# Analysis of LoRaWAN Network Signal Coverage and Quality Parameters in Real-Time: Case Study of Cikumpa River Water Quality Monitoring, Depok City

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## Abstract

In the context of an increasingly advanced era, Internet of Things (IoT) technology has emerged as a significant innovation across a range of fields. One of the most rapidly developing Internet of Things (IoT) technologies is the Long Range Wide Area Network (LoRaWAN). LoRaWAN is capable of long-distance communication while simultaneously consuming minimal power. In this study, we analyze the coverage of the LoRaWAN network in transmitting data with Cikumpa river water objects, with a 100–600 meters distance between the transmitter (TX) and receiver (RX). This study assesses the RSSI network quality, LoRaWAN SNR, and LoRaWAN network QoS quality concerning throughput, delay, jitter, and packet loss parameters. The testing results demonstrated that the LoRaWAN network coverage reaches a maximum distance of 600 meters. Researchers conducted the testing in the Cikumpa River area. They then analyzed the RSSI and SNR test results in the morning, afternoon, and evening. The results of the RSSI test and calculations demonstrate that as the distance between the transmitter and receiver increases, the RSSI value decreases. The RSSI testing conducted in the morning exhibited a range of -99 dBm to -121 dBm, with the SNR values spanning from -3.25 dB to 8.75 dB. The results of the daytime RSSI tests ranged from -104 dBm to -124 dBm, with the corresponding SNR values ranging from -8.50 dB to 9.00 dB. The RSSI test results for the afternoon period exhibited a range of -96 dBm to -120 dBm, while the SNR demonstrated a range of -7.25 dB to 9.00 dB. In addition, the quality of service (QoS) can be considered stable based on the results of the RSSI and SNR for each test. During the testing process, conducted at distances between 100 and 600 meters, there was no packet loss when data transmission occurred. This research demonstrates the potential for utilizing LoRaWAN technology to monitor a desired object remotely.

**Keywords:** LoRaWAN, Throughput, Delay, Jitter, Packet Loss, RSSI, SNR, QoS, IoT.

## I. INTRODUCTION

In the increasingly advanced digital era, Internet of Things (IoT) technology has emerged as a significant innovation across various fields, including environmental monitoring [1]. One of the most rapidly expanding Internet of Things (IoT) technologies is the Long Range Wide Area Network (LoRaWAN). The LoRaWAN technology can communicate over long distances with highly efficient power usage. It is an optimal solution for environmental monitoring applications requiring wide-area coverage and extended battery life [2], [3].

We trialled the LoRaWAN network on the Cikumpa River, which traverses the Sukmajaya subdistrict. The river's length is approximately 7.25 kilometres [4]. However, to ensure optimal data transmission, it is essential to consider the impact of various factors that can influence the signal, including the distance between devices, potential frequency interference, and the environmental conditions during the testing period. These factors have the potential to impact the strength and quality of the signal, underscoring the importance of conducting comprehensive testing to optimize the system's performance and ensure the secure and reliable transmission of data [5].

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Furthermore, an analysis of the quality of service (QoS) of the LoRaWAN network is essential. Quality of Service (QoS) is a metric used to assess the overall performance of a network. It aims to define the characteristics and properties of a service, providing a quantitative measure of its quality. We derive the quality of service (QoS) category by summing all index values for specific parameters, such as throughput, latency, jitter, and packet loss [6]. In this flow monitoring research, QoS is crucial in ensuring the timely delivery of data collected and sent by the sensor [7].

## II. RESEARCH METHODS

This research employs an experimental methodology to evaluate the functionality of the system or tool under development as shown in Figure 1. The papers tested the system using two LoRa-communicating devices that sent and received data. We predetermined the transmission and reception paths and collected the data from the test results [8] [9]. The study commenced with an examination of the existing literature on the application of LoRa in a variety of systems and objects. Subsequently, determine the LoRa parameters for measuring water salinity. Next, initiate the scenario design, select the tools, and assemble the system. Test the system, collect data, and evaluate and analyze the results [10] [11].

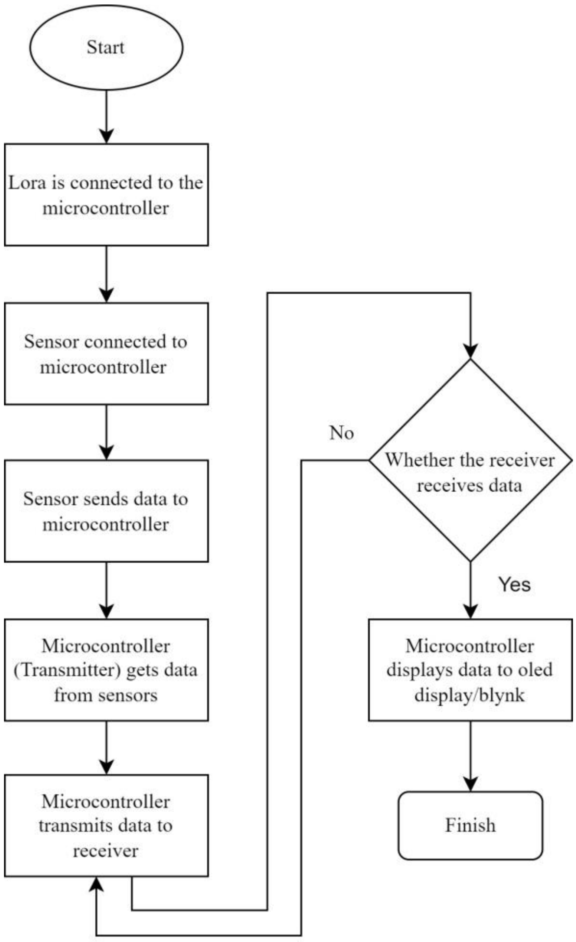

Figure 1. System Flowchart

### A. Long Range Wide Area Network (LoRaWAN)

LoRa is a low-power, wide-area network (LPWAN) communication system that employs modulation techniques to facilitate transmission over extended distances. The modulation employed in LoRa is of the FM variety. This modulation allows the insertion of low-frequency information into the carrier wave [12] [13] [14]. Implementing wireless networks in open areas presents a significant challenge when conducting tests or research. Outdoor environments are open and highly influenced by natural conditions like weather, vegetation, water sources, and mobile organisms. Outdoor environments are subject to more rapid and frequent changes than indoor environments [15]. Therefore, data transmission devices are incumbent upon considering environmental conditions when measuring data to ensure greater accuracy. The presence of outdoor obstacles results in signal attenuation and fluctuations. The presence of attenuation raises the possibility that the distance cannot be accurately determined [16]. In this study, we employed the LoRa SX1278 Ra-02 module as shown in Figure 2, commonly used by researchers, to facilitate communication between data senders and receivers.

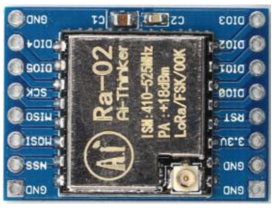

Figure 2. LoRa Module

### B. ESP32 Microcontroller

The ESP32 is a single-chip microcontroller integrated with Wi-Fi and Bluetooth modules (Figure 3). It boasts several noteworthy features, including the ability to serve as a solution for devices with limited resources. Its compatibility with external modules makes it an ideal choice for Internet of Things (IoT) applications [17].

Figure 3. ESP32 Microcontroller

### C. TDS Sensor

The TDS sensor (Figure 4) works using the electrical conductivity method, where two probes are dipped into a liquid to measure the level of conductivity, which is affected by the content of ion particles and electrolyte properties in the liquid. The sensor has three pins: DATA, VCC, and GND. The DATA pin connects to GPIO 27 (analog) on the ESP32, VCC connects to the 3V3 pin, and GND connects to the ESP32 ground. The signal processing circuit on the sensor produces an output that shows the conductivity of the solution based on the working principle of the electrode. [18] [19].

Figure 4. TDS Sensor

### D. Map of Research Points in Cikumpa River

Researchers conducted the study at multiple points along the Cikumpa River, dividing it into two upstream sections, four downstream sections, and one in the middle. The first research point lies 100 meters apart, directly between the receiver and sender. A map of the research points appears in the Figure 5-6 below.

Figure 5. Research Points Upstream on the Cikumpa River

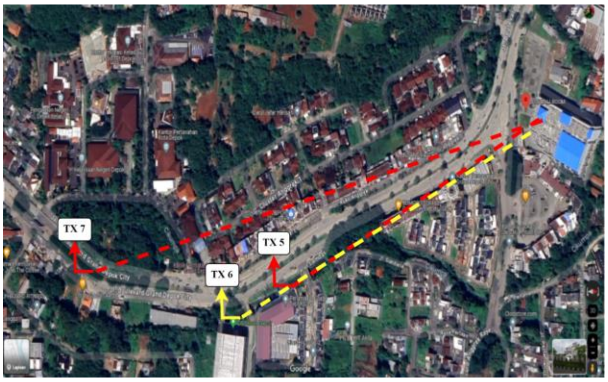

Figure 6. Downstream Research Point on the Cikumpa River

### E. Receiver Wiring

The process of receiver wiring involves integrating cables and components to incorporate receivers into a system or circuit (Figure 7). A receiver is a device that receives signals or information transmitted by a transmitter in a wireless communication, monitoring, or other system.

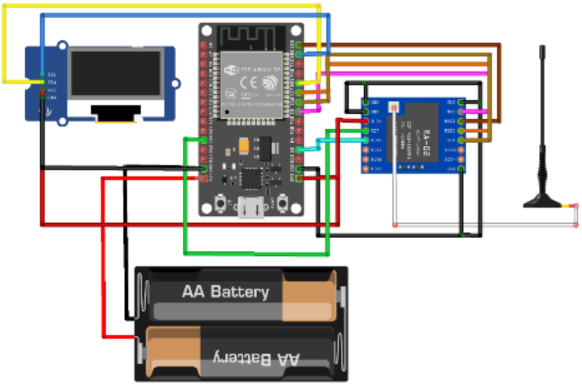

Figure 7. Receiving Device Wiring

### F. Wiring the Transmitter

The function of transmitter wiring is to facilitate the integration of a transmitter into a system or circuit by establishing connections between the relevant cables and components (Figure 8-9). Transmitters transmit signals or information to a designated recipient, such as wireless communication and monitoring systems.

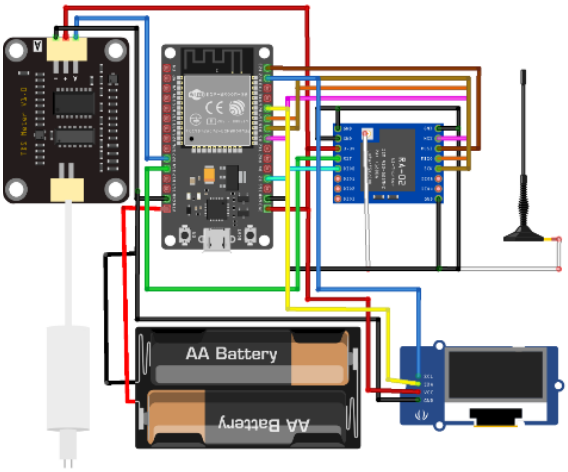

Figure 8. Transmitter Device Wiring

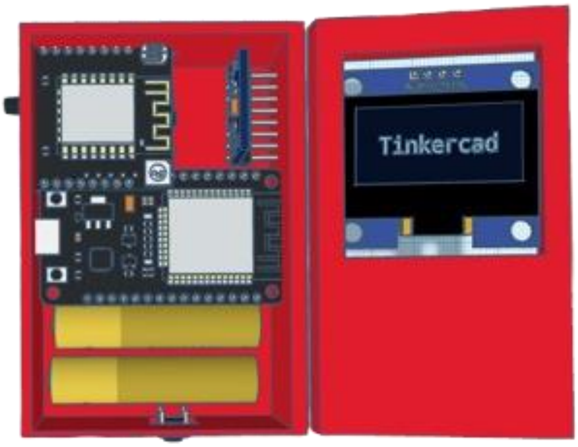

Figure 9. 3D Tool Design

### G. 3D Design

Three-dimensional design creates a three-dimensional visual representation of an object or environment. In three-dimensional design, designers represent objects using three spatial dimensions: length, width, and depth. This approach provides a more realistic or realistically detailed representation than a two-dimensional design. This study created three-dimensional images using Tinkercad software.

## III. RESULTS AND DISCUSSION

The following illustration depicts the results of water quality monitoring tools utilizing LoRa communication. These tools serve as both a LoRa transmitter/sender (sensor) and a LoRa receiver of data from the sender.

Figure 10. Receiving Device

As illustrated in the Figure 10, the receiver device comprises multiple components, including the ESP32 microcontroller, LoRa module (which facilitates network communication between the transmitter and receiver or data transmission), battery (which provides power), and OLED display (which displays data obtained from testing).

Figure 11. Transmitter Device

The Figure 11 depicts the transmitter device, which comprises several principal components. Primarily, the tool system employs an ESP32 microcontroller, while the LoRa module facilitates transmission and remote communication between the transmitter (TX) and receiver (RX). Additionally, the TDS sensor serves as a water quality detector, and the data obtained from the TDS sensor is displayed on the OLED and transmitted to the receiver via the LoRaWAN network. Finally, the battery provides the device with the necessary power supply.

### A. Prototype Testing

This section aims to evaluate the functionality of the previously designed prototype. This evaluation will determine whether the designed system is operating as intended or if any performance deficiencies exist.

### 1. LoRaWAN Network Coverage Distance Testing

The initial assessment evaluates the system or tool's operational range and scope, as illustrated in the Table 1 below.

Table 1. LoRaWAN Network Coverage Testing

| Receiver (Coordinates) | Distance (m) | Transmitter (Coordinates) | Information |
|---|---|---|---|
| **-6.4181179 & 106.828008** | 100 | -6.4177468 & 106.8288499 | Covered |
| **-6.4181179 & 106.828008** | 200 | -6.4170511 & 106.8294708 | Covered |
| **-6.4181179 & 106.828008** | 400 | -6.415761 & 106.830708 | Covered |
| **-6.4181179 & 106.828008** | 200 | -6.4192341 & 106.8294829 | Covered |
| **-6.418785 & 106.827778** | 400 | -6.4219814 & 106.8294397 | Covered |
| **-6.418785 & 106.827778** | 500 | -6.422845 & 106.8297364 | Covered |
| **-6.418785 & 106.827778** | 600 | -6.4239155 & 106.8295483 | Covered |

The tests' results indicate that the LoRaWAN network's coverage distance ranges from 100 to 600 meters. The observed decrease in detection range with increasing distance between receiver and transmitter is attributed to various factors, including environmental conditions, weather, and tall structures, which can impede the transmission of LoRaWAN signals (Table 2).

Table 2. Link Budget [20]

| Parameter | UL | DL |
|---|---|---|
| **Tx-Power (dBm)** | 15 | 20 |
| **Tx-Cable loss (dB)** | -1 | -3 |
| **Tx-Antenna Gain (dB)** | 0 | 9 |
| **Tx-Antenna Height (m)** | 30 | |
| **RX-Antenna gain diversity (dBi)** | 10 | 0 |
| **Rx-Antenna Height (m)** | 1.5 | |
| **Frequency (MHz)** | 920 | |
| **Bandwidth (kHz)** | 125 | |

### 2. RSSI and SNR Testing

This paper should test the quality of RSSI and SNR in data transmission. The RSSI calculation considers the path loss value incurred due to the distance between the transmitter (tx) and receiver (rx). The path loss exponent function calculates the average path loss for large-scale (PL(d)) [21]. RSSI (Received Signal Strength Indicator) and SNR (Signal-to-Noise Ratio) significantly influence the coverage of a LoRaWAN network. RSSI indicates the signal strength received by a device from a LoRa gateway, and the higher the value, the better the connection quality [10]. However, SNR, which measures how well a signal distinguishes from noise in the surrounding environment, also heavily influences comprehensive coverage. Good SNR can still enable communication in areas with weak signals (low RSSI). However, ultimately, the coverage of a LoRaWAN network will be limited if the RSSI is too low or the SNR is too poor because the signal cannot be captured enough by the gateway [16]. Combining the two determines how far a LoRa device can reliably communicate with the gateway. The following equation 1-2 are employed:

$$PL(d)[\text{dB}] = P\bar{L}(d0) + 10\text{n} \log\left(\frac{d}{d0}\right) + \text{X}\sigma \tag{1}$$

$$\text{Pr}(d) = Pt(d) - PL(d) \tag{2}$$

To calculate the RSSI, use the following equation 3:

$$RSSI = Pt(d) - (P\bar{L}\,(d0) + 10\text{n} \log\left(\frac{d}{d0}\right) + \text{X}\sigma) \tag{3}$$

The data transmission system was tested on three occasions, at three different times of day (morning, afternoon, and evening), using the LoRaWAN network and the ESP32 microcontroller. The tests were conducted from 100 meters to 600 meters from the receiver. The subsequent table illustrates the outcomes of the RSSI and SNR values acquired during the system testing phase.

Table 3. RSSI and SNR Result Data

| **Distance (m)** | **Morning** | | **Afternoon** | | **Evening** | | **RSSI Calculation** |
|---|---|---|---|---|---|---|---|
| | RSSI | SNR | RSSI | SNR | RSSI | SNR | |
| **100** | -103 | 8.75 | -104 | 9.00 | -96 | 9.00 | -112 |
| **200** | -99 | 8.00 | -113 | 7.00 | -101 | 0.50 | -120.127 |
| **400** | -109 | -0.50 | -121 | -0.25 | -123 | -2.75 | -128.274 |
| **200** | -107 | -0.50 | -115 | 7.25 | -114 | -6.75 | -120.127 |
| **400** | -109 | -3.25 | -123 | -8.50 | -115 | 7.50 | -128.274 |
| **500** | -119 | 5.00 | -124 | -7.25 | -120 | -7.25 | -130.703 |
| **600** | -121 | 1.75 | -124 | -5.50 | -116 | -6.50 | -133.006 |

A comparison of the results of path loss calculations carried out from a distance of 100 meters to 600 meters and of direct RSSI testing indicates that the two sets of results are similar. This research observed the highest test RSSI result at a distance of 200 meters, with an RSSI value of -99 dBm. In contrast, we recorded the highest calculated RSSI at a distance of 100 meters, with an RSSI value of -112 dBm. As evidenced by the data presented in the table, the RSSI value ranges from -103 dBm to -121 dBm. At a distance of 200 meters, the RSSI value reached -99 dBm, the highest recorded. At 600 meters, the value dropped to -121 dBm, the lowest observed. Based on the RSSI quality parameter, the tests and calculations show that the Lora signal quality remains satisfactory at 100 and 200 meters. However, the signal weakens or decreases as the distance between the receiver and transmitter increases. The morning test calculated path loss using a transmitter and receiver distance ranging from 100 to 600 meters. We employed the equation above to complete this task.

Pt : -58 dBm
n : 2.7 – 3.5 (urban area cellular radio)
d : 100 – 600 meters
d0 : 1 meters
x deviation : 0 dB

In this context, $PL$ $(d0)$ represents the path loss reference distance $(d0)$, which is 1 to 1.5 meters under free space conditions. The path loss exponent, n, is adjusted to reflect the prevailing environmental conditions at the time of testing. The corresponding exponent in Table 4 is provided below for reference:

Table 4. Exponent [21]

| **Environment** | **Path Loss Eksponen (n)** |
|---|---|
| **Free space** | 2 |
| **Urban area cellular radio** | 2.7 – 3.55 |
| **Shadowed urban cellular radio** | 3 – 5 |
| **In building LOS** | 1.6 – 1.8 |
| **Obstructed in building** | 4 – 6 |
| **Obstructed in factories** | 2 - 3 |

1. Distance 100 meters
    Pl = $P\bar{L}0$ + 10 x 2.7 $\log_{10}\left(\frac{1}{100}\right)$ + 0
    Pl = $\log_{10}(100) = 2$
    Pl = 10 x 2.7 x 2
    Pl = 10 x 5.4
    Pl = -54dB

    RSSI = Pt – Pl
    RSSI = -58 dBm -54 Db
    = -112 dBm
2. Distance 200 meters
    Pl = $P\bar{L}0$ + 10 x 2.7 $\log_{10}\left(\frac{1}{200}\right)$ + 0
    Pl = $\log_{10}(200) = 0.031 + 2 = 2.031$
    Pl = 10 x 2.7 x 2.031
    Pl = 27 x 2.031
    Pl = -62.127 dB

    RSSI = Pt – Pl
    RSSI = -58 dBm – 62.127 dB
    = -120.127 dBm
3. Distance 400 meters
    Pl = $P\bar{L}0$ + 10 x 2,7 $\log_{10}\left(\frac{1}{400}\right)$ + 0
    Pl = $\log_{10}(400) = 0.602 + 2 = 2.602$
    Pl = 10 x 2.7 x 2.602
    Pl = 27 x 2.602
    Pl = -70.254 dB

    RSSI = Pt – Pl
    RSSI = -58 dBm – 70.254 dB
    = -128.254 dBm
4. Distance 500 meters
    Pl = $P\bar{L}0$ + 10 x 2.7 $\log_{10}\left(\frac{1}{500}\right)$ + 0

Pl = $\log_{10}$ (500) = 0.699 + 2 = 2.699
Pl = 10 x 2.7 x 2.699
Pl = 27 x 2.699
Pl = -72.873 dB

RSSI = Pt – Pl
RSSI = -58 dBm – 72.873 dB
= -130.873 dBm

5. Distance 600 meters

Pl = $P\bar{L}0$ + 10 x 2.7 $\log_{10}\left(\frac{1}{600}\right)$ + 0
Pl = $\log_{10}$ (600) = 0.778 + 2 = 2.778
Pl = 10 x 2.7 x 2.778
Pl = 27 x 2.778
Pl = -75.006 dB
RSSI = Pt – Pl
RSSI = -58 dBm – 75.006 dB
= -133.006 dBm

The path loss calculation, based on an exponent value of 2.7 (urban area cellular radio) on Table 4, indicates that the highest RSSI value, -112 dBm, is obtained at a minimum test distance of 100 meters. The lowest value, -133.006 dBm, is obtained at a maximum test distance of 600 meters.

As the distance increases, the value in question decreases by the observed trend. As illustrated in the Figure 12-13, the RSSI, an effective testing metric, is at a distance of 200 meters with an RSSI value of -99 dBm. In contrast, the calculated distance is 100 meters with an RSSI value of -112 dBm. The factors that affect RSSI values are not limited to differences in distance; other factors, such as the surrounding conditions and weather, also significantly impact the network when transmitting data. Data was collected on 10 June 2024 with sunny, cloudy weather.

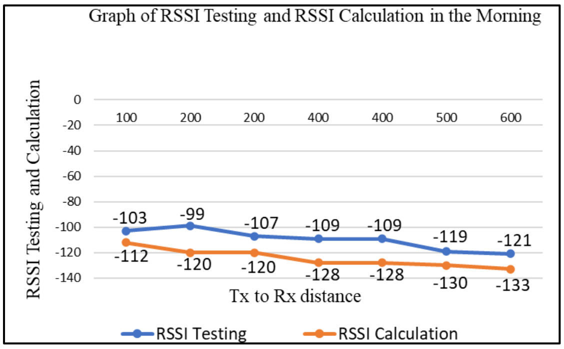

Figure 12. Graph of RSSI Testing and RSSI Calculation in the Morning (6 AM)

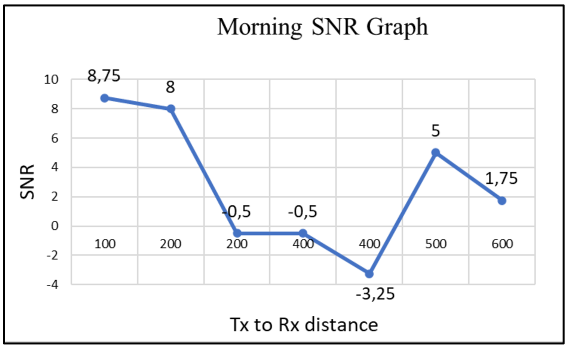

Figure 13. Morning SNR Graph (6 AM)

In addition to the observed fluctuations in RSSI values, the SNR value also demonstrated a notable decline from 100 meters to the next distance up to 600 meters. The SNR value is optimal at the initial transmission, occurring at 100 meters, with an SNR value of 8.75 (dB).

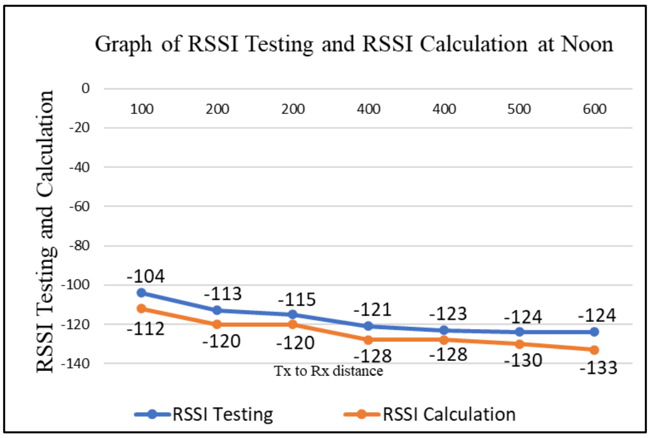

Figure 14. Graph of RSSI Testing and RSSI Calculation at Afternoon (12 AM)

The results of the conducted tests indicate that the RSSI value is inversely proportional to the distance between the receiver and transmitter, with a decrease in signal strength observed as the distance increases (Figure 14). The graph compares the results of RSSI testing and RSSI calculation. We observed the optimal RSSI value at a distance of 100 meters. The RSSI testing yielded -104 dBm, while the RSSI calculation was -112 dBm. At the maximum distance of 600 meters, the lowest RSSI value was recorded, with RSSI testing at -124 dBm and RSSI calculation at -133 dBm.

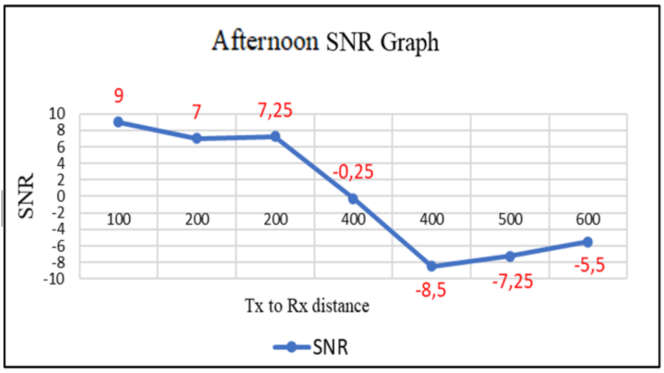

Figure 15. Afternoon SNR Graph (12 AM)

The data obtained from the conducted tests indicate a consistent trend: as the signal source and receiver distance increases, the signal strength decreases. The graph of the test results shows that the signal-to-noise ratio (SNR) remains relatively high at distances between 100 and 200 meters when the SNR value is 9.00 dB and 7.00 dB (Figure 15). At a distance of 400 meters, the SNR drops to its lowest value of -8.5 dB.

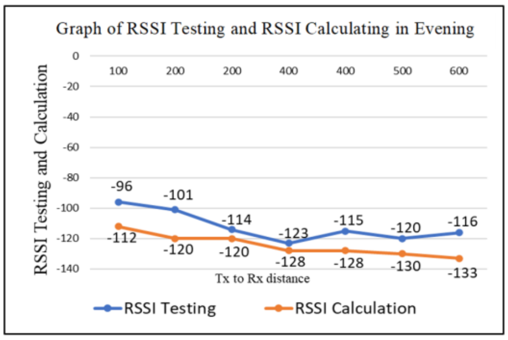

Figure 16. RSSI Graph of Evening Testing and Calculation (5 PM)

The graph in Figure 16 depicts the variation in test RSSI values at varying distances. At a distance of 200 meters, the RSSI values were -101 dBm and -114 dBm. At a distance of 400 meters, the RSSI values were -123 dBm and -115 dBm. However, the RSSI calculation remains constant while the increasing distance of signal strength decreases. We observe the highest RSSI calculation value of -112 dBm at a minimum distance of 100 meters and the lowest value of -133 dBm at a maximum distance of 600 meters.

Similarly, the SNR value demonstrated increased signal strength that diminished with the increased distance between the receiver and transmitter. However, at the same distance, namely 200 meters with an SNR of 0.5 (dB) and -6.75 (dB), and at a distance of 400 meters with an SNR of -2.75 (dB) and 7.5 (dB), the results were consistent. Many factors can influence the signal, resulting in variations in SNR values or signal quality even when the distance remains constant but the environmental or weather conditions differ. Data was collected on 10 June 2024 with sunny, cloudy weather as shown in Figure 17.

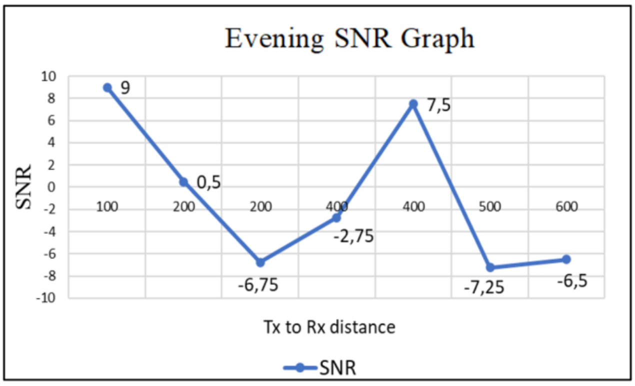

Figure 17. Evening SNR Graph (5 PM)

### 3. Quality of Service (QoS) Testing

The third test assesses the transmission apparatus's functionality, evaluating the LoRa network's efficacy in transmitting and receiving data. We evaluate the delay, throughput, jitter, and packet loss in the NLOS area, ranging from 100 to 600 meters.

In order to ascertain the quality of service or network on LoRa, a network recorder application, specifically the Wireshark application, must be utilized. Furthermore, calculations may be performed with equation 4-7 in order to obtain data regarding delay, throughput, jitter, and packet loss, as outlined below:

1) $$\text{Delay} = \text{time received - time sent} \quad (4)$$
2) $$\text{Throughput} = \frac{(\text{number of bytes})}{(\text{time span's})} \quad (5)$$
3) $$\text{Jitter} = \text{second delay - first delay} \quad (6)$$
4) $$\text{Packet loss} = \frac{(\text{packets sent}- \text{packets received})}{(\text{packets sent})} \times 100 \quad (7)$$

The results of the data transmission testing conducted using LoRaWAN on three occasions (morning, afternoon, and night) yielded the Quality of Service (QoS) metrics, including throughput, packet loss, delay, and jitter. We present the findings in Table 5 below:

Table 5. Throughput and Packet Loss Data

| Distance (m) | Morning | | Afternoon | | Evening | |
|---|---|---|---|---|---|---|
| | Throughput (kbps) | Packet Loss (%) | Throughput (kbps) | Packet Loss (%) | Throughput (kbps) | Packet Loss (%) |
| **100** | 456 | 0 | 372 | 0 | 408 | 0 |
| **200** | 273 | 0 | 287 | 0 | 360 | 0 |
| **400** | 481 | 0 | 353 | 0 | 453 | 0 |
| **200** | 481 | 0 | 429 | 0 | 422 | 0 |
| **400** | 382 | 0 | 555 | 0 | 264 | 0 |
| **500** | 582 | 0 | 583 | 0 | 602 | 0 |
| **600** | 592 | 0 | 421 | 0 | 576 | 0 |

Getting delay and jitter can be seen in the Table 6 below:

Table 6. Delay and Jitter Data

| Distance (m) | Morning | | Afternoon | | Evening | |
|---|---|---|---|---|---|---|
| | Delay (ms) | Jitter (ms) | Delay (ms) | Jitter (ms) | Delay (ms) | Jitter (ms) |
| **100** | 1.321 | 1.301 | 1.630 | 1.604 | 1.482 | 1.458 |
| **200** | 2.167 | 2.070 | 2.124 | 2.093 | 1.686 | 1.657 |
| **400** | 1.047 | 1.040 | 1.716 | 1.548 | 1.332 | 3.310 |
| **200** | 1.235 | 4.509 | 1.406 | 1.386 | 1.423 | 1.343 |
| **400** | 1.587 | 1.561 | 1.082 | 1.065 | 2.334 | 2.291 |
| **500** | 1.033 | 1.016 | 1.031 | 1.014 | 1.001 | 0.987 |
| **600** | 1.016 | 0.999 | 1.450 | 1.416 | 1.042 | 1.036 |

## IV. CONCLUSIONS

The test results show that the LoRa SX1278 component, operating at 433 MHz, transmits when paired with a 12 dBi LoRa antenna at the same frequency. The LoRa network demonstrated the capacity to cover the maximum testing distance of 600 meters from the RX. We conducted the experiment near the Cikumpa River and observed the flow.

The distance between the transmitter and receiver significantly impacts the RSSI and SNR values. The experiments were conducted at three distinct times of day: morning, afternoon, and evening. The RSSI value decreases as the distance between the transmitter and receiver increases. The RSSI testing conducted in the morning yielded results ranging from -99 dBm to -121 dBm. The corresponding RSSI calculations ranged from -112 dBm to -133.006 dBm, with the

SNR values falling between -3.25 dB and 8.75 dB. The results of the daytime RSSI tests ranged from -104 dBm to -124 dBm, with the RSSI calculations ranging from -112 dBm to -133,006 dBm and the SNR ranging from -8.50 dB to 9.00 dB.

Furthermore, the RSSI test results in the afternoon exhibited a range of -96 dBm to -120 dBm, with RSSI calculation results of approximately -112 dBm to -133,006 dBm and SNR values between -7.25 dB and 9.00 dB. In this experiment, we calculated the RSSI using an exponent value of 2.7 (Urban area cellular radio) and estimated the distance to be 1 meter. The overall results demonstrate that, based on the RSSI signal specifications in this test, the signal quality is optimal at distances of 100 and 200 meters. However, signal quality begins to decline at distances of 300 to 600 meters. Such outcomes are contingent upon many variables, including environmental factors, meteorological conditions, and the surrounding circumstances at the assessment time.

The results of the conducted tests indicate that the quality of the network, or QoS, is significantly affected by the distance between the network components. As evidenced by the disparate RSSI and SNR outcomes, the network signal quality diminishes with increasing distance. We conclude that the signal remains stable when we consider the results of the RSSI and SNR tests at different times of day—morning, afternoon, and evening. When testing at distances ranging from 100 to 600 meters on the Cikumpa River, with the NLOS area, no data loss or packet loss occurred during data transmission despite fluctuations in network signal quality. In light of the parameters mentioned earlier about QoS, the quality of the tests can be classified as satisfactory.

## REFERENCES

[1] L. P. Pratama, M. M. Vresdian, D. Junesco, D. B. Widi, H. A. Ananda and H. Rohmat, "Analysis of CO Pollutant Monitoring System Using MAPPI32 LORA in Bekasi City," *Sixth International Conference on Vocational Education and Electrical Engineering (ICVEE),* 2023.

[2] D. M. Ibrahim, "Internet of Things Technology based on LoRaWAN Revolution," *International Conference on Information and Communication Systems (ICICS),* 2019.

[3] F. N. Gustiyana, M. A. Amanaf and D. Kurnianto, "Implementasi Protokol LoRaWAN Pada Perangkat Monitoring Kelembapan Tanah Pertanian," *CENTIVE,* 2019.

[4] H. Budi, "Kajian Manajemen Pengelolaan Pasar Rakyat 2021 Bab 3," 21 12 2021. [Online]. Available: https://www.scribd.com/document/548650650/BAB-3.

[5] D. E. Susilo, A. E. Jayati and P. Muliandhi, "Simulasi Perencanaan Jaringan Long Range (LoRa) Pada Area Kota Semarang Menggunakan Cloud RF," *Jurnal Power Elektronik (POLEKTRO),* 2023.

[6] H. Andre, B. A. Sugara, Baharuddin, R. Fernandez and R. W. Pratama, "Analisis Komunikasi Data Jaringan Nirkabel Berdaya Rendah Menggunakan Teknologi Long Range (LoRa) di Daerah Hijau Universitas Andalas," *Jurnal Ecotipe (Electronic, Control, Telecommunication, Information, and Power Engineering),* 2022.

[7] S. Turangga, Martanto and Y. A. W, "Analisis Internet Menggunakan Parameter Quality of Service Pada Alfamart Tuparev 70," *JATI (Jurnal Mahasiswa Teknik Informatika)*, 2022.

[8] M. Ickbal, F. Imansyah, J. Marpaung, R. Yacoub and E. Kusumawardhani, "Analisis Mutu Pengiriman Data Pada Transceiver SX1276 (Studi Kasus Pada : Panel Surya)," *Journal of Electrical Engineering, Energy, and Information Technology (J3EIT),* 2022.

[9] H. A. Ananda, H. A. Iqbal, V. D. Junesco, M. Mauludi, P. Legenda and Y. Eddy, "Real Time Indoor Air Quality Monitoring System Based on IoT using MQTT and Wireless Sensor Network," *IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS),* 2019.

[10] H. R. Maulida, F. T. Syifa and M. A. Affandi, "Pengujian Sistem RSSI pada Perancangan Prototype Pemantauan Lahan Kebun Teh Berbasis LoRa," *Journal of Telecommunication, Electronics, and Control Engineering (JTECE),* 2022.

[11] D. B. Widi, H. Dwiana, A. Mohammed, V. D. Junesco, H. A. Ananda, A. M. Irsyad and L. P. Pratama, "Design and Simulation of Environment Indoor Air Quality Monitoring and Controlling System using IoT Technology," *International Seminar on Intelligent Technology and Its Applications (ISITIA),* 2023.

[12] F. Muhammad, A. Bhawiyuga and D. P. Kartikasari, "Analisis Kinerja Protokol LoRaWAN untuk Transmisi Data pada Skenario Urban Area," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer,* 2019.

[13] I. Jaya, M. Manfaluthy, L. P. Pratama, A. Jaenul, S. Wilyanti, B. W. Dionova and S. N. S. Al-Humairi, "Designing SMART-PJU Based on LoraWAN for Rural Light System," *EKSERGI Jurnal Teknik Energi,* 2023.

[14] A. A. Nurhadi, D. Darlis and M. A. Murti, "Implementasi Modul Komunikasi LoRa RFM95W Pada Sistem Pemantauan Listrik 3 Fasa Berbasis IoT," *Jurnal Sistem Komputer,* 2021.

[15] T. Liao, K. Hirota, X. Wu, S. Shao and Y. Dai, "A Dynamic Self-Tuning Maximum Correntropy Kalman Filter for Wireless Sensors Networks Positioning Systems," *Remote Sensing,* 2022.

[16] Musayyanah, C. D. Affandi and K. Lebdaningrum, "Penerapan Filter Kalman untuk Estimasi Jarak dan Posisi pada Lokalisasi Outdoor berbasis RSSI dengan Komunikasi LoRa," *Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika (ELKOMIKA),* 2023.

[17] J. Marpaung, F. Imansyah, R. Ratiandi and Marcelina, "Sistem Informasi Real Time Kadar Garam Air Baku Pdam Tirta Khatulistiwa Pontianak Berbasis Teknologi Lora Gateway," *Jurnal Sistem dan Teknologi Informasi (JustIN),* 2022.

[18] F. Chuzaini and Dzulkiflih, "IoT Monitoring Kualitas Air Dengan Menggunakan Sensor Suhu, Ph, dan Total

Dissolved SolidS (TDS)," *Jurnal Inovasi Fisika Indonesia (IFI)*, 2022.

[19] Y. Irawan, A. Febriani, R. Wahyuni and Y. Devis, "Water Quality Measurement and Filtering Tools Using Arduino Uno, PH Sensor and TDS Meter Sensor," *Journal of Robotics and Control (JRC)*, 2021.

[20] P. Rahmawati, A. Hikmaturokhman, K. Ni'amah and M. I. Nashiruddin, "LoRaWAN Network Planning at Frequency 920-923 MHz for Electric Smart Meter: Study Case in Indonesia Industrial Estate," *Journal of Communications*, vol. 17, no. 3, pp. 222-229, 2022.

[21] A. Yanziah, S. Soim and M. M. Rose, "Analisis Jarak Jangkauan LoRa Dengan Parameter RSSI dan Packet Loss Pada Area Urban," *Jurnal Teknologi Technoscientia*, 2020.