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LoRa Performance Analysis with Study Case a Moving Object

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Abstract*— Currently, the development of wireless communication is growing rapidly. One uses Long Range (LoRa) in various applications such as agricultural monitoring, health, animal husbandry, and tracking systems. LoRa implementations are often used for long-distance transmission, so LoRa is becoming a promising technology as a future wireless communication standard for the Internet of Things (IoT). This is supported by its advantages, such as long communication range, low cost, and low power consumption. However, LoRa transmission is susceptible to the surrounding environment, such as buildings, trees, humans, hillsides, and other frequency disturbances, making researchers analyze its capabilities. In this study, we analyzed moving objects (vehicles) as transmitter nodes. We analyze LoRa with distance and speed variables. It will be tested using vehicle speeds of 10 km/hour, 20 km/hour, and 30 km/hour to monitor movement tracking. This study also analyzes LoRa with the distance variable by measuring the RSSI, SNR, and packet loss values, which aim to determine the appropriate performance in sending data in vehicle tracking in Line of Sight (LoS) and Non-Line of Sight (N-LoS) areas. The speed analysis concluded that the higher the speed, the farther the distance between points will be, and the delay will be more significant so that the displayed map will correspond to the actual path traversed by the vehicle.

***Index Terms*— LoRa, Line of Sight, Non-Line of Sight, Packet Loss, RSSI, SNR, Tracking.**

I. INTRODUCTION

Internet of Things (IoT) devices provide connectivity and intelligence to transfer data over a connection without the help of computers and humans[1], [2]. Because of its ability to support the constant transfer of information, IoT is flexible and practical for various industries, including healthcare, agriculture, and transportation [3], [4]. Most IoT applications use sensors to read physical values and use wireless communication technologies such as ESP8266[5], [6],[7] infrared, RFID[8], Bluetooth[9], [10], Zigbee[11], WiFi[12], etc.

In previous research, a logistics truck tracker system has been developed using GPS and WIFI technology[13]. Several disadvantages include high power consumption, short transmission distance, and difficult internet access in rural areas. Specifically for vehicle tracking, at a certain point, the device cannot transmit data in real-time if it loses connection.

LORA became one option to overcome the previous system's weaknesses. LoRa technology is considered capable of overcoming the problem of conventional devices not connected to the internet. LoRa's ability to send small data from 0.3 kbps to 5.5 kbps and its battery consumption allows it to be used long-term [14]. LoRa is also a communication system suitable for mobility services such as a vehicle or object tracking because of its low operating costs, adequate data rates, and low latency[15].

The data transmission is also influenced by the transmitted signal's quality and the transmission media's characteristics. With transmission interference, signal quality will decrease, and the type of transmission media used will affect the data transmission process. LoRa communication coverage is 2-5 km in urban areas and 15 km in sub-urban regions [16]. LoRa modules also have dependencies such as environmental factors used as a test site, environmental and building density, the type of antenna used, and the type of LoRa module used[17].

For this reason, several measurements were carried out to obtain the quality of LoRa performance, especially in rural areas, such as the Received Signal Strength Indicator (RSSI), Signal Noise Ratio (SNR), and packet loss test.

II. STUDY LITERATURE

A. LoRa HopeRF-RFM95W

In this study, the authors used LoRa HopeRF-RFM95W with a frequency of 915 Mhz. This module is used in data transmission systems with a fairly wide range of 8 km with a large enough data capacity. We have also increased the radiation intensity of the LoRa interface using Antenna LoRa 915MHz with a gain of 5 dBi. The LoRa HopeRF-RFM95W has the following specifications[18]:

Table. 1 Specification of LoRa HopeRF-RFM95W

Operating Voltage	3.3V
Frequency	915 MHz
Maximum Senility	-148 dB
Modulation	FSK, GFSK, MSK, GMSK, LoRa and OOK
Power amplifier	14 dBm
Maximum bitrate	300 kbps
Dynamic Range RSSI	127 dB
Minimize network interference	
The packet engine can go up to 256 bytes with CRC.	

B. LORA Performance Parameters

The LoRa parameters used as a reference in this study include[19]:

1) RSSI

Received Signal Strength Indicator is a parameter that measures the received signal strength indicator. RSSI measures the reliability of getting signals from end devices. RSSI is useful for managing many end devices because it is related to sufficient signal to get good connection results. The RSSI value is closer to 0, the better the signal. The RSSI value highly depends on environmental conditions, such as distance and obstructions. RSSI value will decrease if the transmission distance gets farther and the signal propagation barrier gets thicker.

Factors that affect the RSSI value are as follows:

- The path loss model will affect the performance of LoRaWAN applications. When the end node is placed in a different direction from the gateway, the link power attenuation changes due to various land cover types, including trees, land slopes, vehicles, community buildings, and roads along the path[20].

- Antenna Power

The transmitting antenna produces radiofrequency radiation that spreads in space, whereas the receiving antenna receives radio frequency radiation and converts it into the required signal in the receiving device.

Table. 2 Classification of RSSI[21]

RSSI Level (dBm)	Classification
-54 to -30	Excellent
-65 to-55	Very good
-75 to -65	Good
-85 to -75	Average
-95 to -85	Bad
-120 to -95	Extremely Bad

2) Signal Noise Ratio (SNR)

Signal Noise Ratio (SNR) is a parameter that can determine the quality of a signal disturbed by noise. SNR is obtained by comparing the desired and unwanted signals generated by noise[22], [23].

Therefore, the SNR equation can be seen in:

$$SNR\ average = \frac{Receiver\ Signal\ Power}{Noise\ Power}$$

Table. 3 Classification of SNR

SNR (dB)	Classification
> 29dB	Excellent
20,0 dB s/d 28,9 dB	Very good
11,0 s/d 19,9 dB	Good
07.0 dB s/d 10,9 dB	Average
<06,9 dB	Bad

3) Packet Loss

Packet Loss is the proportion of packets lost during data transmission. Packet loss can occur due to errors carried by the physical transmission medium. Things that affect packet loss can also be due to geographical conditions such as fog, rain, radio frequency interference, cell handoff during roaming, and interference such as trees, buildings, and mountains[24].

Table. 4 Classification of packet loss

Category	Packet Loss
Excellent	0-2 %
Good	3-14 %
Average	15-24 %
Bad	>25 %

III. RESEARCH METHOD

This study describes the process of designing a LoRa-based tracking system by explaining the parts of the design and communication system between the sender and the recipient of the data.

A. LoRa-Baseded Vehicle Tracking System Design

The system consists of a LoRa end device attached to the vehicle to provide the function of tracking. This end device comprises GPS NEO6M and HopeRF RFM95W LoRa, assembled in an Arduino Uno. HopeRF RFM95W LoRa provides data transmission using a LoRa radio frequency on the ISM frequency band 915 MHz that can achieve a sensitivity of over -148dBm with a low-cost crystal and bill of materials. The components on the LoRa gateway include ESP32 HopeRF RFM95W and are placed 20 meters above ground level.

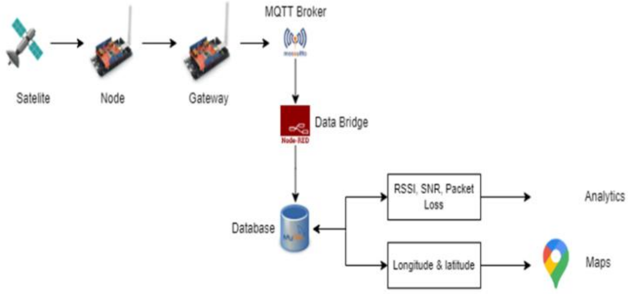

Figure. 1 LoRa-Based Vehicle Tracking System Design

The design model uses a GPS tracker installed on the vehicle. First, the GPS receives coordinate data in latitude and longitude and date and time data packages. After receiving the data, it is sent using the LoRa network from the

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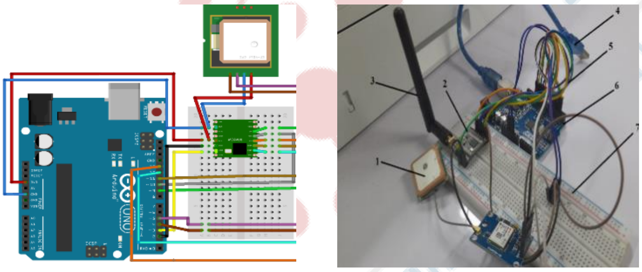
node to the gateway. The gateway will receive data, which will then be forwarded to the cloud database server via Wi-Fi access. The data that the server has received will be stored in a MySQL database. Then, the server will translate the GPS location coordinate data into a vehicle location display as a map displayed on a website. This website is used to monitor the location of the vehicle. Besides that, we also analyze the RSSI, SNR, and packet loss values to see Lora's capabilities in the area

B. Working Principles of Vehicle Tracking System

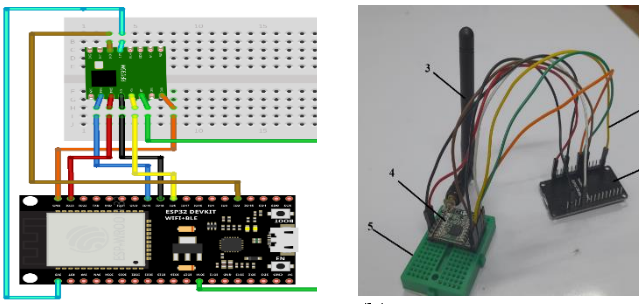
First, input data will be provided by satellite via GPS module, where the GPS module on this node will ask for the position of latitude, longitude, time, and date on the satellite. The node sends data to the Gateway on LoRa transmission: packet data (date and time) and GPS location. In the Node component, there is an Arduino Uno microcontroller, HopeRF RFM95W LoRa, and GPS NEO-6M to determine the current location of a vehicle.

The gateway receives data coordinates and sends them to the database server via Wi-Fi. The gateway component in this system consists of an ESP32 and a LoRa module as a connecting transceiver with the transmitter. In addition, this gateway device also functions as an intermediary for communication with the server. The data received from the node will be forwarded to the server using the publish function, then the broker forwards the data to a server that has subscribed by receiving packets on demand. The website will retrieve coordinate data from the database server to display the vehicle's location as a map. The map displayed on the website is used to monitor the vehicle's position (coordinates).



(a) (b)

Figure. 2 Prototype scheme of LoRa end-device



(a) (b)

Figure. 3 Prototype scheme of LoRa end-device

Tests were carried out in an N-LoS environment at the Institut Teknologi Del, as shown in Figure 4. We placed the gateway on the 4th floor of GD 9 (Building 9) while the node moved from GD 9 to the Antioch dormitory. This test is repeated three times to see the accuracy of the resulting map shape. The system utilizes antennas five dBi on node and gateway to support data capture.

Figure. 4 Experiment Location

This experiment aims to measure the maximum communication range in a suburban area by analyzing its main parameters concerning distance and velocity. The environment contains vegetation beside the track, buildings, people, WIFI access, and other moving vehicles.

IV. RESULT AND DISCUSSION

This study tested the reliability of LoRa at speeds of 10 km/hour, 20 km/hour, and 30 km/hour through the analysis of RSSI, SNR, and packet loss data values on the gateway side.

Data analysis according to speed

A. Measurement of RSSI in Different Speed

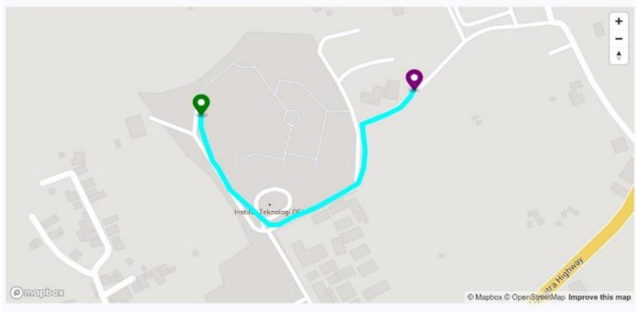


Figure. 5 Map of experiments track

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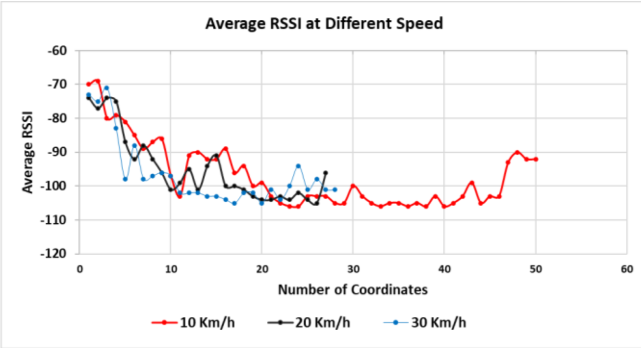

Figure. 6 RSSI Measurement Based on Speed

In this experiment, the Gateway was installed 20 m above ground level on the 4th floor of GD9, and the final device was placed on the vehicle. The trajectory, which is 450 meters, has been determined, as shown above. Data transmission starts from the transmitter to the gateway and is set every second. The average RSSI was obtained at speeds of 10 Km/h (red line), 20 Km/h (black line), and 30 Km/h (blue line). The coordinates obtained at each speed are 50, 27, and 28 data. The 34th data with a speed of 10 km/hour has an RSSI value of -106, the 23rd data with a speed of 20 km/hour has an RSSI value of -104, and the 21st data with a speed of 30 km/hour has an RSSI value of -105. The RSSI value at this point is relatively low because the vehicle passes through dense buildings and trees. However, the Average RSSI at a speed of 10 km / h is better than the value of the RSSI at a speed of 20 km / h and a speed of 30 km / h.

B. Measurement of RSSI in Different Speed

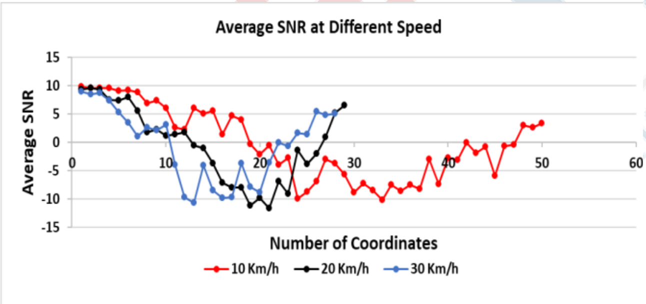

Figure. 7 Measurement SNR Based on Speed

Figure 7 shows a graph of the average measurement of SNR values at speeds of 10 Km/h, 20 Km/h, and 30 Km/h with red, black, and blue colors, respectively. The 37th data at a speed of 10 km/hour has an SNR value of -11.25, the 21st data at a speed of 20 km/hour has an SNR value of -11.75, and the 20th data at a speed of 30 km/hour has an SNR value of - 11.75. This low value is influenced by people passing, buildings, vehicles, and WiFi-transmitting towers in the surrounding area. The number of coordinates successfully recorded is proportional to the RSSI obtained. The SNR data shows that the SNR value at a speed of 10 km/hour is better than the SNR at a speed of 20 km/hour or 30 km/hour.

C. Packet Loss at Different Speed

Packet loss data is obtained through the serial monitor recording and is calculated using the following equation:

$$Packet\ loss = \frac{Transmitted\ packet}{Received\ Packet} x\ 100\%$$

The data sent is 39 data, which contains latitude, longitude, date, and time, as in the following example.

```
Publish message: 2.380259,99.150520, 6/7/2022, 07:41:50
```

Received data packets are data received by the gateway from the node, as in the following example. The received packet is 21 data.

```
Message arrived [topic/GPS] :.;S0186*99'1=0608 6.1'b222<07?>2S4S
```

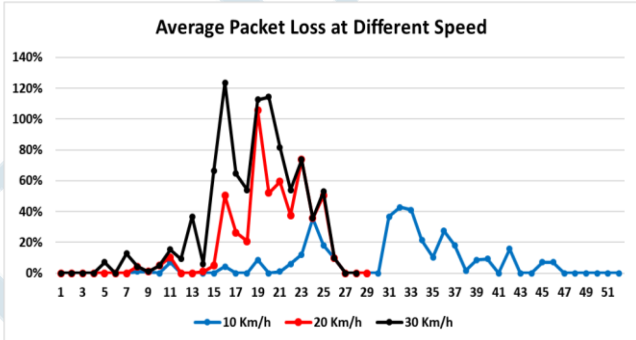

Figure. 8 Measurement packet loss based on speed

Figure 8 shows a packet loss data measurement graph in the first test with variable speed. The graphic shows the difference in the variation of packet loss values at the gateway. Good results were obtained from performance testing with variable speed. The 23rd data at a speed of 10 km/hour has a packet loss value of 51%, the 19th data at a speed of 20 km/hour has a packet loss value of 97%, and the 15th data at a speed of 30 km/hour has a packet loss value of 97%. The packet loss value at the data point is low because, at that point, it passes through the Auditorium side road. At that location, there are obstacles in the form of people, vehicles, and trees. These obstacles significantly affect the value of packet loss. Therefore, the packet loss value depends on the designed hardware's N-LoS environmental conditions and wiring. Based on the graph, it shows that the value of packet loss at a speed of 10 km/hour is better than the value of packet loss at a speed of 20 km/hour and a speed of 30 km/hour.

Table. 5 Packet loss at different speeds

Speed (Km/h)	Experiment	Packet Loss
10	1st test	10
	2nd test	14
	3rd test	10
20	1st test	9
	2nd test	9
	3rd test	9
30	1st test	8
	2nd test	6
	3rd test	6

V. CONCLUSIONS

Speed analysis means that the higher the vehicle speed, the farther the distance between points will be, and the less data obtained, so the displayed map will form a relationship between points according to each coordinate point received. Increasing the distance between the node and the farther gateway will result in lost packets and poor LoRa performance. Based on three tests in the N-LoS area in the Institut Teknologi Del environment with speed variations of 10 km/h, 20 km/h, and 30 km/h, meaning that the faster the vehicle goes, the RSSI value remains stable with a value of around -95 dBm to - 99 dBm with good quality, the SNR value is also stable with a value of -0.144 dB to -0.372 dB with poor quality. At the same time, packet loss fluctuates with values from 7% to 16% with good quality In the Non-Line of Sight area in the Institut Teknologi Del environment with a range of 30 meters to 300 meters. At a distance of 30-100 meters, the RSSI value is -82.3 dBm, then up to a distance of 200 meters, the RSSI value decreases to -95.36 dBm, then up to 300 meters, the RSSI value decreases again to -102.5 dBm. For the SNR value, the farther the vehicle is, the worse the SNR value. At a distance of 30-100 meters, it has an SNR value of 8.55 dB, then up to a distance of 200 meters, it has an SNR value of 4.57 dB; up to a distance of 300 meters, it has an SNR value of -4.5 dB. For packet loss values, the farther the vehicle is, the more data is lost; at a distance of 30-200 meters, it has 0% packet loss; up to 300 meters, it has 9% packet loss.

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