panca Kusuma, and Ibnu Alinursafa

Abstract— **This research is developing the analog value from the NPK sensor to digital using the YL 38 comparator module to obtain detailed Nitrogen (N), Phosphorus (P), and potassium (K) values according to the NPK sensor datasheet. This system is a network based on the Internet of Things (IoT) and LoRa. The IoT and LoRa features installed on this device, meanwhile the measurement and fertilization data can be monitored easily through an Android application. This research using a frequency of 922.4 Mhz, 125 kHz bandwidth, 10 spreading factors, and a code rate of 5. The Network Quality of Services testing i.e. delay, packet loss, SNR, and RSSI. The QoS was measured at 6 locations. different, 1 location 0 km, 4 locations 1 km, 1 location 2.5 km from BTS LoRa. It was concluded that the parameters used are by the conditions and distances in the data collection. It is proven that all the standards in each parameter are met. In testing the LoRa network it can be concluded that the farther the distance from the LoRa BTS the data transmission quality is getting worse.**

***Keywords*—Nitrogen, Phosphorus, Potassium, NPK Sensor, LoRa, Internet of Things, Antares LR-ESP201**

I. Introduction

AGRICULTURE is the main occupation that contributes to addressing food needs. This will be successful only if the farmers can produce high yields in their cultivation. The low yield of cultivation in agriculture [1] affects the increase in income of developing countries. One of the main reasons for the low yields is the improper use of fertilizers by farmers. Fertilizer must be added in an amount according to the nutrient needs in the soil. Therefore, testing the soil for available nutrients for plant growth is unavoidable before adding fertilizer. Soil testing is mostly done to estimate the availability of nutrients in the soil for plant growth. Determination of fertilizer recommendation [2] for effective plant growth is the main outcome of soil testing.

However, soil testing is rarely carried out by farmers because of its complex nature such as laboratory procedures [3]. In general, soil testing for nutrients is done manually in commercial laboratories which cannot facilitate farmers because it requires more time and cost [4].

One of the foodstuffs from the Leguminosae family that is consumed by Indonesians is (Glycine max (L.) Merr.). National consumption is calculated based on total population and per capita consumption per year. The population grows about 1.3% per year, domestic soybean consumption is 35% met from imported soybeans [5]. In 2010, soybean production was estimated at 927.38 thousand tons of dry beans, a decrease of 47.13 thousand tons (4.84%) compared to 2009 [6]. Based on data obtained from BPS (Central Statistics Agency) and the Ministry of Agriculture, it shows that soybean production achievements in 2010-2012 decreased respectively by 0.91 million tons and 0.84 million tons [7].

The high consumption and decreased production of soybean commitment in Indonesia need good and sustainable handling so that yields can be increased again. Increasing soybean yields can be done by providing sufficient nutrients so that plants can grow well. Providing nutrients according to their needs with fertilization, fertilizer management is an important effort to increase plant growth and production and lose various macronutrients in this case nitrogen (N), phosphorus (P), and potassium (K) [8]. Soil tests for macronutrients are carried out separately for nitrogen, phosphorus and potassium [9], it will waste time and not economical for farmers.

The development of information and communication technology is accelerating, one example of the Internet of Things (IoT). IoT itself is a global infrastructure for public information that supports sustainability with interconnection by a sensor based on the development of interrelated information and communication technology [10]. In this final project, the author wants to use IoT in the agricultural sector, especially in soybean farming in the field of presenting fertilizers and the state of nitrogen (N), phosphorus (P) and potassium (K) soil automatically so that the quality and quantity of soybeans increase.

WiFi module was used as a transmission medium and NTP as a source of time data input, in previous studies also the network quality testing process. taken 3 location points with a maximum distance of 15 meters [31]. This system is a network based on the Internet of Things (IoT), internet connectivity is used to exchange information with surrounding objects. The results of this system design are in the form of a tool to measure each element of N, P, and K. With the IoT and LoRa features installed on this device, measurement and fertilization data can be monitored easily through an android application that has been created on an android smartphone.

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The key factor is reduce the power consumption of the micro system [34]. For transmission media, the authors use Low Power Wide Area Network (LPWAN) as a type of wireless telecommunication network with LoRa modulation techniques using communication protocols and LoRaWan system architecture. Due to the superiority of LoRa technology, as a wide area network solution that promises reach with very low power consumption and a good level of security, with thousands of node devices that can be connected in the network so it is very suitable for IoT [11].

In this research, we will design and build a system to meet the fertilizer needs of soybean farming. The system functions to maintain the levels of nitrogen (N), phosphorus (P), and potassium (K) in soybean plants during the growth process. The system is designed using the NPK sensor, water pump, RTC, Antares LR-ESP201 Board as the control center. The NPK sensor will measure nitrogen (N), phosphorus (P), and potassium (K) levels in the soil. Then the mini DC pump will deliver the required fertilizer according to the fertilization time span regulated by the RTC. Data on levels and conditions of nitrogen (N), phosphorus (P), and potassium (K) fertilization will also be presented in an android application using the LoRa modulation technique.

II. RELATED WORKS

IoT for agricultural land is very common in all over the world especially countries with the most advanced technologies. Discussions about precision agricultural process is very interesting because it is highly applicable in many tropical countries [12].

Lavanya, G., Rani, C. and Ganeshkumar, P., 2020,. Research entitled Low-Cost IoT-Based Automatic Fertilizer Estimation System for Intelligent Agriculture. This study uses a new Nitrogen-Phosphorus-Potassium (NPK) sensor with Light Dependent Resistor (LDR) and Light Emitting Diodes (LED). The principle of colorimetry is used to analyze and analyze the material that is in the soil. Data detected by NPK sensors designed from selected fields of agriculture is sent to the Google cloud database to support fast data. The fuzzy logic concept is applied to receive nutrients from sensing data [13].

The next study is a research by Perdana, D., Renaldi, L. and Alinursafa, I., 2020. Research entitled Performance Analysis of Soil Moisture Monitoring based on Internet of Things with LoRA Communications. Designed a system for measuring the levels of elements such as nitrogen, phosphorus and potassium, in the soil to increase crop yields. In addition, the Antares LR-ESP201 Board is used to transmit data to the cloud and Low Power Wide Area Network LoRa is also applied to the 920–923 MHz frequency and can be monitored in realtime via the android application [14].

Perdana, D., Imadudin, M. and Bisono, G., 2019. Research entitled Performance Evaluation of Soil Substance Measurement System in Garlic Plant based on Internet of Things with Mesh Topology Network Scenario. This study measured Nitrogen (N), Phosphorus (P), Real-time potassium (K) levels in plantation land using NPKsensors and nodemcu as a microcontroller and provide real-time information connectivity using a mesh topology and concluded that the accuracy of the measurement data was compared for an analogue meter NPK (Doctor Plant) above 90%. Based on endurance test of devices and systems using Xiaomi power bank of 5000mAh, device and system worked fine for 30 hours without problems. Moreover, the accuracy of the data can and uploaded to the database no error with 100% [15].

Kapse, S., Kale, S., Bhongade, S., Sangamnerkar, S. and Gotmare, Y., 2020. The title IOT Enables NPK Nutrient Detection of Soil Testing. The proposed system for IoT-enabled soil testing is based on measuring and observing soil parameters. The system functions to monitor temperature, humidity, soil moisture and soil pH along with a color sensor for NPK nutrients soil. The data detected by the sensor is stored in the cloud and based on suggestions for development suitable plants are made. The Wi-Fi module presented with the Arduino is used to display test data [16].

Rachmani, A.F. and Zulkifli, F.Y., 2018,. The title Design of IOT monitoring System Based on LoRa Technology for Starfruit Plantation. The focus of this research is the design of a LoRa-based monitoring system in star fruit plantations. using pH and soil moisture sensors for soil conditions in the plantation. From the experimental experiment, the maximum coverage is 700 meters with an RSSI value of -120 dBm and a PDR value below 50%. In the end user interface it is revealed that the interface can be accessed via desktop and smartphone [17].

III. RESEARCH METHOD

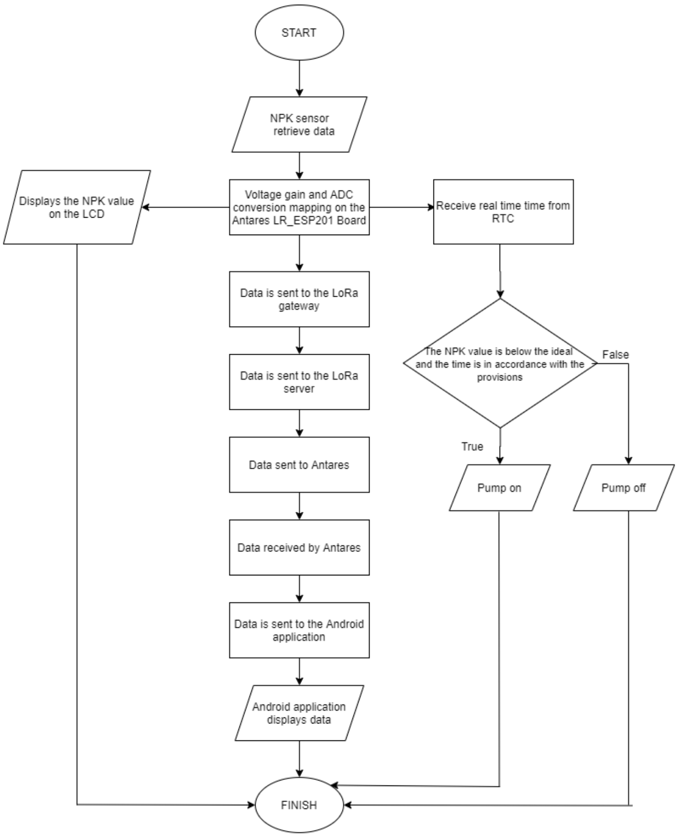

Fig.1. Flowchart System

The flow chart in Figure 1 describes the process of forced sensor data to sending data from Antares to Android. Using the NPK sensor takes data from the soil then sends that data to the Antares LR-ESP201 Board to amplify the voltage and map the

ADC conversion. Antares LR-ESP201 Board here has three tasks, namely sending data to the LCD, sending data to the Android application then carrying out the fertilization process.

A. Inverting Amplifier

The operational amplifier or often called OpAmp is an electronic component which serves to return the signal direct current (DC) or alternating current (AIR CONDITIONING). The operational amplifier consists of ransistors, resistors and capacitors are assembled and packaged in a series integrated (Intregated Circuits) [29]. The inverting amplifier is an electronic circuit that serves to amplify and reverse the polarity of the input signal [30].The YL 38 comparator module is used in this project. With line opamp comparator based on L393 IC. Sensing output voltage the probe is connected to the amplifier inverting [29].

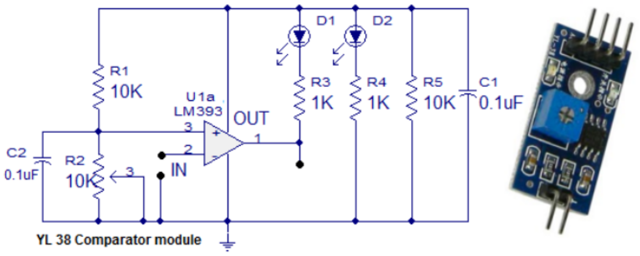

Fig.2. YL 38 Comparator Module [29]

$$Vo = -\frac{R2}{\mathrm{R1}} \times Vi \qquad (1)$$

$$Av = -\frac{R2}{\mathrm{R1}} = -\frac{Vo}{\mathrm{Vi}} \qquad (2)$$

The reinforcement formula of the inverting circuit is obtained from the following equation:

Vo = Output Voltage (Volt)
Vi = Input Voltage (Volt)
Av = Voltage Amplifier (Volt)
R1 = Resistor Input (Ohm)
R2 = Feedback Resistor (Ohm)

B. Design of NPK Sensor

```
float npk_sensor = analogRead(32);
float npkconvert  = map(npk_sensor, 4095, 0, 0, 4095);
float npk  = map(npkconvert, 0, 4095, 1, 300);
nitrogen = map(npk, 1, 300, 0, 200);
phosphorous = map(npk, 1, 300, 0, 14);
potash = map(npk, 1, 300, 0, 200);
```

Fig.3. Mapping of NPK sensor

Based on Figure 3, before determining the ADC (Analog to Digital Converter) value for voltage mapping, the NPK sensor is calibrated to obtain the voltage value results at the minimum and maximum times. The Antares LR-ESP201 Board has an ADC value of 12 bits and reads analog values ranging from 0 to 4095, with a value of 0 corresponding to 0 V and 4095 corresponding to 3.3 V [18].

Because the author uses the YL 38 comparator after calculating the results obtained Vo = -3.3 V and Av = -1 so it can be concluded that the incoming analog value is 4095 to 0, 4095 for 0 volts and 0 for 3.3 volts. Therefore, in the stress mapping process, the value is converted to be 0 -to 4095.
After the analog pin (pin 32) gets the measurement result data then the data is mapped with the initial value from 0 to 4095 becomes 1 to 300. Then the data is divided into each category according to the existing sensor datasheet.

The standards by which the instrument is calibrated are as follows:

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

ppm is defined as parts-per-million

Fig.4. Datasheet of NPK Sensor [19]

Figure 4 shows the value ranges of nitrogen (N), phosphorus (P), and potassium (K). For nitrogen (N) the highest range is at 200 ppm and for phosphorus (P) is at 14 while for potassium (K) is at 200 ppm. Meanwhile, numbers 1 to 300 are obtained from the calculation of the NPK sensor classification.

C. Fertilization System

RTC (Real time Clock) is a digital clock contained in the PLC which is stored in the PLC CPU memory. The author uses RTC as a time input source to adjust the best fertilization time for soybean plants [20]. Fertilization time in the morning, afternoon, and evening, indicating that the stomata open up in the morning. During the day the stomata remain open but not maximally, to reduce evaporation, while in the afternoon the stomata open is greater than during the day. The exact time is 07.00 A.M - 10.00 A.M and 03.00 P.M - 06.00 P.M [21].

Whereas for the ideal soil nutrient availability value for soybean plants, the nitrogen (N) value should not be less than 75 ppm, for the phosphorus (P) value is 11-15 ppm while for potassium (K) is 81-120 ppm [22].

D. IoT Based LoRa

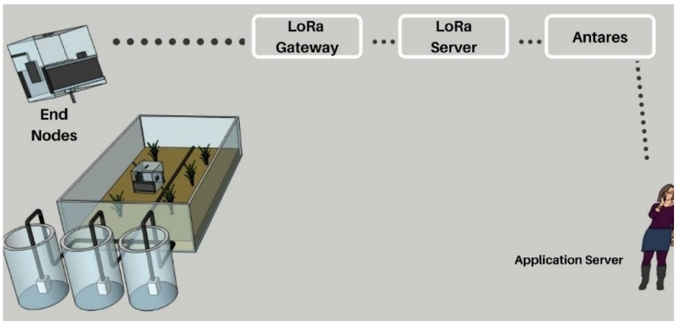

Fig.5. LoRa Network Architecture

LoRa (Long Range) is a radio modulation technology for LPWAN networks based on spread spectrum transmission techniques and CSS modulation (Chirp Spread Spectrum). The data sent is a JSON file because LoRa cannot send data in the form of images, sound, and video [23]. Figure 4 shows the LoRa network architecture with the following functions:

End Nodes function as senders of data sent to the gateway with LoRa RF (Radio Frequency) LoRaWAN [24]. LoRa gateway functions as a device that transmits raw data from End Nodes to the network server with TCP / IP SSL (Secure Socket

Layer) LoRaWAN [24]. LoRa Server is a device that functions to store data and will be sent to the application server with TCP / IP SSL Secure Payload [24]. Antares Database from PT. Telekomunikasi Indonesia. Antares is an IoT platform which function to receive and sends data real time. Antares can also stores historical data so that previous data can be seen and reevaluate for better results [25]. Application Server functions to store and display data to customers [24].

E. Hardware and Components

Table I
Hardware and Components

No	Software	Function
1	Antares LR-ESP201 Board	Microcontroller as a whole system access
2	NPK Sensor	Used to detect the NPK condition
3	Mini DC Pump	To pump water into the soybean plant
4	Relay 5V	For logic switch to activate water pump
5	LCD	To display the NPK condition
6	Solar Panel Power Bank	Energy source fot the device
7	RTC	Time input source to the microcontroller

Table I describes sensors and equipment for the device. There are 7 components that have different functions. For relays, microcontroller, RTC located in the sensor box. Meanwhile, the NPK sensor, LCD, and solar panel power bank are located on the surface of the electronic box. The DC mini pump is located in the NPK fertilizer container.

F. Software and Application

This research requires some software as a program to run the entire system of tools and make applications on the system. Here are some applications and software used.

Table II
Software and Application

No	Software	Function
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

In table II. are shown the software and platforms that can provide an interface from database to application. The first software is the Arduino IDE. Arduino IDE is a software to write and upload program to arduino boards in C and C++ language. Next is the Antares Database from PT.Telekomunikasi Indonesia. Antares is an IoT platform which function to receive and sends data real time. Antares can also stores historical data so that previous data can be seen and reevaluate for better results[25]. The last one is the MIT App Inventor. The MIT App Inventor is a block visual language platform to create android application. It is being managed by Massachusetts Institute of Technology so that people around the world can actualize IoT concept and integrate it from the device to the application. It can receive data from database and display them so it can be read by user. [26]

IV. RESULT AND DISCUSSION

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

A. Transfer and Reading Data Testing

Testing data transfer and reading is required before the IoT process is carried out. This is because if the data transfer fails, the data will not be sent to the database and will not receive the current state of the soybean plant.

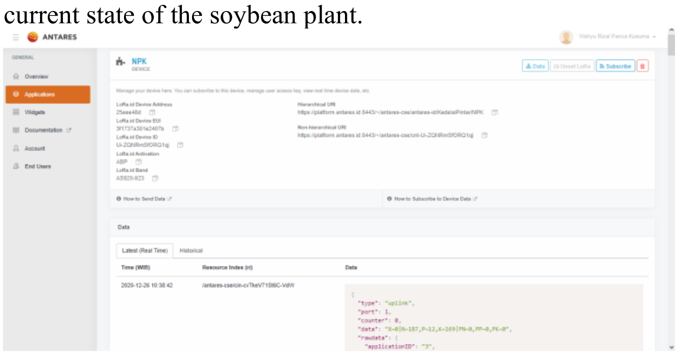

Fig.6. Transfer Data Testing

When sending and reading data, the microcontroller sends the data to Antares. After the data is sent, the microcontroller will run the fertilization process and see the condition of the soybean plants in real time. The process and evidence of data transfer can be seen in Figure 6.

B. Device Functionality Testing

This test is conducted to determine whether the system is successfully operating to monitor and control the automatic watering process of soybean plants. The success parameter used in this test is that the device can operate in accordance with the concept of the system. Following are the test results shown in Table III. below.

Table III
Device Testing

	Component	Function
1	Digital NPK Sensor reads the value of N, P, and K levels in soybean plants	succeed
2	When the NPK value and time are entered in the fertilization parameter, fertilization occurs	succeed
3	LCD displays NPK conditions	succeed
4	Water pump will pump water when the NPK value below the ideal range	succeed
5	Microcontroller will run the command and send data via LoRa to antares	succeed
6	Solar Panel Power Bank will power the device	succeed
7	Display data in android application	succeed

C. Monitoring Testing

This test was conducted to determine the conditions of the nitrogen (N), phosphorus (P), and potassium (K) values in the soybean soil. Following are the results of monitoring carried out. The results of monitoring can be seen in Table IV.

Table IV
Sensor Testing

Soil Sampel	Digital NPK Sensor N (ppm)	P (ppm)	K (ppm)	Value	NPK Sensor Analog Value
Soil Street	12	1	8	6,75	6,77
Rice Fields	128	11	122	5,5	5,5
Rice Fields With 3 grams NPK Fertilizier	300	22	292	<1	<1

It can be seen that the digital NPK sensor can not only display the average NPK value data but can also provide NPK value data separately. With a level of accuracy or data similarity between the analog NPK sensor and the digital NPK sensor of more than 95%.

D. Controlling Testing

This test is carried out to determine whether the automatic fertilization system control is successful according to the instructions given to the microcontroller. The following is the control data for 5 experiments.

Table V
Controlling Testing

Soil Sampel	Digital NPK Sensor N (ppm)	P (ppm)	K (ppm)	Pump Condition Pump N	Pump P	Pump K	Condition
1	125	14	130	OFF	OFF	OFF	>Ideal
2	117	14	128	OFF	OFF	OFF	>Ideal
3	110	15	125	OFF	OFF	OFF	>Ideal
4	90	12	110	OFF	OFF	OFF	>Ideal
5	73	10	78	ON	ON	ON	<Ideal

E. Android Application

Fig.7. Data on Antares

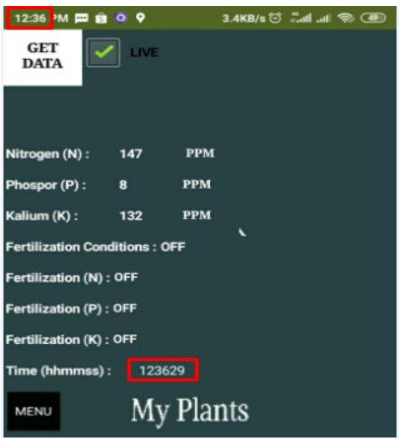

Fig.8. Data on Android Application

It can be seen from Figure 7 and Figure 8 that the data and time received by Antares and the Android application is the same. It can also be seen that the P value is below ideal but fertilization is not running because it is not within the specified time interval. This proves the system is running well.

F. LoRa Network Quality Testing

This LoRa network test is done by disconnecting the LoRa RFm95W antenna, which later functions as a LoRa network receiver from the LoRa gateway located at STO Telkom DDS Bandung. Selection of the appropriate method for determining the current the exact value to the raw data that can influence the results obtained and interpreted thereafter [33]. This testing process is carried out by measuring SNR, packet loss, and delay. The test was carried out for 30 minutes with 6 locations. different, 1 location is 0 km, 4 locations are 1 km away, 1 location is 2.5 km from BTS LoRa.

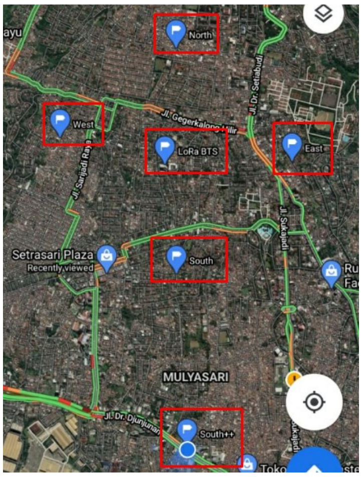

Fig.9. Data on Android Application

G. Delay

The total time to find destination involves broadcasting time and waiting time [32]. Delay is the time it takes for data to be sent to its destination. Delay can be divided between packet length (L, packet length (bit / s)) divided by link bandwidth (R, link bandwidth (bit / s)) [27]. Here are the formulas based on TIPHON.

$$Delay = \frac{Packet\ length}{Link\ bandwidth} \quad (3)$$

Table IV
Delay Category by TIPHON

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

The delay test is divided into 6 locations. different, 1 location is 0 km, 4 locations are 1 km away, 1 location is 2.5 km. The following is a graph of the results of the delay measurement that has been carried out.

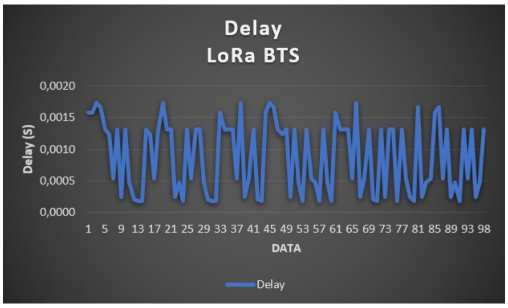

Fig.10. Delay in 0 km

Figure 10 is the result of the delay at 0 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 1 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 0 km from the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

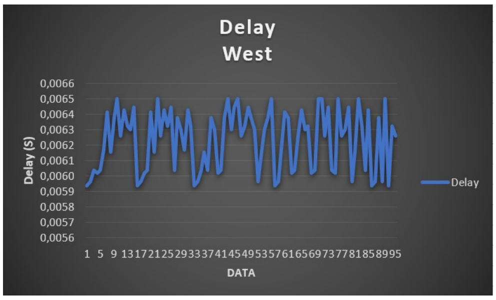

Fig.11. Delay in West Distance 1 km

Figure 11 is the result of the delay at 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 6.3 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 1 km from west the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

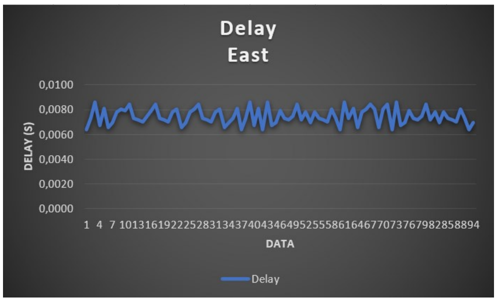

Fig.12. Delay in East Distance 1 km

Figure 12 is the result of the delay at 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 7.5 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 1 km from east the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

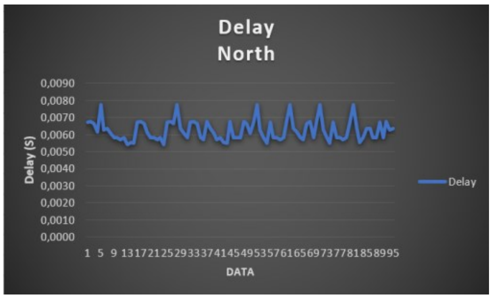

Fig.13. Delay in North Distance 1 km

Figure 13 is the result of the delay at 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 6.2 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 1 km from north the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

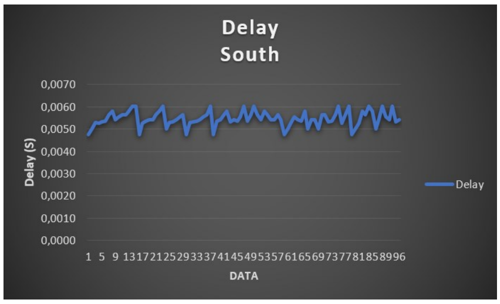

Fig.14. Delay in South Distance 1 km

Figure 14 is the result of the delay at 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 5.5 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 1 km from south the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

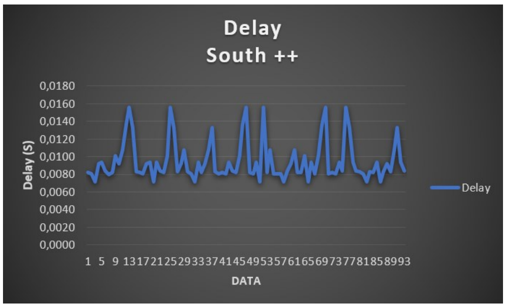

Fig.13. Delay in South Plus Distance 2.5 km

Figure 11 is the result of the delay at 2,5 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average delay of 9.6 ms. As can be seen in Table IV, this score falls into the "very good" category. So it can be serviced that LoRa shipments at a distance of 1 km from west the LoRa gateway get a delay in the "very good" category according to TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks).

From the three average delays that have been obtained, all the average delay results fall into the "very good" category according to TIPHON. When further analyzed of the three values, it shows that the farther the delivery distance from the LoRa gateway, the lower the quality of the resulting delay and the closer the data transmission from the LoRa gateway will increase the quality of the resulting delay.

H. Packet Loss Testing

Packet Loss is a parameter that describes a condition that shows the total number of packets lost, which can occur due to collisions and congestion in the network. If the packet fails to be sent, the packet will not be sent back, or in other words, the packet is lost [27]. The formula for determining Packet Loss and Packet Loss categories is based on TIPHON.

$$\frac{\text{Number of packages sent} - \text{Number of packages received}}{\text{Number of packages sent}} \times 100\% \qquad (4)$$

Table V
Packet Loss Category by TIPHON

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

The packet loss test is divided into 6 locations. different, 1 location is 0 km, 4 locations are 1 km away, 1 location is 2.5 km. This test is done to find out how many failed packets sent to Antares. In this study, data transmission was carried out in 18 seconds once for 30 minutes. This means that the amount of data to be sent to Antares is 100. The following is the packet loss test table for each parameter.

Table V
Packet Loss Testing

Category	Distance (km)	Packet Received	Value	Category
LoRa BTS	0	98	2	Very Good
East	1	94	6	Good
West	1	95	5	Good
North	1	95	5	Good
South	1	96	4	Good
South ++	2.5	93	7	Good

As shown in Table V for the number of packets received and the packet loss value along with the categories according to TIPHON. It can be concluded that for packet loss value, the farther the location from BTS LoRa, the packet loss quality decreases. Even though the distance between 4 locations is the same as 1 km, it also has different values because of the different RSSI values. The average packet loss at a distance of 1 km is 5%.

I. SNR

Signal Noise Ratio (SNR) is a data packet received from a sender whose signal is disturbed by noise interference. The SNR value represents the noise disturbance during the data transmission process on the data quality. The greater the SNR value, the better the received data quality [28]. The following is the formula for getting the SNR value.

$$\text{SNR (dB)} = 10 \log 10 \text{ (S/N)} \qquad (5)$$

The packet loss test is divided into 6 locations. different, 1 location is 0 km, 4 locations are 1 km away, 1 location is 2.5 km. in this study using the spreading factor 10 and minimum SNR value is -12.5 dB. The following is a graph of the results of the SNR measurement that has been carried out:

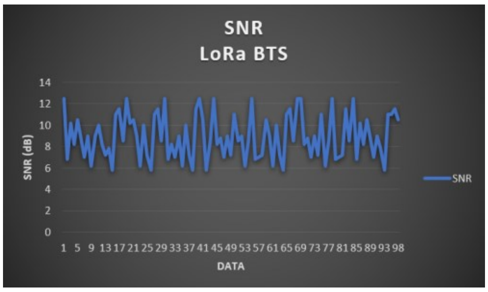

Fig.14. SNR in Distance 0 km

Figure 14 is the result of the SNR at 0 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of 8.9 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at a distance of 0 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

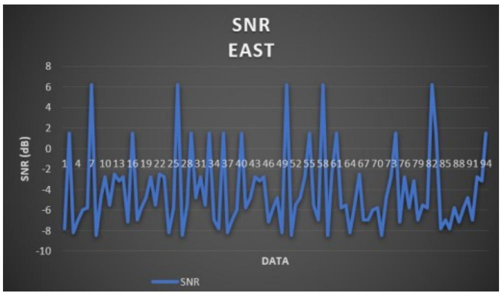

Fig.15. SNR in East Distance 1 km

Figure 15 is the result of the SNR at East 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of -4.22 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at East distance of 1 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

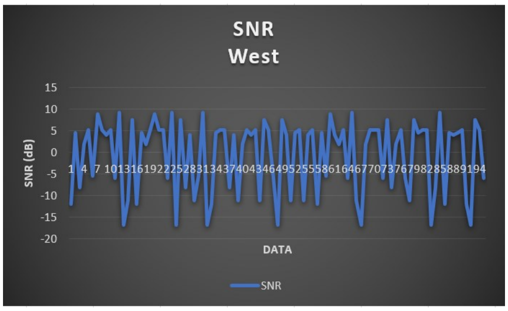

Fig.16. SNR in West Distance 1 km

Figure 16 is the result of the SNR at West 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of -0.6 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at West distance of 1 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

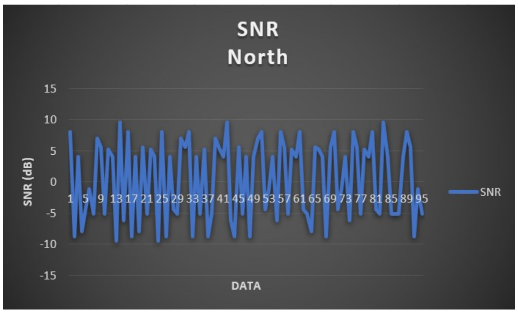

Fig.17. SNR in North Distance 1 km

Figure 17 is the result of the SNR at North 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of 0.44 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at North distance of 1 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

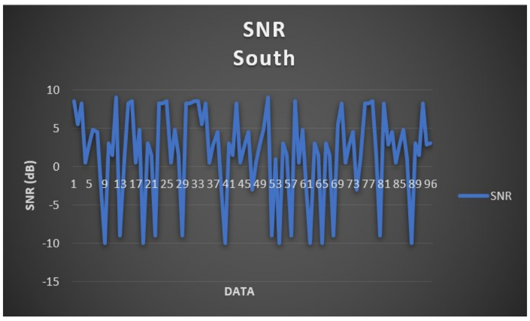

Fig.18. SNR in South Distance 2.5 km

Figure 18 is the result of the SNR at South 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of 1.66 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at South distance of 1 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

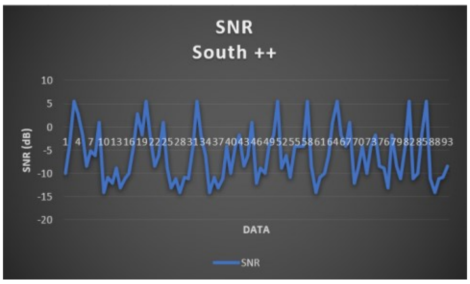

Fig.19. SNR in South Plus Distance 2.5 km

Figure 19 is the result of the SNR at South Plus 1 km from the device to the LoRa gateway. Data was sent for 30 minutes and got an average SNR of -5.88 dB. This score pass the minimum value to use a spread factor of 10. So it can be serviced that LoRa shipments at South Plus distance of 1 km from the LoRa gateway get a SNR value that is suitable for the use of the spreading factor 10.

From the three average SNR that have been obtained, all the average SNR results pass the minimum value to use a spread factor of 10. When further analyzed of the three values, it shows that the farther the delivery distance from the LoRa gateway, the lower the quality of the resulting SNR and the closer the data transmission from the LoRa gateway will increase the quality of the resulting SNR.

J. RSSI

Received Signal Strength Indicator (RSSI) is a parameter to measure the signal strength indicator received by the device. The RSSI value depends on the distance and barrier conditions, the farther and more obstacles the RSSI value will decrease. The maximum value of the RSSI is -120 dBm [28]. The formula for determining the RSSI value is:

$$\text{RSSI (dBm)} = \text{TXPower (dBm)} + \text{TXGain (dBi)} - \text{FreeSpacePathLoss} + \text{RxGain (dBi)} \quad (5)$$

The formula for finding Free Space Path Loss:

$$\text{FSPL (dB)} = 20\log10\,(d) + 20\log\,(f) + k \quad (6)$$

Information:
1. TX Power = transmit power at the transmitting antenna.
2. TX Gain = Gain on the transmitting antenna.
3. RX Gain = Gain on the receiving antenna.
4. d = distance between sender and receiver (km).
5. f = frequency (MHz).
6. K = 32.44 [28].

RSSI is a parameter to measure the signal strength indicator received. The RSSI value depends on the distance and barrier conditions, the farther and more obstacles the RSSI value will decrease. The maximum RSSI value is -120 dBm.

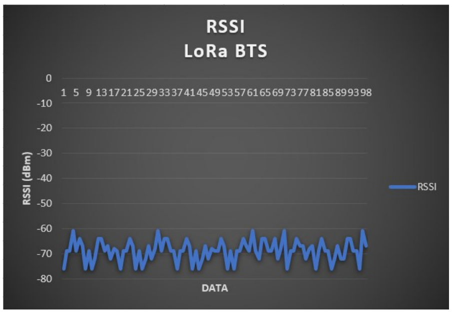

Fig.20. RSSI in 0 km

RSSI results at the LoRa BTS location are 0 km from the LoRa BTS and get an average RSSI of -68.89 dBm and are still below the maximum RSSI value.

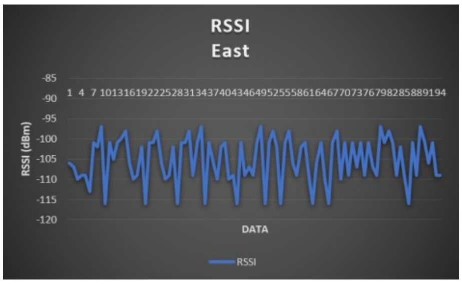

Fig.21. RSSI in East Distance 1 km

RSSI results at the East location are 1 km from the LoRa BTS and get an average RSSI of -105,18 dBm and are still below the maximum RSSI value.

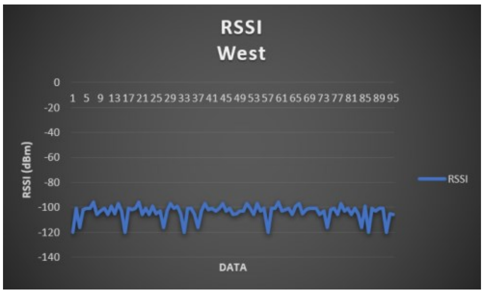

Fig.22. RSSI in West Distance 1 km

RSSI results at the West location are 1 km from the LoRa BTS and get an average RSSI of -102,88 dBm and are still below the maximum RSSI value.

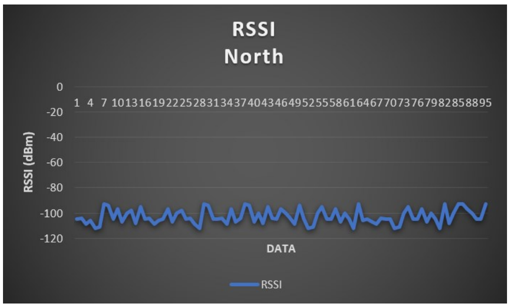

Fig.23. RSSI in North Distance 1 km

RSSI results at the North location are 1 km from the LoRa BTS and get an average RSSI of -103,57 dBm and are still below the maximum RSSI value.

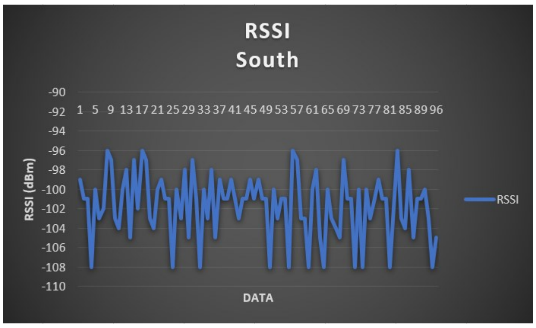

Fig.24. RSSI in South Distance 1 km

RSSI results at the South location are 1 km from the LoRa BTS and get an average RSSI of -101,62 dBm and are still below the maximum RSSI value.

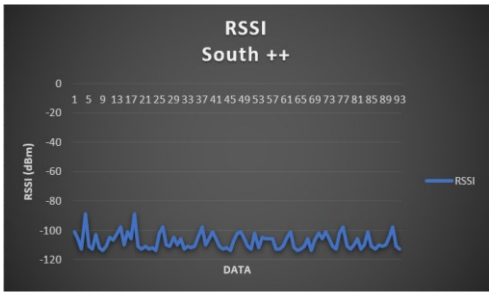

Fig.25. RSSI in South Plus Distance 2.5 km

RSSI results at the South Plus location are 2.5 km from the LoRa BTS and get an average RSSI of -103,31dBm and are still below the maximum RSSI value.

If further analysis of the six values, it can be seen that the farther the transmission distance from LoRa BTS, the lower the quality of the resulting RSSI and the closer the delivery distance from LoRa BTS will improve the quality of the resulting RSSI.

CONCLUSION

We conclude that the total functionality of the system and the device is functioning properly. The fertilization and reading of the value go according to the parameters. To test the quality of network delay, packet loss, SNR, and RSSI at 1 location 0 km, 4 locations 1 km, 1 location 2.5 km from BTS LoRa. For delay and packet loss, the average is included in the excellent category according to TIPHON. For SNR and RSSI all results meet the parameters. So it can be concluded if the parameter selection is suitable for this test and it can be concluded that the farther the transmission distance from BTS LoRa is followed by a decrease in network quality.

REFERENCES

[1] Tamoghna Ojha, Sudip Misra, Narendra, “WSN for agriculture: state of the art in practice and future challenges,” *J. Comput. Electron. Agric.*, 2015, 66–84.

[2] E. Ben-Dor, A. Banin, “Near infrared analysis as a rapid method to simultaneously evaluate several soil properties,” *Soil Sci. Soc. Am. J.* 1993, 364–372.

[3] W. Van Lierop, “Determination of available phosphorus in acid and calcerous soils with the Kelowna multiple-element extractant,” *Soil Sci.*, 1988, 284–291.

[4] A.B. Ghosh, J.C. Bajaj, R. Hasan, Dhyan Singh, “Soil and Water Testing Methods: A Laboratory Manual,” *Division of Soil Science and Agricultural Chemistry,* IARA, New Delhi, 1983.

[5] Aldillah, Rizma, Harianto Harianto, and Heny Kuswanti Suwarsinah Daryanto. “Analisis Simulasi Kebijakan untuk Meningkatkan Produksi Kedelai Nasional,” *Jurnal Agribisnis Indonesia (Journal of Indonesian Agribusiness)* 2.1 (2014): 33-62.

[6] Badan Pusat Statistik, Produksi Padi, Jagung, Kedelai (Angka Ramalan III tahun 2010). Berita Resmi Statistik No. 68/II/Th. XIII, 1 November 2010.

[7] Departemen Pertanian, Mutu Kedelai Nasional Lebih Baik dari Kedelai Impor [Siaran Pers], Jakarta: Badan Litbang Pertanian, 2008.

[8] Azni IN. Formulasi Bahan Makanan Campuran Berbahan Dasar Kedelai, Beras Merah, Dan Pisang Kepok Untuk Makanan Pendamping-Asi. Jurnal Teknologi Pangan dan Kesehatan, *Journal of Food Technology And Health*, 2019, May 27,1(1):1-7.

[9] A.B. Ghosh, R. Hasan, “Nitrogen fertility status of soils of India,” Fertilizer News 25 (11), 1980.

[10] P. Guillemin, F. Berens, M. Carugi, M. Arndt, L. Ladid, G. Percivall, B. De Lathouwer, S. Liang, A. Bröring, P. Thubert, “Internet of Things

Standardisation—Status, Requirements, Initiatives and Organisations," *RIVER PUBLISHERS SERIES IN COMMUNICATIONS*, 2013, p.259.

[11] E.D. Widianto, D. Eridani, R.D. Augustinus, M.S. Pakpahan, "Simple LoRa Protocol: Protokol Komunikasi LoRa Untuk Sistem Pemantauan Multisensor," *TELKA-Telekomunikasi, Elektronika, Komputasi dan Kontrol.* 2019, Nov 27, 5(2):83-92.

[12] P. Rekha, V.P. Rangan, M.V. Ramesh, K.V. Nibi, "High yield groundnut agronomy: An IoT based precision farming framework," in *IEEE Global Humanitarian Technology Conference (GHTC),* 2017, October. (pp. 1-5).

[13] G. Lavanya, C. Rani, P. Ganeshkumar, "An automated low cost IoT based Fertilizer Intimation System for smart agriculture," *Sustainable Computing: Informatics and Systems*, 2020, *28*, p.100300.

[14] D. Perdana, L. Renaldi, I. Alinursafa, "Performance Analysis of Soil Moisture Monitoring based on Internet of Things with LoRA Communications," *Journal of Southwest Jiaotong University*, 2020, *55*(5).

[15] D. Perdana, M. Imadudin, G. Bisono, "Performance Evaluation of Soil Substance Measurement System in Garlic Plant based on Internet of Things with Mesh Topology Network Scenario," *International Journal of Communication Networks and Information Security*, 2019, *11*(3), pp.417-423.

[16] F. Siva, "Smart fertilizer recommendation through NPK analysis using Artificial Neural Networks," Doctoral dissertation, Strathmore University, 2019.

[17] A.F. Rachmani, F.Y. Zulkifli,. "Design of iot monitoring system based on lora technology for starfruit plantation," in *TENCON 2018-2018 IEEE Region 10 Conference* 2018, October, pp. 1241-1245.

[18] N. Cameron, "Radio frequency communication," in *Electronics Projects with the ESP8266 and ESP32*, Apress, Berkeley, CA, pp. 399-436.

[19] Datasheet and Instruction of NPK Sensor.2012. [online]. http://www.lusterleaf.com/img/instruction/1865_instruction.pdf.

[20] G.M. Drown, P. Lu, inventors; Intel Corp, assignee. Integrated circuits for generating input/output latency performance metrics using real-time clock (RTC) read measurement module. United States patent US 10,853,283. 2020 Dec 1.

[21] T. Meirina, S. Darmanti, S. Haryanti, "Produktivitas kedelai (Glycine max (L.) Merril var. Lokon) yang diperlakukan dengan pupuk organik cair lengkap pada dosis dan waktu pemupukan yang berbeda," *Anatomi Fisiologi*, 2009, *17*(2), pp.22-32.

[22] A.G. Manshuri, N. Pemupukan, "P dan K pada kedelai sesuai kebutuhan tanaman dan daya dukung lahan," *J Penelitian Pertanian Tanaman pangan*, 2010, *29*(3), pp.171-179.

[23] J. Rubio-Aparicio, F. Cerdan-Cartagena, J Suardiaz-Muro, J. Ybarra-Moreno, "Design and implementation of a mixed IoT LPWAN network architecture," *Sensors*, 2019, *19*(3), p.675.

[24] A. Dash, S. Pal, C. Hegde, "Ransomware Auto-Detection in IoT Devices using Machine Learning," *no. December*, 2018, pp.0-10.

[25] A.F. Rachmani, F.Y. Zulkifli, "Design of iot monitoring system based on lora technology for starfruit plantation," in *TENCON 2018-2018 IEEE Region 10 Conference*, 2018, October, pp. 1241-1245.

[26] E.D. Widianto, M.S. Pakpahan, R. Septiana, "LoRa QoS Performance Analysis on Various Spreading Factor in Indonesia," in *2018 International Symposium on Electronics and Smart Devices (ISESD)* 2018, October, pp. 1-5.

[27] L. M. Aversa Villela, "Analisis Parameter Lora Pada Lingkungan Outdoor," *J. Chem. Inf. Model.*, 2020, vol. 53, no. 9, pp. 1689–1699.

[28] D. P., S. K. M., and N. C., "Automatic Plant Irrigation using Solar Panel," *Int. J. Web Technol.*, vol. 5, no. 2, pp. 114–115, 2017, https://doi.org/10.20894/ijwt.104.005.002.00.

[29] Nuryanto, Lilik Eko., "Penerapan Dari OP-AMP (Operational Amplifier)," *Orbith: Majalah Ilmiah Pengembangan Rekayasa dan Sosial*, 2017, 13.1.

[30] Raditya Yoga Asditama, "Prototype of Automatic Fertilization Control System for Soybean Plants Based on the Internet of Things," 2020.

[31] K.P. Mhatre, U.P. Khot, „Minimizing Delay Using New Dynamic Blocking Expanding Ring Search Technique for Ad hoc Networks," *International Journal of Electronics and Telecommunications*, 2020, Nov 22, 66(4):723-8.

[32] K. Kuliński, A. Heyduk, "Frequency response testing of zero-sequence current transformers for mining ground fault protection relays," *International Journal of Electronics and Telecommunications*, 2020, Nov 22, 66(4):701-5.

[33] K. Kuczynski, A. Bilski, P. Bilski, J. Szymanski, "Analysis of the magnetoelectric sensor's usability for the energy harvesting," *International Journal of Electronics and Telecommunications*, 2020, 66.