Testing the Range and Analysis of WSN LoRa Sx1278 Parameters in Coastal Areas

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Abstrak – *This research discusses the testing of the range and analysis of other parameters of Wireless Sensor Network (WSN) technology using LoRa technology at 433 MHz frequency in coastal areas. This study aims to provide important information for the development of WSN and LoRa technology, especially in coastal areas. The research method used is the design of the device, the creation of transmitter and receiver firmware, and field testing using the continuous method in Teluk Sebong, Berakit on May 26, 2022. The results showed that the maximum range achieved by the receiver was 7.3 km with a packet loss of 56.84%. Data transmission using LoRa experienced a significant delay, especially at a range of 4.2 km with a delay time of up to 18 seconds. In addition, the study also analyzed the LoRa network performance, such as the map of measurement and data loss points, the distribution of RSSI values, and the distribution of SNR values divided into several distance ranges. This research is expected to provide important information for the development of WSN and LoRa technology, especially in coastal areas*

Keywords*:* LoRa, Coastal Area, Packet Loss, Delay, RSSI, SNR.

1. Introduction

Coastal areas have potential that needs to be properly managed so as not to damage their resources. The use of Wireless Sensor Networks (WSN) in coastal areas can be used for various purposes, such as environmental monitoring of the coastal regions [1], earthquake and tsunami detection [2], and monitoring of illegal fishing [3]. WSN functions as a parameter data retrieval which is then sent to the central node for processing [4]. Low Power Wide Area Network (LPWAN) technology enables low-power wireless communication with relatively low data transfer rates, and Long Range Wide Area Network (LoRaWAN) technology is an LPWAN that allows devices using LoRa technology to communicate with each other in a wide area [5], [6].

Chirp Spread Spectrum (CSS) modulation technology used in the LoRa technology is more suitable for long-distance data transmission and more resistant to interference than Frequency Shift Keying (FSK) [7]. LoRa Sx1278 is the type of LoRa used in this study and requires more power than the LoRa Sx1272 type to reach longer distances [5]. The frequency range on the LoRa Sx1278 ranges from 137 – 525 MHz, with the 433 MHz frequency used in this study [8].

The WSN system consists of a gateway and a sensor node. The sensor node is placed at the point to be measured and sends data to the gateway. Factors that affect the performance of data transmission systems include delivery delay parameters, Receiver Signal Strength Indicator (RSSI), Signal Noise Ratio (SNR), packet loss, and distance [9], [10]. This study aims to test the Sx1278 LoRa Chip 433 MHz range and to analyze other parameters that can determine the quality of data transmission media, such as transmission delay, RSSI, SNR, and Packet Loss. In addition, this research was conducted in coastal areas to get the LoS (Line of Sight) position so that the farthest distance can be reached [5], [7], [11].

Based on previous research, the range of LoRa at 433 MHz varies greatly, such as 1 Km [5], 2 Km [11], and 3 Km [7]. But that research just focuses on the maximum distance without considering other parameters such as RSSI, SNR, and packet loss and is only conducted on land. Therefore, this research needs to be conducted in the coastal area to determine the maximum range of LoRa at 433 MHz and to analyze other supporting parameters. This research is expected to provide important information for developing WSN and LoRa technology, especially in coastal areas.

2. Research Method

2.1. Transmitter and Receiver System Design

The equipment design in this study consists of two main systems: the transmitter and the receiver device system. The system in the transmitter device is responsible for sending data through the LoRa transmission medium to the receiver device system. Figure 1 shows the block diagram of the transmitter and receiver system design.

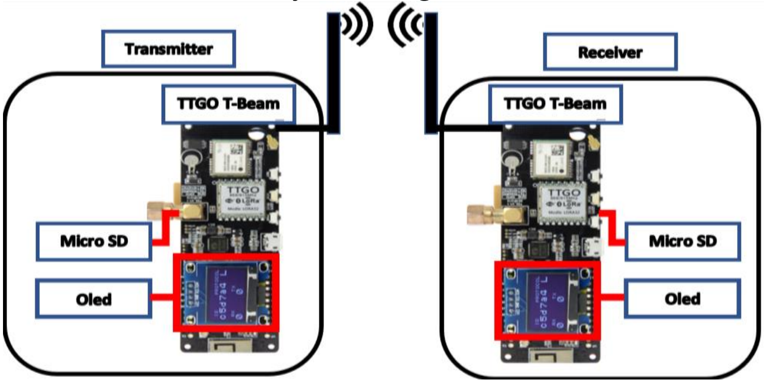

Figure 1. Block diagram of transmitter and receiver system design.

The data sent by the transmitter device is in the form of coordinate and time data. Coordinate and time data are obtained from the Neo 6m GPS module, which has been integrated with the TTGO T-Beam ESP32 SX1278 433 MHz. The data is stored on the transmitter's Micro SD Card, displayed on the OLED Display, and sent to the receiver device through the LoRa transmission medium. First, the receiver device will receive data from the transmitter device. Then the received data will be processed by the ESP32. After processing, the data will be stored on the receiver's Micro SD Card and displayed on the receiver device's OLED Display.

2.2. Firmware Design

The firmware for the transmitter and receiver devices is created using the Arduino IDE. The transmitter and receiver programs share several lines of code. The firmware design process begins with initializing libraries used by components such as AXP Power Management, OLED, Micro SD module, GPS module (Neo 6M), and LoRa module. Next, the pins for each component are defined for use on the ESP32 microcontroller after the library is initialized. Finally, variable declarations include the Neo 6M GPS module variable, AXP power management, OLED display, and Micro SD Card.

The void setup function starts with serial communication. Pin declarations follow it for wake-up sleep, SDA and SCL pins for the OLED display, GPS, SPI Micro SD Card, SPI LoRa, and AXP Power Management. AXP Power Management has several specific settings to control the power flow in a system that uses it. For example, AXP can turn on/off components such as GPS, LoRa, and even the LED indicator charger on the device. The void setup function on the device ends by waiting for GPS data before proceeding to the next program. The program will only continue if the GPS has obtained the coordinates. This stage is also passed by reset devices to ensure that GPS is active during operation.

The void loop function is different from the receiver program in the transmitter program. The flowchart for the transmitter firmware can be seen in Figure 2. The transmitter firmware flowchart starts with initializing libraries and ends with data storage. The program is closed when the device is turned off. The syntax used to send data to the receiver device is LoRa.beginPacket(). The data is written to the packet to be sent using LoRa.print() syntax and closed with LoRa.endPacket() syntax.

In the void loop function, the program first opens a file to write data to the Micro SD Card, followed by writing data to serial communication. Data transmission through LoRa media uses LoRa.beginPacket(), LoRa.print(), LoRa.endPacket() syntax, and then data is written to the Micro SD Card. Commands to display data generated by the device on OLED and commands to save data to the Micro SD are also executed. The void loop() program starts with the command to open the Micro SD. The next step is to write data using the root.print() syntax is then closed again using the root.close() syntax.

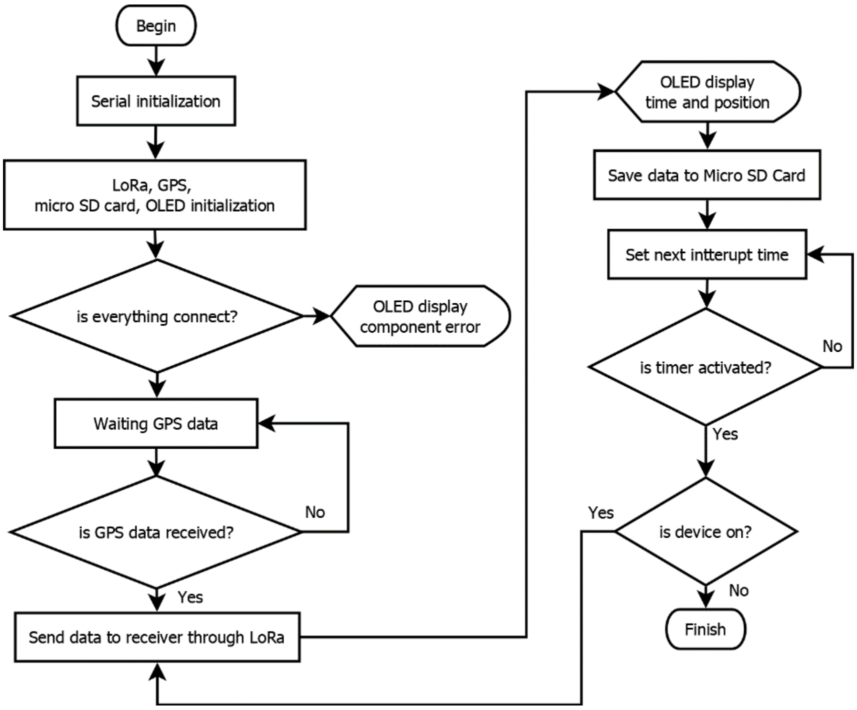

Figure 2. Transmitter firmware flowchart.

The data displayed on the OLED screen greatly affects the field testing process. The syntax display.clearDisplay() is used to clear the previous program display. The syntax Display.setTextColor(WHITE) is used to set the color of the displayed text (white). The syntax Display.setTextSize(1) is used to select the text size, and the syntax Display.setCursor(0, 0) is used to set the text position.

The flow diagram for the receiver firmware is almost the same as the transmitter firmware flow diagram. However, there is an additional process in the receiver firmware, which consists of receiving data from the transmitter and processing it to obtain the LoRa RSSI and SNR parameters. The flow diagram for the receiver firmware can be seen in Figure 3. The program for both devices is almost the same, with the only difference being in the receiver's Void loop() section. In the receiver's Void loop() section, we use the syntax LoRa.parsePacket(). LoRa.parsePacket() is a special syntax of the LoRa receiver that functions to parse the received data packet. The Void loop() program on the receiver separates the received data packet based on commas, periods, or other symbols.

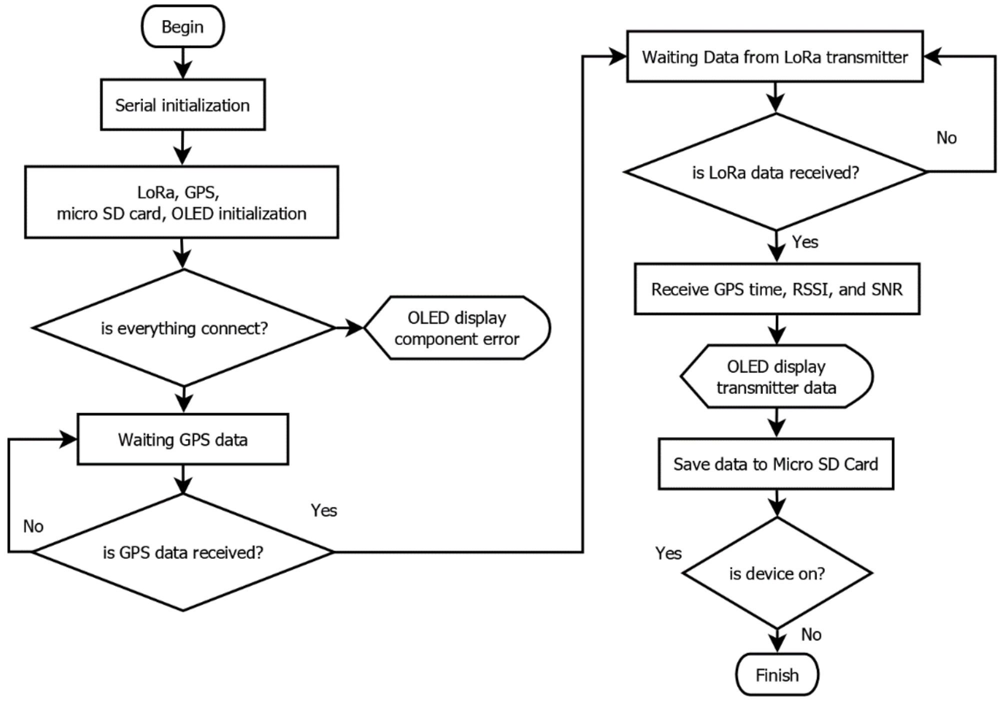

Figure 3. Receiver firmware flowchart.

2.3. Data Analysis

The data analysis in this study uses several parameters that can determine the quality of a data transmission system, namely delay, packet loss, RSSI, SNR, and distance. The processed data includes the coordinate data, packet loss data, time data, RSSI, and SNR. The transmitter device sends coordinate and time data that the receiver device receives.

Delay is a parameter that can measure the time delay between data transmission from the transmitter device and its reception at the receiver device. Comparing the GPS time of each device gives the delay. Distance, congestion, physical media, and long processing time can influence delay [12].

Packet loss is a situation that indicates how many packets are lost in numbers. It can occur due to collisions and congestion in the network [12]. Packet loss can be obtained by comparing the sent packet numbers with the received ones.
Distance is obtained by converting coordinates to length using the haversine formula, a method used to determine the distance between two coordinate points [13]. For example, the following formula makes it easy to convert coordinates in radians to distance (in km) with the radius of the Earth (R) being 6371 km.

$$a = sin^2\left(\frac{\Delta lat}{2}\right) + \cos(lat1) \times \cos(lat2) \times sin^2\left(\frac{\Delta long}{2}\right) \quad (1)$$

$$c = 2a\tan 2\left(\sqrt{a}.\sqrt{1-a}\right) \quad (2)$$

$$d = R.c \quad (3)$$

where, d is the distance between the two points (along the surface of the sphere). R is the radius of the sphere (in this case, the radius of the Earth 6371 km). lat1 and lat2 are the latitudes of the two points. Δlat is the difference between the latitudes. Δlon is the difference between the longitudes. atan2 is a special function that computes the arctangent of the quotient of its arguments.

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3. Result and Discussion

3.1. Field Test

On 26 May 2022, a field test was conducted in the coastal area of Sebong Bay, Berakit. The research area was cloudy and windy during the trial, with the sea at low tide. Before the test, the receiver device was placed on the lighthouse tower owned by the Navigation District Class I Tanjung Pinang, Ministry of Transportation, located in Tg. Berakit at the height of 70 m above sea level. The device was placed at that height to ensure it had an LoS (Line of Sight) position when it reached the farthest distance. Figure 4 shows the position of the transceiver placement.

Next, the transmitter device was taken to the sea to conduct the test at the maximum possible distance until the receiver could no longer receive data. The test was performed continuously by carrying the transmitter device away towards the sea with data transmission every 1 second. Each transmitted and received data was automatically saved in a micro SD transceiver as a text file.

Figure 5 shows the data on the transmitter (a) and the data on the receiver (b). The data in transmitter log file of sending data consist the repetition, latitude coordinate, longitude coordinate, and time received from GPS (hour, minute, second). The receiver will saved the incoming data from transmitter in log file. The log file consist of repetition, latitude coordinate, longitude coordinate, time received from GPS (hour, minute, second), RSSI, and SNR.

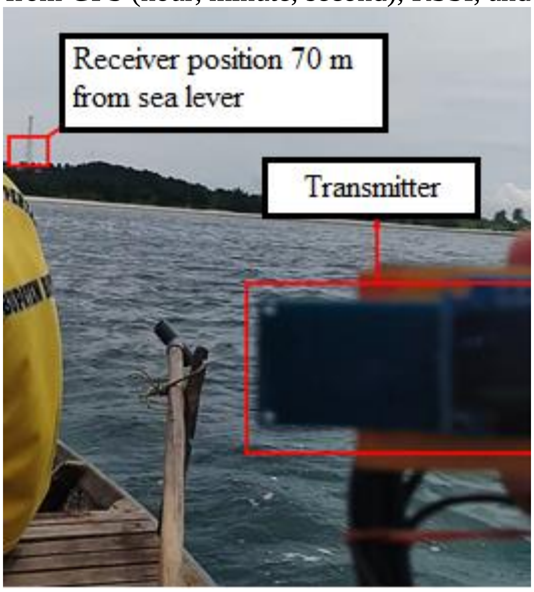
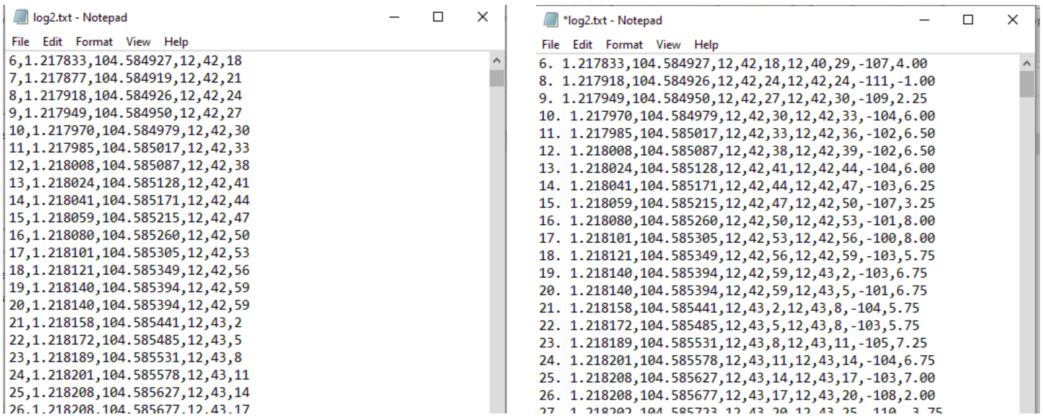


Figure 4. The position of the transceiver placement.



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8,1.217918,104.584926,12,42,24
9,1.217949,104.584950,12,42,27
10,1.217970,104.584979,12,42,30
11,1.217985,104.585017,12,42,33
12,1.218008,104.585087,12,42,38
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20,1.218140,104.585394,12,42,59
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22,1.218172,104.585485,12,43,5
23,1.218189,104.585531,12,43,8
24,1.218201,104.585578,12,43,11
25,1.218208,104.585627,12,43,14
26,1.218208,104.585677,12,43,17
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File Edit Format View Help
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11. 1.217985,104.585017,12,42,33,12,42,36,-102,6.50
12. 1.218008,104.585087,12,42,38,12,42,39,-102,6.50
13. 1.218024,104.585128,12,42,41,12,42,44,-104,6.00
14. 1.218041,104.585171,12,42,44,12,42,47,-103,6.25
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19. 1.218140,104.585394,12,42,59,12,43,2,-103,6.75
20. 1.218140,104.585394,12,42,59,12,43,5,-101,6.75
21. 1.218158,104.585441,12,43,2,12,43,8,-104,5.75
22. 1.218172,104.585485,12,43,5,12,43,8,-103,5.75
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24. 1.218201,104.585578,12,43,11,12,43,14,-104,6.75
25. 1.218208,104.585627,12,43,14,12,43,17,-103,7.00
26. 1.218208,104.585677,12,43,17,12,43,20,-108,2.00
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(a) (b)

Figure 5. The data on (a) the transmitter and (b) the receiver.

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3.2. LoRa Network Performance Analysis in Field Testing

The maximum distance the receiver achieves in the continuous method field test is 7.3 km. The map of measurement points and packet loss shows a pattern of loss points from close to far distances. Figure 6 shows the map of measurement points and packet loss. A comparison was made from the log file between the transmitter and receiver. A red circle shows the data loss, and a green circle shows the data received. The amount of packet loss in this field test reached 56.84%, as shown in Figure 6, and red circles dominated in the further distance.

From the results of this field test, packet loss data were analyzed and divided into three boxes. Figure 7 shows that in boxes 1 and 3, there is a periodic pattern of data loss points. In box 3, there are data loss points that are not caused by collision or congestion. Box 2 shows the LoRa points that do not experience collision or congestion, possibly because that area has a better Line of Sight (LoS) position.

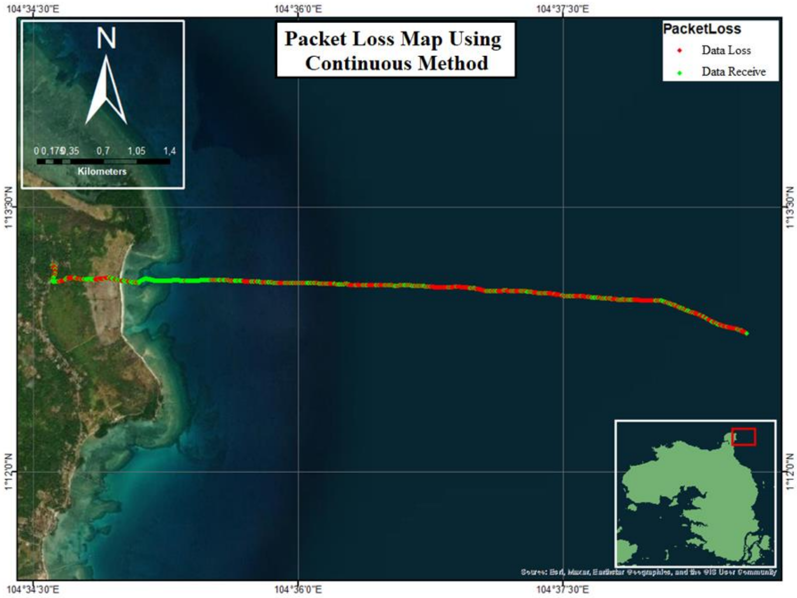

Figure 6. Map of measurement points and packet loss.

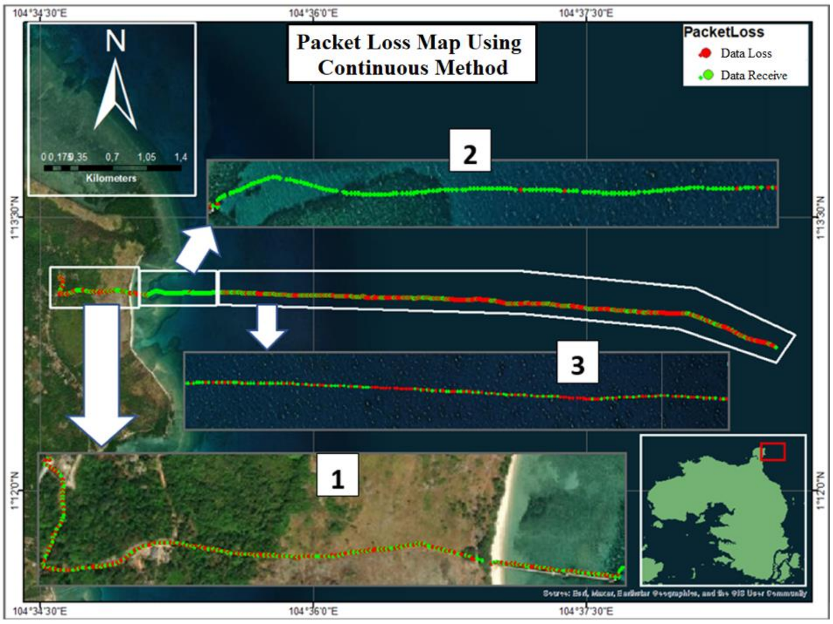

Figure 7. Continuous method packet loss segment.

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The delay parameter is calculated from the time difference between data transmission and reception. The delay is then grouped into five categories, namely 0-5 seconds, 6-11 seconds, 12-17 seconds, 18-22 seconds, and 23-27 seconds. As a result, data transmission using LoRa experiences a fairly long delay. In this test, data transmission points experience the highest delay at a distance of 4.2 km with a delay value of up to 18 seconds. However, generally, the delay value is dominated by 3 seconds.

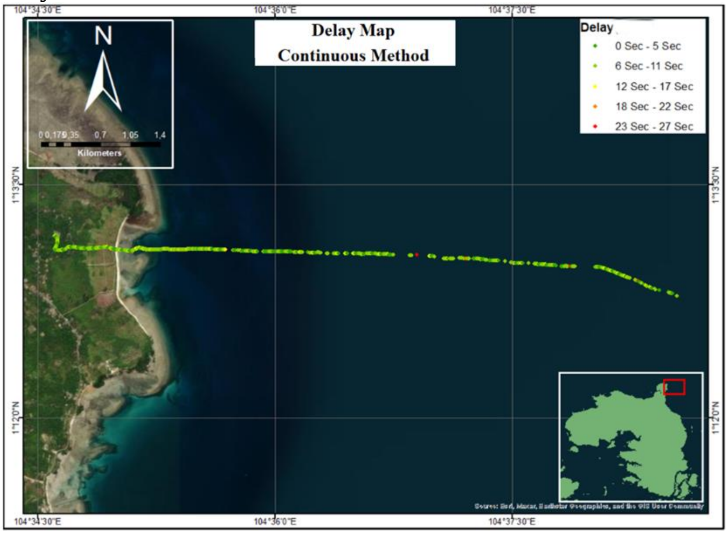

Figure 8. LoRa delay point map.

In Figure 9, the distribution of RSSI values is divided into three ranges, namely 0-2.5 km, 2.5-5 km, and 5-7.5 km. The most frequently occurring RSSI value is -109 dBm, with a minimum value of -75 dBm and a maximum of -15 dBm (Table 1). In Figure 10, the distribution of SNR values is divided into five classes, namely -24 – -14, -13 – -7, -6 – 0, 1 – 5, and 6 – 13. The maximum SNR value reached 13 dBm, and the minimum was -23.25 dBm (Table 2).

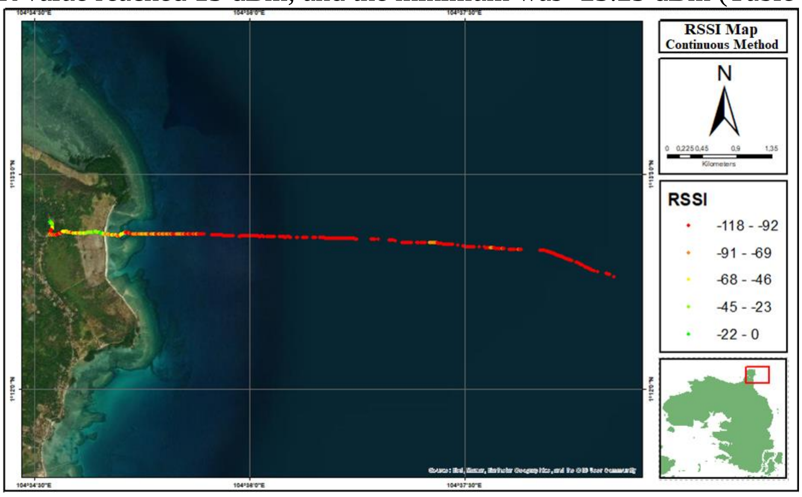

Figure 9. RSSI point map.

Table 1. RSSI data based on range distribution.

Range (Km)	Modus RSSI(dBm)	RSSI Max(dBm)	RSSI Min(dBm)
0 - 2,5 Km	-109	-75	-111
2,5 - 5 Km	-109	-104	-110
5 - 7,5 Km	-111	-104	-115

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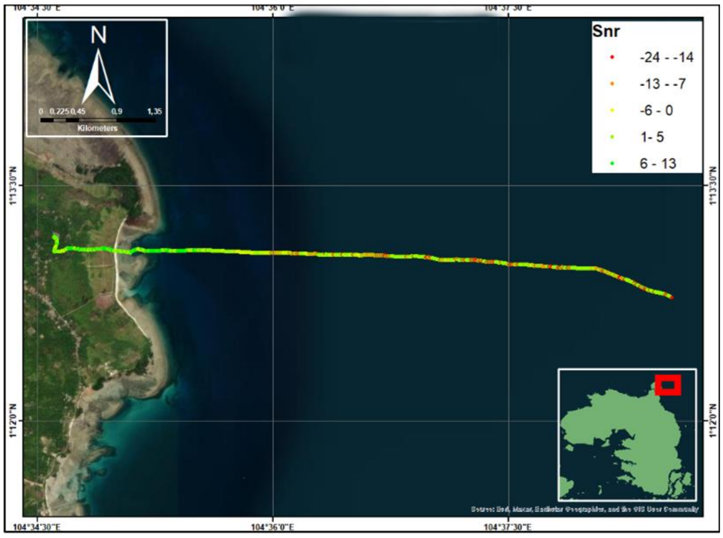

Figure 10. SNR point map.

Table 2. SNR data based on range distribution.

Range (Km)	Modus SNR (dBm)	SNR Max (dBm)	SNR Min (dBm)
0 - 2,5 Km	6,25	12,75	-16,25
2,5 - 5 Km	-16,25	13	-23
5 - 7,5 Km	-16,75	-7	-23,25

3.3. Discussion

Based on field testing in the coastal area of Teluk Sebong, Berakit showed that the maximum distance the receiver could successfully reach was 7.3 km. However, the test results also showed that the packet loss came to 56.84%, possibly caused by sending data too quickly. It is suspected to be due to collision or congestion resulting in lost data packets [14]. In addition, obstacles also affect the packet loss parameter [15]. Wiyadi [8] stated that LoRa could be used in forests with packet loss of up to 86%.

In the test, packet loss data were analyzed and divided into three boxes. In boxes 1 and 3, there were periodic patterns of data loss points. In box 3, data loss points were observed that were not caused by collision or congestion. Box 2 showed the LoRa points that did not experience collision or congestion, possibly because the area had a better Line of Sight (LoS) position.

The results of this study noted that the highest delay occurred at the data transmission point at a distance of 4.2 km with a delay value of up to 18 seconds. Although, in general, the LoRa delay that occurred was dominated by 3 seconds, LoRa data transmission experienced a significant delay. Packet loss and LoRa delay can be influenced by distance and obstacles in the research area [16].

In addition, the measurement of RSSI parameters showed that most of the RSSI values were below -92 dBm, indicating that the signal received by the antenna was relatively weak. Meanwhile, measuring the SNR parameter showed that the SNR value tended to decrease with increasing distance. The lower the SNR value, the worse the signal quality received by the antenna due to the increasing transmission distance [17].

Previous research conducted by Augustin et al. [18], Jorke et al. [19], and Zhang et al. [7] also showed that different environmental conditions highly influence the performance of LoRa networks. LoRa network performance in urban areas can reach 4.8 km [19]. Zhang et al. [7] showed successful data transmission up to 3 km with relatively low packet loss (less than 1%), while other research showed less favorable results with high packet loss [20]. It shows that environmental factors greatly influence the performance of LoRa networks. The success of LoRa is highly dependent on the position of the transmitter and receiver devices to achieve maximum distance.

4. Conclusion

Based on the research conducted in the coastal area of Teluk Sebong, Berakit, it can be concluded that the maximum distance achieved by a LoRa receiver is 7.3 km, but with a packet loss of 56.84%. Distance and obstacles in the research area influence packet loss and delay. Measurements of RSSI and SNR parameters indicate that the performance of the LoRa network is highly dependent on different environmental conditions. These findings are consistent with previous research showing that environmental factors strongly influence the LoRa network performance. Therefore, the position of the transmitter and receiver devices should be carefully considered to achieve maximum range in LoRa devices. Future research should focus on mitigating coastal challenges, developing adaptive algorithms, and conducting comparative studies across diverse maritime environments to enhance LoRa network reliability and efficiency.

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