Low-Cost Remote-Sensing-Node based on LoRa Mesh Network for Smart Agriculture

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Abstract

The advanced technology of the internet of things (IoTs) is currently a low-cost and low power solution, and able to transmit data remotely, resulting in the transformation of traditional agriculture into smart agriculture. Therefore, this paper presents the development of low power and low-cost remote communication system based on the Heltec WiFi LoRa 32 microcontroller for smart agriculture. The proposed system divides into two parts: (i) the wireless network (Mesh network) is to communicate data between three sensor-nodes and server-node at a distance no more than 100 meters, (ii) the radio frequency signal at band 868.125 MHz on the device itself is to communicate between server-node and gateway that is far more than 500 meters. Then send data via the internet service provider (ISP) on the CloudMQTT to monitor the required data. The development of this remote communication system can apply to large-scale agriculture that is far from the ISP to know environmental data such as the temperature and humidity. The experiments determine the test area covering an area of 1,200 square meters. Discussions present the data of distances that can send data from the signal station (LoRa-Node-Server) to the receiving station (LoRa-Gateway) then send data via the ISP to the cloud server in another area, at 710 meters, especially.

Keywords: IoTs, LoRa, CloudMQTT, Heltec WiFi LoRa 32

I. INTRODUCTION

The internet of things (IoTs) can help and allow monitoring of the information that submitted, as well as can control from anytime and anywhere in the world where the internet connected. The LoRa IoTs is quite a hot issue in many industries and agriculture like the smart city and smart farm. Large-scale agriculture has introduced many IoTs technology, depending on the application, especially the intelligent agriculture and the precision agriculture that has introduced IoTs technology. It depends entirely on communication between devices, allowing data to transmit and receive or transfer quickly. Cycleo (Slats, 2020) was developed the LoRa and released in 2012 as a non-licensed technology. While it is also considered as non-3rd Generation Partnership Project (3PPP) standard which is not the same as NB-IoT, EC-GSM, etc. Recently, in Hayati & Suryanegara (2017)'s study was proposed the tracking and monitoring the patient with mental disorder by using LoRa as the main communication platform of devices which showed the feasibility of LoRa network performance, power of the battery and the scalability. In Huh & Kim (2019)' study analyzed LoRa-based mesh networks for IoT by a modified LoRaWan that supports mesh network and TEDS to detect the collision rate in the network. In Andrade & Yoo (2019)'s work presented the LoRa in field of smart city by analyzed the qualitative that carried out about the development of the smart city solutions such as transportation, health monitoring, and pollution level measurements. In Ray (2017);s study proposed a comprehensive review of IoT deployment for smart agriculture based agriculture framework to leverage full-fledged combination between agriculture and IoT. An

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IoT solution to control and manage irrigation proposed in Fernandez et al. (2019) that related to connectivity and energy availability in the rural areas. However, the challenges of LoRa for agriculture have many solutions led to a high reliability, low-cost and low power solutions either in terms of investment or operation. This paper presented low-cost remote-sensing-node based on LoRa mesh network for smart agriculture to measure temperature and relation humidity of soil and ambient on the crop area.

The paper consists of five sections. Section I is the introduction. Section II presents the overview of the system. Section III provides the proposed system design while Section IV discusses the evaluation of the proposed system. The conclusion and the future work show in Section V, respectively.

II. OVERVIEW OF THE SYSTEM

A. Heltec WiFi LoRa 32

The heltec WiFi LoRa 32 board shown in Figure 1, is recommended for this project due to its capability is adequate and lowest-cost for the price comparing with the other board devices. Furthermore, the board incorporates a 0.96-inch OLED display. Their features are CP2102 that includes USB to UART converter, Flash memory 32 MB, and Lithium battery charger, etc. The power supply for the Heltec WiFi LoRa 32 board is another important point in the design of equipment selection for this project. Must know, how much power the device needs? By considering (Fernandez et al., 2019) the needs of the board, can divide into three modes: (i) Running mode, microprocessor read sensor, (ii) transmitting mode, data sent to the controller or gateway. When the data transmission process is complete, the device will select the operation to be in the low-power mode until it instructs to send it again. During this time, the device will be in (iii) Deep sleep mode. In this mode, the device's CPU, LoRa module and WiFi module will stop connecting.

Table I. The electric parameters for Running Mode, Transmitting Mode, and Sleeping Mode (Fernandez et al., 2019).

I_r (mA)	I_{tra} (mA)	I_{ds} (mA)	T_{tra} (sec)
50.1	71.7	11.9	0.2384

That are

I_r = Running Mode Current (mA),
I_{ta} = Transmitting Mode Average Current (mA),
I_{ds} = Deep Sleep Mode Current (mA), and
T_{tra} = Transmitting Time (sec).

B. Temperature & Humidity Sensors

There are many types of measuring devices or sensors using to measure the environmental factors, such as temperature and humidity, depending on the option in conjunction with the control equipment or controller. In this project, the sensor IC number SHT10 has used, considering the price and durability of the device to monitor temperature and humidity values. It can divide into two types according to the usage characteristics. Figure 2 shows the form of the waterproof encapsulating material container of the soil temperature and humidity sensor that can be measured both

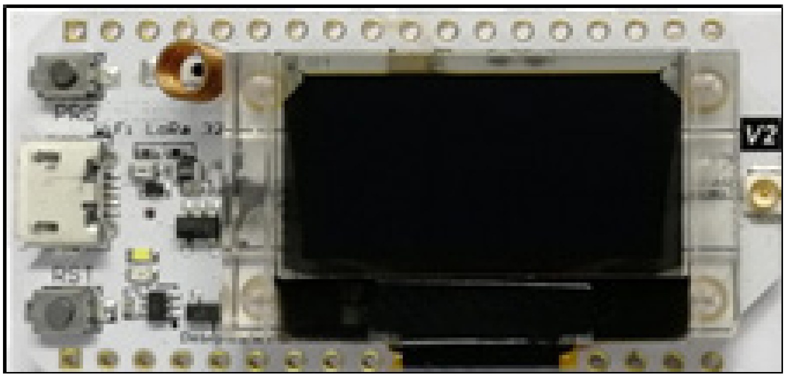

Figure 1. Heltec WiFi LoRa 32

Figure 2. The IC sensor number SHT10 encased with the waterproof metal container.

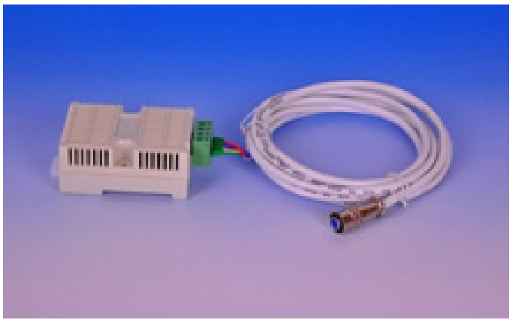

Figure 3. The IC sensor number SHT10 encased with the plastic container.

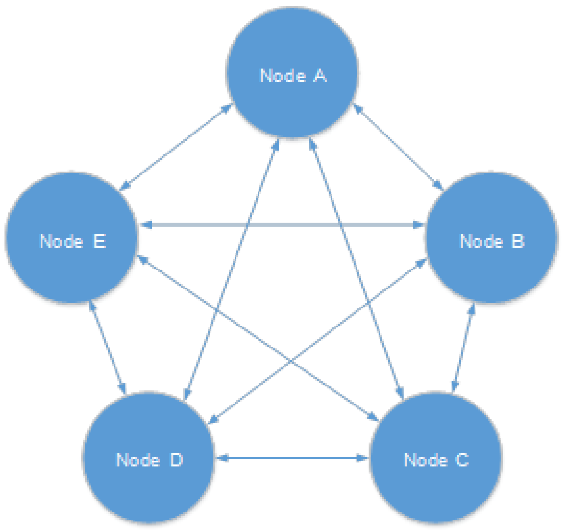

Figure 4. The Mesh Network

in ambient and in non-flooded soil. The SHT10 is in a plastic material container as shown in Figure 3. The SHT10 is a low-cost integrated sensor that measures relative humidity and ambient temperature. It provides the measurements using a proprietary two-wire serial communication protocol. The accuracy of relative humidity and ambient temperature provide +/- 4.5%RH between 0 and 100%RH and +/-0.5oC between -40oC and +123.8oC, respectively. The response time is 8 second of relative humidity and 5-30 second of ambient temperature. The operating supply voltage is between 2.4 volts and 5.5 volts.

C. The Mesh Network (Huh & Kim, 2019)

A wireless network known as a mesh network protocol is using with the wide-area-network, in which communication is the path between data between all nodes and all other nodes, resulting in data routes. Multiple paths of the mesh network will safe from the occurrence of system failures, as shown in Figure 4. All node devices are both a data receiver and a data transmitter.

III. THE PROPOSED SYSTEM DESIGN

The design and the programming of the remote-sensor-node connected with the LoRa-Gateway to bring data to MQTT Cloud Server and send to recipients. The details of the remote-sensor-node development project has shown in Figure 5.

- Determine three Sensor-nodes (Heltec WiFi LoRa 32+SHT10)
- Define one LoRa-server-node (Heltec WiFi LoRa 32)
- Set one LoRa-gateway (Heltec WiFi LoRa 32)
- Set Wi-Fi Router to connect data over the internet to MQTT Cloud Server

The project has considered an outdoor agriculture area of 1,200 square meters. This crop area is divide into three plots, each plot spanning 400 square meters. In agriculture, the soil and ambient environmental parameters play an important role in crop yield. The soil moisture and soil temperature sensors have used for measuring the soil parameters. Their parameters measured include relative humidity (%RH) and ambient temperature (°C). Each plot has only one sensor-node. Three node sensors interface with the LoRa-server-node based on the mesh network and then will send their data to the LoRa-server-node, which will then upload their data by using the radio frequency, band 868.125 MHz to a LoRa-gateway through the internet to the Cloud MQTT server. The real-time hardware implementation of the network has discussed in the next section.

A. The SHT10 Sensor Deployment

The SHT10 encased with the two material containers have been chosen that encapsulated in a sintered metal enclosure protecting electronics from direct contract with water to measure temperature and humidity of soil. The SHT10 encased with the plastic container is used for measuring ambient. The proposed project measures four environmental parameters, namely soil temperature, soil relative humidity, ambient temperature and ambient relative humidity. The SHT10 is the sensor measuring the temperature and relative humidity, accurately and environmentally resistant. The deployment of the SHT10 divided into two features: (i) By using IC sensor number SHT10 contain in the encapsulated waterproof metal material as shown in Figure 2. (ii) By using the IC sensor number SHT10 contain in the plastic container as shown in Figure 3.

B. The Hardware Deployment

The proposed network for monitoring agriculture is consisted of the spatial distribute three sensor-nodes shown in Figure 6, and a LoRa node server based on the mesh network of wireless platform.

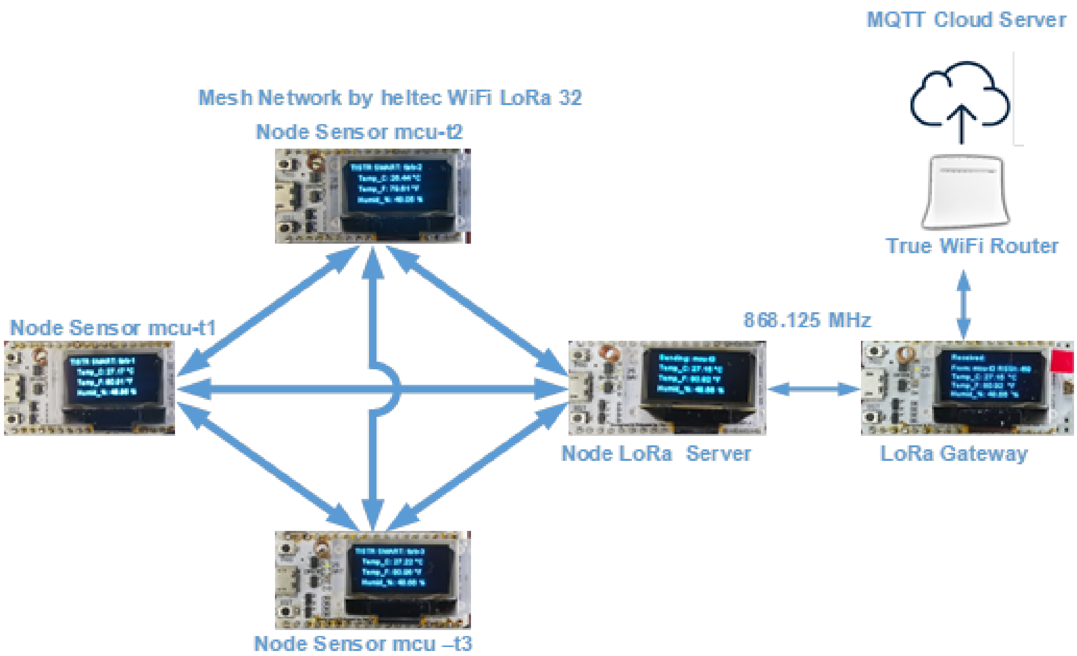

Figure 5. The Design of the Proposed System

Figure 6. Three Sensor-Nodes.

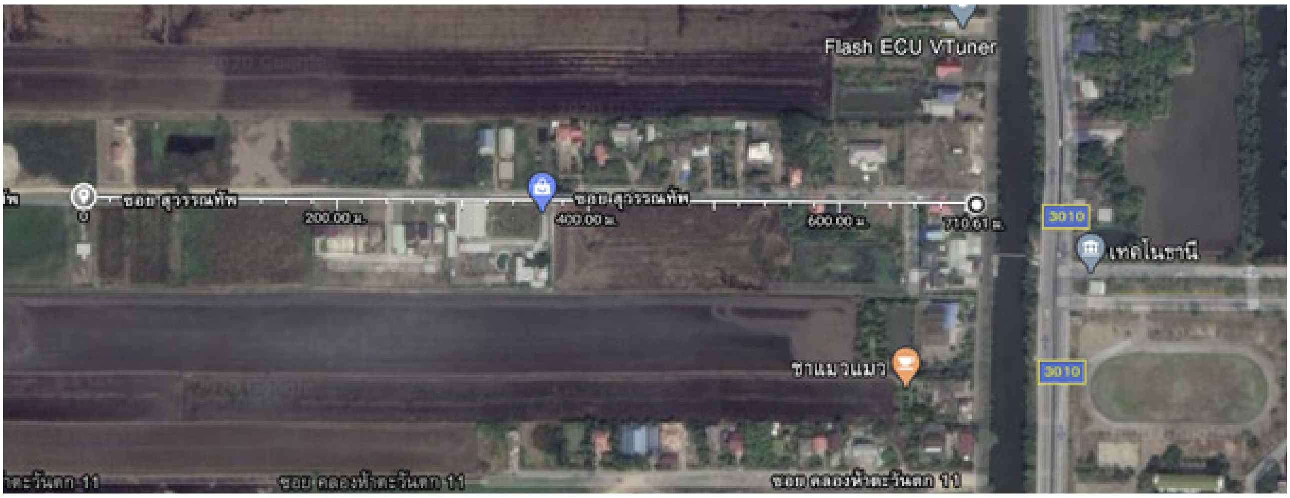

Figure 7. The devices installed in the crop area and data transmission distance.

Figure 8. The soil sensor-node deployed in the crop area.

Figure 9. The ambient sensor-node deployed in the crop area.

The sensor-nodes is a line of sight range of about 50 meters, which means that the sensor-node of transmission range covers the whole crop area and can easily reach the LoRa-server-node. The data of their sensor-nodes send via the mesh network protocol to the LoRa- server-node every 30 minutes and then go to the sleep state to conserve the power consumption. The LoRa-server-node is always on and transfers the collected data through the radio frequency band 868.125 MHz to the LoRa-Gateway, which then pushes the data to the internet into the cloud MQTT server with the help of the ISP True 4G Router. Since the experimental area is in a location without the ISP, the project is using the ISP True 4G Router to connect the node-LoRa-server to the internet. The LoRa-Gateway has powered on since it requires 7-12 volts' supply installed far from the crop area 710.61 meters, as shown in Figure 7. The soil sensor-node deployed in the crop area has shown as Figure 8, and the ambient sensor-node deploys in the crop area have shown as Figure 9, respectively.

IV. EVALUATION OF THE PROPOSED SYSTEMS

The evaluation of the proposed system presents low power, low-cost and long-range transmission data by measuring the power consumption, cost and the data transmission distance. In the following section

For evaluating, the power consumption of sensor-node has considered the electrical current. The power consumption of sensor-node has included of the Heltec WiFi LoRa 32 board and SHT 10 sensor measured by FLUKE 289 TRUE RMS multimeter. The electrical current parameters of running mode (Ir), transmitting mode (Itra), and deep sleep (Ids) mode have shown in Table 2.

Table 2. The electric current parameters of sensor-node.

I_r (mA)	I_{tra} (mA)	I_{ds} (mA)
54.3	75.2	15.5

Next, the battery of sensor-node has used the alkali battery size AA, 1.5 volts, 3,000 mAh and 3 units. They connected in series to get a total of 4.5 volts. The formula for calculating the lifetime of the battery for sensor-node has the following:

$$Battery\ Life = \frac{Battery\ Capacity\ in\ mAh}{LoadCurrent\ in\ mA}$$

Running Mode;

$$Battery\ Life = \frac{3{,}000\ mAh}{54.3\ mA} = 55\ Hrs\ 24\ Min$$

Transmitting Mode;

$$Battery\ Life = \frac{3{,}000\ mAh}{75.2\ mA} = 39\ Hrs\ 8\ Min$$

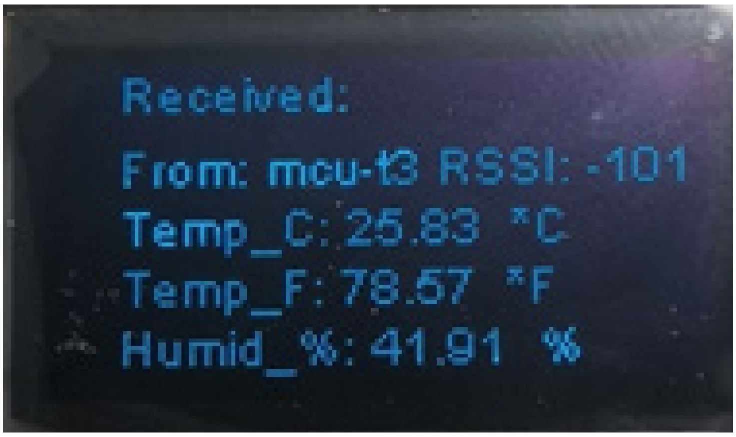

Figure 10. Show the received signal strength indicator (RSSI) of LoRa Gateway.

Deep Sleep Mode;

$$Battery\ Life = \frac{3{,}000\ mAh}{15.5\ mA} = 193\ Hrs\ 54\ Min$$

The maximum distance of data transmission has measured the line of sight about 850 meters from LoRa server-node to LoRa Gateway through the radio frequency band 868.125 MHz. The received signal strength indicator (RSSI) is -101 dBm as shown in Figure 10. According to the characteristic of the board, the best RSSI of the board is -98 dBm

V. CONCLUSION AND THE FUTURE RESEARCH

This paper presents the development of low power, low-cost and long-range communication systems with the Heltec Wi-Fi LoRa 32 microcontroller board and the SHT 10 sensor. The wireless frequency network design called Mesh network has used for data communication between each sensor-node and LoRa server-node. Then transmits a long-range communication by using the radio frequency band 868.125 MHz to enable remote communication devices between LoRa server-nodes and LoRa gateway. The development of this remote communication system can apply for large-scale agriculture that far from the internet, which needs to monitor environmental data such as temperature and humidity of soil and ambient. Specifically, the crop area for the test system, we install equipment consisting of sensor-nodes 1, 2, and 3, and install LoRa server-nodes covers 1,200 square meters of agricultural plot. The LoRa server-nodes can send data to the receiving station (gateway) and transmit data through the internet service provider to the MQTT cloud server in other areas installed at a distance of 710 meters. According to the experimental results of the long-range transmission, using the radio frequency band 868.125 MHz, with the capability of the proposed system can transmit and receive data, clearly at a distance of 850 meters at the received signal strength indicator (RSSI): -101 dBm. All devices use the default IPEX antenna. The data transmission distance depends on the characteristics like transmitted power, and the type of antenna.

The future work will develop the antenna to enable the devices to transmit signals farther than the original server-node or may change the gateway by using LoRa WAN Gateway RAK831+Raspberry Pi 3 hardware, which can support more devices. Moreover, develop web applications or a Dash Board on a smartphone to monitor various environmental data. Finally, it will be the electrical system for the node devices by using solar cells to charge a battery, which can recharge so that the equipment can use at all times.

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