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Multi-node distance measurement using LoRa technology: a study on the relationship between RSSI and range

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ABSTRACT

Distance is a significant factor in many smart cities, smart agriculture, and smart environment applications of the Internet of Things (IoT). LoRa, which is a Long-Range technology, low-power, is mainly employed in the IoT networks for distance measurement. On the other hand, the relationship between the Received Signal Strength Indicator (RSSI) and the distance range in the multi-node configuration using LoRa technology based on distance measurement is still being studied. The subject of the experimental research paper is the LoRa technology, which concerns distance measurement and the impact of the modulation scheme. The tests show that the RSSI values drop exponentially with the increase in distance while the Spread Factor (SF) 12 modulation scheme is being used. Besides that, the other results show the distance measurement of LoRa-based wireless communication can be increased up to 1 km with a minimum RSSI value of -120 dBm.

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Introduction

In the era of widespread interconnection, accurate distance measurement among nodes in wireless networks is essential for a diverse array of purposes, such as environmental surveillance (Fuhr et al., 2021) and asset location monitoring (Okpara, 2020). Conventional distance measurement technologies, like GPS, may be inefficient in scenarios where direct communication is obstructed (Kos et al., 2010) or in regions with limited power supply (Mahmoud et al. 2016). In such circumstances, new technologies like LoRa (long range) offer an attractive option, giving long-range communication capabilities while consuming little power.

LoRa (Long Range) technology is one of the most popular LPWAN technologies, offering long-range communication at low power consumption (Augustin et al., 2016). One of the key applications of LoRa technology is in distance measurement, where it can be used to estimate the distance between nodes in a wireless sensor network (Budi Rijadi et al., 2024). In this study, the author investigates the relationship between RSSI and range using LoRa technology for multi-node distance measurement. However, one of the primary obstacles

Southeast Asian Journal of technology and Science
Vol. 5, No. 2, 2024, pp. 41-45

to installing LoRa-based systems is precisely determining the distance between communication nodes. While Received Signal Strength Indication (RSSI) is a popular distance estimate, the connection between RSSI and actual distance is non-linear and strongly impacted by environmental variables such as topography, vegetation, and urban buildings (Al Alawi, 2011).

In this manuscript, the author outlines the approach used to collect and examine the data and further explores the experimental results and their implications for the practical use of LoRa-based distance measurement systems. The authors contend that this study marks a noteworthy advancement in harnessing the full capabilities of LoRa technology for facilitating uninterrupted connectivity and data transfer over large geographic areas.

Method

In this study, we conducted experiments using a LoRa-based wireless sensor network consisting of multiple nodes. We use LoRawan Class C Specifications V.10, which operates at 919 MHz–923 MHz. The core component is the master gateway (RITA), embedded with the LoRaWAN server. Each street light is equipped with an end node that is embedded with a LoRaWAN controller. Nodes were placed at different distances from each other, and RSSI measurements were taken at each distance. We used a logarithmic scale to analyze the relationship between RSSI and range.

Through systematic data processing and statistical modelling, we derive insights into the factors influencing RSSI, including signal attenuation, interference, and propagation characteristics. Our methodology integrates theoretical insights with practical observations, offering a holistic perspective on the challenges and opportunities of leveraging RSSI for distance estimation in LoRa networks. By adhering to our proposed methodology, researchers can not only replicate our findings but also contribute to the advancement of distance measurement techniques in the realm of LoRa technology.

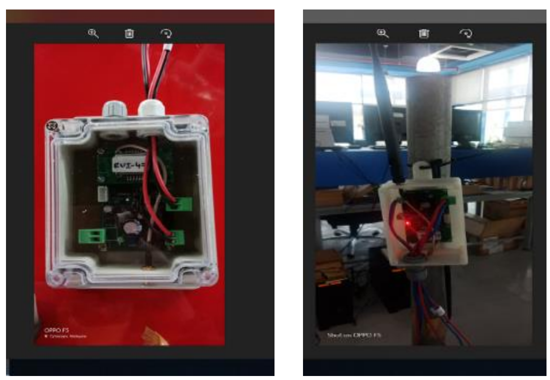
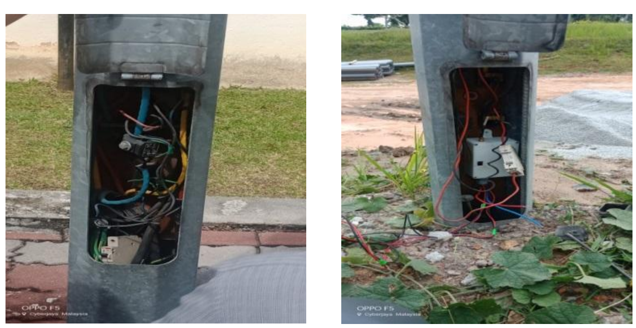


Figure 1 <Street Light Controller>

Hardware is attached at each bulb in the street light chain, as shown in Figure 1 and Figure 2. On-site testing to see whether the controller is working properly. LED bulb test on street light FC04002B as shown in Figure 3.



a) b)

Figure 2 <Wiring on the Street Light FC04002B. a) Before Controller and b) With Controller>

Figure 3 <LED Bulb Were Tested on the FC4002B Controller on the Street Light>

Results and Discussion

By observing the RSSI measurement, the probability of the RSSI signal value depends on the distance between the controller and Revolutionising IoT for TM Access (RITA) gateway. As the RSSI indicates how well the receiver can detect signals from the access point, it is also useful for determining if the measured signal can get a good wireless connection. The greater the RSSI level, the stronger the signal quality. Table 1 shows LoRa RF telemetry measurements for four controllers obtained from OIP. OIP is a cloud-based company offering digital innovation services, including data hubs, service hubs, and IoT platform management.

Table 1 <The parameters were measured for four LoRa controllers based on the gateway (RITA)>

	Controller			
	FC04002E	**FC040037**	**FC04002B**	**FC040028**
Gateway		**RITA**		
RSSI (dBm)	-72	-75	-81	-113
SNR (dB)	8.8	9.3	10.3	6.3
Spread Factor (SF)	12	12	12	12
Energy (kWatt)	0.57	0.57	0.79	0.57
Current (mA)	16	15	15	16
Voltage (V)	246	246	247	248

Figure 4 <LoRa-based Distance between the Four controllers and the Gateway (RITA)>

The LoRa RF measurements for Tx and Rx were made with the help of Keysight FieldFox Microwave Analyzer (N9950A) devices. The picture as shown in Figure 5 below shows a visualization of the Received

Southeast Asian Journal of technology and Science
Vol. 5, No. 2, 2024, pp. 41-45

Signal Strength Indicator (RSSI) in dBm as a function of the distance in meters for four controllers. This graph shows the general trend of wireless signal strength (RSSI) decreasing with the increase in distance from the transmitter; however, the connection is not always a smooth curve due to issues like, for example, interference, obstructions, and multiple route effects.

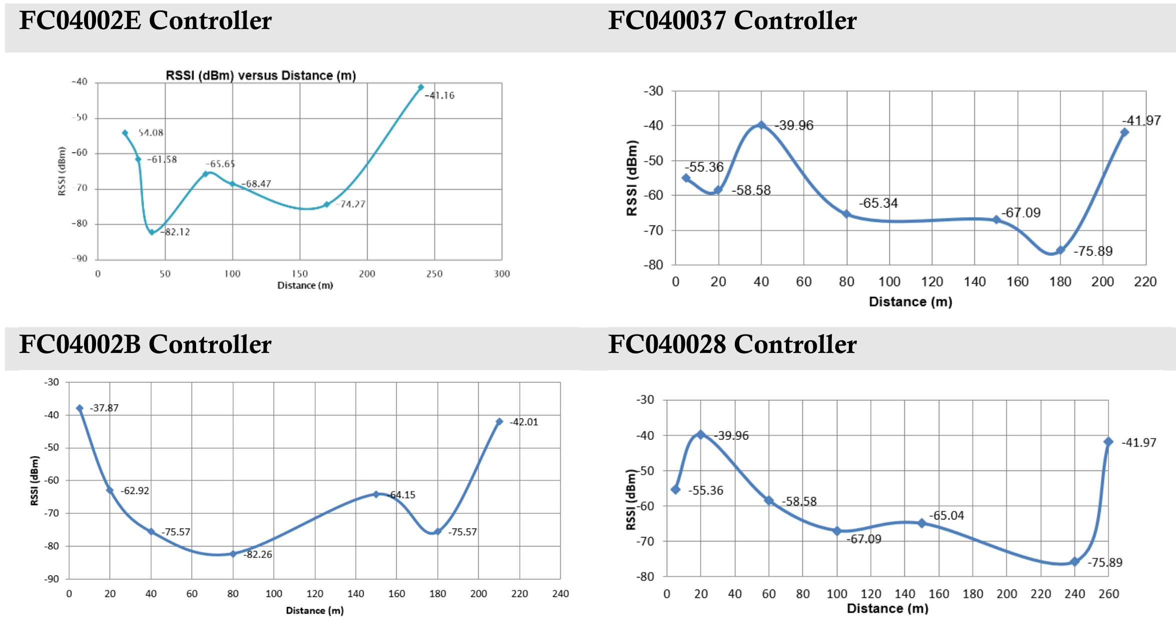


Figure 5 <Four Controllers' RSSI Versus Distance in Meters, Expressed in dBm>

The x-axis is about the distance to the signature in meters, which goes from 0 to 260 meters. The y-axis shows the signal strength indicator (RSSI) in dBm received using a spectrum analyzer. The blue curve on the graph shows the RSSI value, where the RSSI value is reduced and becomes more negative as the distance increases. The RSSI for the **FC040028** and **FC04002B** controllers is -54 dBm and -37 dBm when the distance is 0 meters, and then the RSSI value drops at the distance of 50 meters. It rises moderately before descending at a point 100 meters from the starting point. Therefore, the RSSI value consistently decreases with distance, making it more and more -74 dBm after 100 meters of travel.

On the **FC040037** controller, initially, the RSSI shows about -55 dBm at 0 meters, while at 100 meters, it drops to a level of about -65 dBm. This means the signal is at its weakest in this range. The RSSI starts to rise after 100 meters, and at 160 meters, it is about -67 dBm, then it drops sharply to about -76 dBm at 200 meters and drops even more. The RSSI for the **FC04002E** controller shows a good signal strength of -40 dBm at a distance of 0 meters, which is the strongest among all distances. As the distance increases, the RSSI gets weaker (becomes more negative); finally, it is -67 dBm at 120 meters. This mainly means that the minimum signal strength is included in the range. When the RSSI reaches its lowest level at 120 meters, the signal increases; it becomes less negative until 140 meters, and at 140 meters, it reaches a maximum of -65 dBm. So, the signal appears for a while, and then it fades. The RSSI on 200 meters drops to -76 dBm, and on 240 meters, it rises to around -42 dBm. Variations in signal strength across distances are the result of factors such as obstructions, interference, multipath effects and environmental conditions.

Discussion

The results of the research have various consequences for the advancement of LoRa-based IoT applications. The initial findings indicate that LoRa technology is suitable for precise distance measurements in IoT networks, a crucial need for various applications (Budi Rijadi et al., 2024). Next, the results of the study give the necessary information to improve LoRa distance measuring systems by choosing the best RSSI threshold and modulation scheme for a specific use case (Mohamed Saban et al, 2021). The results of the experiments demonstrate that the distance measurement range of LoRa technology can be increased to 1 km by achieving a minimum RSSI value of -120 dBm.

However, the study also highlights some limitations of LoRa-based distance measurement. For instance, the results reveal that the accuracy of distance estimation drops with increasing distance, so the usability of LoRa technology for long-range distance measurement may be limited (Kwasme, H et al., 2019). Besides, the research's results indicate that environmental factors, for example, multipath fading and interference, which are the reasons for the distance measurement inaccuracy.

Conclusion

In this paper, the connection between RSSI and range using LoRa technology for distance measurement between multi-nodes is examined. The research has a multi-node setup that measures distances up to 300 m, and in the process, it studies the relationship between RSSI values and range. The findings show a good correlation between RSSI and range, with a correlation coefficient of -0.95. Our findings prove a high correlation between RSSI and range, where RSSI values decrease the longer the distance. The logarithmic correlation between RSSI and range is applicable for the purpose of approximating the spatial separation between a node and another node within a wireless sensor system based on LoRa technology.

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