PERFORMANCE ANALYSIS OF LORA COMMUNICATION IN LONG-DISTANCE CONDITIONS

T.S Pasqual [*] ***and H.M.S.M Herath***
Department of Electrotechnology, Wayamba University of Sri Lanka, Sri Lanka

The limited signal transmission range of Wi-Fi and Bluetooth poses a challenge for the operation of Internet of Things (IoT) devices that depend on this type of connectivity. Existing traditional wireless approaches are quite expensive in the case of IoT. Hence it is crucial to discover more efficient and affordable long-distance IoT networking. LoRa (Long Range) is specially developed for long-range applications that enable devices to transmit data over great distances. The purpose of this study is to analyze LoRa performance under different conditions. In this study, the LoRa Ra-02 SX1278 module is used to measure parameters of data rate, range, and power consumption. Further, LoRa performance under different conditions such as in crowded situations in urban areas is also examined. A prototype was designed to test and collect the data of selected parameters. Testing was done by both the transmitter and the receiver which were connected through an Arduino Uno board. To monitor testing parameters, an OLED (organic light emitting diode) display was installed at both ends. The analysis revealed that the LoRa module consumes less power. In the open space test, data was successfully transmitted up to a distance of 100 m, but there was a tendency to lose data beyond that distance. The speed of data transmission can be increased by positioning the transmitter at a higher level relative to the ground level. Even in crowded places data can be transmitted but it can be affected or in some cases completely obstructed? by obstacles such as large vehicles. These findings are useful for evaluating LoRa performance in long-distance communication situations and recognizing its potential as a low-cost solution for IoT connectivity over long distances. Parameter testing was conducted under practical, real-world conditions by selecting geographical locations (university and town) as data transmitting and receiving points. Overall, the paper reveals the prospect of LoRa for distance IoT networks. These results contribute to IoT technology development and highlight the need for improved communication solutions over a long range.

Keywords: LoRa Ra-02 SX1278, Wireless communication, Performance, IoT, Crowded environment, Range

[*] *Corresponding Author: pasqualsupun@gmail.com*

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INTRODUCTION

Traditional wireless technologies such as Wi-Fi Bluetooth face challenges in communication across long distances and Internet of Things (IoT) devices require connectivity over extended ranges. The devices used for the IoT can be expensive when relying on these traditional wireless methods. Therefore, it is important to find better and more affordable ways to provide IoT devices with communication over long distances. Therefore, LoRa was designed with a focus on long-range communication, enabling devices to transmit data over large geographical areas. LoRa is a new generation wireless technology which has the potential to revolutionize the world of IoT and embedded systems with high range and low power consumption. The advantages of LoRa can be mentioned as low cost, flexibility, high range, adaptability, and data security. Disadvantages of LoRa include low data rate, constrained bandwidth, tendency to interfere, and limited support for mobile (Dasiga et al., 2020). LoRa technology is used in several applications such as smart meters, streetlight control, smart cities, hospitals, and airports and it is mostly useful in applications where data transfer is done in small packets at intervals (Devalal & Karthikeyan, 2018). The study done by Kolesnikov et al pointed out that the LoRa packet delivery rate (PDR) decreased with the distances and the obtained PDR rates were 100% for shorter distances and 0% for greater distances. This experiment showed that the maximum distance achieved was about 179 m and the corresponding PDR was 12% at this range (Kolesnikov et al., 2022). Semtech invented the LoRa physical layer, which enables low-power, low-throughput, long-range communications. This utilizes the 433 MHz, 868 MHz, or 915 MHz ISM frequency bands based on the region where the device is used (Augustin et al., 2016).

Therefore, the aim of this research is to assess the performance of LoRa under various conditions, particularly in crowded situations. This testing was done in practical and real-world conditions by selecting geographical locations as data transmission and receiving points. The performance analysis of LoRa is done based on the parameters including data rate, range, power consumption, and the effect of obstacles in data transmission. These details will provide better insight into LoRa performance in different conditions.

METHODOLOGY

LoRa Ra-02 SX1278 433MHz module was connected to an Arduino Uno to implement the intended prototype for testing parameters. Further, 18650 Li-ion rechargeable batteries were added to both modules and a 0.96-inch 128X64 OLED display was connected to both transmitter and receiver in Arduino boards to display the output. Also, RF 433MHz Antenna 2-3 dBi was connected to both transmitter and receiver modules to create the prototype as shown in Figure 1. Using the prototype the parameters such as data rate, power consumption, range, and data transmission in different conditions (crowded situation) were measured. INA219 current sensor was used to calculate the current and voltage consumption. When measuring the power consumption two tests were conducted to measure power consumption over 30 minutes. The first test assessed the power consumption of the entire circuit and the second test focused on the power consumption of the LoRa module. To conduct the testing under real-world conditions, the parameter testing was done based on geographical locations (such as university and town). For the data rate testing, two locations within the university were selected. Four different sizes of data packets were transmitted to each location. Two data points in the most crowded area in the town were selected for data transmission to test the LoRa performance under different conditions. Additionally, to compare the results, data transmission was also performed under uncrowded conditions. In the range test, two types of tests were conducted. Initially, the open space test was conducted and the obstacle test was carried out after that. For each data type, three attempts were made, and average values were calculated to ensure high accuracy of the testing results.

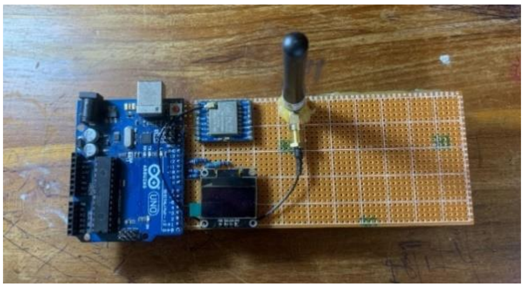

Figure 1: Prototype scheme of LoRa device (LoRa Ra-02 SX1278)

RESULTS AND DISCUSSION

Range Test

1. **Open space test:** Measured data transmitted over a straight-line distance of 25m to 225m in 25m increments at three attempts per distance to increase accuracy as shown in Figure 2.

Figure 2: Maximum distance in open space test

Figure 3: Relation of distance to PDR

According to Figure 3, there was an inverse relationship between distance and PDR. When packet loss begins, it means that some transmitted packets are not arriving successfully at their intended destination. Data transmission using LoRa is limited by several causes, including weather conditions that alter the intensity of the wireless signal, interference, signal attenuation, and obstacles within the communication channel. In the open space test, while the transmission of data was possible within the range of 100 m, some of the data was lost beyond this distance due to the above effects until a distance of 250 m.

Obstacle course test: Data transmission was evaluated at three locations: Open Theater, Sewana Garden, and behind Pandith WD Amaradewa Auditorium.

Table 1: PDR with physical obstacles

Location	Distance (m)	PDR (%)	N_T	N_R
Open theater	135	94.44	18	17
Sewana Garden	140	83.33		15
Behind the Auditorium	155	0		0

Figure 4: Testing the data range with obstacles

The transmitter was fixed at the student center (SC) and conducted three attempts at each location as shown in Figure 4. Data for Open Theater and Sewana Garden has been transmitted successfully as shown with the PDR of 94.44% and 83.33% respectively in Table 1. But for Pandith Amaradewa Auditorium, data failed to transmit through because the building blocked the signal. This means that the PDR is inversely proportional to the distance and it can be calculated using:

$$PDR = \frac{No\ of\ Packetsreceived\quad (N_R)}{No\ of\ Packettransmitted\ (N_T)} * 100 \tag{1}$$

Data Rate

The student center (SC) and the open theatre were at the same level and lower distance (135m) compared with the university main gate which is located at a lower level and greater distance (250m) as in Figure 5. Therefore, the hypothesis was that there would be a considerably high data rate from the SC to the open theatre. However, according to Table 2, it can be mentioned that there is a slightly different data rate for each number of bits. This is due to the position of the transmitter which was set up in a higher position compared to the ground level.

Table 2: Data rate analysis of Lora

No of data set	Distance (m)	Time (s)	Number of bits	Data rate (bps)
1	135	0.412	456	1106.7
	250	0.451		1012
2	135	0.719	77	107.02
	250	0.791		97.32
3	135	0.722	126	174.44
	250	0.818		154.01
4	135	0.823	525	637.99
	250	0.914		574.65

Figure 5*:* Testing the data rate to the fixed points

Crowded Situation

As the crowded area, the Mathugama town was selected as in Figure 7, and the area in the university garden as the uncrowded area, as shown in Figure 6. According to Table 3, the average time taken for data transmission for both crowded area and uncrowded area was slightly different for all two data sets. Consequently, the crowded situation did not affect data transmission but when heavy vehicles covered the transmission path, then data was not transmitted.

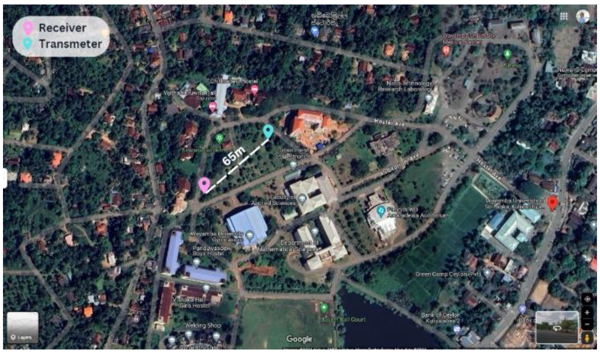

Figure 6: Location of uncrowded area (University)

Figure 7: Location of crowded area (Town)

For each situation, four data sets were used to calculate the average time taken for data transmission using the following equation.

$$T = \frac{\sum_{i=1}^{N} T_i}{N}$$

Where T = Average time taken for the data transmission; N = Number of data sets; T_i = Time difference for the i-th data set

Table 3: Testing data of crowded area and uncrowded areas

Situation	Avg time taken for data transmission (s) 525 bits	Avg time taken for data transmission (s) 77 bits
crowded	0.849	0.921
uncrowded	0.725	0.815

Power consumption

According to Table 4, it can be identified that the LoRa Ra-02 SX1278 module consumes 1.28 mW. Power consumption (P) was determined by multiplying average current (I) with average voltage (V) through the power equation (P =VI) by measuring the current and voltage from the INA219 current sensor. This indicates that LoRa module consumes low power.

Table 4: Power Consumption of LoRa

Time taken (30min)	Average voltage (V)	Average current (mA)	Average power (mW)
Full Circuit	8.66	50.1	434.44
LoRa module	3.28	0.38	1.28

CONCLUSION

In conclusion, during the open space test, the range was up to 225 m but when the transmitter is placed at the SC rooftop the range can extend up to 250 m and although the environmental conditions may hinder the data transmission, positioning of the data transmitter at a higher position compared to the data receiver extended the range and the data rate dramatically. In the range test, it was observed that the PDR was inversely proportional to the distance. Lora module that used for tests, consume low power (1.28 mW). The future direction of this research therefore entails comparing LoRa with other Wireless technology like Wi-Fi to get better insight about LoRa performance. These findings underscore the potential of LoRa technology as a cost-effective and efficient communication solution for IoT applications such as agriculture monitoring requiring long-range connectivity.

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