Performance Analysis of LoRa in IoT Application of Suburban Area

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***Abstract*— This research succeeded in analyzing LoRaWAN performance, especially in suburban areas. This research aims to determine Lora technology's effectiveness when transmitting data in suburban environments. For this reason, we define the observed Lora transmission parameters, such as transmission range, RSSI, SNR, and packet loss. The case study raised is the Lora network for transmitting data from air quality sensors such as MQ7, MQ4, and dust sensors. These parameters are analyzed through variations in data transmission measurement distance, Spreading factor (SF) 7-12, coding rate 5-8, and bandwidth 125 kHz, 250 kHz, and 500 kHz. The measurement distance will start from 100 m to the farthest reach of Lora with an interval of 100 m. From the analysis results obtained, it was found that SF 7 and SF 8 send superior signals by offering high data integrity, while CR 5 shows better performance than CR 6-8. The BW that provides the most extended range is 125 kHz with a distance of 600 m, and the 250 kHz BW offers a more reliable transmission in terms of SNR. It is hoped that the results of this research can be a reference for Lora-based IoT users, especially in suburban areas.**

Keywords— Lora, RSSI, SNR, Spreading Factor, Coding rate, bandwidth, packet loss

I. Introduction

The rapid development of the Internet of Things (IoT) has encouraged the development of various wireless communication technologies for more efficient data exchange[1]–[3]. Long-Range Wide Area Network (LoRaWAN) technology has emerged as a solution that offers low-power communications and long-distance data transmission. Lora technology is an up-and-coming communications technology because of its advantages, such as low energy consumption, long-distance transmission range, and ease of installation. Because of this, there has been a lot of recent research on Lora. In particular, Lora's performance can be determined based on the Spreading Factor (SF), Code Rate (CR), and packet loss.[4]–[7].

Environmental parameters, such as population density, buildings, trees, and community activities, classified into urban, suburban, and rural areas, will also influence Lora's performance. The application of Lora technology in these three environments has different challenges[8], [9]. Lora-based IoT is a promising choice because of its advantages, such as smart homes[10], intelligent cities[11]–[14], and environmental monitoring[15]–[17]. However, suburban areas have a combination of buildings, trees, and ground conditions that tend to be hilly, which provides challenges when implementing long-distance wireless communications such as LoRa.

This research was conducted to analyze the effectiveness of LoraWAN communication to obtain a LoraWAN communication design, which has become a standard design for suburban areas. Various parameters that will be examined are RSSI (Receive Signal Strength Indicator), SNR (Signal Noise Ratio), and data transmission packet loss. These parameters will be analyzed based on SF (Spreading Factor), CR (Code Rate), BW (Bandwidth), and transmission distance.

It is hoped that the results of this research can become a reference for Lora technology communication designs in suburban areas, especially air quality monitoring applications. Other researchers only use the best parameter values based on this research. This will make it easier for practitioners, students, or other actors to implement LoraWAN in their projects.

Lora Technology Parameters

Bandwidth: One of the parameters that has an important role in Lora Technology is bandwidth, which is the width of the transmission frequency band from high frequency to low frequency. Lora's bandwidth is relatively narrow, typically between 125 and 500 kHz, which results in low data rates but offers longer distances. When compared with other technologies, for example, WIFI operates at a much higher bandwidth of 20-80 MHz, cellular networks with a bandwidth of up to 20 MHz allow high-speed data transmission but have data transmission that tends to be shorter.

TABEL I. LORA TECHNOLOGY PARAMETERS SETTING AND ITS EFFECT ON COMMUNICATION PERFORMANCE[18], [19]

Parameter setting	Value	Effect
Bandwidth	125 kHz, 250 kHz, and 500 kHz	Bandwidth significantly influences data speed from the transmitter to the receiver. The greater the bandwidth, the faster the data transmission, and vice versa. However, this will reduce the transmission distance and sensitivity.
Spreading Factor	7,8,9,10, 11,12	Low SF increases the bit rate for the specified bandwidth and code rate. On the other hand, increasing SF will increase the

2023 29th International Conference on Telecommunications (ICT) | 979-8-3503-6110-0/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICT60153.2023.10374037

	chips/symbol	data transmission distance because it will increase the processing gain.
Coding Rate	4/5, 4/6, 4/7, 4/8	Increasing CR can increase SNR; the effect is that data quality will be better, but by increasing CR, the capacity of transmitted data will also increase, thereby increasing transmission time.
Transmission Power	−4,….. 20 dBm	Increasing the transmission power will also increase the transmission distance but will increase the SNR, resulting in better data quality.

RSSI (Received Signal Strength Indicator) is an indicator that determines whether the receiver node is getting a strong enough signal from the transmitter or vice versa. The receiver and transmitter must have a substantial RSSI value to ensure transmission continues. RSSI is measured in dBm, which has a negative value. The RSSI value is getting closer to 0, indicating the signal quality is getting stronger. Specifically, if the RSSI value is -30dBm, this shows a strong signal. Meanwhile, if the RSSI is -120dBm, then this indicates that the transmission signal is feeble [20]–[22].

SNR (signal-to-noise ratio) is the ratio between the received signal and baseline noise strength levels. A noise floor is an external signal that interferes with the primary signal. This signal will always exist because it comes from various signals around the transmitter and receiver. Choosing a suitable antenna can be one way to reduce noise. Several possible SNR values are obtained: if the SNR is greater than 0, the received signal operates above the noise floor, and if the SNR value is less than 0, the received signal works below the noise floor. SNR noise levels generally range between -20 dB and +10dB, where proximity to +10 implies minimal interference with the received signal[22].

II. RESEARCH METHOD AND DESIGN

This research aims to analyze the performance of the LoRa (Long Range) network (Fig. 1) in the context of monitoring air quality using the LoRa Shield Lora, MQ-4, MQ-7, and dust sensors which can detect methane gas. (CH_4) and carbon monoxide (CO) concentrations and dust levels are indicated on the node's side. The data generated by the transmitter node will then be sent to the receiver via the LoRaWAN protocol. This node consists of Lora, ESP32, and Arduino modules, which have their respective functions. Through ESP 32, data will be forwarded to the internet using the MQTT protocol. Next, the MQTT broker stores the data temporarily before passing it to the next stage. Next, the MQTT Broker will subscribe to Node-Red. Node-Red is used to process and insert data into the InfluxDB database. This way, the stored data can be accessed using the Grafana application.

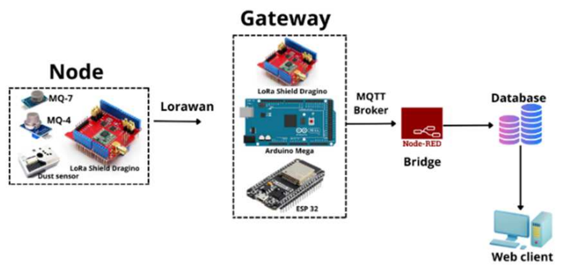

Fig.1. Network architecture

To achieve this, we assemble all the necessary equipment, such as sensors and microcontrollers (Lora, Arduino, and ESP32), and test based on predetermined parameters. In the experiment, the receiver was placed 1.5 meters above the ground, as was the transmitter. This study has not considered the influence exerted by the Fresnel zone between the transmitter and receiver. We test data transmission based on distance. The initial distance is 100 meters to the furthest distance the Lora can reach with an interval of 100 m. The SF we use varies from SF7 to SF12, the CR used is CR5 to CR8, and the BW used is 125 kHz, 250 kHz, and 500 kHz. We record RSSI, SNR, and Packet loss transmission for each point, which will be used for analysis.

III. RESULT AND DISCUSSION

A. Effect of Spreading Factor

SF greatly influences data transmission, as shown in Fig. 2. Different SF will provide various signal qualities. When observing LoRa behavior at 100 meters in Fig. 2(a), it is clear that lower SFs, such as SF7 and SF8, consistently provide superior results in terms of RSSI (black line) and SNR (red line). The SF7 showed an RSSI of -98.875 dBm, an SNR of 9.6 dB, even with a packet loss of 20%, while the SF8 topped it with an RSSI of -99.8 dBm, an SNR of 10.75 dB, and zero packet loss. However, when the SF is higher, including SF9, SF10, SF11, and SF12, there is a significant increase in packet loss, shown by SF10 and SF12 reaching around 40%. This confirms that although higher SF provides broader coverage capabilities, it reduces packet reliability, making it less suitable for applications with strict data integrity requirements.

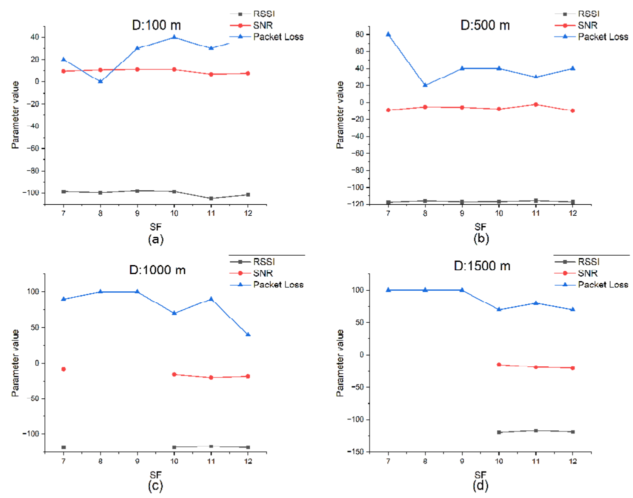

Fig. 2. Lora's performance over SFs

As shown in Fig. 2, Lora's performance decreases significantly at a distance of 500 meters. SF 7 recorded an RSSI of -117.5 dBm, SNR of -9 dB, and a packet loss of 80%. So, for this research case, a distance of 500 meters is unsuitable for Lora. However, this differs from SF8, which shows good results, with an RSSI of -115,875 dBm, SNR of -5,125 dB, and packet loss of 20%. However, the packet loss is also higher when the SF is higher. The situation worsens in Fig. 2(C) measurements at a distance of 1000 meters. SF8, SF9, and SF10 all exhibit severe packet loss, reaching 100%, making it impractical for reliable communications at this range. SF7 and SF11 show slightly better performance in terms of packet loss but are still far from reliable communication. Only the SF12 managed to sustain 40% packet loss, offering some potential for long-distance communications but with substantial limitations. At 1500 meters in Fig. 2(d), most SFs (SF7, SF8, and SF9) produce 100% packet loss, indicating a complete breakdown in communication reliability. SF10, SF11, and SF12 show some improvement in packet loss, with SF12 being the most promising at 70%. However, even the SF12 had difficulty ensuring reliable communications over long distances. Meanwhile, the furthest distances for each SF we found were SF7 at 1200 m, SF8 at 900 m, SF9 at 700 m, SF10 and 11 at 1500 m, and SF12 at 1600 m.

B. Effect of Bandwidth

In this section, we test Lora's reliability in terms of bandwidth: 125 kHz, 250 kHz, and 500 kHz, at various distances. BW 125 kHz, as shown in Fig. 3(a), shows that as the distance increases, the RSSI drops significantly, which causes packet loss to become higher, especially beyond 400 meters. On the other hand, at the 250 kHz bandwidth in Fig. 3 (b), as the distance increases, the RSSI is relatively stable, and the SNR decreases slightly, so the performance of Lora is better than BW125 kHz. Furthermore, the 500 kHz BW shows slightly better RSSI values at shorter distances but suffers from a decrease in SNR as the length increases, as depicted in Fig. 3(c).

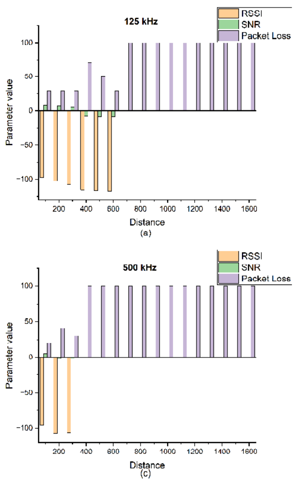

Fig. 3. Lora's performance over bandwidths

If observed more closely, using BW 250 kHz provides a more consistent RSSI value at all distances. At a distance of 100 meters, the RSSI is around -96.71 dBm, with an SNR of 8.71 and packet loss of 30%. Even at a distance of 200 meters, RSSI is relatively stable at around -110.29 dBm, while SNR drops to -1.46, but packet loss remains at 30%. This analysis shows that BW 250 kHz is superior at longer distances compared to BW 125 kHz, which tends to provide shorter distance measurements. Therefore, it can be said that the stability of the RSSI value shows its suitability for applications that require a more comprehensive communication range.

The results vary slightly when we measure and observe transmissions at BW 500 kHz. It can be observed that RSSI has better values at short distances, for example, -95.875 dBm at a distance of 100 meters; besides that, the SNR decreases. At a distance of 200 meters, RSSI drops to -106.83 dBm, with an SNR of -1.67 and packet loss of 40%. These results show that, although the bandwidth is higher, it can provide better results at shorter distances.

In short, bandwidth usage must be chosen wisely according to your application needs in utilizing Lora technology. From the results of the analysis, we can see that narrower bandwidths offer transmission distances that tend to be longer, such as BW127 kHz, compared to wider bandwidths such as 250 and 500 kHz. However, if we look at its reliability, BW 250 kHz is still superior for short-distance data transmission compared to BW 125 kHz and 500 kHz.

C. Effect of Coding Rate

Analysis of data transmission with CR variations has been performed. Fig. 4 provides a comparison between CR and RSSI. As CR increases, RSSI tends to decrease. For example, in CR 5 in Fig. 4(a), RSSI has values ranging from -99.71 dB at 100 meters to -117.67 dBm at 800 meters. In contrast, at level 8 coding in Fig. 4(d), the RSSI varies from -102.57 dBm to -115.67 dBm at the same distance. This proves that the greater the CR, the greater the data redundancy, which causes an increase in the capacity of the data sent, which also affects signal quality, especially the error correction capability at lower CR levels.

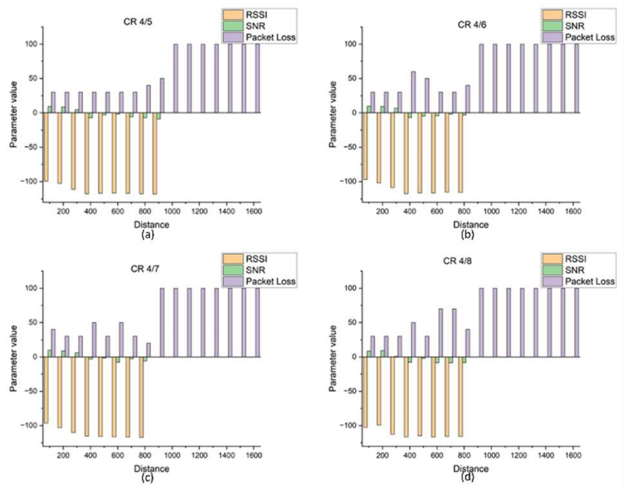

Fig. 4. Lora's performance over coding rates

The quality will get worse if the SNR value decreases. This situation will also affect the integrity of the transmitted packet. Higher CR tends to increase packet loss, especially over longer distances. At CR 7, as depicted in Fig. 4(c), packet loss remains consistent at 100% at 800 meters, while at CR 5, packet loss reaches 40% at 800 meters. The results obtained in the experiment are in line with the Lora technology principle that the higher the CR, the more reliable error correction will be. However, this increases data capacity, thereby increasing the possibility of packet loss during transmission, especially in areas filled with buildings, trees, and hilly ground conditions.

IV. CONCLUSION

This research has carried out an analysis of Lora's performance, especially in Suburban Areas that have varying environmental conditions. We analyzed several main factors in LoRa communication; firstly, the best SFs in LoRa technology are SF7 and SF8, which provide better reliability and transmission distance than SF9-SF12. The second factor is bandwidth. The best bandwidth is 125 kHz for a more extended range and 250 kHz for more reliable communication. Other factors, such as code rate (CR), are essential in determining signal strength, quality, and packet loss in LoRa communications. A high CR will provide a higher level of data error correction in transmission but will be exposed to higher range, signal quality, and packet loss. This research further confirms that selecting LoRa parameters, including SF, bandwidth, and coding speed, is critical to obtaining signal quality, data integrity, and communication reliability.

Acknowledgment

I sincerely thank all parties who have contributed to completing this research. First, I would like to express my profound appreciation to the D3TK Study Program for its invaluable support, guidance, and contribution during this research. Furthermore, I would like to express my gratitude for the generous support provided by the Ministry of Education, Culture, Research and Technology (Kemdikbudristek) through research funding. Without their financial assistance, this research would not have been possible. I would also like to thank various sources, references, and institutions whose work and sources have been referred to and cited in this journal. Their contributions have greatly enriched the depth and quality of this research.

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