2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT)
April 09-11. 2021, ISTTS Surabaya, Indonesia

A Performance of ES920LR LoRa for the Internet of Things: A Technology Review

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2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT) | 978-1-6654-0514-0/20/$31.00 ©2021 IEEE | DOI: 10.1109/EIConCIT50028.2021.9431912

***Abstract*—In this research, the LoRa used is the ES920LR. LoRa ES920LR is used in Japan with a frequency of 920 MHz, LoRa ES920LR has small dimensions, its size is 24.00 x 17.0 x.2.3 mm, and a range of 3 km at Free Space Path Loss (FSPL); the RSSI value (-dBm) is found to be different in different outdoor environmental conditions. Furthermore, the ES920LR is used as a transmitter and receiver for human heart rate data. The heart rate sensor used is a Pulse Sensor placed on the tip of a human finger. At the Line-of-sight of Building position, the RSSI value (-dBm) shows -119 dBm at a distance of 710 meters, and the PRR (%) is 93.94%. Furthermore, the ES920LR is combined with the Leafony Board to become the Leafony Board LoRa ES920LR. Due to its small size, it is possible to place it on a drone or UAV coupled with GPS as navigation in the analysis and analysis of the ES920LR Spreading Factor and Signal Power LoRa.**

Keywords— LoRa, IoT, FSPL, ES920LR, Pulse

I. INTRODUCTION

Recently, Low Data Rate (bps) transmitting technology in Internet Of Things technology continues to increase. With the LoRa (Long Range) Radio Frequency and other competitor devices such as NB-IoT. It is seen in terms of the data transmitting distance (km) and dimensions or size. The smaller the LoRa size or measurements, the more flexible it is in the analysis.

Moreover, on point-to-point communication and the multipoint mesh analysis of LoRa server capabilities, research is carried out by analyzing LoRa Quality of Service (QoS) on Radio Propagation Outdoor Environment conditions will cause attenuation signals and Packets. Different loss (-dBm) and Small Throughput LoRa data, in this research, research was carried out in the health monitoring sector by combining a heart rate sensor placed on the tip of a human finger [1] sent using the Long Range (LoRa) ES920LR. LoRa ES920LR supports LoRaWAN applications [2], [3] LoRAWAN allows LoRa End node sensor data to be displayed in real-time on the application server. In research [4], LoRAWAN [5] testing used a simulation with MATLAB Software. In a study [2], LoRa Quality of Service analysis was carried out, namely on Packet Loss or data drop and data transmission. In research [6], the sensor used is the BME280 sensor, and the LoRa used is the Dragino 915 MHz in the outdoor environment test.

II. THEORY

A. ES920LR LoRa Board for Tx & Rx

ES920LR is a LoRa radiofrequency device with a frequency of 920 MHz, issued by EASEL to support the Internet of Things (IoT) devices. As shown in Fig. 1, LoRa Dimension Fig. 2. Moreover, Table I compares LoRa with other Wireless Sensor Network devices in terms of coverage distance and transmission speed. LoRa signal modulation, known as CHIRP signal, has been described in research. In this research, signal processing was carried out by signal analyzer LoRa. By using Matlab software, you can also find CHRIP Signal using the parameters in equations 1,2,3 and 4.

t=0:0.05:40; A=1; omega=2; s_t = t.^2/4.

$$y\_t=A*\cos(omega*t + s\_t) \quad (1)$$

$$\sin(1/2\ \pi((2x/3+1)\ \hat{}2\text{-}1)) \quad (2)$$

$$\sin(\pi((\pi+1)\ \hat{}2\text{-}1)) \quad (3)$$

$$y(a,b,c,d)=c \sin\{\pi/(b\text{-}a)\ [((b\text{-}a)\text{-}x/d+a)\hat{}2\text{-}a\hat{}2\ ]\} \quad (4)$$

The combination of the Leafony Board and EASEL ES920LR was tested in the Kanazawa University Laboratory design process (MeRL), the connection between the LoRa ES920LR and the Leafony board is shown in Table II. Furthermore, the LoRa Layer consists of the LoRa Protocol Frame, i.e., Physical Layer, MAC Layer, and Application Layer. The relationship between layers can be seen in Fig. 1 and 2.

Fig. 1. EASEL Inc ES920LR (MeRL Data)

Fig. 2. ES920LR Dimension (MeRL Data)

TABLE I. THE RANGE, POWER, AND TRANSMISSION SPEED OF WIRELESS TECHNOLOGY

Technology	Wireless Communication	Range	Tx Power	The Transmission Speed (bps)
Bluetooth	Short Range	~10 m	2.5 mW	±3 Mbps
ZigBee / IEEE 802.15.4	Short Range	~ 120 m (LoS)	~2 mW	250 kbps
WiFi	Short Range	~50 m	80 mW	± 11 Mbps
3G/4G	Cellular	~ 5 km	5000 mW	± 12.5 Mbps
LoRa	LPWAN	~ 2-5 km (urban) ~5-15 km (rural) > 15 km (LOS)	20 mW	±250 bps

TABLE II. LEAFONY BOARD AND ES920LR PIN CONNECTION

Leafony board			ES920LR	
No	*Pin*	*Desc*	*Pin*	*Desc*
F1	3V3	3.3 Volt DC	2 & 13	VCCRF,VCC
F11	8	RXD	9	RX
F13	9	TXD	8	TX
F27	GND	GND	1 & 26	GND

B. ES920LR on Leafony Board and Mini Drone

Fig. 3 shows the LoRa ES920LR design on the Leafony Board. The next goal is to place the LoRa ES920LR on the Drone and analyze it at the deployment level or SF 7-12. Plus, the Drone's GPS to find out the Drone position using the analysis parameters is Signal Power (-dBm) [7]. In research [8], a LoRa-IoT analysis was carried out using a drone.

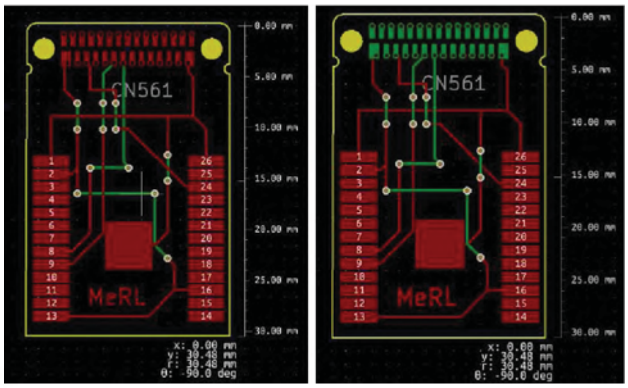

Fig. 3. ES920LR Leafony PCB Board (MeRL Data)

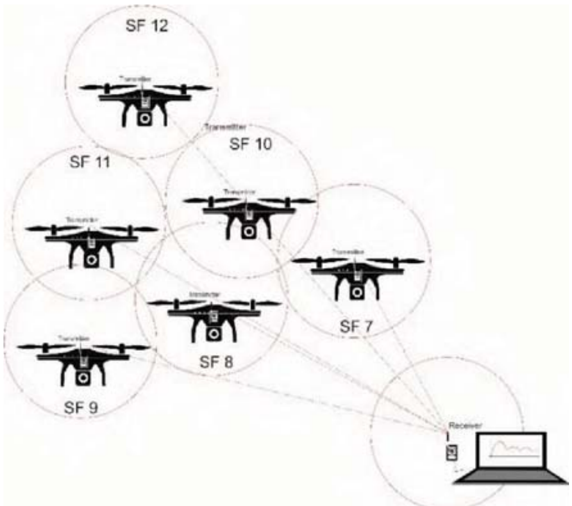

Fig. 4. ES920LR on Drone, analyze measurement (MeRL Data)

Fig. 4 is the design when measuring the QoS ES920LR in an outdoor environment. Drones with different locations and positions show additional SF (SF 7-12). SF shows the appointment of the transmitter and receiver Fig. 5. The greater the SF is equal to the distance Tx and Rx, the farther away. The attenuation signal (-dBm) is more significant at large SF, RSSI (-dBm) is getting bigger at small SF. ES920LR BW 125 kHz specification, Wireless Channel 10. Furthermore, the LoRAWAN class must understand LoRa with an Internet of Things (IoT) approach. Moreover, this research use Things-peak Mathworks.

There are three classes in LoRaWAN, i.e., Class A (All), B (Beacon), and C (Continues). As shown in Fig. 6, the difference is in the device configuration to communicate between the end node and the gateway in Class A Transmitter sends data to the receiver 1 (Rx1) at time t1 or Trx_delay1, at the same time sending to receiver two at different distances from the time Trx_delay2, therefore, that the values of ToA_TxRx1 and ToA_TxRx2 can be deduced. And it can be concluded that PRR (%), Energy of sensor node (Etx), and Receive signal strength. Accordingly, the position of Rx1 and Rx2 is closely related to the SF's parameter values. In Class A, the uplink and downlink process, the end node sends the data to the gateway, this is the uplink process, versa, from the gateway, send the data to each end node this process name is downlink, on the different time, e.g., Tx to Rx1, after finishing Tx to Rx2, for that there is a delay time.

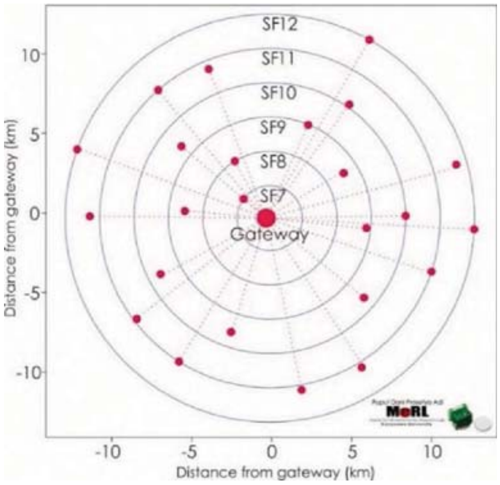

Fig. 5. Spreading Factor and distance comparison [15]

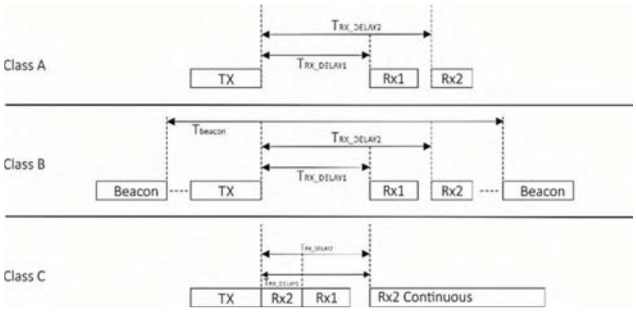

Fig. 6. Class of LoRaWAN

Furthermore, Class B is almost the same as Class A. The difference is in Beacon. Beacon 1 and Beacon 2 are static state transmitters, which are at a certain distance. Therefore, the data needs to be forwarded from RX 1 to Beacon 2, in this case, the need to add Receiver (Rx2) until the information reaches Beacon 2., therefore need the addition of receiver, i.e., Rx 3, Rx 4, and so on until the data arrives at Beacon 2 with the Beacon time. Furthermore, class C is a condition where the transmitter (Tx) sends data to Rx1 and Rx2, which is continued by Rx 3 and so on in the uplink process until it reaches the expected Tx Node, so-called Rx continues. Please note that Class A, B, and C have a different configurations or functionality. In research [9], Low Power Wide Area's efficiency with Framing Technique was carried out.

The LoRa parameters are given in the following equations. Equations 5,6,7 and 8 are the equations to get the values for Ts, Rs, and Rb. This shows the quality of LoRa. The greater the BW, the better the QoS quality of LoRa. While the ToA in equations 9 and 10 shows the QoS LoRa, which can be seen from CHIRP LoRa [10]. Furthermore, RSSI (-dBm) [11]–[13], in theory, can be seen in equation 11.

$$T_S = \frac{2^{SF}}{BW} \quad (5)$$

$$R_S = \frac{BW}{2^{SF}} \quad (6)$$

$$R_b = SF \times \frac{BW}{2^{SF}} \times CR \quad (7)[14]$$

$$Rb = SF \times \frac{\left[\frac{4}{4+CR}\right]}{\left[\frac{2^{SF}}{BW}\right]} \times 1000 \quad (8)$$

$$\text{ToA or } T_{Packet} = T_{Preamble} + T_{Paylaod} \quad (9)$$

$$T_{Preamble} = (n_{Preamble} + 4.25)T_s \quad (10)$$

$$\text{RSSI\_LoRa (dBm)} = -10n \log10(d) + A \quad (11)$$

III. Methods and Hardware

Adaptive Data Rate (ADR) algorithm in conditions the transmitter is static or not moving. However, in driving situations, a mechanism is needed to regulate energy or power consumption (mW). Several methods regulate power consumption, including the routing method, by placing the edge router and end node in each group. Only the edge router sends data to the receiver. The second method is sending data (bps) using a delay from an end node 1, end node 2, etc, or scheduling method [16], [17]. alternately t data; therefore, data collisions do not occur that cause packet loss and overload when receiving data simultaneously. LoRa Method Next is to use Sleep mode, pay attention to the program, and use Pseudocode in this research. In research [18], optimization of the number of IoT LoRa nodes with the Power Consumption approach is to use the Collision Avoidance Resource Allocation (CARA) algorithm.

The resulting hardware is still imperfect in terms of size or dimensions Fig. 7. However, it represents the completion of research on the process of sending data and analyzing data propagation. Moreover, BPM output consists of 3 criteria, i.e., normal, tachycardia, and bradycardia which are described in Arduino Software Processing, and data is sent to the Thingspeak Application Server.

```
1. Analyze the ES920LR Library
      #include <LoRa.h>
      #include <avr/sleep.h>

2. Command to Sleep
     void Going_To_Sleep(){
     rf95.sleep();
     sleep_enable();
     attachInterrupt(0, wakeUp, LOW);
     set_sleep_mode(SLEEP_MODE_PWR_DOWN);
     digitalWrite(LED_BUILTIN, LOW);
     delay(1000);
     sleep_cpu();
     Serial.println("Stop Transmit data LoRa and
      Sleep! ");
     digitalWrite(LED_BUILTIN,HIGH);

3.  Command to WakeUp
     void wakeUp()
     Serial.println("Transmit data LoRa!");
     sleep_disable();
     detachInterrupt(0);

      === Sleep Mode on End Node LoRa ====
```

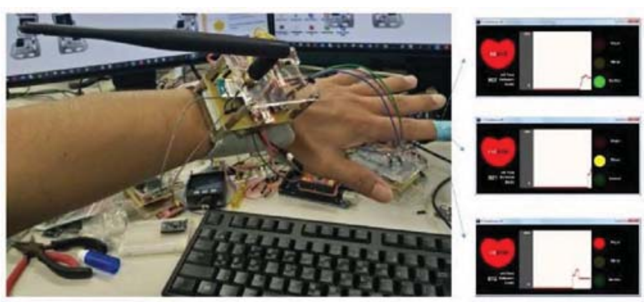

Fig. 7. Prototype ES920LR LoRa

IV. Results and Discussion

The outputs displayed in Chapter IV are the results of measurement tests in an outdoor environment. According to equation 9, Time on Air (ToA) is determined by Tpreamble and Tpayload but also determined by BW or Bandwidth and SF. The greater the BW, the faster Time on Air (ToA) on ms will be faster. Vice versa, the smaller the BW value, the longer the Time on Air (ToA). Moreover, The more significant the Spreading Factor value, the longer it takes to complete the data transmission process. The comparison of SFs can be seen in Fig. 8. It is also the same with the LoRa ES920LR Bit Rate in Equations 7 & 8. The greater the BW and with a small SF, a significant Bit Rate (bps) will be produced. Vice versa, with a small BW and large SF, will create a little Bit Rate Value (bps). Consider Fig. 9.

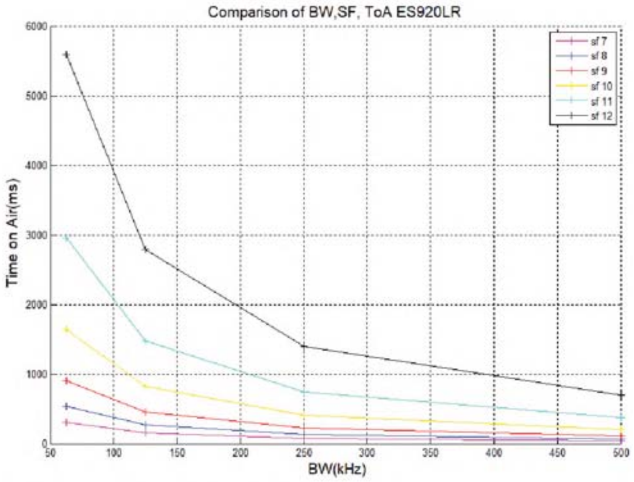

Fig. 8. Time of Air (ToA) of ES920LR LoRa

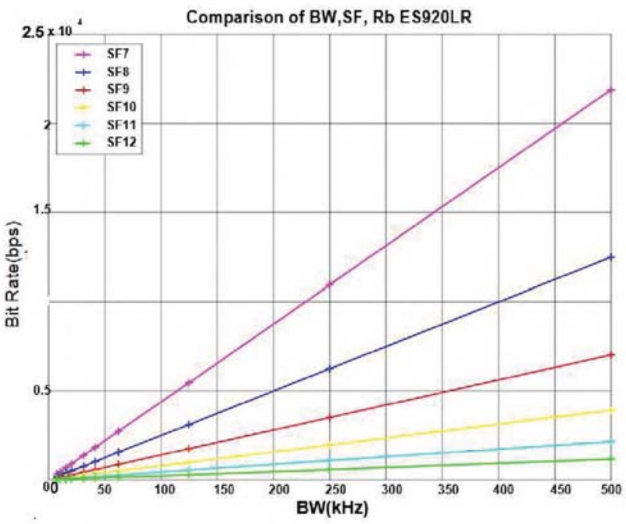

Fig. 9. Bit Rate and BW of ES920LR LoRa

Fig. 10 shows 2 LoRa parameters, namely Signal Power LoRa ES920LR at 920.6 MHz Frequency and CHIRP LoRa at 920.6 MHz frequency center [19]. These results are shown in realtime when sending LoRa signal data at the 920.6 MHz frequency from the LoRa ES920LR transmitter to the LoRa ES920LR receiver. The value of the ES920LR LoRa signal is -30 dBm at a distance of 1 meter of the Transmitter and Receiver. While the CHIRP ES920LR shows that data can be sent correctly, data transmission is also determined by the delay given for each End Node in transmitting data.

The test results for transmitting the LoRa ES920LR data are created using a bar chart showing RSSI (-dBm) in several conditions, i.e., Hill Obstacles and Line of Sight Buildings, as well as PRR or Packet Receive Ratio (%). At a distance of 846.37 meters, it shows an RSSI value of -140 dBm in Fig. 11. Whereas at the Line of Sight (LOS) at a distance of 710.18 meters, the resulting RSSI is -119 dBm in Fig. 12, which is quite significant, indicating dreadful Hill obstacles when passed by the LoRa ES920LR signal. Moreover, the PRR (%) ES920LR LoRa shows a decrease at a distance of 1 km by 7%, in Fig. 13.

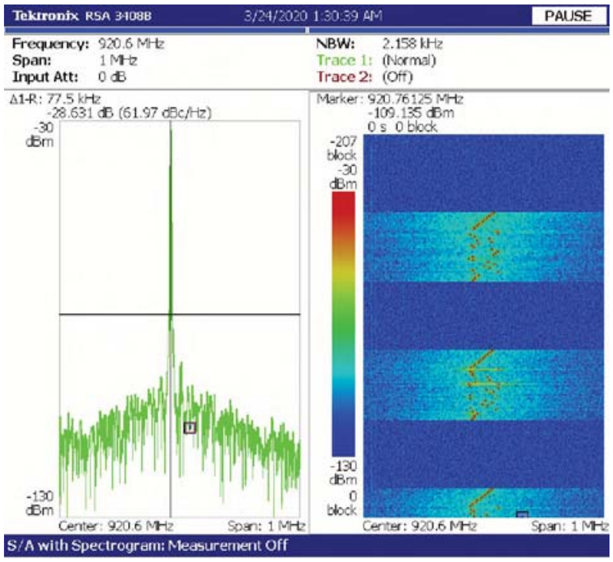

Fig. 10. Realtime Signal Power and CHIRP Signal of ES920LR LoRa

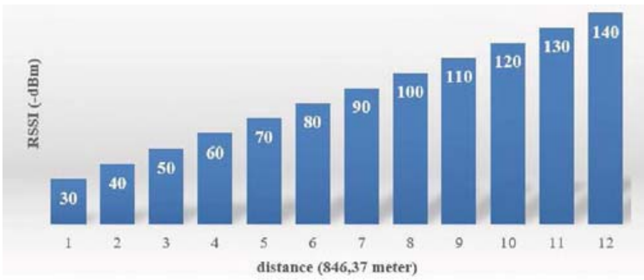

Fig. 11. RSSI on Hill obstacles 846.37-meter Tx-Rx

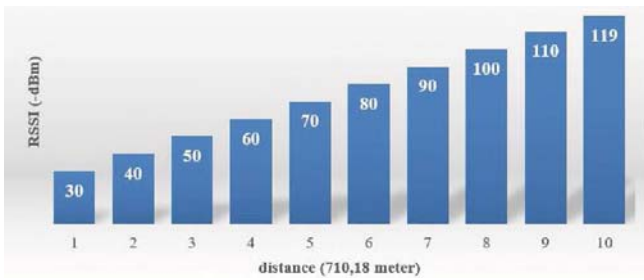

Fig. 12. RSSI on Line of Sight Building 710,18 meter Tx-Rx

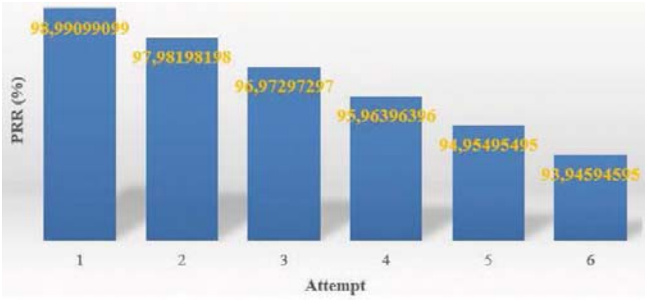

Fig. 13. Packet Receive Ratio (%) ES920LR LoRa

Fig. 14 is the value of the RSSI (-dBm) generated from the actual measurement in the outdoor environment. the RSSI shows a start value at -60 dBm at a distance of 1 meter to 100 meters, there is a decrease in signal strength at -80 dBm and at a distance of 200 meters a reduction in the signal at -100 dBm to -110 dBm. At a distance of 200 meters to 800 meters, the RSSI size doesn't change due to the position of the transmitter, which changes with different types of obstacles or materials. This material causes other attenuation signals. In Fig. 15, there is a tree source data, Free space, Line of Sight Building, and Obstruction Building. Fig. 15 shows a significant attenuation of the Obstruction Building, reaching more than -160 dBm at a distance of 1 km, which, if taken with free space, is only -80 dBm so that the attenuation comes -80 dBm from conditions without obstacles.

Fig. 16 is a comparison between RSSI and SF on LoRa ES920LR. In SF 7, the signal strength obtained is better than SF 12, which is -10 dBm adrift. This shows that SF determines the signal strength, which is influenced by distance (meters). The farther space is the same as having SF 12; it will require a long Time on Air (ToA) and produce a little bit rate (bps). This is due to the presence of packet loss (byte), delay (second), and attenuation signal (-dB), which is getting bigger

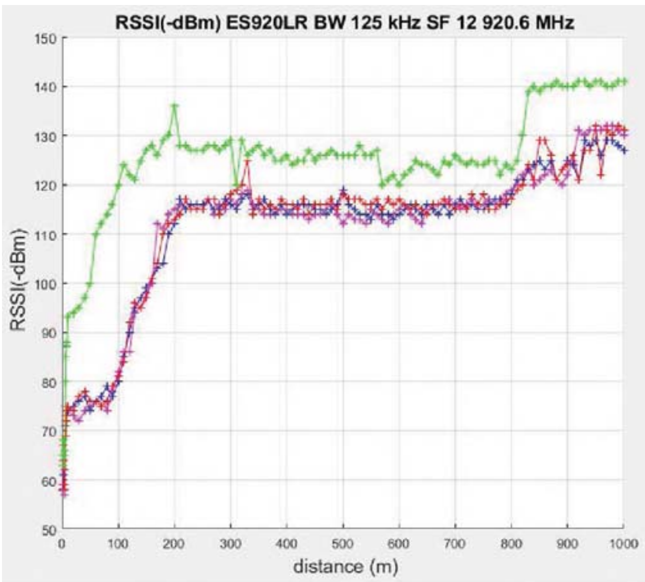

Fig. 14. RSSI (-dBm) ES920LR BW 125kHz 12 SF, 920.6MHz

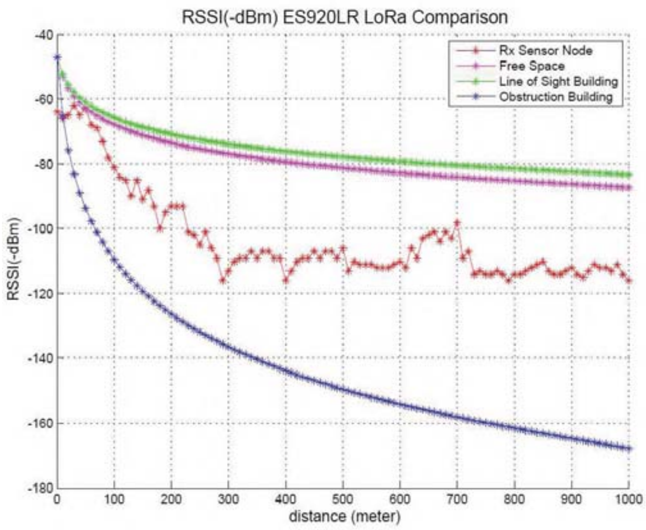

Fig. 15. RSSI (-dBm) ES920LR BW on different Obstacles

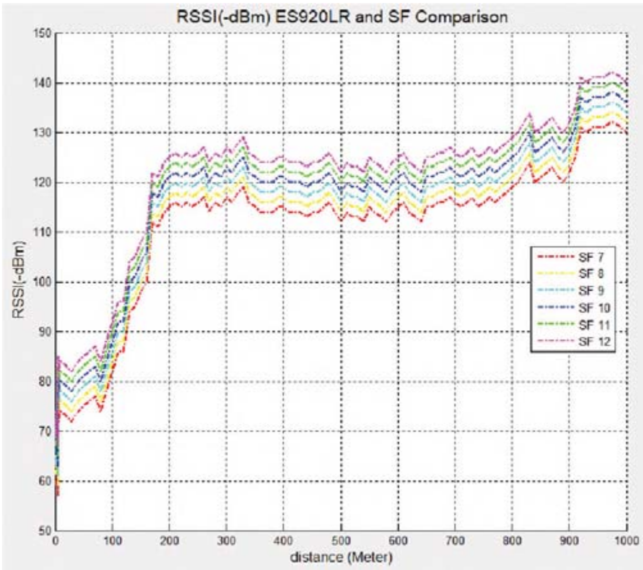

Fig. 16. RSSI and SF Comparison

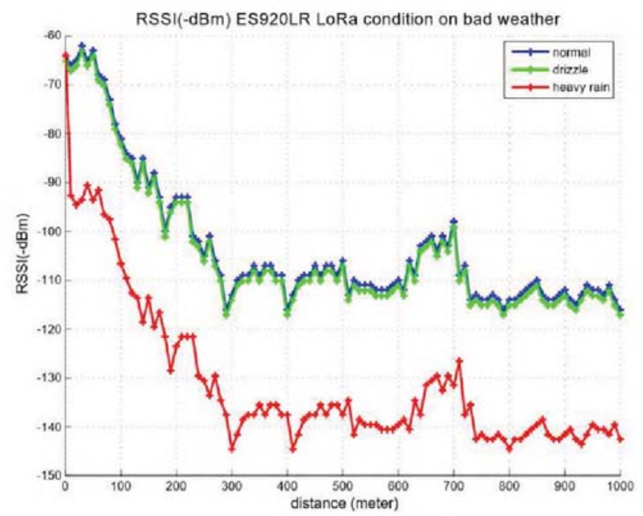

Fig. 17. RSSI ES920LR on the Bad Wheater

In Fig. 17, the test conditions are carried out under bad weather conditions, namely heavy rain. The Kanazawa area, Ishikawa, Japan, is one of Japan's regions with extreme weather conditions, besides strong winds, storms, heavy snow, and heavy rain. For these factors, this research tries to approach the lousy weather factors that affect the state of the ES920LR LoRa signal. In Fig. 17, there is a tree of weather conditions, namely when the weather is average, weather with drizzle, and heavy rain, in normal conditions and rainfall does not show significant attenuation signal (-dBm), but during heavy rain (-dBm), attenuation is obtained. Signal (-dBm) reaches -30 dBm at a distance of 1 km Tx and Rx. Fig. 18 is an example of the realtime heartbeat of the thingspeak IoT application server. Thingspeak is one of the Free IoT application servers [20] from MathWorks, although not all Free, in Fig. 18, is the recording of the heartbeat that is obtained on the sensor node in realtime, this sensor data can be downloaded and printed in image format (* .jpg), pdf or excel (* Xls) as data reporting, in the previous research use a MQTT for the standard messaging protocol for the Internet of Things (IoT) [1], [21].

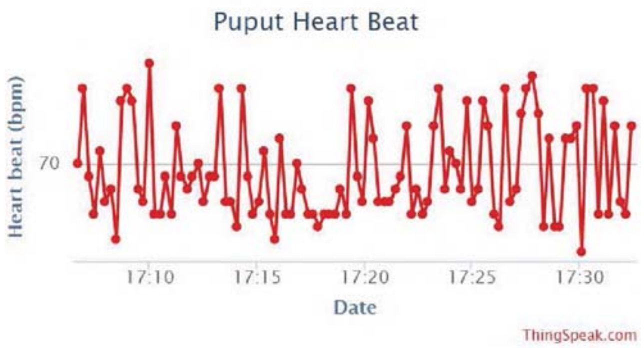

Fig. 18. Realtime heartBeat on Thingspeak IoT

V. Conclusion

Based on the experiment, the RSSI on the ES920LR LoRa experiences attenuation based on the types of obstacles that are traversed in the Radio Propagation process. The Line of Sight signal has an RSSI of -119 dBm at a distance of 710 meters and a PRR (%) of 93%. And the signal drop is also not affected by length alone. Still, obstacles such as in the experiment of sending ES920LR data at a distance of 200 meters to 800 meters have the same relative size, i.e., -110 dBm to -120 dBm. They have recently experienced significant signal attenuation at a distance of> 800 meters. Moreover, the spread factor is affected by distance. The farther the distance experienced by the LoRa ES920LR transmitter and receiver, the weaker the signal will be. Moreover, the value of SF determines attenuation and signal Power or Receive Signal Strength. In heavy rain conditions, the attenuation signal reaches -140 dBm at a distance of 1 km, decreasing ~ 25 dB.

Acknowledgment

Thanks to my teachers and supervisors, Professor Akio Kitagawa, Professor Junichi Akita, Professor Mambo Masahiro, and a Micro-Electronics Research Laboratory (MeRL) and ifDL Laboratory for providing all the resources needed to complete the research, especially the LoRa ES920LR, which was imported from Tokyo, and the Leafony Board which is a new microcontroller device. And thanks for all colleague at the Department of Electrical Engineering, University of Merdeka Malang, Indonesia

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