Smart Farm Monitoring Using LoRa Enabled IoT

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***Abstract*—Agricultural practices need to be transformed in order to overcome future food scarcity due to overpopulation across the globe. By employing emerging, disruptive technologies like IoT in the agricultural sector, it is possible to monitor farm fields using low-cost and low-power consuming devices, to automate irrigation systems for efficient usage of water resources. Weather forecast using IoT can help to plan farm filed activities like sowing, harrowing, harvesting, etc. This reduces negative impacts like yield losses due to uncertain weather changes. LPWAN technologies serve IoT applications in a better possible way so that these applications can overcome bandwidth, power and coverage constraints which are main drawbacks in other wireless communication technologies. In agricultural fields, LoRaWAN protocol or LoRa in LPWAN space gives additional advantages like scalability, security and robustness in designing IoT applications. In this paper, a smart farm monitoring model is proposed. This model utilizes LoRa communication mechanism to send sensor data like temperature ($^{\circ}C$), humidity (%) and soil moisture (%) from the transmitter node to receiver node. The receiving node which is Wi-Fi enabled uses MQTT services to monitor the data in IBM Watson IoT platform and to store the same data in IBM cloud DB service.**

Index terms: Agriculture, IoT, LPWAN, LoRaWAN, IBM Watson IoT platform and IBM cloud DB service.

I. Introduction

A. Internet of Things in Agriculture and Recent works

According to UN Food and Agriculture Organization, 70% more food is needed to feed the additional 2.3 billion people across the globe by 2050. To make this happen it is required to adopt the emerging technologies into the agricultural sector. IoT can be implemented in some use cases in the agricultural sector like:

1) Real-time monitoring of farm
2) Weather prediction modeling
3) Custom fertilizer profiles based on soil chemistry
4) Water conservation using IoT

To make better decisions in the nowadays farming sector, Using IoT, the farmers can deploy different types of sensors like environment and soil sensors and they can make use of insights from sensed data. IoT driven sensor data like CO_2, rainfall, temperature, humidity, soil moisture and plant health can improve the operational efficiency and helps in making strategic plans for higher productivity and profitable crop yield. These real-time monitoring applications to check nutrients present in the soil can minimize the wrong pattern fertilization practice in agriculture. The non-economic existing chemical lab testing practices can be replaced by IoT designs. With small affordable sensing devices, it is possible to monitor pH, temperature and humidity of the soil in more effective and convenient manner. The data from different sensors like temperature, humidity and pH sensors are measured using wi-fi enabled micro-controllers and stored in the cloud. The data is processed and about the soil quality to the user customized feedback is tailored.

As per the lack of knowledge about the weather forecast information, farming sector is facing many problems due to climate changes. Farmers can make strategic decisions to prevent the damages due to uncertain weather changes using the Internet of Things weather predictive models. And farmers can easily predict the rains, control pesticide waste, they can build advanced irrigation systems. For a suitable planning of a farm or to perform form operations, the weather forecast is necessary. Right from withheld or undertake sowing, to irrigate a crop or not, to know when to apply fertilizer, to start complete harvesting or withhold it, in storage and transportation of food grains, in taking right measures to fight frost, in managing other activities like plugging, harrowing the soil, etc. And to protect livestock weather forecast helps [1]. Designing smart irrigation meters and to implement smart water conservative methods in agriculture using IoT are important to preserve the available water resources for the future use.

In [2], [3] the authors proposed an IoT based agricultural devices which are portable hand-held devices to find the state of environment and soil. These devices consist temperature, humidity sensors, pH sensor, EC sensor and a colour sensor for both soil and environment and also GPS, ZigBee modules for radio communication. The sensed data is sent to cloud service at regular intervals for analysis purpose. In [4], [5], [6], it is given that weather forecast can be done using data from low-powered IoT devices and sensors. Formation of time series data of each variable like temperature and humidity used for weather forecast models with some predictive analytics. The sensed data is being analyzed and processed using structural and time series based algorithms like Multiple linear regression, Linear regression, Autoregressive integrated moving average and Support vector regression in a central server by combining real weather attributes. Based on the performance evaluation of mentioned algorithms using root mean square error parameter the author suggested Autoregressive integrated moving average is the best prediction model. Even though

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water is a scarce resource, overall 50% of water is wasted in agriculture due to the improper scheduling of irrigation [7]. In this context, the real-time monitoring of water usage in the fields can prevent misusage of water [8]. In [9], The author proposed a system which is designed using IoT consists of soil Hygrometer and GSM module. Based on the requirement of irrigation indicated by the sensor, using SMS service from the mobile, the motor can be turned ON or OFF. This gives way out to reduce the water wastage.

B. Drawbacks in different wireless communication technologies for IoT applications

Cellular networks are widely popular for the high-speed data coverage they offer. High-speed data is not a major requirement for IoT applications. Devices using cellular networks often have very poor battery life and there are several gaps in the network coverage. ZigBee type mesh networks are being widely used in home automation. This is because of the performance it offers at low to medium distances. But, when it comes to long distances (few Kms), these fail terribly. Bluetooth/BLE offers moderately good data rates but is greatly limited by range. The range offered is simply not acceptable for long range IoT applications. The IEEE802.11 WLAN standard is undoubtedly one of the most widely used standards among all the wireless standards. This is solely because of the high data rate and bandwidth it offers. Sadly, its range is very limited and it is very heavy on the battery. Devices using Wi-Fi do not last long and must often be close to the Wi-Fi access point in order to communicate properly. Due to the high operating frequencies (2.4 and 5 GHz), the waves do not penetrate through obstacles easily. In order to overcome these drawbacks, LoRaWAN technology is emerging very rapidly and it is going to be adopted by IoT driven applications in many areas.

C. LPWAN and LoRa

To build a smarter world in a few years global and national regional networks will connect trillions of wireless devices which are connected to send and receive a vast amount of data. An open nonprofit collaborative association, LoRa alliance brings Low power wide area networks to enable the Internet of Things to build carrier-grade communication networks and sensing applications. LoRa wide area network protocol also knows as LoRa can guarantee interoperability among LPWAN networks with added advantages like easy installation, more economic, flexibility, scalability, bi-directional, security, encryption, etc. LPWAN (Low-power wide area network) technologies support a large portion of billions of devices to forecast Internet of Things. This LPWAN technology offers efficient battery life-time for projected volumes of sensor-based IoT driven applications where the only small amount of sensed data needs to be sent over long distances. To optimize range, battery-lifetime, cost for such IoT applications LoRaWAN is designed in the LPWAN space [10]. This long range, low data rate based communication link establishment technology is designed by SEMtech.

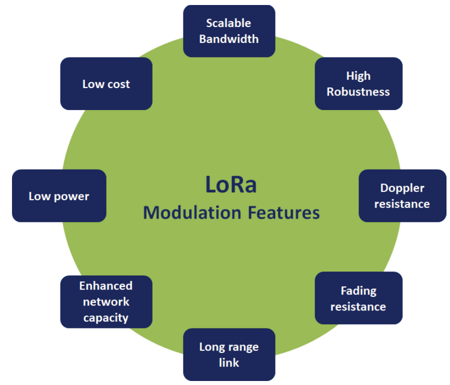

Fig. 1. The key features of LoRa

In MAC layer of the LoRa protocol stack, The end devices are classified into three different classes based on uplink time slots and power consumption. Class A devices which are bidirectional and consumes very less power among three classes. class A devices uplink data to gateway along with two simultaneous short windows for downlink. Class B devices are bi-directional and these devices have scheduled receiver slots where a sync-beacon is periodically sent by the gateway to the end device to ensure that the end device is listening. Class C devices have maximum continuous receiver slots. These Class C devices consume more power.

The comparison of different features of LoRa technology with other wireless communication technologies are given in TABLE I. The comparison of different LPWAN technologies along with LoRa are given in TABLE II.

II. Proposed Smart Farming model using LoRa enabled IoT devices

The block diagram of the proposed scheme is shown in Fig. 2 where two smart devices communicate each other using LoRa scheme and at the receiver end the data is stored in a cloud platform using MQTT service.

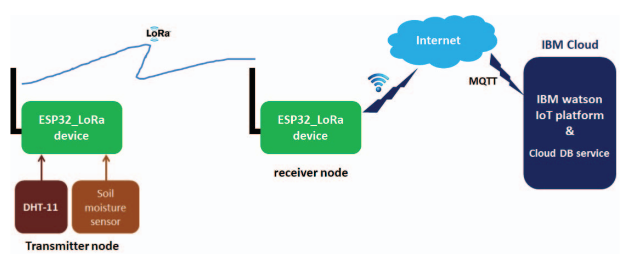

Fig. 2. The block diagram of proposed model

A. Hardware

a) Heltec ESP32 LoRa module: The LoRa based Heltec development board makes use of an ESP32 based SOC to handle the computation and processing work and makes use of the Semtech SX1276 LoRa transceiver module to send and receive messages over the air interface.

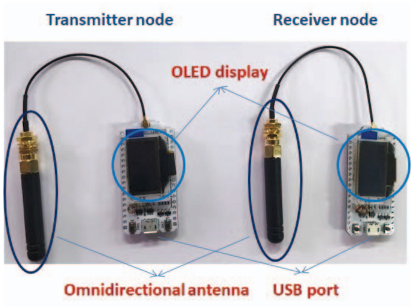

Fig. 3. Heltec ESP32 LoRa transmitter and receiver nodes [14]

The SX1276 makes use of LoRa spread spectrum technology which enables it to achieve very long range when compared to existing systems based on FSK modulation. Even when it is operating at the highest data rate, its sensitivity is at least 8dB greater than FSK. LoRa also has better selectivity and blocking performance which improves the communication reliability. The spread spectrum modulation bandwidth (BW), error correction rate (CR) and spreading factor (SF) are to be selected by the user. Each spread factor is orthogonal to one another which lets the use of multiple signals on the same frequency channel without much interference. The standard FSK based systems can also co-exist with the LoRa signals. The module can also be used to generate FSK, OOK and HMSP modulated signals in addition to LoRa signals. The list of some important features of SX1276 is tabulated in TABLE III.

TABLE I
SX1276 FEATURES

Maximum link budget	168dB
Sensitivity	-148dBm
Dynamic Range (RSSI)	127dB
Packet engine	256 bytes (CRC included)
High efficiency PA	+14dBm
Constant RF output	+20dBm
Bit rate	upto 300 kBits/sec

B. Experimental Setup and Results

The experimental setup for the proposed farm monitoring model with DHT-11 sensor, soil moisture sensor and Heltec ESP32 lora modules is shown in Fig. 4. The DHT-11 sensor is used to find the surrounding temperature and humidity values. The soil moisture sensor gives water level present in the soil. The transmitter nodes consist of one Heltec LoRa ESP32 module which is connected with the sensors, programmed as per the requirement and placed in the farm that senses temperature, humidity and soil moisture in the field environment. The transmitted senors information is observed in OLED display at the transmitter node. Using LoRa modulation scheme, the transmitter nodes send data to the receiver node.

TABLE II
ESP32 FEATURES

CPU	Xtensa Dual-core 32-bit LX6 600
Wi-Fi 802.11 b/g/n	Wi-Fi baseband , Wi-Fi MAC
Read only memory	448 KB
Random access memory	520 KB
Operating current	80 mA
Operating voltage	3.3 V
Frequency range	2.4 GHz to 5 GHz
Network Protocols	HTTP, IPV4&IPV6, FTP, TCP, UDP
GPIOs	36
ADC	12-bit

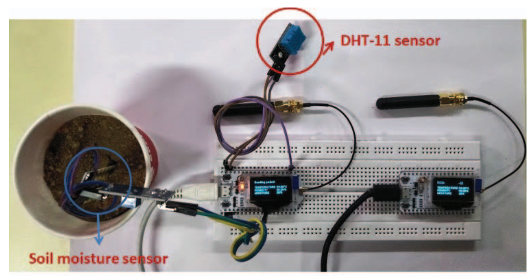

Fig. 4. Experimental setup for the smart farm monitoring proposed model

III. CONCLUSION

LPWAN supports a large number of IoT driven applications in various fields. Particularly LoRaWAN satisfies all the requirements for designing IoT applications. It became appropriate technology to adopt in agricultural sector since LoRa can increase the scalability in order to deploy IoT devices in farm fields. These LoRa based end devices which are cost efficient, energy efficient and also overcome bandwidth constraints as well. In this paper, importance of IoT in agricultural sector is explained. And drawbacks of different wireless communication technologies like Wi-Fi, Bluetooth/BLE, ZigBee, LTE, etc. in designing IoT driven applications are mentioned. Adopting LoRaWAN technology in IoT applications is most suitable method to overcome all those drawbacks. In this work, a smart farm monitoring model is proposed based on LoRa technology. The end nodes which are sensor enabled can be deployed on a large scale in the farm field. These nodes transmit data to the receiver node. The received data like temperature, humidity and soil moisture are monitored in IBM Watson IoT platform and stored in IBM cloud DB.

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