A LoRa-based Low Power Wide Area Network Application for Agricultural Weather Monitoring

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Abstract-Meteorological events (hail, frost, snowfall, flood, drought and storms) have a major influence on the agriculture by affecting crop production. Knowing real-time weather condition parameters like air temperature and humidity, barometric pressure, light intensity, rain, speed and direction of wind gives the best possible yield and quality in agricultural production. This study presents a LoRa technology based wide area network (WAN) application for weather monitoring in agricultural fields. In proposed system, the weather stations with several sensors are placed over large-scale agricultural area. Each weather station collects the data of the connected sensors and send it to the gateway at a distance of up to 1500 meters. The gateway then relays the collected data to the network server. The farmers can be access the weather data from anywhere through the web-enabled devices. Our goal is to examine the feasibility of the LoRa-based LPWAN technologies and provide a flexible solution for future works on the IoT applications in precision agriculture.

Keywords- LoRa, Weather Monitoring, Precision Agriculture

I. INTRODUCTION

The application of meteorology to agriculture is essential, since every facet of agricultural activity depends on the weather. High-resolution monitoring of weather condition parameters helps to take precautions early on about critical issues [1]. With the rapid development of the information technologies, the traditional agriculture has increasingly been replaced by modern techniques. In modern agriculture, it is needed to new technologies that will enable to increase the efficiency of production and quality of crops. Precision agriculture incorporates information and communication technologies (ICTs) into farm management systems to reduce unit costs in order to improve profitability [2, 3]. The last decade has brought on a revolution in the precision agriculture, whereby increasingly wireless communication based applications have become popular. Wireless technologies allow farmers to get connected to their farms from anywhere and anytime through the web-enabled devices [4].

Internet of Things (IoT) describes an emerging global network in which everyday objects equipped with sensing and actuation functionalities will be connected to the Internet through wired/wireless networks [5, 6]. Low-Power Wide Area Network (LPWAN) is a group of technologies to fulfill the communication requirements of the IoT at low data-rate and low power consumption. Among such LPWAN technologies, LoRa (long-range) is a leading technology which operates in a non-licensed band below 1 GHz (433, 868, 915 MHz) for long range wireless connection [7]. LoRa defines the physical layer properties of the radio channel (i.e. RF link and modulation) which is described by Semtech Corporation. Semtech's LoRa modulation provide robust alternative to the traditional spread-spectrum communication techniques by generating a chirp signal that continuously varies in frequency [8, 9].

On the other hand, LoRaWAN defines upper layers of protocol stack from medium access control (MAC) to application standards on the top of the LoRa technology. Indeed, LoRaWAN defines the communication protocol and system architecture for battery operated devices in IoT applications that only need to transmit small amounts of data in a long range [10]. LoRaWAN architecture is laid out in star-of-stars topology, which includes end-devices, gateway and network server in the back-end. The end-devices communicate with one or more gateways by using LoRaWAN protocol. The gateways work as protocol converters, forward the data packets received from the end devices to the network server over backhaul links, typically Ethernet, Wi-Fi, cellular or satellite connection. The network server aggregates and analyzes the reported data packets. It provides information regarding monitored parameters throughout the overall network and also generates alerts to supervisors [11-13].

IoT promises the connected farm management systems for agriculture industry to make the farmer's job as easy as possible through innovative applications [14-16]. This study aims to present the development of agricultural weather monitoring system that capable of remotely monitor the meteorological conditions over large scale areas. We have designed the hardware and firmware of complete system components. We have also connected them to the LPWAN through LoRa-based RF transceivers. During the development of hardware prototypes, Arduino Nano board is used as an open-source electronic prototyping platform, which consists of an Atmel microcontroller mounted on a circuit board.

The rest of study is organized as follows. Section II describes the system model and framework of our scheme. Implementation details are provided in section III. Finally, the conclusions reached with recommendations are drawn for LoRa-based agricultural monitoring in section IV.

II. SYSTEM OVERVIEW

The proposed system is composed of a number of weather stations as end-devices and a gateway. Fig. 1 shows the overall model of proposed agricultural weather monitoring system. With a long-range star network topology layout, the weather stations have a direct (one-hop) connection to the single gateway. Each weather station is equipped with sensors and necessary electronic circuits to provide related measurements, store the collected data and establish communication with the gateway. The gateway relays the data packets between the end-devices and network server by using Wi-Fi connection.
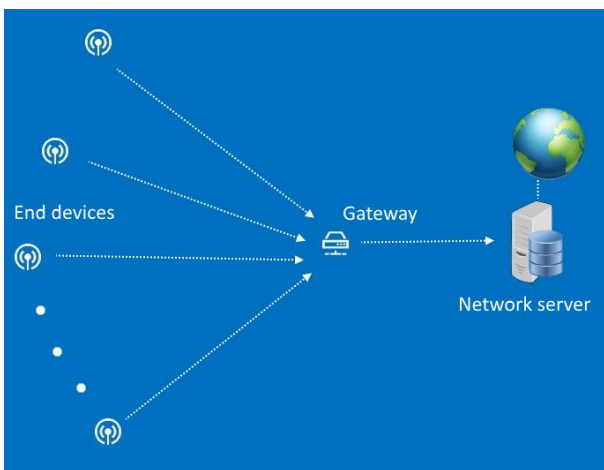

Figure 1. System model of LoRa-based LPWAN application

The weather station is equipped with Bosch BME280 environmental sensor, Texas Advanced Optoelectronics Solutions (TAOS) TSL2561 luminosity sensor and SparkFun weather meters to measure temperature, humidity, barometric pressure, light intensity, rain, wind speed and direction. It is built on the breadboard-friendly Arduino Nano board which includes ATmega328 chip with a clock speed of 16MHz. The hardware design of weather station is shown by Fig. 2.

Bosch BME280 sensor provides temperature, humidity and barometric pressure readings. The BME280 supports Serial Peripheral Interface (SPI) and Inter-Integrated Circuit (I2C) interfaces to communicate with the microcontroller. TSL2561 incorporates both infrared and visible light sensors to transform the light intensity to digital signal output. In our design, the BME280 and TSL2561 sensors are connected with Arduino Nano board through the I2C interface (SDA and SCL lines). TSL2561 use the default address of (0x39) and BME280 has a (0x77) default address for I2C communication. Fig. 3 shows the BME280 and TSL2561 sensors, respectively.
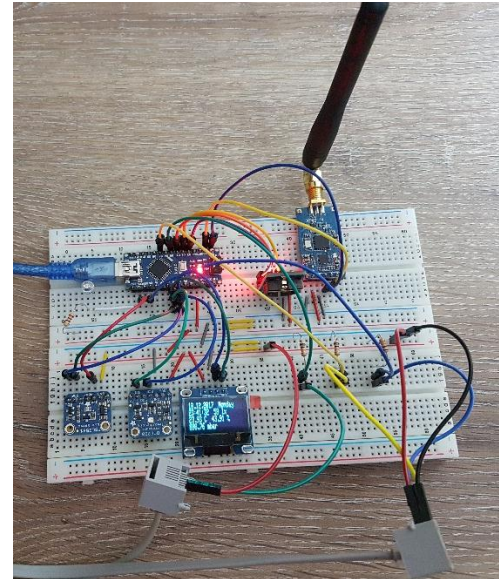

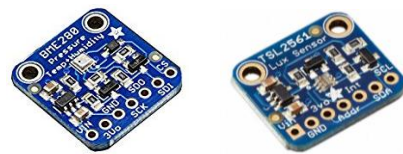Figure 2. The hardware design of the weather station

Figure 3. BME280 environmental sensor and TSL2561 luminosity sensor

The SparkFun weather meters are used to provide the wind speed, direction and rain gauge for full weather station capabilities. It includes a wind vane, cup anemometer and tipping bucket rain gauge sensors as shown in Fig. 4. These sensors are fully passive and use sealed magnetic switches and magnets to take measurements.

Figure 4. Sparkfun weather meters (wind vane, anemometer and rain gauge)

The wind vane has 8 magnetic switches and each of them connected to a different resistor. Voltage divider circuit is used to measure the resistance from the wind vane. When the vane magnet close to the magnetic switch, the wind direction can be determined at 16 different positions. An external pull-up resistor (10 KΩ) is used to form a voltage divider. Thus, the voltage produced at the output is applied to A0 (analog input) pin of Arduino Nano board.

Anemometer measures the wind speed by closing a contact as a magnet moves past a switch in each rotation. 2.4 km/h

wind speed causes a contact every second. The number of time the switch activates per period of time can be used to calculate the wind speed. The switch generates an interrupt on the falling edge of the pulse when the switch is closed by the anemometer. The anemometer is attached to the D3 (digital input with interrupt) pin of Arduino Nano board via pull-down resistor (10 KΩ) between the signal output and ground. Timer interrupts increase the counter's accumulated value and measure a given time interval.

The weather station also utilizes a rain gauge to record daily rainfall accumulation. 0.2794 mm increase of rain causes one momentary contact closure that can be evaluated as interrupt input on microcontroller. The rain gauge is attached to the D2 (digital input with interrupt) pin of Arduino Nano board via pull-down resistor (10 KΩ) between the signal output and ground. As shown in Fig. 5, the anemometer / wind vane and rain gauge are connected to the Arduino Nano board via RJ11-terminated cables. The rain gauge is connected through 2-center pin of the RJ11 cable / jack. The anemometer and wind vane are connected through the other RJ11 cable / jack.
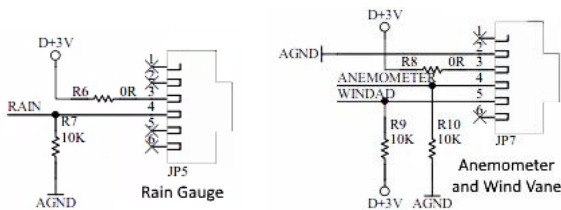

Figure 5. The wiring diagram of Sparkfun weather meters

In our design, an Organic Light Emitting Diode (OLED) is used to locally display the data from BME280/TSL2561 sensors, DS1302 real-time clock (RTC) module and weather meters. 128*64 graphical OLED display includes SSD1306 driver chip and uses I2C interface to communicate with Arduino Nano board. We use the DS1302 module to obtain current date and time. Finally, Dorji DRF1278DM LoRa-based RF transceiver module is used to enable low-power solution for long range wireless data transmission. The low-cost DRF1278DM module is based on Semtech's SX1278 LoRa chip and it is designed for operations in 433MHz ISM band. The long type whip antenna with 90-Degree SMA connector is screwed into end of the DRF1278DM module. Fig 6. shows the DRF1278DM LoRa module and the antenna.
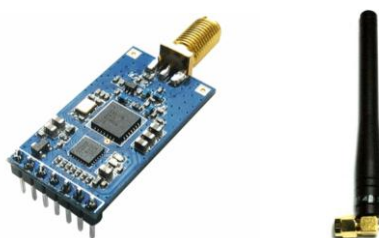

Figure 6. Dorji DRF1278DM RF transceiver module and antenna

The gateway bridges the data flows between the LPWAN and IP-based network, which is designed on Arduino Nano Board. The hardware design of gateway is shown by Fig. 7. In considered scenario, we assume that the gateway is located near the farmhouse with Wi-Fi connection. So, the collected data is forwarded from gateway to the network server by using ESP8266 ESP-01 Wi-Fi module from Espressif Systems. But, the data transmission between the gateway and network server is out of the scope of this paper, as we focus on LoRa-based LPWAN application and hardware design issues.
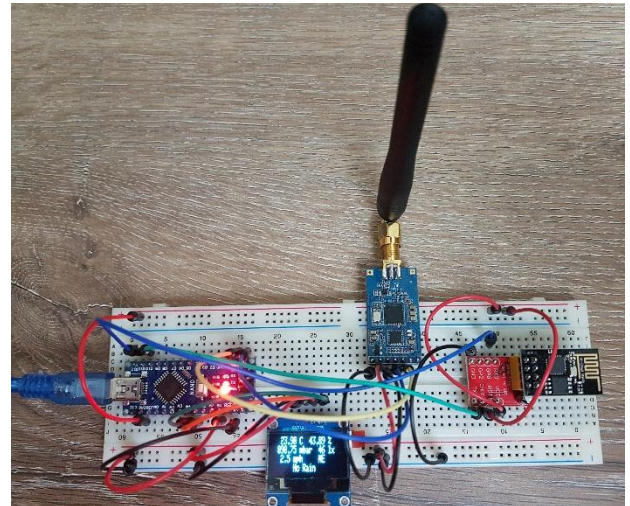

Figure 7. The hardware design of the gateway

III. IMPLEMENTATION

This section presents the methodology of our experimental study. At the beginning of our study, we have connected only one weather station to gateway in standard (transparent) mode. In there, the weather station sends data to the gateway through serial port (UART). After that, we have extended our network with virtual weather stations in star network mode. We have allowed one-way data transfer from weather stations to the gateway. Each weather station has a different ID (0~65535) which separates them from each other. Before use the DRF1278DM LoRa modules, we have configured them by using PC based DRF127xDM v2.7 tool from Dorji as shown in Fig. 8. Thus, the communication parameters can be adjusted according to the network topology, operating conditions and user requirements.

In our experimental study, we have revised and used the LoRaLib Arduino library (available on GitHub) [17] for LoRa modules based on SX1278 chip. Each transmitted data packet contains a source address, destination address, packet length and data in its payload field. It is assumed that the weather stations are powered with either batteries or batteries recharged with solar panels. In order to prolong their lifetime, we try to reduce the power consumption by keeping them in sleep mode as long as possible. The experimental setup of our study is shown in Fig. 9. Tests are carried out to understand the system

success and the obtained results are quite satisfactory. The results show the integrity and interoperability of proposed LoRa-based LPWAN application is good enough for remote monitoring of non-critical agricultural systems. The gateway successfully gathers data from three weather stations which are placed different locations on the open field.
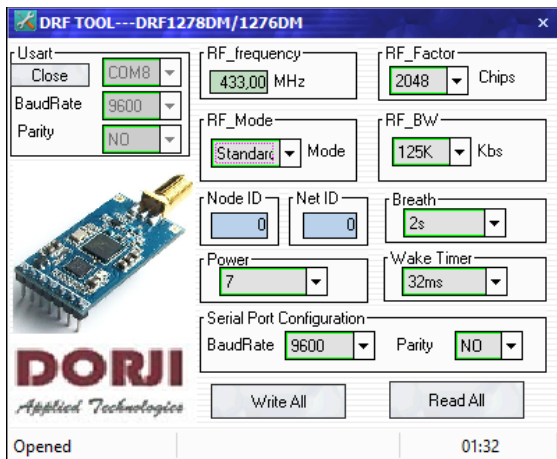

Figure 8.   Setting operation parameters with DRF127xDM configuration tool

Figure 9.   The experimental setup of weather station tests

IV.   CONCLUSION

In this study, the design and implementation of LoRa-based weather monitoring system for precision agriculture is discussed and presented. The system was implemented using Arduino Nano boards, DRF1278DM RF transceivers, ESP8266 Wi-Fi module, several sensors and weather meters to experimentally validate the proposed model. The major utilization advantage of LoRa technology is that the large-scale areas could be covered by one gateway and several end devices. Coupling LoRa-based LPWAN applications with precision agriculture not only promises long range connectivity, but also opens a whole new space of applications. We hope that the insights gained in this study will inspire further discussions and researches in precision agriculture to make it easy LPWAN applications. In the future, we would like to add the missing features of proposed system.

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