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DISTANCE TESTING ON POINT TO POINT COMUNICATION WITH LORA BASD ON RSSI AND LOG NORMAL SHADOWING MODEL

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ABSTRACT: *Big cities are currently implementing the smart city concept, where Internet of Things (IoT) sensors are placed on the roads, then the data is collected and processed by smart devices to solve urban problems. IoT implementation is suiTbl using LoRa technology. In this paper, distance testing is carried out on point to point communications with LoRa in urban areas at a frequency of 915 MHz. The RSSI (Received Signal Strength Indicator) parameter value is what is observed, and the log normal shadowing model is used to compare the RSSI values computationally. The test results for the farthest distance were 3.37 km with an RSSI value of -104.5 dBm. The error value between the measured and calculated RSSI values is 7.3% where a path loss exponent (n) of 1.6 from the measurement results.*

KEYWORDS: *LoRa, Internet of Things (IoT), RSSI*

I. INTRODUCTION

Long Range (LoRa) is a wireless connectivity technology primarily intended for IoT systems. There are many advantages of LoRa technology, as a wide-area network solution that promises coverage distance with very low power consumption and secure data transmission, with thousands of node devices that can be connected in the network so that it is very suiTbl for IoT in smart cities [1],[2],[3],[4].

LoRa operates in unlicensed Industrial, Scientific, and Medical (ISM) frequency bands such as 2.4GHz, 868MHz, 915MHz, and 433MHz depending on each region's regulations. In Indonesia, this regulation will be regulated by Kominfo and will follow the LoRa frequency standard set by the LoRa Alliance for the Asian region which is at frequencies of 923-925 MHz (AS923) [5], [6], [7].

Received Signal Strength Indicator (RSSI) is a parameter used to measure the signal strength indicator received by a wireless or wireless device. RSSI is a measurement of the power received by a wireless device. Measurements are made based on Signal Strength or the strength of the signal received. This aims to determine the level of accuracy of measurements and calculations using wireless. In the measurement of an RSSI value there are several limitations because RSSI is influenced by noise, transmit power, multi-path fading, and other disturbances that can affect the quality of the received signal strength [8]. The unit of RSSI uses dBm (decibel milliWatt) and is a negative value due to signal attenuation by the surrounding environment. The maximum value is -30 dBm while the minimum value is -120 dBm. The closer to 0 or towards a positive number, the better the signal quality while the closer to -120 dBm, the worse the signal quality [9].

Previous related research was the study of signal propagation in forest, urban and sub-urban environments, the results of which stated that LoRa signal stability is highly dependent on the environment, and is more sTbl in suburban areas than in high-density urban areas [10]. Another study focused on the coverage distance, which resulted in the longest distance obtained with a reasonable percentage of packet loss being 5-10 Km in urban areas, 15-30 Km in open water areas and 1.6 Km in complex environments [7],[11].

II. DATA TRANSMISSION AND PROPAGATION MODELS

In sending data from one data source to the data receiver, the configuration is done to connect the devices that will communicate in a way: 1. Point to point, which is specifically connecting two devices that will communicate, 2. Multipoint, which is one channel connected to several devices.

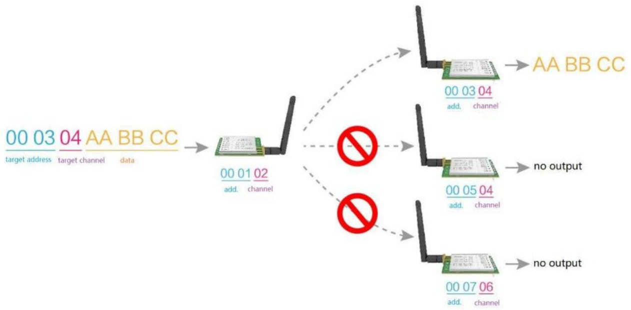

Fig 1. Fixed Transmission-Point to Point

When a signal is transmitted in the air there is radio wave propagation, whose signal strength will be attenuated by multipath, obstacles and other factors. Free space Path Loss is an ideal transmission, where factors that affect signal propagation are ignored, written with the following Friis Transmission equation [12]:

Loss = 32.44 + 10n log d (Km) + 10n log f (MHz) (1)

The Log Normal Shadowing Model (LNSM) is a more general propagation model suiTbl for indoor and outdoor environments, which considers the path loss value that occurs for the distance between TX and Rx. [13] :

$$PL(d) = PL_o + 10n \log\left(\frac{d}{d_o}\right) + X\sigma \quad (2)$$

Where PL(d) is the path loss at distance d (meter) outdoor, PL_o is the reference path loss at distance d_o with free space conditions obtained from the Friis equation. The reference distance is 10-100 meters for outdoor [13]. d is the distance between TX and RX in meters, n is the pathloss exponent (PLE) adjusted to the test environment (Tbl 1), shadowing effect $X\sigma$ is a gaussian distributed random variable with zero mean and standard deviation σ (dB), the value is between 2-14 [8].

Tbl 1. Path loss exponent of different environments [13]

Environment	Path loss exponent, n
Free space	2
Urban area cellular radio	2,7 - 3,5
Shadowed urban cellular radio	3 - 5
In building LOS	1,6 -1,8
Obstructed in building	4 - 6
Obstructed in factories	2 -3

So the RSSI calculation is as follows [8],[14]:

$$RSSI = P_T - PL_o + 10n \log\left(\frac{d}{d_o}\right) + X\sigma \quad (3)$$

Where RSSI is in (dBm), P_T is the Tx transmit power in (dBm).

III. METHODS

The configuration of the data transmission communication line is point to point. The design of the measurement tool consists of a LoRa Ebyte E220-900T22D module with a 5 dBi antenna and ESP32 on the Transmitter (Tx) while on the Receiver (Rx) an OLED display is added to display the RSSI value. Configuration of each LoRa with a frequency of 892.125 MHz, channel 42, and transmitting power of 22 dBm.

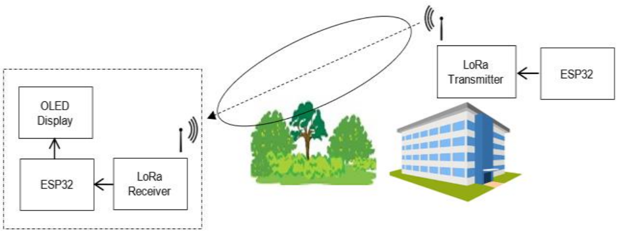

Fig 2. Simulation of NLOS condition measurement

Measurements were made by placing Tx and Rx at a certain distance, then measuring RSSI and distance. Tx was placed on the 2nd floor of the building with a height of 9 m and programmed to send a character to Rx. Measurements were taken at several locations until the maximum distance was reached or the Rx could not receive the characters sent by the Tx according to the RSSI level. The measurement distance is determined at 100 m, 500 m, 1 Km, 2 Km, >2 Km at Tx coordinates (Lat, Long) = -6.598767, 106.809704

Tbl 2. Measurement Distance Determination

Rx point	Lat	Long	Distance (Km)
1	-6.59738	106.80974	0,15
2	-6.5953	106.80949	0,38
3	-6.59188	106.81025	0,76
4	-6.59182	106.81449	0,94
5	-6.58552	106.81667	1,66
6	-6.58167	106.81782	2,09
7	-6.57065	106.81552	3,18
8	-6.5686	106.80532	3,37

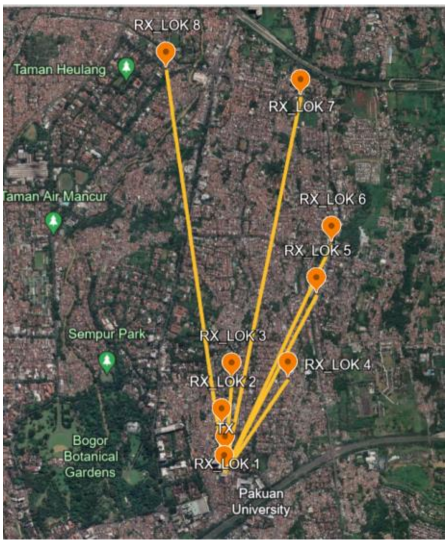

Fig 3. Measurement Point

IV. RESULTS AND DISCUSSION

The RSSI conversion value in dBm is obtained by dBm = -(256 - RSSI). The measurement results for each distance in tbl 3 show that the power received by the Rx is affected by the distance, which is marked by the RSSI value which decreases at each point of measurement distance farther from the Tx.

Tbl 3. RSSI measurement results

Distance (Km)	RSSI Value		
	Min	Max	Average
0,15	-64	-49	-54,9
0,38	-105	-86	-93,3
0,76	-94	-88	-91.3
0,94	-102	-93	-98
1,66	-104	-101	-102,5
2,09	-105	-103	-104
3,18	-105	-102	-103,5
3,37	-106	-103	-104,5

The RSSI value is calculated according to the measurement environment conditions that have buildings and trees along the signal propagation path using the log normal shadowing model by considering the path loss that occurs between the Tx and Rx distances. The addition of the shadowing effect means that the signal strength received at a point with the same distance (d) from the transmitter has a different value and has a lognormal distribution. Using equation (3) with the addition of the shadowing effect ($X\sigma$) = 2, as well as the path loss exponent value (n) = 1.6 measured and (n) = 2.7 in theory, the calculated RSSI value can be seen in Tbl 4.

Tbl 4. RSSI Value Calculation

Distance (Km)	RSSI Value		
	Measurement	Calculation of n=1.6	Calculation n=2.7
0,15	-54,9	-64,4	-70,8
0,38	-93,3	-78,7	-89,5
0,76	-91.3	-89,4	-103,5
0,94	-98	-92,6	-107,6
1,66	-102,5	-101,5	-119,3
2,09	-104	-105,2	-124,1
3,18	-103,5	-111,7	-132,6
3,37	-104,5	-112,6	-133,8

In the Tbl 4 above is the RSSI value in Non Line Of Sight (NLOS) conditions where the signal from the transmitter passes through obstacles such as buildings, trees etc., before reaching the receiver. The signal will experience reflection, refraction, diffraction, absorption and scattering which affects the received signal strength. In both measurements and calculations, the received signal strength decreases logarithmically with distance. At a distance of 3.37 km, the maximum distance is reached where the value is close to the minimum RSSI value of -120 or the distance beyond that the signal power is very weak and the characters sent cannot be received.

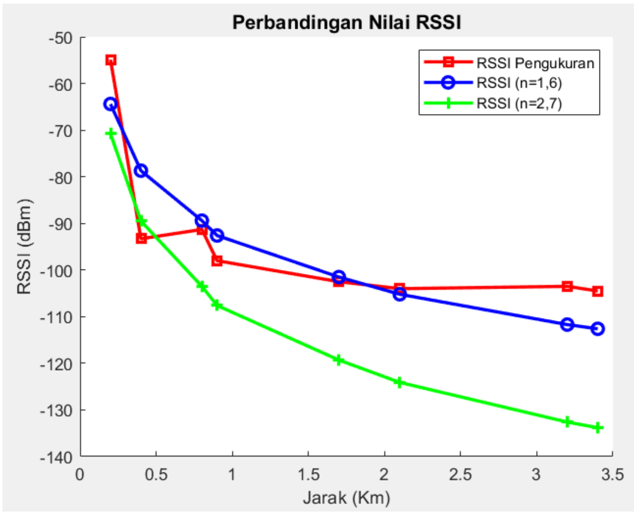

Fig 4. Comparison of RSSI Values

In Fig 4, the x-axis shows the measurement points or the distance between the transmitter and receiver in (Km). The y-axis shows the receiving power or RSSI in (dBm). The change or decrease in RSSI value at the measurement distance of Rx1 to Rx2 is quite significant compared to the calculated RSSI value, this is possible because at the measurement distance of Rx1 the environmental conditions are almost no obstacles in the signal transmission process, then the measurement distance of Rx2 to Rx8 the measurement environmental conditions are between houses, buildings and trees. Comparison of the three RSSI values between the measurement results, calculations at a value of n = 1.6 and n = 2.7 was carried out to confirm the RSSI values obtained. The path lost exponent value is used as a reference for calculating the log normal shadowing model. The value of n = 1.6 is obtained from the calculation results at a reference distance $d_{o,}$ or a linear regression is used which is modeled with the pathloss equation empirically.

$$Y = a + b\,X$$

$$PL(d) = PL_0 + 10nlog\left(\frac{d}{d_0}\right)$$

$$PL = a + b\,X$$

With the variable *a* as the initial value of pathloss which is *free-space loss* at a reference distance d_o , b is the pathloss exponent value multiplied by 10, and X is the logarithmic value of the receiver distance divided by the reference distance, so that the pathloss exponent value is b/10. While n = 2 is based on theory (tbl 1) adjusting to the test environment. The comparison results on the graph show that the blue line is close to or almost coincides with the red line, meaning that the environmental conditions that are close to the measurement results are at the path loss exponent (n = 1.6) according to Tbl 1 in the range for the in building LOS environment. The percent measurement error value is calculated by :

$$\%\ error = \left|\frac{RSSI\ pengukuran - RSSI\ perhitungan}{RSSI\ pengukuran}\right|\ x\ 100\%$$

The calculation at n = 1.6 obtained the % error value of the entire measurement is 7.3%.

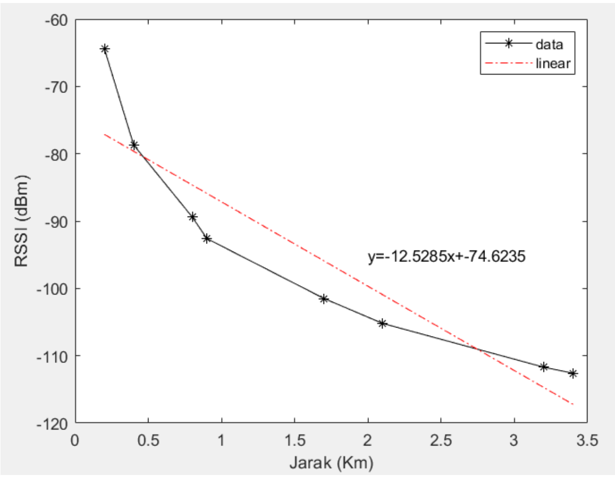

Fig 5. Correlation of Distance and RSSI Value

From the measurements of the average RSSI and distance in the outdoor environment, the LNSM model can be estimated, which is the relationship between the average RSSI and the logarithmic scale of the distance. The regression estimation line yields the following equation.

$$RSSI\ (dBm) = -12{,}5285log\left(\frac{d}{d_o}\right) - 74.6235$$

V. CONCLUSION

In this paper successfully designed distance testing on point to point communication with LoRa, the results of which the farthest distance that can be achieved is 3.37 Km, where the results have not reached the theoretical distance of 5 Km. This is due to the variety of buildings and trees along the signal propagation path, the proximity of the Rx device to the ground (measurement position 1.5 m from the ground), and the frequency used is at the GSM uplink frequency, all of which have contributed to reducing the signal strength obtained by the receiver.

The pathloss exponent (PLE) value of the measurement results can be said to be incompatible with the environment based on the theory in the Tbl, but it can be verified by the suitability of the PLE paremeter value used to find the estimated RSSI value using the log normal shadowing model whose results are close to the RSSI value of the measurement results.

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