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Performance Analysis of LoRaWAN Class A and Class C in the Measurement of Nutrient Content Systems

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Abstract: This research was evaluated the measurement of the nutrient contents of Nitrogen (N), Phosphorus (P), and Potassium (K) in the soil using Antares LR201 microcontroller board and LoRaWAN class A and class C networks with ANTARES platform as the network server. Later the data was monitored and controlled using an Android application which aims to compare the two types of networks. In this study, several tests were carried out, namely SNR, RSSI, delay, and packet loss. The test was carried out in the city of Bandung with different LoRa signal strength that could be seen on Telkom IoT web. Based on experiment, LoRaWAN class C has higher QoS performance for delay, SNR, RSSI, and packet loss than LoRaWAN class A for test location distance of 0, 1, 2, and 4 km away from BTS LoRa. According to the ITU-T G.1010 standard, the delay value produced in this experiment is in the "Very good" category, packet loss value is in the Very good "category", and the RSSI value is in the "Enough" category. And the SNR value is in the recommended category of SF10. Also, it can be concluded that the redder LoRa coverage location map reveals, the better QoS value obtained. In testing the sending and receiving of downlink data in terms of delay, according to the downlink data mechanism in class A, downlink data can be sent if the uplink data has been sent. While class C downlink data can be sent at any time.

Keywords: Delay, IoT, LoRaWAN, Nitrogen, Phosphorus, Potassium, RSSI, SNR.

1. Introduction

Indonesia is an agricultural [1] country where most people do farming both as farmers on small lands and as farmers in industrial plantations [2]. It is widely known that soil fertility is an important aspect in agriculture and fertilization is important in soil [3-5] fertility management strategy for yielding the crops. However, in Indonesia, farmers are recently still fertilizing the soil in a traditional way, by doing manual fertilization, i.e. going directly to agricultural land to do the fertilization.

Internet of things (IoT) [6-9] can connect people with devices and can share data in real time. IoT makes it easier for humans to do various jobs. IoT has an important role to save energy and time in doing work leading to the work efficiency [10, 11]. IoT can be applied to various sectors because it can work as a monitor and controller [12, 13].

One of the networks used is the LoRa (Long Range) network which is one of the types of LPWAN (low power wide area network) communication systems [14, 15]. LPWAN is a type of network that has a wide coverage area and is a wireless telecommunication that allows a long-distance communication. LoRa network is claimed to be accessible up to a distance of 100 kilometers [16].

LoRaWAN [17] is a protocol from LoRa which has several types, namely class A, B, and C. In previous research, a tool that uses IoT technology has been made to monitor soil nutrient fertilization using LoRa (long range) technology with class A LoRaWAN type. Based on the previous research, the contribution of this research are we evaluate the smart watering system based on NPK value, and we also analysed the 2 types of LoRaWAN class, i.e., Class A and class C in terms of quality of service (QoS) with SF10 to monitor and control the levels of nutrients (nitrogen (N), phosphorus (P), and potassium (K)) contained in the soil. Hence, the soil nutrient is controllable and plant fertilization is easier. Test location distance from base station (BTS) LoRa varies between 0, 1, 2, and 4 kilometers. QoS parameter measured including delay, SNR, RSSI, and packet loss. The result conducted from this research will be able to recommend the best LoRaWAN class used in a system based on QoS and specified distance.

The rest of this paper is divided into several sections: section 2 presents some previous related works, section 3 details our system model, section 4 covers our experiment result and discussion, section 5 provides the conclusions of this research.

2. Related works

There have been some studies related to LoRa. One of them is a design and analysis of soil substance measurement system on chili plant based on LoRa LPWAN radio access technology [18]. This study tried to create a device that could measure the levels of Nitrogen (N), Phosphorus (P), Potassium (K) in chili plantation land directly using an NPK sensor that was connected to the internet. This device was connected to the internet using the concept of the internet of things and using LPWAN LoRa technology resulted in broad coverage and power saving. Sensor detection results could then be displayed via an Android application. This study used LoRaWAN class A network protocol and a 2400mAh battery in its application. The study revealed that the device could last up to 5 hours in a full-featured state and last up to 7 hours without the use of LCDs. LoRa radio parameter testing was carried out in 2 locations at a distance of 712 meters and 3.47 kilometers from the central gateway. It is obtained from the distance of 712 meters that the average RSSI value was -96.921 dBm and average SNR value was 7.284 dB, with a delay of 0.012 seconds and a packet loss of 20 %. However, it is obtained from the distance of 3.47 km that was an average RSSI value of -113.314 dBm and an average SNR value of -9.685 dB. With a delay of 0.064 seconds and a packet loss of 61 [19].

Previous studies had also resulted in the prototype of automatic fertilizer control system in soybean plant based on internet of things and LoRa. This study however tried to design a prototype of an automatic fertilization system for chilies based on the values of nitrogen (N), phosphorus (P), and potassium (K).

The system design is integrated with internet and can be accessed by users in real time through an Android application which is the concept of the internet of things (IoT). The data transmission in this system, however, uses LoRa (Long Range) radio modulation technology. Antares LR-ESP201 Board is used as the microcontroller while this system also sends data to Antares as the database.

Further, this study used a digital NPK sensor that has been calibrated resulted in accuracy rate is 95 %. This research was conducted at 8 test points, namely 1 location at 0 km away, 4 locations at 1 km away, 1 location at 2.5 km away, 1 location at 8.5 km away, and 1 location at 9 km away from BTS LoRa. The results of the test parameters are RSSI, the worst RSSI value was -113.11 dBm at the distance of 8.5 km and the best was -68.89 dBm at the distance of 0 km. Related to SNR testing using spreading factor 10 towards the six average SNR data obtained, all the average SNR results passed the minimum value to use spreading factor 10. In the delay test using 125 kHz bandwidth and code rate 45, all delay values obtained were in the “very good” category according to TIPHON [20] while in the packet. However, the automatic fertilizer system can run 100 % [21].

The implementation, monitoring and controlling system of nutrients and soil moisture in chili plants based on IoT using LoRa. Additionally, this research tried to design a system that can measure the levels of Nitrogen (N), Phosphorus (P), and Potassium (K) in the soil in chili plantations directly (real time-monitoring) using NPK sensors and maintain soil moisture with an automatic watering system (real time-controlling) using YL-69 sensor and Antares LR-ESP201 Board as the microcontroller. The cloud used in this research was ANTARES, while LPWAN LoRA technology at a frequency of 920-923 MHz is used in this system as the data transmission communication. The device made in this study used a 5000mAh power bank as a power supply that could last up to 12 hours without any problems. The delay required to send data from the device to ANTARES was 3.4 seconds [22].

Table 1. Hardware and components

No	Hardware	Function
1	Antenna LoRa	To receive and transmit signals at a frequency of 921.4 MHz
2	Antares LR201 board	As a microcontroller
3	LCD 20x4	To display the data
4	Power bank	Energy source for the device
5	Relay	As a switch for the water pump
6	NPK Sensor	To scanning soil nutrient levels

Table 2. Software and platforms

No	Software	Function
1	Arduino IDE	As a platform for coding Microcontrollers
2	Antares IoT Platform	As a cloud to store data and integrate devices
3	MIT App	As a platform for creating Android applications

Table 3. Datasheet NPK sensors

No	Nutrient Elements	Too little	Ideal	Too much
1	Natrium (N)	50 ppm	50-199 ppm	> 200 ppm
2	Phosphor (P)	4 ppm	5-13 ppm	> 14 ppm
3	Kalium (K)	50 ppm	51-199 ppm	> 200 ppm

Table 4. SNR category [29]

No	Spreading factor	Signal to noise ratio (dB)
1	8	-17.5
2	9	-15
3	10	-12.5
4	11	-10

Table 5. RSSI category [30]

No	RSSI (dBm)	Category
1	>-70	Very Good
2	-70 to -85	Good
3	-86 to -100	Enough
4	<-120	Bad

3. System model

3.1 Hardware

Table 1 lists equipment used in this study. Each device has a different function. Antares LR201 board is as a microcontroller with RFM95 LoRa transceiver module and ESP32 module embedded on the board [23]. To receive and transmit signals to the research board, a LoRa antenna works at a frequency of 921.4 MHz. The NPK sensor is used to measure the levels of nutrients such as nitrogen (N), phosphorus (P), and potassium (K) [23, 25]. The LCD is used to display the results of NPK nutrient levels. Power bank is used for device power supply. And the relay is used as a switch to turn the pump on and off. And the relay is used as a switch to turn the pump on and off.

3.2 Software

Table 2 shows the software and platforms used in this study. Arduino IDE is used as the software to program microcontrollers [26]. ANTARES IoT Platform is the cloud used to store data from IoT sensors that can be accessed anytime and anywhere. ANTARES is agnostic to various sensors and connectivity and supports several IoT protocols. MIT App inventor is an open-source web application developed by Google. MIT App Inventor is an easy web application for novice users Who are trying to make their first Android applications. Android application is used to display NPK sensor measurement results.

3.3 System design

This system uses Antares LR201 board as the microcontroller in which the ESP32 module and LoRa module are embedded as shown in Fig. 1. For communication between devices using a LoRa gateway with class A and C LoRaWAN network protocols. LoRaWAN has a data encryption function to build a secure wireless network. LoRaWAN has some specifications where it is open source and supported by the LoRa Alliance. This system uses a frequency of 921.4 MHz.

KOMINFO notifies that in Indonesia, LoRaWAN occupies a frequency of 920 MHz to 923 MHz. In this system, NPK sensors are used to scan soil nutrients. The data obtained by the NPK sensor is then displayed on an LCD. The data obtained is also sent to the ANTARES IoT platform and then processed in such a way in the MIT App Inventor application so that it becomes an Android application that can display data from NPK sensors and control soil fertilization.

Fig. 2 shows the system workflow. It started from the integration of the source code on Antares LR201 board. Then the NPK sensor scans the soil nutrient levels.

The data generated by the NPK sensor was then received by the Antares LR201 board. Prior to that, the data went through a conversion process from analog values to digital values so that the data could be received by the Antares LR201 board.

The received data was then displayed on the LCD and sent to the ANTARES platform via the LoRaWAN network with the LoRa gateway. The data received by the ANTARES platform was then sent and displayed in the Android application. The data displayed in the Android application can be monitored by the user of the application. Users can also add fertilizer by clicking the button on the application.

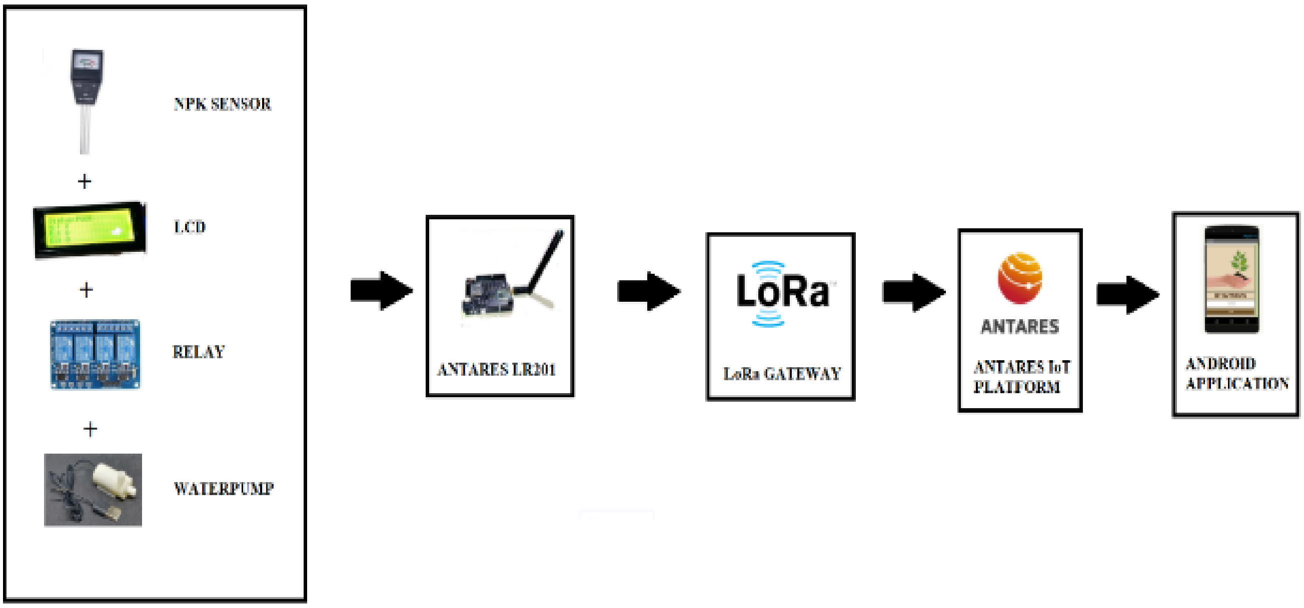


Figure. 1 System design

3.4 NPK sensor design

Fig. 3 shows mapping requires the maximum output voltage emitted from NPK sensor. 3.3 Volt voltage was chosen because it is more stable when it is used with ADC bits going into ESP3212 bits or about 4095 [27]. The status used to indicate the data is generated by the NPK sensor. The status indications used are” Ideal”,” Poor”, and” Too much”.

Table 3 shows the datasheet of the NPK sensor which has 3 status indications, namely “Ideal”, “Too little”, and “Too much” based on the table from the NPK sensor datasheet above, each status has a different range [28].

3.5 Uplink and downlink mechanism

Fig. 4 shows flowchart of the data uplink mechanism of LoRaWAN class A and C. In terms of sending uplink data, there is no difference between the two types of LoRaWAN. In this study, data uplink was the process of sending data from a device to an application. First, the device sent data. Second, the data was sent to the LoRa gateway. Third, data from the LoRa gateway was forwarded to the LoRa network server. Fourth, the network server sent data to the ANTARES platform.

Fig. 5 shows flowchart of the data downlink mechanism in LoRaWAN class A. First, the downlink command was received by the ANTARES platform from the Android application. Second, the ANTARES platform sent downlink commands to the network server. Third, the network server prepared the downlink request and sent it to the ANTARES platform. Fourth, the ANTARES platform processed the downlink request, generated the downlink payload and sent the downlink request to the network server. Fifth, the network server received the download payload and stored it. Sixth, the device sent an uplink message to the network server. Seventh, the network server got the stored downlink payload and immediately generated the downlink message and sends it to the device. Eighth, the end device received the downlink message and executed the downlink command.

Fig. 6 shows flowchart of the data downlink mechanism in LoRaWAN class C. First, the downlink command was received by the ANTARES platform from the Android application. Second, the ANTARES platform sent downlink commands to the network server. Third, the network server prepared the downlink request and sends it to the ANTARES platform. Fourth, the ANTARES platform processes the downlink request, generates the downlink payload and sends the downlink response to the network server. Fifth, the network server gets the stored downlink payload and immediately generates the downlink message and sends it to the device. Sixth, the end device receives the downlink message and executes the downlink command.

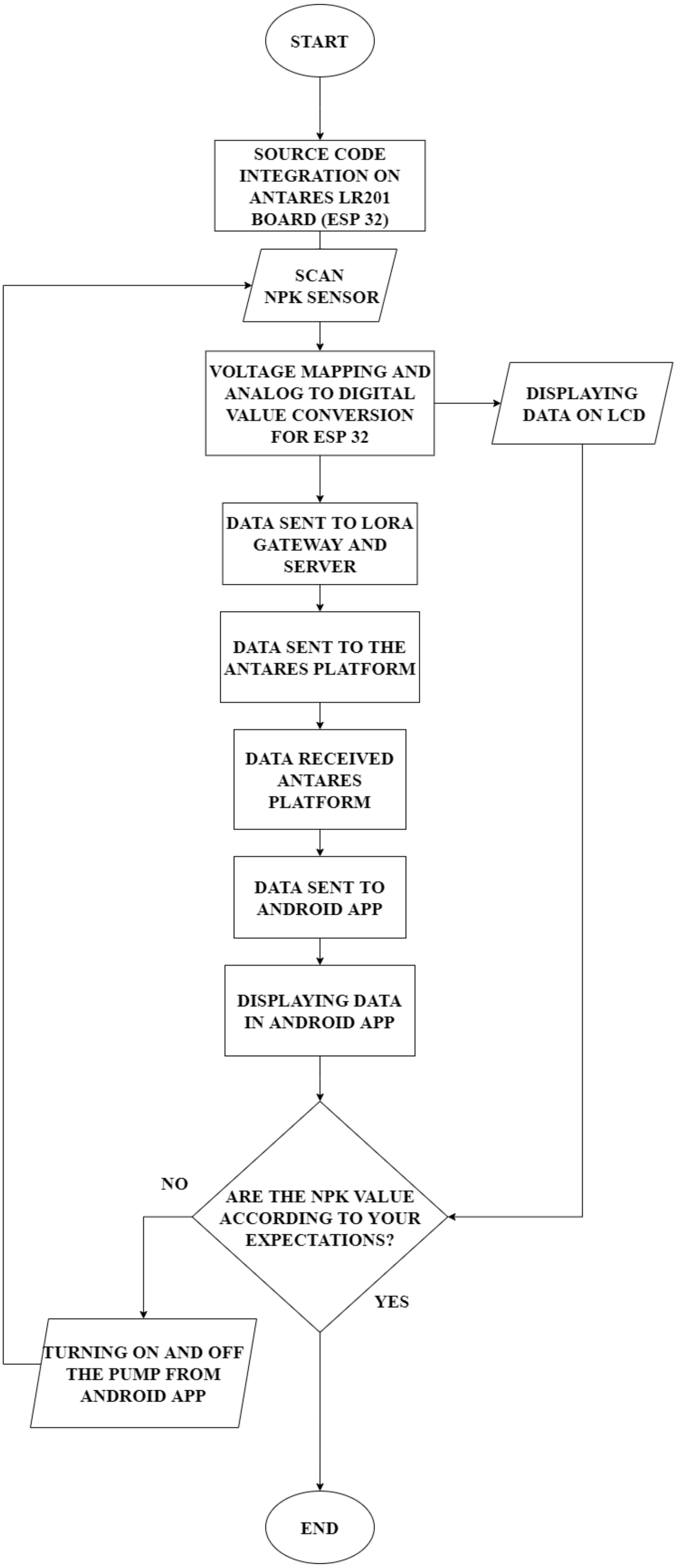
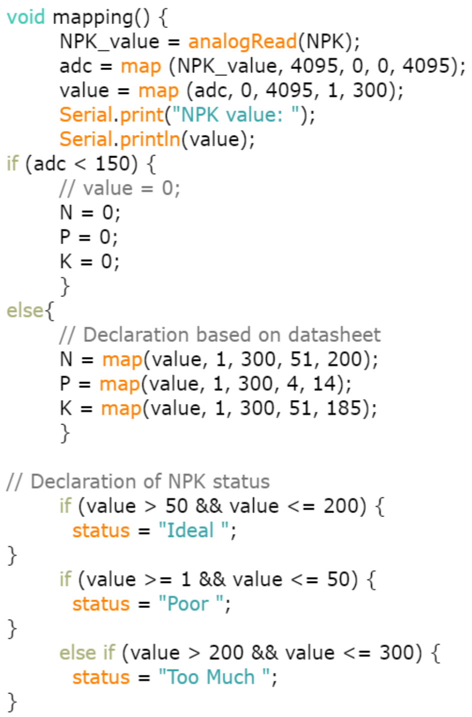


Figure. 2 Flowchart design



```
void mapping() {
        NPK_value = analogRead(NPK);
        adc = map (NPK_value, 4095, 0, 0, 4095);
        value = map (adc, 0, 4095, 1, 300);
        Serial.print("NPK value: ");
        Serial.println(value);
if (adc < 150) {
        // value = 0;
        N = 0;
        P = 0;
        K = 0;
        }
else{
        // Declaration based on datasheet
        N = map(value, 1, 300, 51, 200);
        P = map(value, 1, 300, 4, 14);
        K = map(value, 1, 300, 51, 185);
        }

// Declaration of NPK status
        if (value > 50 && value <= 200) {
          status = "Ideal ";
}
        if (value >= 1 && value <= 50) {
          status = "Poor ";
}
        else if (value > 200 && value <= 300) {
          status = "Too Much ";
}
```

Figure. 3 Mapping voltage

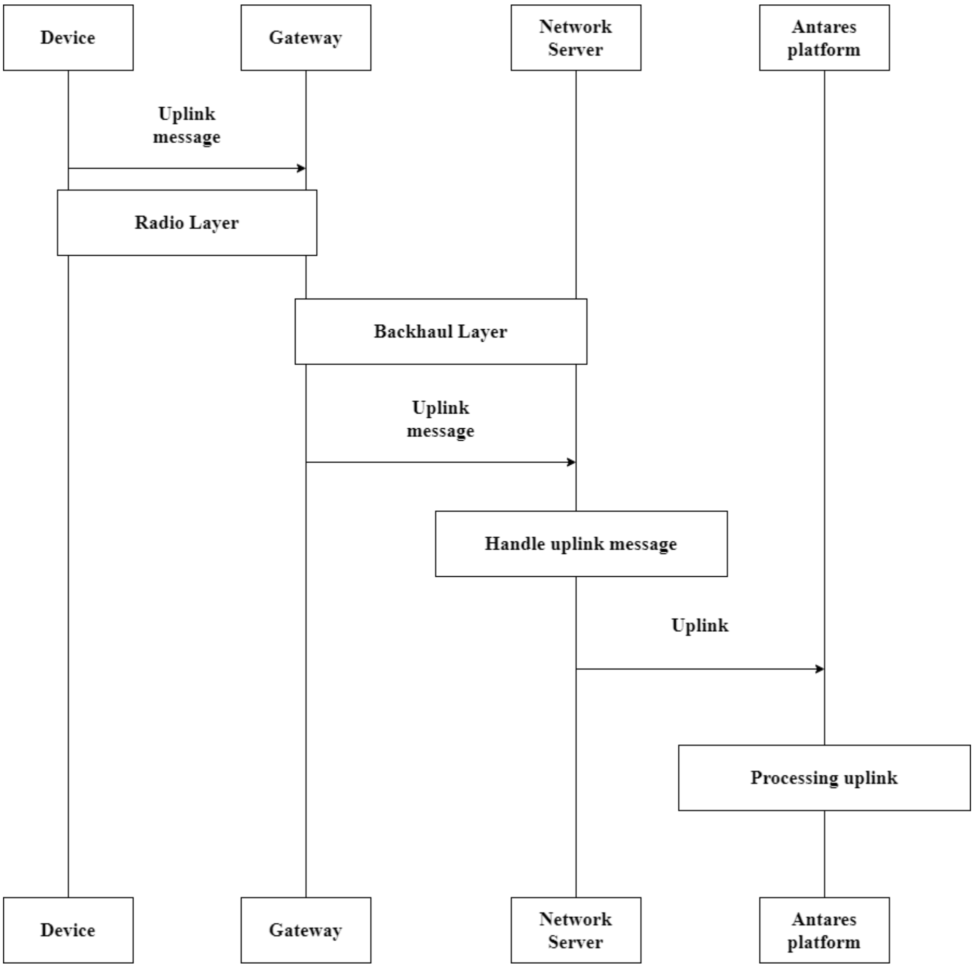


Figure. 4 Flowchart uplink data

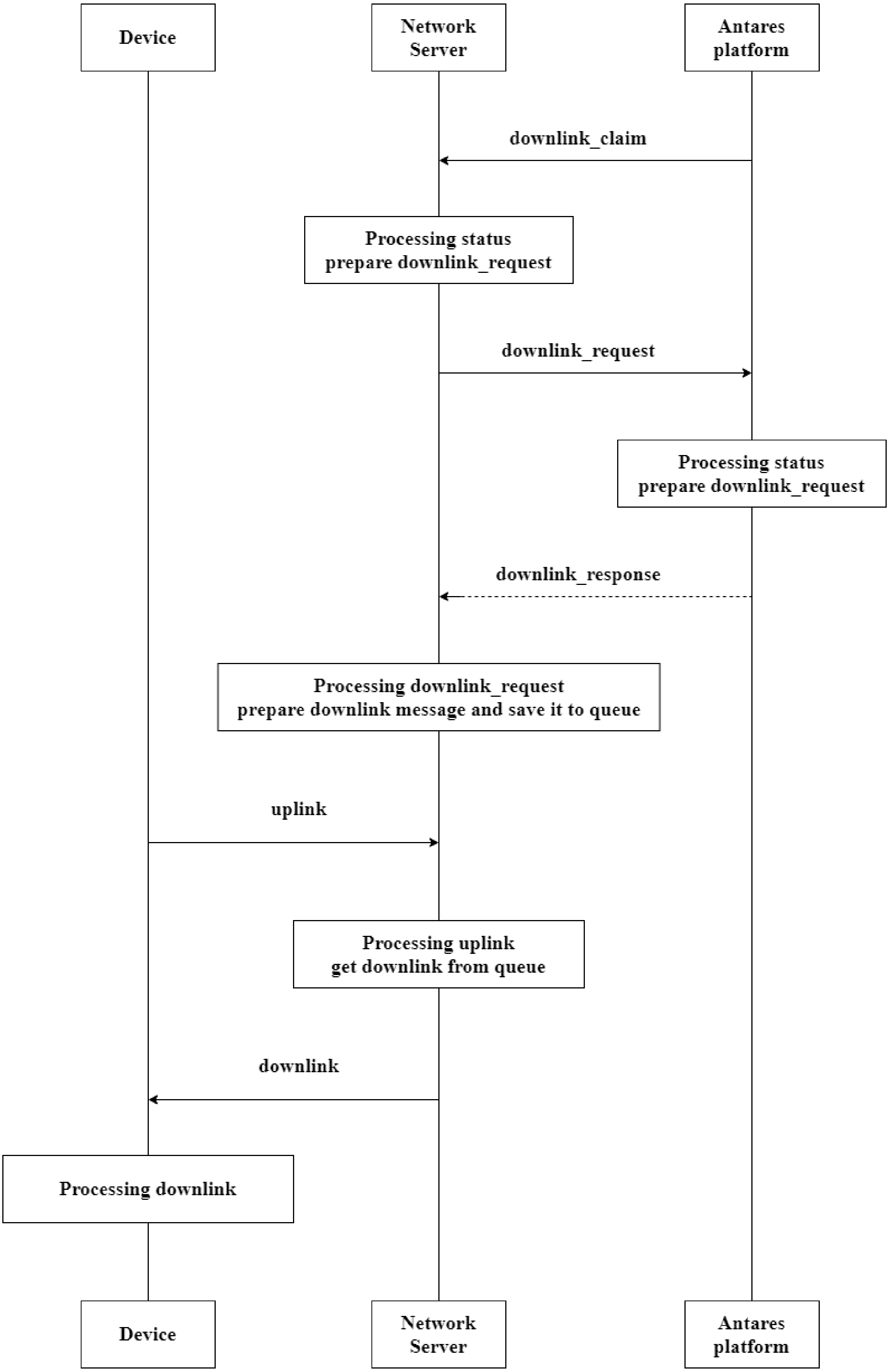


Figure. 5 Flowchart downlink data class A

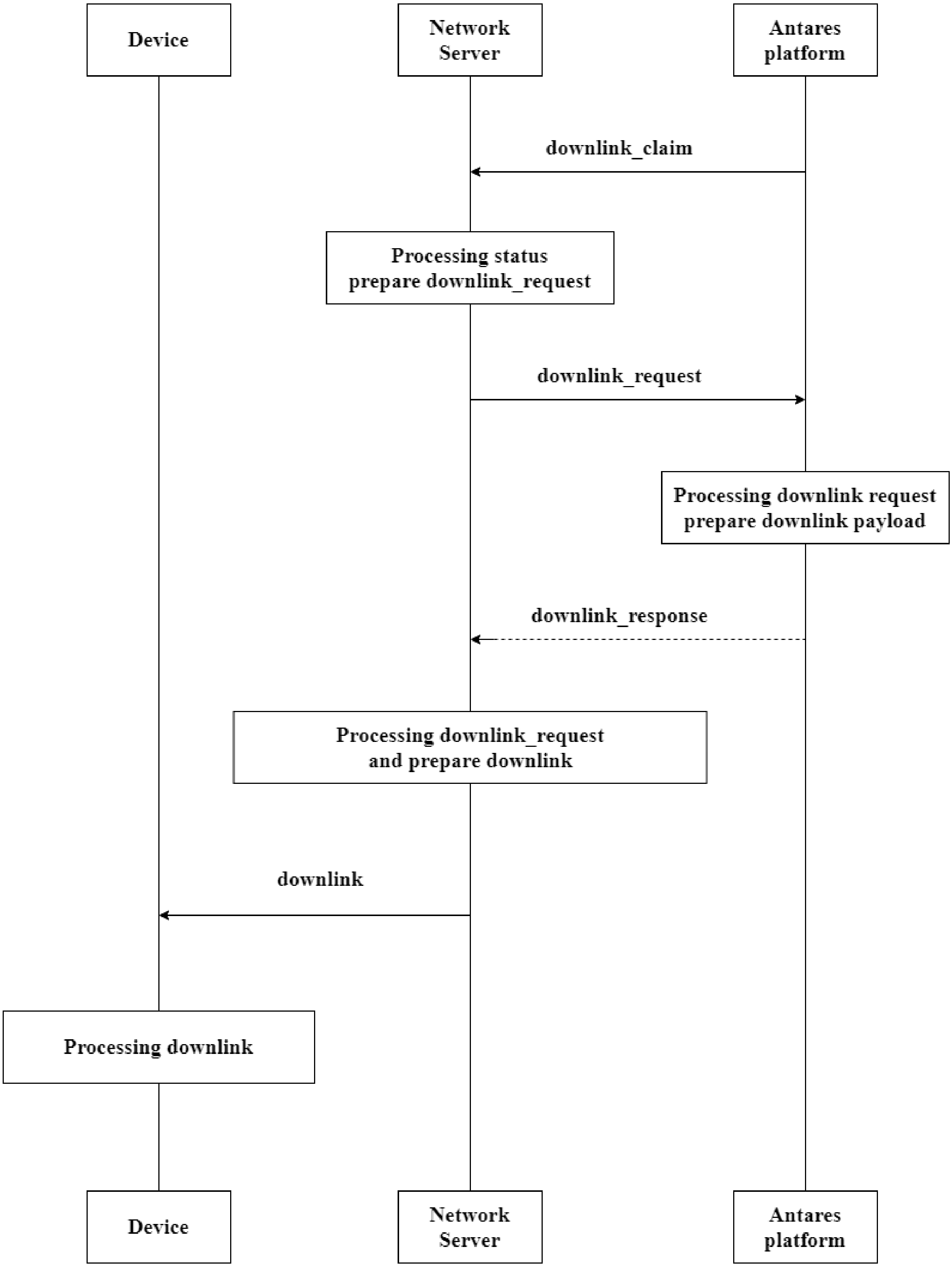


Figure. 6 Flowchart downlink data class C

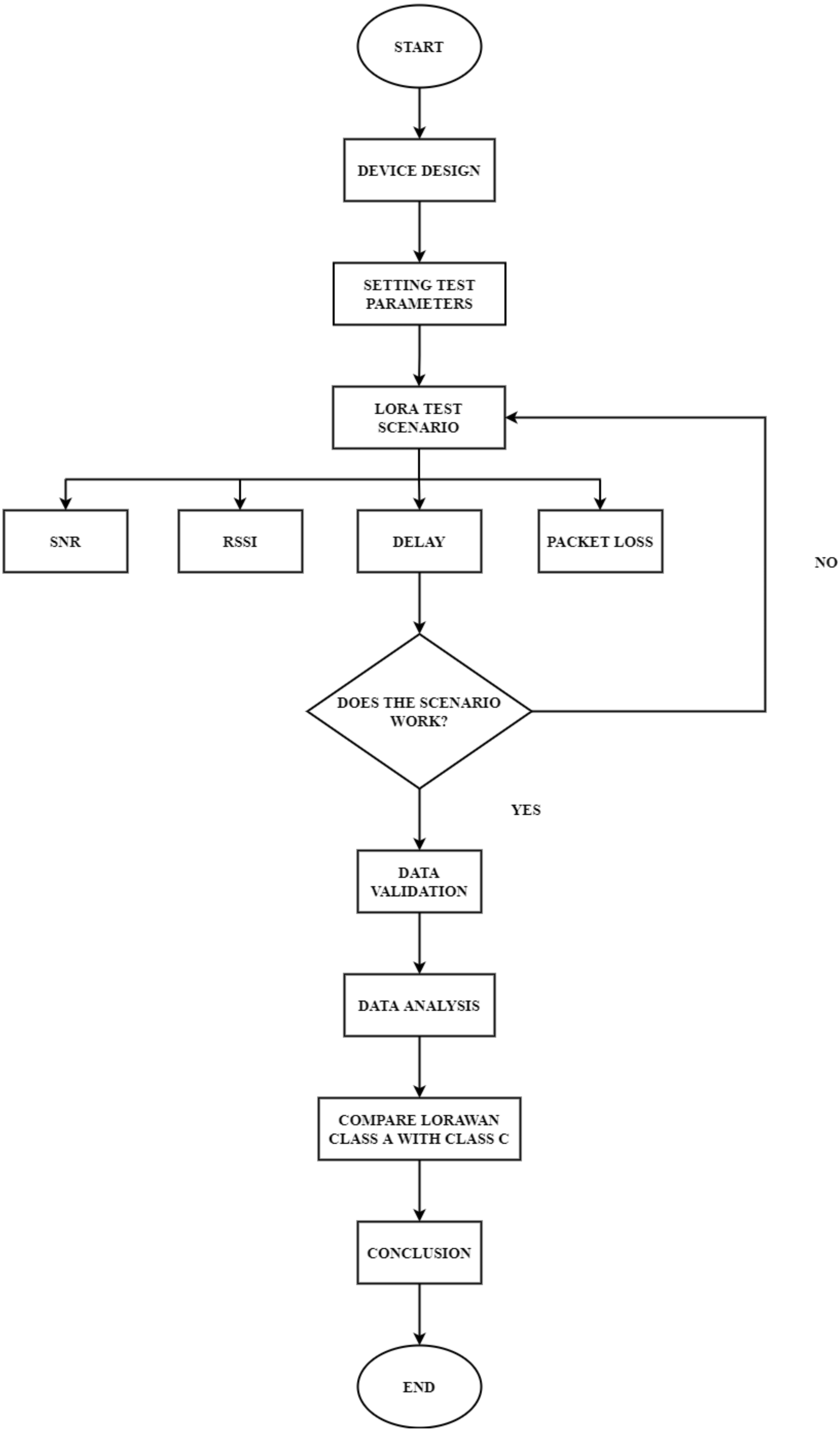


Figure. 7 Test system

Table 6. Delay category [31]

No	Delay (ms)	Category
1	<150	Very Good
2	150 to 300	Good
3	300 to 450	Enough
4	>450	Bad

Table 7. Packet loss category [20]

No	Packet Loss (%)	Category
1	0 to 2	Very Good
2	3 to 14	Good
3	15 to 24	Enough
4	>25	Bad

Table 8. Device testing

No	Hardware	Result
1	Antenna LoRa can receive and Successful transmit signals at a frequency of 921.4 MHz	Successful
2	Antares LR201 board can send data and integrated with another components & Successful	Successful
3	LCD 20x4 can display data from microcontroller and sensors	Successful
4	Power bank can supply power to the device	Successful
5	Relay can switch on and off the pump	Successful
6	NPK Sensor can scan the soil nutrient levels	Successful

3.6 Test system

The system is tested and analyzed using system measurement parameters shows in Fig. 7. In this study, 2 systems with different network protocols, namely LoRaWAN class A and Class C were compared compared and analyzed. The test results were compared with the LoRa and QoS (quality of service) parameters with the ITU-T G1010 standard. In this study, the parameters of the test were SNR, RSSI, delay, and packet loss.

3.7 SNR (signal to noise ratio)

SNR is used to measure the power signal received by the user by the strength of the noise (interference) shows in Table 4. The smaller the SNR value, the less power the user gets. The SNR value is determined in dB (decibels). In the LoRa network, the SNR value is related to the spread factor of the value. The spread factor is the signal spread factor in the LoRa network that affects the sensitivity of the receiver. The following is the formula for calculating the SNR value:

$$SNR(dB) = 10\ log_{10}\left(\frac{S}{N}\right) \qquad (1)$$

3.8 RSSI (received signal strength indicator)

RSSI is a parameter that shows the receiving power of the overall signal in the channel frequency band used. The RSSI value is expressed in dBm shows in Table 5. The further the RSSI value is from 0, the worse the signal will be. RSSI has a minimum value of -120 dBm. The following is the formula for determining the RSSI value:

$$RSSI(dB) = T_xPower(dBm) + T_xGain(dBm) - FreeSpacePathLoss + R_xGain(dBm) \qquad (2)$$

3.9 Delay

Delay is the amount of time a packet takes to travel from source to destination. Delay defines the speed and capacity in the network [32]. The delay value is expressed in second shows in Table 6. The following is the formula for determining the delay [29]:

$$Delay\ =\ Time\ Packet\ Received - Time\ Packet\ Sent \qquad (3)$$

3.10 Packet loss

Packet loss is the number of packets that fail to reach their destination when sending packets. If the packet fails to be sent then the packet will not be sent back, or it can be concluded that the packet is lost [33]. The packet loss value is expressed in percentage shows in Table 7. The following is the formula for determining packet loss:

$$PacketLoss = \frac{DataPacketSent - DataPacketReceived}{DataPacketSent} \times 100\% \qquad (4)$$

4. Result and discussion

This chapter discusses tool functionality testing and comparison of data results on class A and C class LoRaWAN networks.

4.1 Device testing

This test was carried out to determine the end node (sensor) used to work properly according to the desired function. The results can be seen in the Table 8. The results obtained from the device that has been made. It worked well as expected. The device was successful in monitoring soil nutrient levels N, P, K by displaying indications of soil nutrient status,

Table 9. Result of analog and digital sensors

Soil sample	Monitoring data					Conclusion
	NPK sensor digital				NPK sensor analog	
	N	P	K	Status	Status	
Sample 1	0	0	0	Poor	Poor	Successful
Sample 2	137	9	128	Ideal	Ideal	Successful
Sample 3	151	10	141	Too much	Too much	Successful

namely” Ideal”,” Poor”, and” Too much” according to the data sheet used. In testing this NPK sensor, the original analog sensor was used as a comparison of results. If the device made produces the same value as the original analog NPK sensor, then the test is said to be successful.

In the test, three status indications were used to represent the levels of NPK elements in the soil. The first is” Poor” which means the soil contains too little NPK content. The second is” Ideal” which means the soil contains sufficient NPK element. The third is” Too much” which means the soil contains too much NPK element.

4.2 Monitoring testing

The results obtained from the device that has been made. It worked well as expected. The device was successful in monitoring soil nutrient levels N, P, K by displaying indications of soil nutrient status, namely” Ideal”,” Poor”, and” Too much” according to the data sheet used. In testing this NPK sensor, the original analog sensor was used as a comparison of results. If the device made produces the same value as the original analog NPK sensor, then the test is said to be successful.

In the test shows in Table 9, three status indications were used to represent the levels of NPK elements in the soil. The first is” Poor” which means the soil contains too little NPK content. The second is” Ideal” which means the soil contains sufficient NPK element. The third is” Too much” which means the soil contains too much NPK element.

4.3 Uplink data test

In this study, the data uplink was sent from the device to the ANTARES IoT platform and the Android application with delivery set every 20 seconds in a duration of 20 minutes a duration of 20 minutes.

The results of the data uplink on LoRaWAN class A. The data was successfully sent with a delivery delay from the serial monitor to the ANTARES platform and the Android application of 1 second.

The results of the uplink data on LoRaWAN class C. The data was successfully sent with a delivery delay from the serial monitor to the ANTARES platform and the Android application of 1 second and testing on LoRa radio parameters and QoS LoRa radio parameter testing is done by retrieving radio parameter data that can be accessed through the ANTARES platform. The test was carried out in the city of Bandung at 4 different points, namely at Location 1 for Telkom DDS Gegerkalong at 0 km away from BTS LoRa, location 2 for Pertamina Setiabudi gas station at 1 km away from BTS LoRa, location 3 for Warung Sate Bu Ngantuk at 2 km away from BTS LoRa, and location 4 for Balakecrakan Punclut at 4 km away from BTS LoRa.

There is a map of LoRa signal strength coverage in the city of Bandung. There were 5 colors to indicate LoRa signal strength. Red color indicates” Strong” LoRa signal, orange means” Medium” LoRa signal, yellow means” Weak” LoRa signal, green means” Very weak” LoRa signal, and blue means” No signal” [34].

4.4 Delay test

Fig. 8 is a graph of the average delay value at all test points. The following is a description of the average delay value at each point:

1. Location 1 for Telkom DDS Gegerkalong at 0 km away from BTS LoRa: Class A had an average delay of 0.001978534763 milliseconds (ms), while class C had an average delay of 0.001686661978 ms. In that area, the average delay value from class C was smaller than class A.
2. Location 2 for Pertamina Setiabudi gas station at 1 km away from BTS LoRa: Class A had an average delay of 0.004928093692 ms, while class C had an average delay of 0.004009956921 ms. In that area, the average delay value from class C was smaller than class A.
3. Location 3 for Warung Sate Bu Ngantuk at 2 km away from BTS LoRa: Class A had an average delay of 0.00634218816 ms, while class C has an average delay of 0.006148413606 ms. In that area, the average delay value from class C is smaller than class A.
4. Location 4 for Balakecrakan Punclut at 4 km away from BTS LoRa: Class A has an average delay of 0.008794122655 ms, while class C had an average

delay of 0.007137477201 ms. In that area, the average delay value from class C is smaller than class A.

According to the TIPHON standard in Table 6. The delay value generated in this study is in the "Very Good" category.

4.5 SNR test

Fig. 9 shows the average SNR value at all test points. The following is the description of the average SNR value at each point:

1. Location 1 for Telkom DDS Gegerkalong at 0 km away from BTS LoRa: Class A had an average SNR of 9.823333333 decibels (dB), while Class C has an average SNR of 9.61866667 dB. In that area, the average SNR value of class C is smaller than class A.
2. Location 2 for Pertamina Setiabudi gas station at 1 km away from BTS LoRa: Class A has an average SNR of 1.895 dB, while class C has an average SNR of -1.3825 dB. In that area, the average SNR value of class C is smaller than class A.
3. Location 3 for Warung Sate Bu Ngantuk at 2 km away from BTS LoRa: Class A had an average SNR of -3.553333333 dB, while class C has an average SNR of -2.194915254 dB. In that area, the average SNR value of class C is smaller than class A.
4. Location 4 for Balakecrakan Punclut at 4 km away from BTS LoRa: Class A had an average SNR of -4.050847458 dB, while Class C has an average SNR of -6.045 dB. In this area, the average SNR value of class C is greater than class A.

According to the TIPHON standard in Table 4. The SNR value generated in this study corresponds to the spreading factor 10 scale used, namely -12.5 dB to +10dB.

4.6 RSSI test

Fig. 10 is a graph of the average RSSI value at all test points. The following is the description of the average RSSI value at each point:

1. Location 1 for Telkom DDS Gegerkalong at 0 km away from BTS LoRa: Class A had an average RSSI of -73.65 decibel-milliwatt (dBm), while class C has an average RSSI of -77.35 dBm. In that area the average RSSI value from class C is greater than class A. According to the TIPHON standard in Table 5, the RSSI value generated in that area was in the" Good" category.
2. Location 2 for Pertamina Setiabudi gas station at 1 km away from BTS LoRa: Class A had an average RSSI of -108.7666667 dBm, while class C had an average RSSI of -107.4666667 dBm. In that area the average RSSI value from class C was smaller than class A. According to the TIPHON standard in Table 5. The RSSI value generated in that area is in the “Poor” category.
3. Location 3 for Warung Sate Bu Ngantuk at 2 km away from BTS LoRa: Class A had an average RSSI of -113.35 dBm, while class C has an average RSSI of -110.8135593 dBm. In this area the average RSSI value of class C is greater than class A.
4. Location 4 for Balakecrakan Punclut at 4 km away from BTS LoRa: Class A had an average RSSI of -110.6779661 dBm, while class C has an average RSSI of -112.05 dBm. In that area the average RSSI value from class C is greater than class A.

According to the TIPHON standard in Table 5, the RSSI value generated in that area was in the “Enough” category.

4.7 Packet loss test

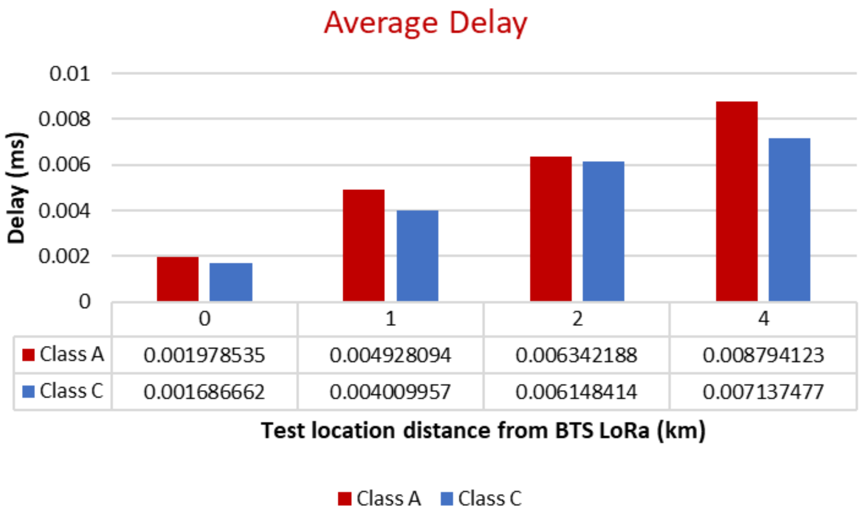
Table 10 shows the result of packet lost at all test points. In this study, data collection was carried out for 20 minutes with a delay of 20 seconds for each delivery at each test point. The amount of data to be sent to Antares was 60 data per location point. According to the TIPHON standard, the packet loss results obtained in this study were in the” Very good” category. The higher the percentage of packet loss is, the lower the network quality.

4.8 Downlink data test

In this study, the data downlink process was carried out when controlling manual fertilizer was carried out from an Android application made with MIT APP Inventor. In the downlink test, the resulting delay data is taken and then a comparison conclusion is made from class A and class C. In the application, 6 ON and OFF buttons were made for each N, P, and K fertilizer. The following is a snippet of the data downlink command that occurs when the user clicks the ON and OFF buttons for the fertilizer: The commands:

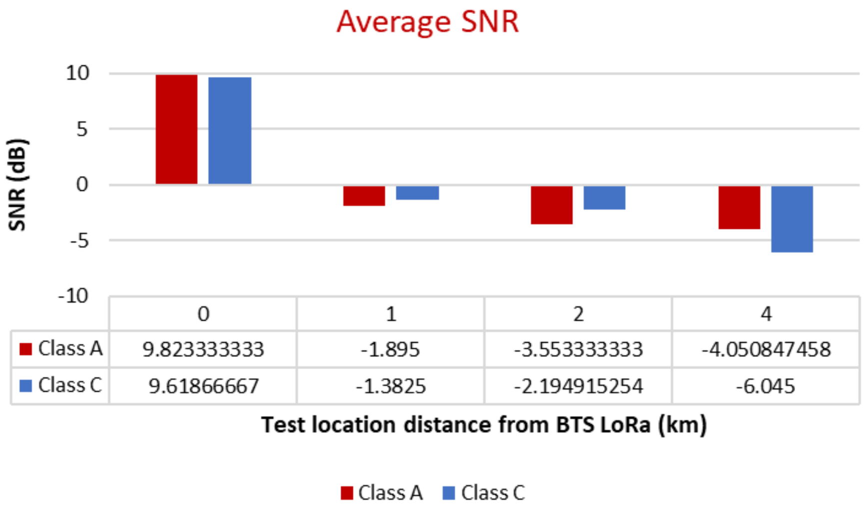
```
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"a\" }"}}
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"b\" }"}}
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"c\" }"}}
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"d\" }"}}
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"e\" }"}}
{"m2m:cin":{"con":"{\"type\":\"downlink\", \"data\": \"f\" }"}}
```

The snippet of the data downlink command created in the MIT App Inventor application. From the Android application, the user can control the fertilizer by pressing the ON and OFF buttons in the application. Explanation of the above commands:



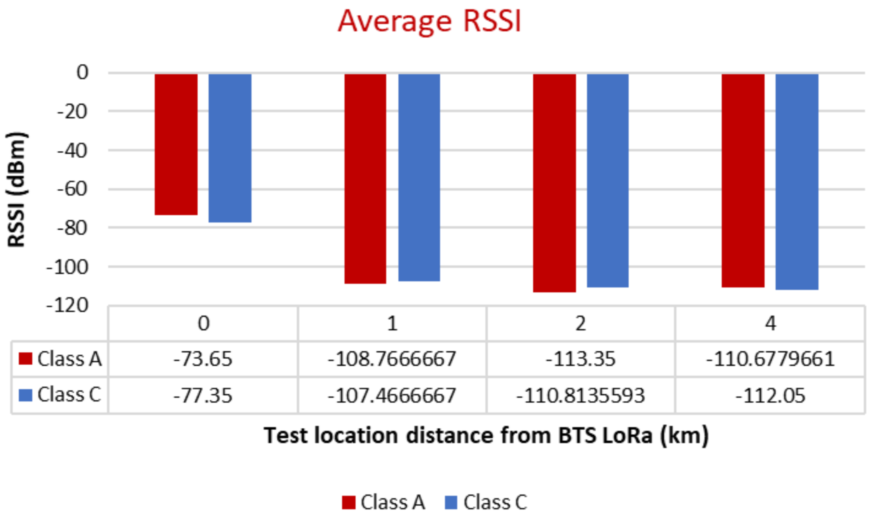
	0	1	2	4
🟥 Class A	0.001978535	0.004928094	0.006342188	0.008794123
🟦 Class C	0.001686662	0.004009957	0.006148414	0.007137477

Figure. 8 Result of average delay



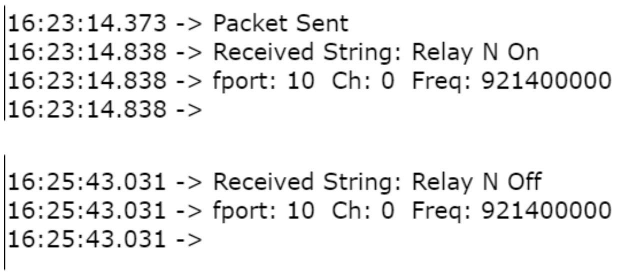
	0	1	2	4
🟥 Class A	9.823333333	-1.895	-3.553333333	-4.050847458
🟦 Class C	9.61866667	-1.3825	-2.194915254	-6.045

Figure. 9 Result of average SNR



	0	1	2	4
🟥 Class A	-73.65	-108.7666667	-113.35	-110.6779661
🟦 Class C	-77.35	-107.4666667	-110.8135593	-112.05

Figure. 10 Result of average RSSI



```
16:23:14.373 -> Packet Sent
16:23:14.838 -> Received String: Relay N On
16:23:14.838 -> fport: 10  Ch: 0  Freq: 921400000
16:23:14.838 ->

16:25:43.031 -> Received String: Relay N Off
16:25:43.031 -> fport: 10  Ch: 0  Freq: 921400000
16:25:43.031 ->
```

Figure. 11 Downlink data displaying on serial monitor

Table 10. Result of packet loss

Location distance from BTS LoRa (km)	**Data received by class A**	**Data received by class C**	**Packet loss by class A (%)**	**Packet loss by class C (%)**
0	60	60	0	0
1	60	60	0	0
2	59	60	1.67	0
4	59	59	1.67	1.67
Total	238	239	3.34	1.67

Table 11. Result of downlink data

Location distance from BTS LoRa (km)	**Delay by class A**	**Delay by class C**
0	12 minutes 1 second	1 second
1	12 minutes 4 second	3 second
2	12 minutes 5 second	4 second
4	12 minutes 17 second	5 second

Data “a” for Nitrogen fertilizer ON button
Data “b” for Nitrogen fertilizer OFF button
Data “c” for Phosphor fertilizer ON button
Data “d” for Phosphor fertilizer OFF button
Data “e” for Potassium fertilizer ON button
Data “f” for Potassium fertilizer OFF button

The downlink command data that goes to the ANTARES platform from the Android application. The data is then passed to the device. If the downlink data is received by the device, then the data will be visible on the serial monitor.

Fig. 11 shows that the downlink data that was successfully sent to the device.

4.9 Downlink data result

At the time of testing, from the data generated shows in Table 11. It is revealed that every 12 minutes of the send of data tested, at location 1 for Telkom DDS Gegerkalong at 0 km away from BTS LoRa in class A show that there was a delay of 2 seconds, while in class C, the delay was 1 second. Class A network at location 2 for Pertamina Setiabudi gas station at 1 km away from BTS LoRa showed a 44-second delay, while class C showed a 3- second delay. At location 3 for Warung Sate Bu Ngantuk at 2 km away from BTS LoRa in class A, there was a is a delay of 5 seconds and in class C there was a delay of 4 seconds. And in location 4 for Balakecrakan Punclut at 4 km away from BTS LoRa in class A, there was a delay of 17 seconds and in class C, there was a delay of 5 seconds. These results can be affected by the coverage of the test area. The results of the downlink in Class A had a longer delay than the Class C because in Class A, the downlink data were received together with the uplink data process. However, in class C, downlink data could be received at any time because the mechanism for downlink data from the two types of LoRaWAN is different as described in section 3.

5. Conclusion

The analysis to the results leads to the following conclusion. Based on the test results, all hardware and software in this study were successfully executed and functioned properly as expected. In terms of uplink data transmission, the data generated on packet loss parameters with a percentage of 1 and 1.01 are in the” Very good” category according to the TIPHON standard. In terms of sending uplink data, the smallest average delay value in class A is revealed at Location 1 for Telkom DDS Gegerkalong area at 0 km away from BTS LoRa of 0.001978534763 ms. However, the average value of the largest delay is revealed at location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa of 0.008794122655 ms with overall 4 test point average of 0.005510734818 ms. In class C, the smallest delay is revealed at location 1 for Telkom DDS Gegerkalong area at 0 km away from BTS LoRa of 0.001686661978 ms. The average value of the largest delay is revealed at location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa of 0.007137477201 ms with overall 4 test point average of 0.004745627427 ms. When the overall average delay values of class A are compared to those of class C, it is revealed that the class C has the smallest delay values with “very good” category under the TIPHON standard.

In terms of sending uplink data, the data generated on the RSSI parameter with the smallest RSSI average value in class A is in the location 1 for Telkom DDS Gegerkalong area at 0 km away from BTS LoRa, which is -73.65 dBm. The largest RSSI average value is revealed at location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa of -101.6111582 dBm with overall 4 test point average of -101.6111582 dBm while in class C, the smallest RSSI in the revealed at location 1 for Telkom DDS Gegerkalong area at 0 km away from BTS LoRa of -77.35 dBm. The average value of the largest delay at location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa is of -112.05 dBm with the overall 4 test point average of is -101.9200565 dBm.

When the overall RSSI average value of class A is compared to that of class C, class A shows the smallest delay value with “Poor” category according to the TIPHON standard in terms of sending uplink data, from SNR parameter with spreading factor 10, reveals that the minimum SNR value according to the TIPHON standard is -12.5 dB and the maximum value is +10 dB. In class A the worst SNR value is in the Location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa, which is -4.05 dB, and the best SNR value is in the location 1 for Telkom DDS Gegerkalong area, which is 9.82 dB with the overall average SNR value of the 4 test locations, which is 0.0810381355 dB. While in class C the worst SNR value is in the location 4 for Balakecrakan Punclut area at 4 km away from BTS LoRa, which is -6.045 dB and the best SNR value is in the location 1 for Telkom DDS Gegerkalong area at 0 km away from BTS LoRa, which is 9.61 dB with the overall average SNR value of the 4 test locations is -0.00093714675 dB. When compared, the overall average SNR value of class A and class C, the best SNR value is class A according to the TIPHON standard. From the QoS data in terms of sending the resulting uplink data, it can be concluded that the redder on the lora coverage location map, the better the QoS value obtained. In testing the sending and receiving of downlink data in terms of delay, according to the downlink data mechanism in class A, downlink data can be sent if the uplink data has been sent. While in class C downlink data can be sent at any time. Sending and receiving data goes as expected. All components of the device can work optimally. Antares LR201 micro-controller can send data to the Antares platform, Android applications can display data according to the data on the Antares platform, and the process of controlling fertilizer from the Android application has been successfully carried out by the device.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

Conceptualization, methodology, writing—review and editing: Doan Perdana and Dini Annaiya Alfatikhah, Validation: Doan Perdana, Dini Annaiya Alfatikhah, and Ibnu Alinursafa; Formal analysis, writing—original draft preparation, and software: Abdul Aziz Marwan.

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