LoRa Network Based Multi-Wireless Sensor Nodes and LoRa Gateway for Agriculture Application

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Abstract*— Our research proposed the prototypes of a Long Range (LoRa) network for agriculture application, which focuses on low-cost and effectiveness with multi-wireless environment sensor nodes in a network. each sensors node consisting of several sensors such as a soil moisture sensor, a temperature and humidity sensor, a raindrops sensor, and a light intensity sensor. The soil moisture sensor has been designed with 4 copper sensing-rods that a longest copper rod act as a ground signal level and other copper sensing-rods using for measures moisture at each soil depth. The different levels of soil depth with respect to the ground surface. A Heltec LoRa esp32 sx1276 acts as a LoRa wireless communication module for long-range environment data transfer. The proposed network that operating with two wireless communication frequency bands, 925.2MHz for node-to-gateway communication and 2.4GHz (WLAN) for gateway-to-cloud communication. Furthermore, the proposed network with three wireless sensor nodes and a single LoRa gateway was experimental. From the experimental results, the sensor node able to environmental sensing and transfer data to the gateway. The environmental data of soil moisture under the ground surface 20cm, 40cm, and 60 cm more than 90% accuracy compared to the standard instrument. Additionally, the LoRa transceiver range is approximately 600 meters (Non-line-of-sight: NLOS) and the LoRa gateway automatically transmits environmental data to the cloud storage every 15 seconds.

***Keywords*— LoRa, wireless sensor nodes, LoRa gateway.**

I. Introduction

Now, we are living in the era of the internet of things (IoT) technology that electronic devices in daily lift becomes smart things or smart devices for more convenient lift. Smart things are commonly designed with wirelessly device-to-device (D2D) data transfer. The IoT technology has immerging in a decade of years, that most focusing to develop in some places such as smart home, smart infrastructure, smart farm, or smart city. In Thailand, more than 30% of Thai population are agriculture farmers. Because terrain of Thailand mostly consists of lowlands that suitable for agriculture. From Agricultural Economic Report: 1st Quarter 2021 and Outlook for 2021, Office of Agricultural Economics, Thailand, we will see that the agricultural production index for January to March 2021 increase with 2.8 percentage when compared to the same period of 2020.

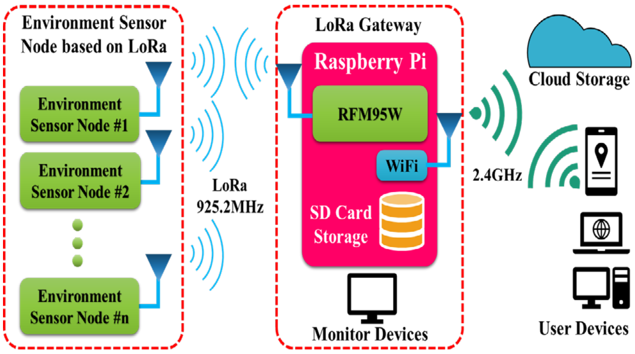

Fig. 1. The LoRa network architecture for agriculture area.

LoRa technology is a technology that not only long-range wireless communication but also low power consumption and secure data transmission [1], [2]. LoRa is the emerging technology which plays an importance role in currently smart IoT architecture. The chirp spread spectrum modulation technique was deployed in LoRa [3], which persistent to signal interference and noise. Thus, LoRa technology has interesting in field of studied, developed or implementation. Various literature focusing on combinate a LoRa technology with smart farming, smart homes, or smart buildings [4]–[6]. The authors in [4] and [5] presented a survey of smart buildings and homes using LoRa networks. That designed to user-command for controlling household appliances. In [6] proposed LoRa based smart farming with modular IoT architecture which presented several platforms architectural communication of multi-nodes and a gateway. Furthermore, authors in [7] provided the feasibility of networking technology for smart farm between LoRa technology and Automatic Packet Reporting System (APRS). From the experiment test results shown that LoRa network was more feasible wireless connection than APRS in the smart farm IoT system. Also, a raspberry Pi as a smart LoRa gateway was proposed in [8] which only focused on the designing of gateway protocol with dummy wireless sensors. The results showed that the smart gateway could handle both of communication and monitoring LoRa system.

Therefore, from the importance and advantage of the LoRa network for the agriculture area in literature above, so in this work presents a design and implementation of LoRa network

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with multi-wireless environment sensor nodes and a LoRa gateway for agriculture application. The rest of this paper is organized as follows. Section II. introduces a methodology of this work which consists of the designing of LoRa network, sensor node and LoRa gateway. While, in Section III experimental setup and results are discussed. Finally, in Section IV we draw some conclusions.

II. Methodology

In methodology of this research, there are 3 main parts, the first main part is the proposed LoRa network design that consisted of multi LoRa wireless environment sensors node and single LoRa gateway. This part explains the whole of the proposed LoRa network. While the second main part is a wireless environment sensor node design which describes only the structure of each sensor node. The third main part presents the design of the LoRa gateway with Raspberry Pi.

A. *LoRa network design*

The designing of LoRa network for agriculture area application was consisted of multiple LoRa environment sensor nodes (example in Fig.1, consists of n number of sensor nodes) with microcontrollers, LoRa gateway, and cloud storages. The designed LoRa network was shown in Fig. 1 that was separated to two sections as:

1) Hardware section: Each environment sensor nodes were collected environmental data in difference agricultural areas. Then 925.2MHz wireless transmitting data to a Raspberry Pi that dedicated to central processing unit of a LoRa gateway. Finally, all environmental data has been uplink from LoRa gateway to cloud storage with 2.4GHz of WiFi frequency band.

2) Software section: Sofware design has divided into three sections that depending on microcontrollers and cloud storage. In Microcontrollers Heltec LoRa and ATmega2560 were used Arduino IDE computer software. While Raspberry Pi operating with Rasbian OS. ChirpStack LoRaWAN® Network Server served as an opensource platform cloud storage. Also, Grafana Dashboard represent to a graphics environmental data monitor and analysis.

B. *Sensor nodes design*

Typically, a wireless sensor node (WSN) consists of a power source, analog or digital sensors, a microcontroller for data processing and a suitable wireless transceiver protocol. In this work, the environment wireless sensor nodes have been designs based on low-cost low complexity but high sensing accuracy. The designing split into two sections as:

1) Hardware section: Each environment sensor nodes comprised of various types of sensors such as soil moisture sensor, temperature and humidity sensor, light intensity sensor, and raindrops sensor. The structure of each sensor node illustrated in Fig. 2. There are microcontrollers Heltec LoRa esp32 and ATmega2560 act as a processor for data evaluation in various situations, also transmit data to LoRa gateway. ATmega2560 microcontroller provided to collected environmental data from each sensors with real-time clock (RTC) and SD card as a self-storage. Node LoRa esp32 low power microcontroller dedicated to a 925.2MHz wireless communication unit between sensor node and LoRa gateway.

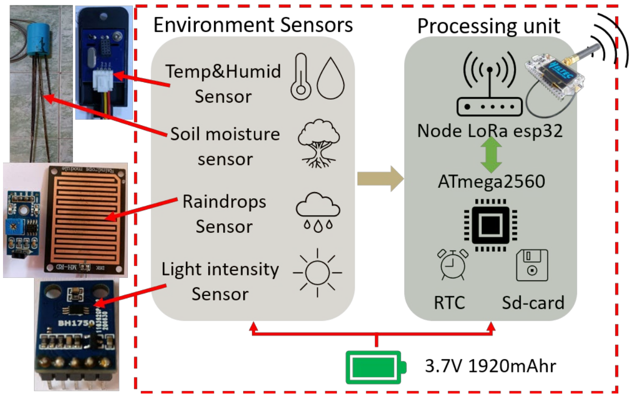

Fig. 2. The structure of a LoRa environment sensor node.

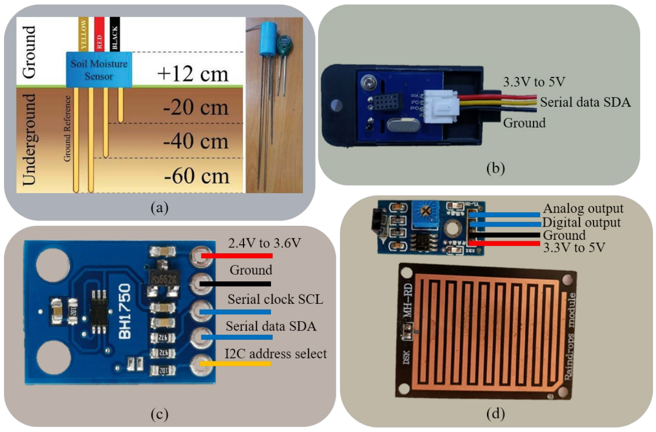

Fig. 3. Sensors of LoRa environment node (a) A soil moisture sensor [9], (b) A DHT21 temperature and humidity sensor, (c) A BH1750 light intensity sensor and (d) A raindrops sensor.

Furthermore, a 3.7V 1920mAhrs small battery intended for sensor node self-operating, from calculation the sensor node able to inside-battery self-powered around 13 hours and 30 minutes. Several sensors in a LoRa environment sensor node decribes as below:

a) Soil moisture sensor: The design of this sensor based on literature in [9] and [10] that previously our works. The sensor consist of four copper sensing-rods as shown in Fig. 3(a) a longest copper sensing-rod is a ground voltage reference level and other rods represent moisture sensing at each underground depth with 20cm, 40cm and 60cm respectively. This sensor sending three analog data of each depth to microcontroller.

b) Temperature and Humidity sensor: In Fig. 3(b) DHT21 is digital temperature and humidity sensor using for sensing air temperature and humidity in agricultural area with I2C communication protocol. It uses a dedicated digital module acquisition technology to ensure that the sensor has a very high reliability and excellent long-term.

c) Light intensity sensor: BH1750 is a small size digital light intensity sensor with 2 wires I2C communication protocol that show in Fig. 3(c).

d) Raindrops sensor: In Fig.3(d) a raindrops sensor serves to detect raining in the target area which analog data between “0” to “255” (8 bits) output depending on rainfall quantity. When data is maximun to “255” that mean no rain, while data is decreansing that the raining occurs.

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2) Software section: Several sensors in a environment sensor node has difference communication protocols namely temperature and humidity sensor, light intensity sensor use an I2C protocols, when soil moisture sensor sending a moisture data as analog voltage signal between 0V to 5V depending on soil moisture of each soil depth. A raindrops sensor sensing a rain on a sensing surface then sending a analog data to processing unit. From several sensor-processor communication protocols so, the algorithm designing of processing unit should be carefully and correctly. After processing environmental data, Node LoRa esp32 will wirelessly transmitting all data to LoRa gateway with long-rang 925.2MHz. LoRa sensor node microcontrollers were executed by Arduino IDE computer software with several open-source libraries.

C. *LoRa gateway design*

The LoRa gateway has designed based-on

1) Hardware section: In this work combination with a Raspberry Pi and a RFM95 module to operate as a LoRa gateway that illustrated in Fig. 4. The Raspberry Pi is a small-size computer that relative lightweight and can be run computer programs. The RFM95 is a 925.2MHz LoRa communication between each sensor nodes and LoRa gateway. Also 2.4GHz of WiFi frequency band using for transmitting collected environment data to internet cloud server.

2) Software section: LoRa gateway operating with Rasbion operating system with a Raspberry Pi version 3 module B. Also, on-board 802.11n 2.4GHz Wi-Fi, module equipped. ChirpStack and memory card served as an received environment data self-storage and cloud network storage.

III. EXPERIMENTAL SETUP AND RESULTS

The proposed LoRa network with multi-environment wireless sensor nodes has been investigated and experimental at the outside wide area with three LoRa environmental nodes and a single LoRa gateway which importance experimental parameters shown in Table I which refer to data sheets specification. The nodes-gateway distance of three nodes are 350, 400, and 600 meters, respectively. The outdoor wide-area experimental setup show in Fig. 5. LoRa sensor node and LoRa gateway is wireless communication with an unlicensed frequency band of 925.2MHz. While LoRa gateway using another unlicensed 2.4GHz WiFi frequency band to communicate with a cloud storage server. The LoRa gateway were installed at 2 meters height above ground level. Each sensor node was separately installed in a different outdoor field. The first node has located at roadside with small buildings on both side of the road. While the second and third node have placed among of buildings but different of location. The result from the experiment shown that the longest non-line-of-sight (NLOS) wireless communication is 600 meters which first sensor node is transfer data correctly. Because the location of the first node is less obstructions than the second and the third node. That mean first node location less large-scale fading than other nodes. Therefore, the node installation location should be considered that is a key importance for improving the performance of data transfer. Furthermore, the LoRa gateway is automatically environmental data transfer every 15 seconds to the cloud storage network.

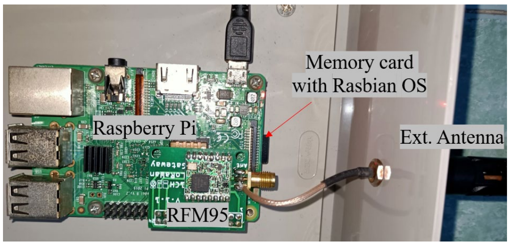

Fig. 4. LoRa gateway with Raspberry Pi and RFM95 module.

Fig. 5. Experimental outdoor setup of proposed LoRa network.

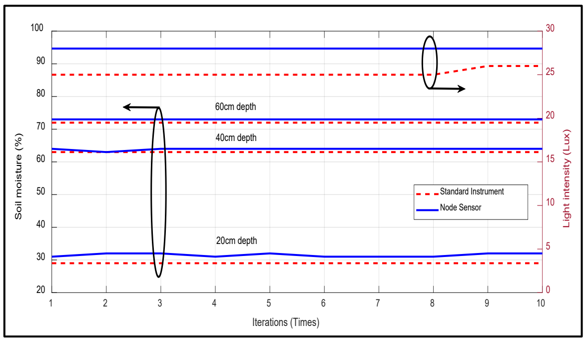

Fig. 6. Comparison of environment data between LoRa sensor node and standard instrument.

TABLE I. EXPERIMENTAL PARAMETERS

Parameters	Value
Sensor Node-Gateway frequency	925.2MHz
Gateway-Cloud frequncy	2.4GHz
LoRa wireless communication distance	NLOS 350 – 600 meters
Sensor node ext. antenna gain	2dBi
Sensor node transmit power	+20dBm
Sensor node receiver sensitivity	-139dBm
Gateway ext. antenna gain	10dBi
Gateway receiver sensitivity	-134dBm
Gateway transmit power	0dBm

To validate environment measurement data deal with by comparison to standard instruments. The comparison of soil moisture with each soil depths and light intensity measurements between proposed LoRa sensor node and standard instruments with 10 iterations described in Fig. 6. the three-soil moisture values for 20cm, 40cm, and 60cm difference of soil depths was shown in percentage on left y-axis. It shown the example measurement values, from the results indicated that the standard instrument (red dot line) is slightly higher than LoRa sensor node (blue solid line) with errors approximately 9%, 1.5% and 1.3%, respectively. In Fig. 6 on the right y-axis show the outdoor-light intensity value of LoRa sensor node and standard Lux meter. From comparison show that both values have a little different which LoRa sensor node has around 11% errors of light intensity with compared to the standard instrument along the test period.

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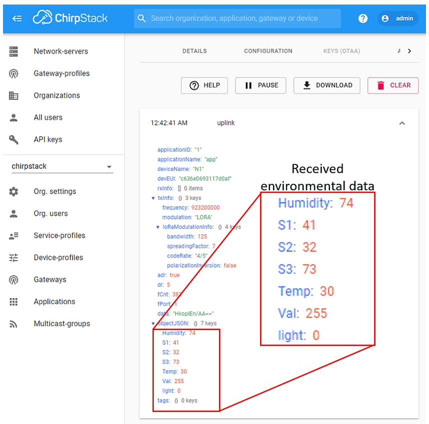

Fig. 7. Visualization of ChirpStack display of a environmental sensor node.

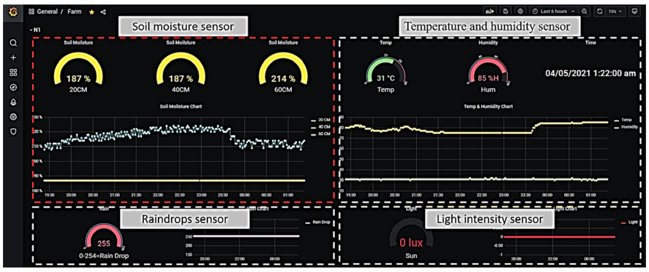

Fig. 8. Screen capture of Grafana Dashboard.

The Fig. 7 and Fig. 8 show the environment data from wireless sensor node. In Fig. 7 illustrated a visualization of ChirpStack software on Raspberry Pi that separated each environmental integers data of single LoRa sensor node. Besides, we also make real-time environmental dashboards of each wireless LoRa sensor node with Grafana software as a graphical data monitor. The screen capture of Grafana dashboard shown in Fig. 8. That is a helpful to data visualize, alert and data analytics.

Fig. 7 is a screen capture of ChirpStack software on Raspberry Pi. That 7 integer numbers show the environmental data of agriculture area from LoRa sensor node. The first integer data was shown “Humidity: 74” that mean the air humidity in this area are 74%. The next three integer data “S1: S2: and S3:” are soil moistures with 3 differences of soil depth (20cm, 40cm and 60cm) in the measured area. From an example we can see that, in 20cm 30cm and 60cm soil depths are 41%, 32% and 73% of moistures, respectively. Next values are showing “Temp: 30” where, it is 30-degree Celsius of an air temperature. The two-last value “Val: 255” and “Light: 0” are raining condition and the light intensity, respectively. When “Val: 255” is mean the 5V level of analog value incoming to microcontroller which no raining occur, but if analog voltage level decreasing analog become less than “255” that mean raining condition. While the intensity of light value is between 0 – 255 then mapping to 0% to 100% of light intensity.

Grafana dashboard in Fig. 8 was shown environmental data of a single LoRa sensor node that consisted of 4 subsets namely soil moisture data (top left), temperature and humidity data (top right), raindrops data (bottom left), and light intensity data (bottom right). In the dashboard was displayed not only real-time data but also recorded data.

IV. Conclusion

A LoRa network based multi-wireless environmental sensor nodes has been proposed. To enable real-time environment monitoring such as soil moisture, light intensity, temperature, and humidity in wide agriculture area. There is combination of multi-wireless sensor nodes which is environment data sensing, data collecting and data transfer to LoRa gateway. A single LoRa gateway represented a data logger and data transmitter to cloud storage. Cloud is used for data monitoring in a visualization also, it can use as data analytics tools. Outdoor non-line-of-sight (NLOS) wireless channel based three-wireless sensor nodes with difference wireless communication distances was experimented. From experimental show that, the proposed LoRa network properly operation with longest wireless distance of 600 meters. Furthermore, the environment data of LoRa wireless sensor node has validated environment data of LoRa node with standard instrument. The results of single soil moisture sensor which three different in soil depth indicated that all measurement error was less than 9%. Additionally, the LoRa gateway capable work with two mode, first environment data self-storage and second, environmental data transfer to cloud storage via wireless communication network.

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