LoRa System with IOT Technology for Smart Agriculture System

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***Abstract*—LoRa (short for long-range) refers to the RF modulation under the low-power wide area networks (LPWANs) that offers the potential of smart solution under various environment conditions using the long-range communication capability. Nevertheless, the performance of this technology varies depending on the surrounding conditions as well as the presence of obstructions between the end-to-end transceivers. This paper describes the LoRa project that was developed to foster the local rural agriculture business by implementing smart agriculture applications based on LoRa. The Reyax RYLR890 LoRa transceiver is used to allow bi-directional communications between multiple nodes to operate two different agriculture systems remotely without using the intenet. The communication performance was investigated by studying the changes in the receiving signal strength indicator (RSSI) and signal-to-noise ratio (SNR) against distance in the urban and rural areas. The initial hypotheses stated that LoRa communicates better in rural areas. However, it is highly dependent on the placement of the transceiver.**

Keywords—energy, communication, long distance, security, agriculture, multiple nodes.

I. Introduction

The Chirp Spread Spectrum (CSS) modulation method, which was evolved from the spread spectrum modulation scheme with integrated forward error correction (FEC), is the core of the LoRa wireless technology [1]. This modulation method was introduced by Hedy Lamarr and was initially used for military purposes [2]. Generally, the concept involves a single bit of information being taken and transformed into another sequence of bits that is then distributed across the wideband. In other words, information or signal are being dispersed across the wideband, allowing a large coverage area of message transmission.

Multiple press releases were published on the Semtech website, describing the recent development project based on LoRa [3]. The agriculture business is among the industries that have been positively impacted through the implementation of LoRa in various agrarian solutions and applications. For instance, in August 2017, Semtech's LoRa technology offered a livestock management solution to prevent cattle thefts by sending alerts whenever the animal deviates from its normal path [4]. The WaterBit automatic irrigation system was developed in February 2018, based on the analysis of the collected granular, ground-truth data such as the line flow and pressure, soil moisture and temperature to streamline farming operations across Central California [5]. Later on, in September 2019, the LoRa-enabled sensors were further improved for the FarmLife® smart agriculture service, which was able to identify estrus in the cattle and pushed for better feeding practices, and to forecast the start of disease [6]. In September 2020, ICT International developed LoRa-based environmental sensors which enabled smart monitoring of crops, which has boosted the crop yield of avocado farms [7]. Moving on, recent collaboration between Semtech Corporation and Smart Padlock to develop Bluebell has introduced a smart global positioning system (GPS) to manage the livestock in a real time location detection as well as the cattle's behavior [8]. Indeed, the LoRa technology has become more feasible to modernize the conventional agrarian practice in this industry to create a more sustainable and productive agriculture resource globally.

In Malaysia, there are two channel plan bands available for the LoRa implementation: AS923 and EU433, with frequencies of 919-924Mhz and 433-435Mhz, respectively [9]-[10]. Several projects based on LoRa have been published, focusing on the implementation of this technology to provide remote solutions and IOT applications [11]-[18]. However, there is less implementation of LoRa in rural areas due to the limitation of internet connectivity and access to technology, especially those that involve remote applications such as the IOT application. In this project, the operational performance of LoRa were tested in the rural and urban area to study the implementation of LoRa communication in Malaysia. A prototype that operates two different systems were designed to allow the deployment of integrated smart agriculture system. This system will manage the crop fertigation and swallow bird nest security system remotely over long distances. Based on the findings of this project, comparative analyses were conducted to support the concluding remarks.

II. Methodology

The core purpose of this project is to develop a LoRa-based system to foster the rural agriculture business by manipulating the long-range data communication, which will be implemented in Balingian, Sarawak (2°59'05.8"N, 112°24'26.1"E) for a longhouse community of Rh. Aji Anak Buli as shown in figure 1.

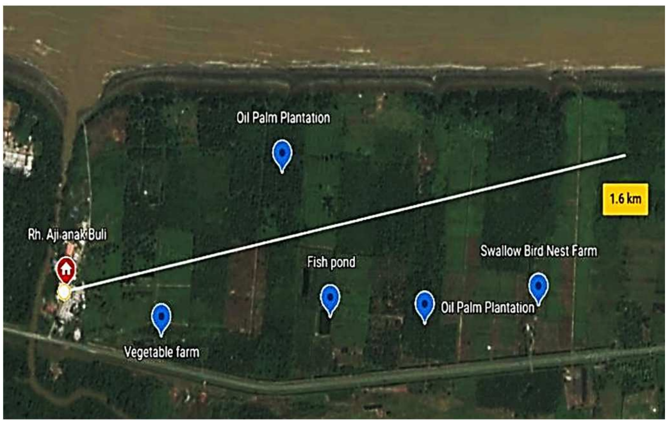

Fig. 1 Satellite image of study area.

2022 IEEE 20th Student Conference on Research and Development (SCOReD) | 978-1-6654-7488-7/22/$31.00 ©2022 IEEE | DOI: 10.1109/SCORED57082.2022.9974084

The primary economic source of the community in the proposed location is based on agriculture. Overall, there are three weaknesses and difficulties in the existing agriculture business faced by the community of the longhouse. Firstly, there is no adoption of any smart technology in farming activities and mostly are currently done in the conventional method (e.g., manual vegetable fertigation). The farm yields were scattered and mostly done on a small scale for self-consumption to feed their own families. While the swallow bird's nest would return a good fortune, the frequent theft activity in the area is burdening the community with extra costs to replace the equipment to operate the premises. Nevertheless, this location has good economic potential if all these limitations were solved.

Thus, to address these problems, it is necessary to have a designated network that would manage and monitor the smart agriculture system and the anti-theft system for the swallow bird nest. The planned architecture of the designed system consists of the transmitter (node 1 and node 2) and the receiver (gateway) as shown in figure 2. The gateway will be located at the farmers' house, while the nodes will be placed on the field to manage two different systems. Generally, this system will enable farmers to manage and monitor their farms remotely without actually going to the field.

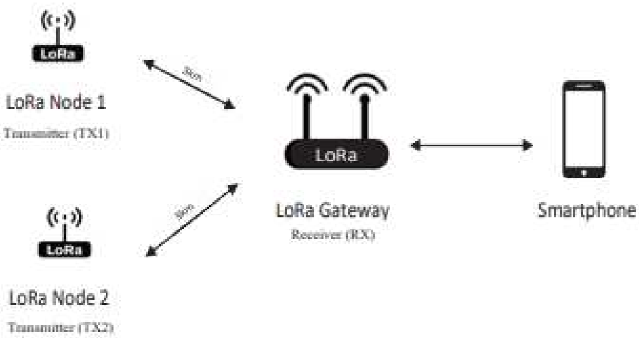

Fig. 2 Overall architecture of the system.

The project engages in two-way communication with each LoRa transceiver at the other end that controls each of the system features as illustrated in figure 3.

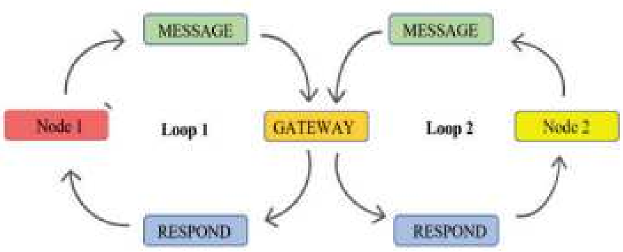

Fig. 3. 2-way multiple node configuration.

The LoRa gateway is the control center of the system where all the status of both systems will be received and processed. The status of each node will be displayed on the LCD screen that shows the ongoing operation of each system. In addition, the user could use buttons and switches to control different parts of the system manually. The block diagram and flowchart that describes the components of the gateway is shown in figure 4 and 5 respectively.

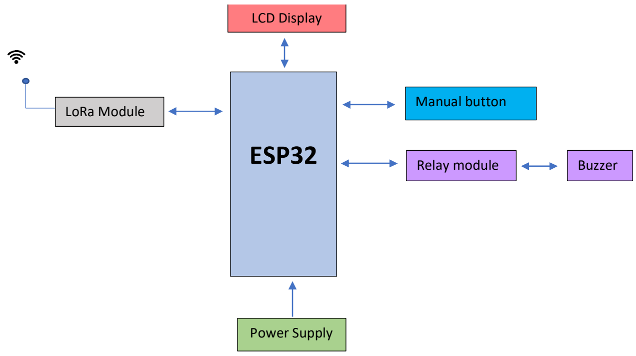

Fig 4 Block diagram of the LoRa gateway.

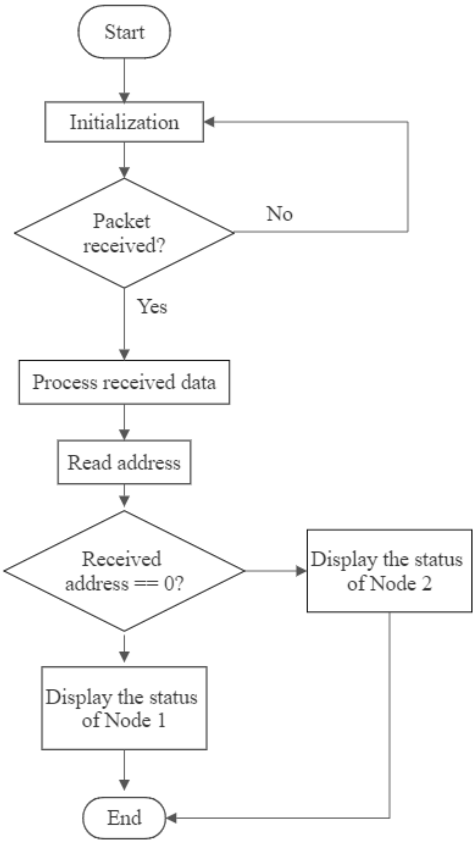

Fig 5: Flowchart of the gateway.

The first node (Node 1) will be designed to manage the smart fertigation system as described in figure 6 below:

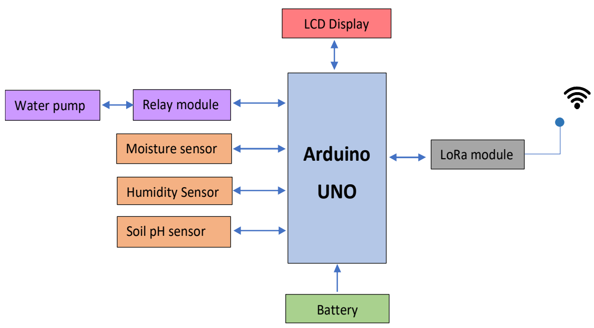

Fig. 6 Block diagram of node 1.

The second node (Node 2) will monitor the anti-theft system of the swallow bird nest by constantly displaying the status of the motion sensors as illustrated in figure 7.

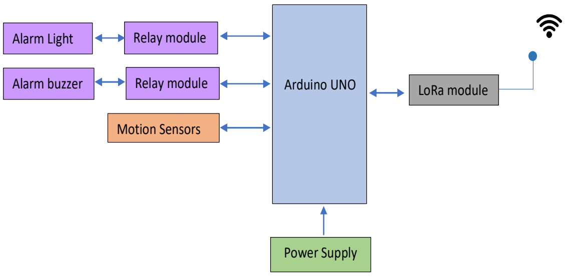

Fig. 7 Block diagram of node 2.

Generally, the respective developed system consists of the combination of Arduino UNO microcontrollers, relay modules, sensors and external output devices. The 915 MHz LoRa transceiver will be used in the simultaneous message transmissions between the gateway and respective nodes.

III. Results and Discussion

In this project, the testing of the LoRa system were performed using the 915 MHz LoRa. The transmitter will be placed at a stationary position while sending instructions to turn on and off the LED at the receiver side simultaneously. The distance between the transmitter and receiver will be increased accordingly, with a 100 m increment for each test. During the transmission, the receiver side will display the signal performance parameters, the RSSI, and SNR, via the LCD IC2 module as shown in figure 6. These information will be collected to the LoRa performances under different conditions.

Fig 8: Testing method.

The first testing of the 915 Mhz LoRa module was done in Persiaran Perdana, Putrajaya, an urban area surrounded by government agency offices. Due to the geographical constraint, the maximum distance that could be tested was 1.8 km as illustrated in figure 7. As we can see in figure 8 and 9, the projected SNR against distance drops drastically after a distance of 300 m, while the RSSI fluctuates consistently every 100 m. Nevertheless, the transmitter and receiver could communicate up to 1.8 km.

Fig. 9 Testing at Persiaran Perdana, Putrajaya.

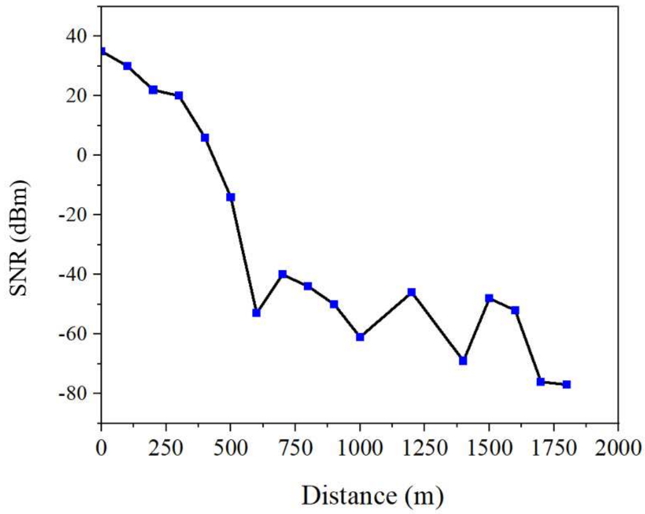

Figure 10 Distance against SNR for test 1.

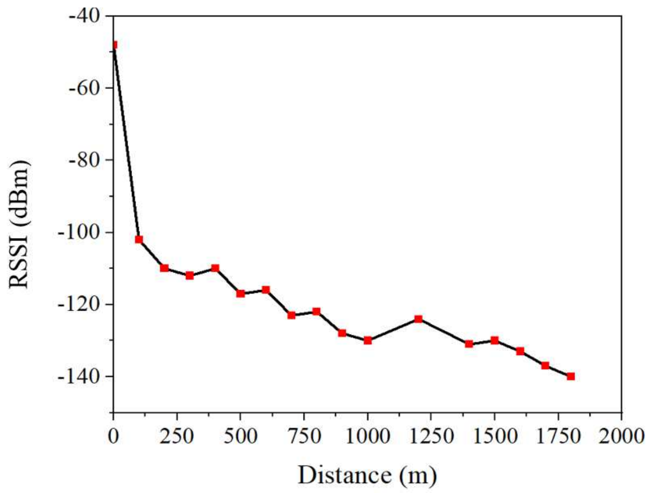

Fig 11 Distance against RSSI for test 1

The next location for testing was in the rural area, where a similar procedure of testing was conducted at the beachside of the study area as shown in figure 10 and 11. The STRAVA app was referred to determine the distance of every measurement. The results of the testing are shown in figure 12 and 13.

Fig. 12 Transmitter and receiver module used for testing.

Fig. 13 Satellite image of testing location (Via STRAVA app).

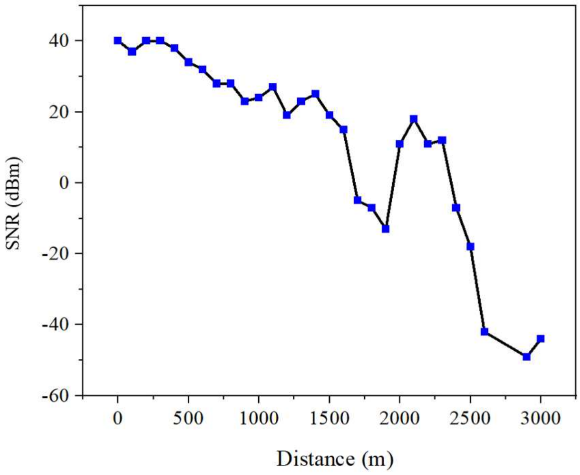

Fig. 14 Distance against SNR for test 3.

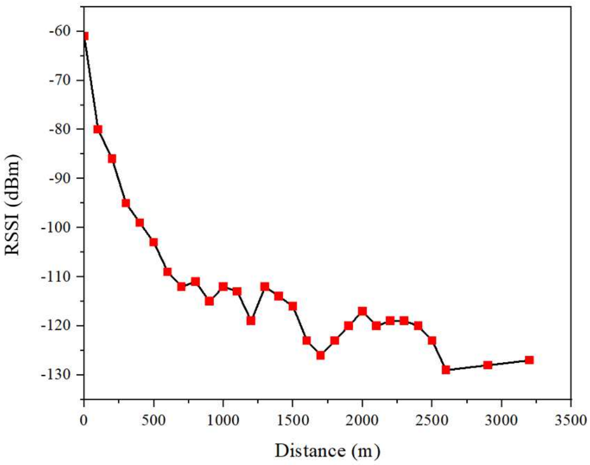

Fig. 15 Distance against RSSI for test 3.

In any wireless system projects, the testing of the signal transmission performance is vital to ensure the system functions perfectly before the final commencement. However, the testing often shows inconsistency and varying results due to the unpredictable changes in the noise measurement and fading effects in the environment [3]. In this project, the proposed testing method involves the analysis of the signal performance parameters, the RSSI and SNR, where their changes against distance will be studied. Generally, in wireless applications, the signal transmission performance will fluctuate as the distance increases. However, the criticality of the fluctuation varies depending on the location. Therefore, in this project, the performance of the 915 MHz LoRa will be studied in urban and rural area to determine the potential development of this system in both areas.

In urban areas, the deployment of wireless systems has to cater for the challenge of traffic loads and the harsh radio frequency (RF) environment from the surrounding infrastructure and geographical conditions. In the harsh RF environment, multi-path effects and thermal cycling are common because of the presence of moving or static metallic structures as well as RF noise from machineries (i.e., motors and power generators) or other RF devices [19]. Furthermore, physical factors such as wall barriers, temperature and weather conditions can all contribute to signal loss. The result of the testing performed in the urban area of Putrajaya showed a huge fluctuation of RSSI and SNR projection after 300 m and the communication performance between the transceivers was generally poor. As discussed by the author in [20], this poor signal quality problem can be mitigated by placing the gateway as well as the end-nodes at a higher position so that the RF path loss is less while passing through the surrounding conditions. Hence, testing at the rural area was performed at the beachside near to the location of the study area. As there was no obstruction in between the wireless communication paths, the message transmissions occurred in a line-of-sight environment and this would significantly reduce interference for more effective communication [21]. In past research, an experiment on the performance of LoRa was performed in the rural, suburban and urban areas in the state of Perlis, Malaysia [22]. The authors explained that the test shows a better performance in the rural areas because the interference of building heights as well as motor noises has disrupted the RSSI and SNR signals are generally less [22]. The result of testing for the rural area of this project showed a good performance of signal transmission with rapid and instant response time, which indicates that the signal is strong, resulting in effective communication between the LoRa transmitter and receiver. Besides, the RSSI value at each distance was mostly above the threshold of value 69 of -120 dBm, indicating less packet losses and signal corruptions. The testing of the reading was stopped after 3.2 km. This is due to the geographical constraint where a thick mud and river interrupt the testing. Nonetheless, based on the results, we can predict that the LoRa system could still communicate over longer distances. This was proven by research in [23], where, with a clear view and a LOS path, an effective LoRa communication with a high packet success ratio over a distance of 30 km could be reached. In summary, the hypotheses developed in these studies generally address the external factors influencing LoRa data transmissions. The result of the testing proves that the performance of LoRa is better in rural areas due to less electromagnetic interference, radiofrequency interference, cross talk and environmental factors compared to urban areas. Nevertheless, LoRa transmission can work excellently in urban areas if the transceiver is placed high enough to have a clear line of sight. However, more studies are required to improve the LoRa signal performance via other methods such as the mitigation of internal noises, like the method of grounding, adequate shielding, wiring techniques and design layout of the transceiver.

IV. CONCLUSION

The aggregate of a complete set of smart wireless systems was successfully developed using the LoRa-based technology. Generally, the project focuses on developing two different systems, which are the security system for swallow bird nests and the smart fertigation system. The two systems were integrated as a multiple-node system with bi-directional communication ability where the farmers could monitor and control them as intended. In each node, various features of input and output were designed to be controlled both automatically and manually with respect to different deliverables. From the result analysis, the long-distance communication ability was investigated, and based on the relationship of the performance parameter against distance, it was demonstrated that the system could potentially control a large area parameter effectively in the rural area. The crucial achievement of this project was to solve the limitations of smart technology in agricultural activity for the local rural community. The fundamental idea is to establish long-distance wireless communication without using any internet or mobile communication network to enable large scale control for smart agriculture using the LoRa communication technology.

The future development of this LoRa-based project will be focusing on the alternative of the power-over-fiber (PoF) technology implementation to supply low-power to the sensors and the remote devices. Major advantages in terms of immunity to electromagnetic perturbations and flexibility of the system in hostile environments could be achieved

ACKNOWLEDGMENT

The authors acknowledge the Project U-TD-RD-20-02 and UNITEN BOLD J510050002/2022019 for the funding and support.

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