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Analysis of Service Quality and Coverage Based on LoRaWAN Network: A Case Study of Air Quality Monitoring in Grand Depok City

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***Abstrak* :**
Smart living is an evolution of the Internet of Things (IoT). The concept of smart living itself refers to the ability to control and connect everything in the surrounding environment to the Internet. The research method used in this study is observational, focusing on the range of LoRa usage with parameters including Receive Signal Strength Indicator (RSSI) and Signal to Noise Ratio (SNR). The study results show that the average RSSI is -94.6 dBm at 50 meters, -105.4 dBm at 100 meters, -106.8 dBm at 150 meters, -111 dBm at 200 meters, -106.6 dBm at 250 meters, and -108.8 dBm at 300 meters. Meanwhile, the highest SNR value was recorded at 50 meters with 11 dB, while the lowest was at 300 meters with -8 dB. The highest error rate was observed at 250 meters, with an error value of 88%. Lack of error value indicates that as the distance between the transmitter and receiver increases, the signal's strength and quality tend to decrease, ultimately affecting communication reliability. Noise becomes more dominant at greater distances than the received signal. Air quality that can

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1. INTRODUCTION

Smart Living is one of the developments in the Internet of Things (IoT). Smart living refers to the concept where everything in the surrounding area can be controlled and connected to the internet. According to research, 16 million IoT connections are spread across various sectors, such as smart homes, innovative industries, and even smart cities [1]. Some devices commonly used in IoT applications include gas particle sensors that can detect air quality [2] and public street lighting (PJU) systems that can be controlled remotely [3].

Air pollution is when air quality in a particular area exceeds the limits the Air Pollution Index (API) sets. The API calculation is based on seven parameters: PM10, PM2.5, NO2, SO2, CO, O3, and HC. The inclusion of two additional parameters, HC and PM2.5, in the previous set of parameters further refines the measurement [4].

This study focuses on the range of LoRa usage, particularly measuring the Received Signal Strength Indicator (RSSI) and Signal-to-Noise Ratio (SNR). RSSI is the leading indicator of how well a device captures signals; the closer the RSSI value is to 0, the better the signal reception . SNR, or Signal-to-Noise Ratio, is a parameter used to compare the desired signal strength to the surrounding noise level, expressed in decibels (dB) [5].

Several studies have examined RSSI and SNR to assess whether a device can effectively capture LoRa signals. For example, one study [6] found that RSSI values on two different frequencies, 433 MHz and 915 MHz, were higher than -120 dBm, concluding that LoRa at 433 MHz performed better than at 915 MHz, with an SNR of -2.58 dB. These results meet the minimum requirements for a reliable communication system.

Another study [7] found that distance affects the performance of data packet transmission via LoRa. As the transmission distance increases, the RSSI value decreases, evidenced by a result of -101.6 dBm at a distance of 180 meters. The SNR at 180 meters was -3.175 dB, compared to 8.05 dB at 10 meters, indicating that the greater the distance between sender and receiver, the lower the resulting SNR [8].

In this study, researchers used a Point-to-Point topology. Point-to-Point topology is a type of network setup where two devices are directly connected [9]. This topology provides a cost-effective solution for connecting two distant areas wirelessly, reducing the need for extensive cabling over long distances [10].

2. METHOD

This study uses LoRa networks to measure the RSSI and SNR during communication between the transmitter and receiver. The researchers used an observational method by examining the range of LoRa usage in urban areas [11]. The following is the plot or flowchart of this research. A research flowchart makes it easier for researchers to determine what steps and how to do them first, such as preparing materials and equipment to start research in Fig. 1

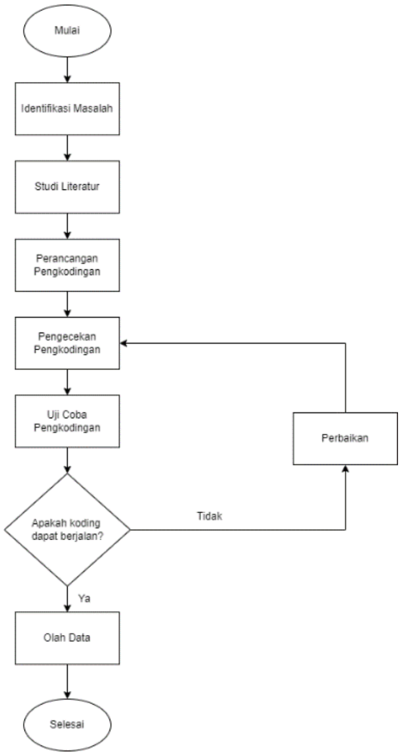

Figure 1 Research Flowchart

A. Received Signal Strenght Indicator (RSSI)

RSSI is based on measuring the power present in a signal between the receiving station and objects. RSSI readings observed at the receiving stations, which can be used to estimate the corresponding distances from the receiving stations, with the use of mathematical models (known as path loss models), where the signal attenuation is correlated with distance through mathematical formulas[5].

B. Signal-to-Noice Ratio (SNR)

SNR, or Signal-to-Noise Ratio, is a measurement parameter used to compare the desired signal to the level of noise or interference from the surrounding environment. SNR can be described as the ratio of signal power to noise power, and it is typically expressed in decibels (dB)[6].

C. Research Sites

Data collection was conducted on Boulevard Grand Depok City. The data gathering was limited to a distance of 300 meters between the transmitter and receiver, based on sample points. This distance was divided into 6 lighting points, each separated by 50 meters. The study involved examining each point with a designated time duration of 5 minutes per location[8].

Tabel 1 Distance

Distance	*Latitude*	*longitude*
50 meters	-6.419136	106.827064
100 meters	-6.419294	106.827569
150 meters	-6.419524	106.827962
200 meters	-6.419823	106.828190
250 meters	-6.420207	106.828374
300 meters	-6.420713	106.828591

D. Wiring LoRa

The wiring for the LoRa Transmitter and LoRa Receiver wiring can be seen in the image below.

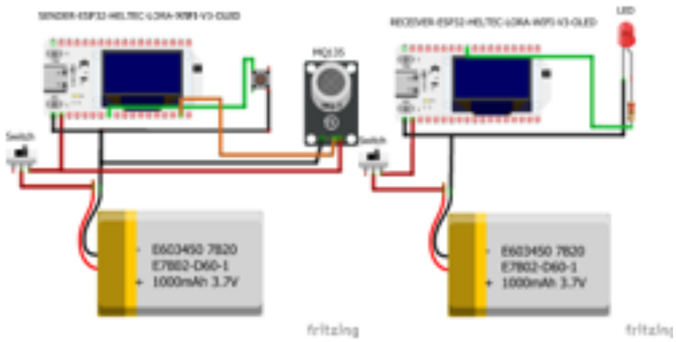

Figure 2 Wiring LoRa Transmitter (Left) and LoRa Receiver (Right)

Fig. 3 above show that MQ135 pin sensor has been attach to pin that in LoRa heltec v3, there are namely the vcc sensor pin connected to the 5v/V in LoRa board which it shown using red cable. The ground pin that connected to GND pin in LoRa that shown using black cable. Then the sensor's analog pin (A0) is connected to pin 32 LoRa heltec, which is shown using the green cable. The MQ135 sensor here uses an analog pin because, in this study, the output is only the value of the measurement results, not accompanied by logic[9].

3. RESULT DAN DISCUSSION

A. Tools Implementation

Figure 4 shows a system that functions as a transmitter, where the transmitter acts as an analyzer and sends data from sensor readings to the receiver [12]. In this study, the data displayed on the transmitter includes sent packets, gas sensor readings, transmitted data, packet loss, and latency. The transmitter module can also trigger signals to turn on the lights.

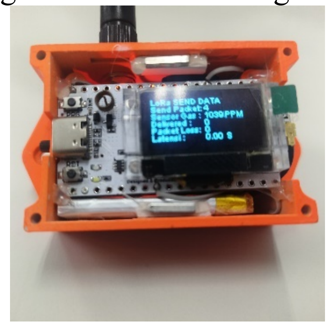

Figure 3 Transmitter

Figure 4 Receiver

Figure 5 shows a system where the receiver functions as a device that receives data sent by the transmitter, which is then displayed on an L.E.D. display [13]. The receiver processes data to be displayed, including gas sensor readings, RSSI, SNR, and the number of packets received. The receiver can also accept transmissions from the transmitter to turn on the lights.

B. Configuration

Before data collection proses calculation about range RSSI must be done first so that the reading result get valid data. The unit RSSI result are form in dBm can be getting by using this equation [14]:

$$PL = PL_0 + 10 \times n \log_{10}\left(\frac{d}{d0}\right) + x\sigma \qquad (1)$$

Information :

PL = Path loss
n = Path loss reverence
d = Distance between transmitter and receiver
d0 = Distance reference (usually 1 meters)
xσ = Deviation random variable

From the (1) is equation to defind about Path Loss and can be determind to find RSSI, where :

$$RSSI = Pt - PL \qquad (2)$$

Information :

Pt = Transmission power
PL = Path Loss

Where PL $(d0)$ is the path loss reference distance $(d0)$ which is 1 to 1.5 meters with free space conditions and n is the path loss exponential which is adjusted to the environmental conditions at the time of testing [15].

Tabel 2 Path Loss Exponent

Enviroment	Path Loss Exponent (n)
Free Space	2
Urban area celuller radio	2.7 – 3.5
Shadowed Urban celluler radio	3 – 5
In Building Line-Of-Sight	1.6 – 1.8
Obstructed in Building	4 – 6
Obstructed in Factories	2 – 3

Based on the table, the following calculations are obtained :

1. Distance 50 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{50}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 50$$
$$PL = 27 \times 1.699$$
$$PL = 45.9\, dB$$

RSSI

$$RSSI = -47 - 45.9\, dB$$
$$RSSI = -92.9\, dBm$$

2. Distance 100 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{100}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 100$$
$$PL = 27 \times 2$$
$$PL = 54\, dB$$

RSSI

$$RSSI = -47 - 54\, dB$$
$$RSSI = -101\, dBm$$

3. Distance 150 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{150}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 150$$
$$PL = 27 \times 2.178$$
$$PL = 58.752\, dB$$

RSSI

$$RSSI = -47 - 58.752\, dB$$
$$RSSI = -105.752\, dBm$$

4. Distance 200 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{200}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 200$$
$$PL = 27 \times 2.301$$
$$PL = 62.127\, dB$$

RSSI

$$RSSI = -47 - 62.127\, dB$$
$$RSSI = -109.127\, dBm$$

5. Distance 250 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{250}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 250$$
$$PL = 27 \times 2.398$$
$$PL = 64.746\, dB$$

RSSI

$$RSSI = -47 - 64.746\, dB$$
$$RSSI = -111.746\, dBm$$

6. Distance 300 meters

$$PL = 0 + 10 \times 2.7\, log_{10}\left(\frac{300}{1}\right) + 0$$
$$PL = 27\, log_{10} \times 300$$
$$PL = 27 \times 2.477$$
$$PL = 66.879\, dB$$

RSSI

$$RSSI = -47 - 66.879\, dB$$
$$RSSI = -113.789\, dBm$$

Based on the path loss calculation above and calculations using an exponent value of 2.7 (shadowed urban cellular radio) from the calculation results it can be seen that the highest RSSI value is at a minimum distance of 50 meters, on -92.9 dBm. Meanwhile, the lowest value of -113.789 dBm was obtained at the maximum testing distance of 300 meters.

Tabel 3 ISPU Table

Category	*Status Color*	*Range of Number*
Good	Green	1-50
Moderate	Blue	51-100
Unhealthy	Yellow	101-200
Very Unhealthy	Red	201-300
Hazardous	Black	≥300

Based on the description of the air pollution components mentioned in Table 4, air pollution can be categorized into several categories: Good, Moderate, Unhealthy, Very Unhealthy, and Hazardous. These categories are derived from the Air Quality Index (AQI) [4].

C. LORAWAN Testing

Testing of the data transmission system using the LoRaWAN network using LoRa Heltec V3 as a microcontroller was carried out at five times. Testing was carried out from a distance of 0 meters to a distance of 300 meters from the receiver.

The following is a table of results of the RSSI and SNR values obtained during system testing [16]:

Tabel 4 RSSI

RSSI (meters)	1	2	3	4	5
50	-92	-99	-96	-93	-93
100	-105	-106	-106	-102	-108
150	-108	-105	-108	-104	-109
200	-112	-110	-109	-113	-111
250	-110	-108	-106	-103	-106
300	-111	-113	-109	-109	-102

Based on table 5 at a distance of 50 meters, the RSSI value from the research is -94.6 dBm and the calculation result is -92.9 dBm. At a longer distance, such as 300 meters, the research RSSI value is -108.8 dBm, while the calculation result is -113.8 dBm. The difference between the research RSSI values and the calculation results shows that there are differences in results, this could be due to the fact that the research was not carried out at a straight distance but turned based on the research location. Nevertheless, the calculated values remain in a fairly close range to the research results, indicating that the results of this research have a good level of accuracy and can be used to estimate signal strength based on distance.

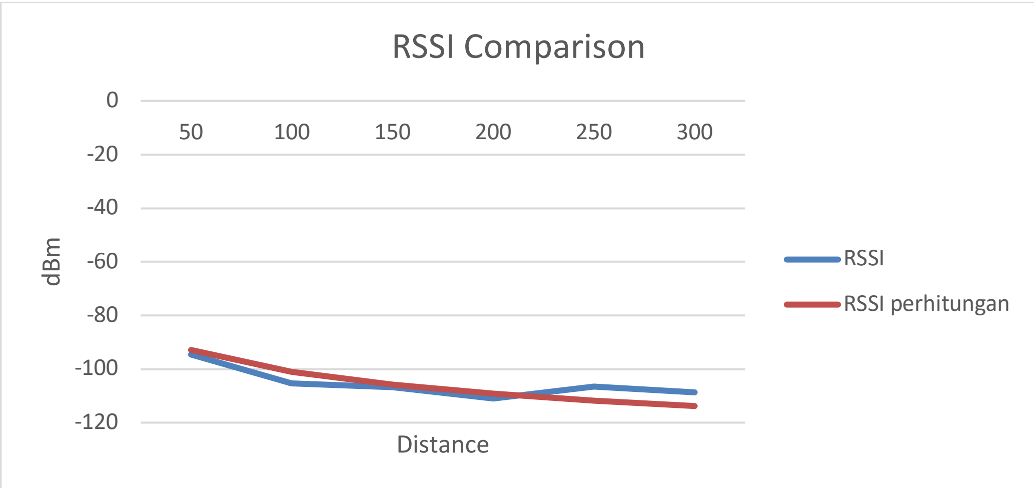

Figure 5 RSSI Comparison

In Figure 6, at a distance of 50 meters, the measured RSSI value is -94.6 dBm, while the calculated value is -92.9 dBm. At a farther distance, such as 300 meters, the measured RSSI value is -108.8 dBm, whereas the calculated value is -113.8 dBm. The difference between the measured and calculated RSSI values indicates some discrepancies, possibly due to the research needing to be conducted in a straight line instead of with turns based on the research location. Nevertheless, the calculated values remain relatively close to the measured results, indicating that the research has a good level of accuracy and can be used to estimate signal strength based on distance.

Tabel 5 SNR

SNR (meters)	1	2	3	4	5
50	11	9	10	11	11
100	6	5	5	8	3
150	3	7	3	6	2
200	-4	0	-2	-7	-1
250	1	3	5	7	5
300	-3	-8	2	8	1

Based on an SNR (Signal-to-Noise Ratio) showing the variation of SNR over distance. At a distance of 50 meters, the SNR is at a high value of around 10 dB. As the distance increases to 150 meters, the SNR decreases significantly until it reaches a low value of around -4 dB. After that, at a distance of 200 meters, the SNR starts to increase again and reaches a peak of around 11 dB at a distance of 250 meters. However, after a distance of 250 meters, the SNR decreases again to nearly 0 dB at a distance of 300 meters. These SNR changes indicate that signal quality varies depending on distance, with the lowest point at around 150 meters and the highest point at around 250 meters.

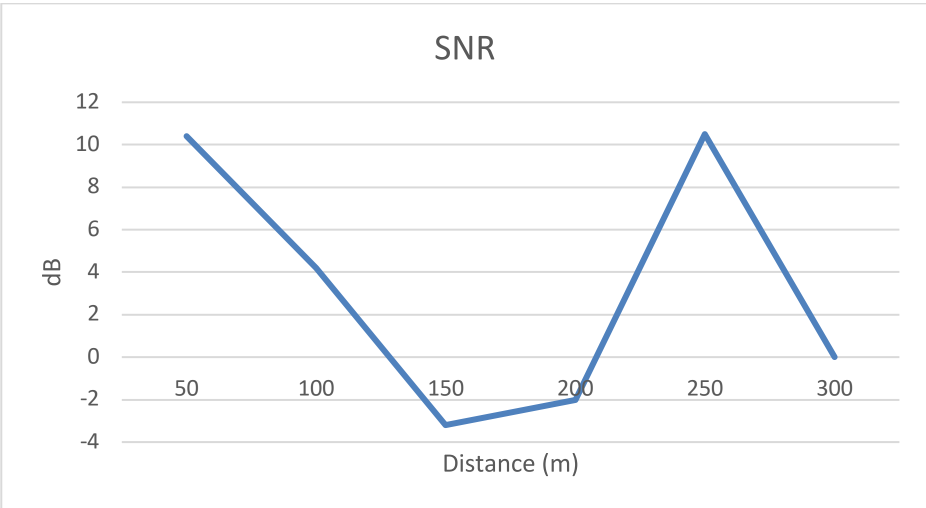

Figure 6 SNR

Figure 7 is a graph of the Signal-to-Noise Ratio (SNR) showing variations in SNR concerning distance. At 50 meters, the SNR is relatively high, around 10 dB. As the distance increases to 150 meters, the SNR decreases significantly, reaching its lowest point at around -4 dB. Then, at 200 meters, the SNR rises again, peaking at approximately 11 dB at 250 meters. However, beyond 250 meters, the SNR declines once more, approaching 0 dB at 300 meters. This variation in SNR indicates that signal quality fluctuates depending on the distance, with the lowest point around 150 meters and the highest point around 250 meters.

Tabel 6 Co2 Testing

No	CO2 Testing		Error %
	Sensor MQ135 (PPM)	CO_2 Detector (PPM)	
1	477	480	0.6%
2	490	475	3%
3	496	478	3.8%
4	519	500	3.6%
5	509	523	2.7%

Based on Table 7, the sensor calibration results are within ±5%, with the highest error percentage observed in the third trial at 3.8%, while the lowest error is in the first trial at 0.6%. It can be concluded that the system performs well.

4. CONCLUSION

The research results showed that the average RSSI was -94.6 at 50 meters, -105.4 at 100 meters, -106.8 at 150 meters, -111 at 200 meters, -106.6 at 250 meters, and -108.8 at 300 meters. Meanwhile, the most significant SNR value was at 50 meters, with a value of 11 dB, and the smallest was at 300 meters, with a value of -8 dB. Gas monitoring system demonstrates good stability in measuring gas levels at various distances from the sensor. Although there is variation in the measured gas levels—ranging from 467 PPM to 651 PPM—the gas condition remains consistently good across all measurement distances, from 50 meters to 300 meters. Additionally, the indicator light remains on at all tested distances, indicating the system is responsive and effective in maintaining gas levels within a safe range. These results confirm that the system can accurately and consistently monitor gas levels, without being significantly affected by the distance from the sensor.

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