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An efficient LoRa-based smart agriculture management and monitoring system using wireless sensor networks

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ABSTRACT

The objective of this paper is to build up a LoRa-based smart agricultural management and monitoring system using Wireless Sensor Networks (WSNs) in rural areas, in order to replace the current technology of the agricultural monitoring system. A private network server is created and interfaced with a gateway that collects data or signals from end nodes and transmits the data to the cloud without the use of routers. The data can be used for end user application. The network interface is fulfilled by LoRa by solving communication failure problems and energy saving data transmission. This intelligent agriculture platform improves the efficiency of agricultural techniques.

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LoRa; smart agriculture; Wi-fi; wireless sensor networks; temperature

1. Introduction

In recent years, due to the decrease in the usage of water and an increase in the crop yields, the implementation of the automated agricultural monitoring system is an important thing (Suresh et al. 2020; Karthik et al. 2020; Subasri et al. 2020). The availability of computer systems and modern electronics in the field of agriculture has shaped new research challenges. In recent years, many surveys and studies were conducted to measure the impact of agriculture transformation. In the past years, ZigBee and Bluetooth standards majorly established the low-power and short-range networks, enabling the users to use mesh network topology (Nishikori et al. 2017; Xiao and Li 2020). Even though they are considered for low cost, their major drawback is the coverage, usually up to 100 m (Dharshan et al. 2021; Kaushik et al. 2021; Patel et al. 2021; Senthil Kumar et al. 2021 Sharmila et al. 2021). Low Power Wide Area Network provides another solution for building long range and power, and also low rate transmission technology (Kabeel et al. 2020; Sheela et al. 2020; Ashokkumar et al. 2021). Long-range radio links are the major difference between LPWAN and previous technologies (Mekki et al. 2019). Another important key characteristic of LPWAN is star topology. LoRaWAN, NB-IoT and Sigfox are some examples of LPWAN. Each and every technology has its own advantages and disadvantages. All these technologies have a coverage distance of several kilometres and have their own advantages and disadvantages, in terms of the scalability, cost, data rate and power consumption. Among them, Lora is a new technology having the highest of which the LoRaWAN protocol operates (Germani et al. 2019). It has the highest radio link budget and the best cost effective in this range against power tradeoff among its models. That is the reason for choosing LoRa modem as a radio link. At present, there are lot of developments happening in LPWAN networks. But, single technology cannot provide solutions to all the challenges. Thus LPWANs area unit employed to handle exclusively some on challenges in IoT. LPWANs are used specifically when there is a need for extended coverage, need of low power consumption network, involving devices with high data rates and with some delay tolerance. Particularly, monitoring the system conditions is perfect where LPWANs work perfectly. The main objective of the paper is to incorporate IoT and transreceiving technology into the smart field environment (Siddique et al. 2019). Various types of sensor data are measured with their accuracy and these data integrated into the input of the sensor component.

An automatic miniaturised greenhouse monitoring system was developed (Ibrahim et al. 2019). This system will monitor constantly and continuously on environmental factors in the orangery, to make sure that it stay in preset levels of temperature and humidity. If the greenhouse surrounding condition is slightly diverge from preset values, and then the monitoring system will automatically turn the sensors in the devices to compensate the preset level conditions. For this monitoring system, four different types of sensors were used for automatic greenhouse monitoring setup implementation. All the data and signals from the sensor are given to the microcontroller which acts as the main control unit. These values are transferred to the

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user interface or main control unit through the LoRa module. In previous systems, humans manually measured the moisture, temperature, humidity and various factors in the agricultural fields (Raj and Ananthi 2019). Their main aim is to check the condition and alert other farmers for manually alter the field. Some other existing methodologies incorporate Wi-fi and Zigbee technology. For Wi-fi, WSN802G modules are used. Based on this module, wireless sensor nodes are used. The data from these nodes are transmitted wirelessly to the main server, where data gets collected, analysed and displayed based on the farmer needs. Another technique is known as ZigBee, having many advantages like low cost and power. The topology used here is a wireless mesh network, which is a standard used for battery-operated devices particularly in wireless monitoring and control applications. It also provides low-latency communication. The above methods are perfect for smart agriculture. But these methodologies have some of the common disadvantages. Even though the above methods were identified for smart farming, there are some common limitations among them. Direct human involvement increases the errors in the output as the viewing angle and direction differs for different people. The human prediction may lead to half of the error because of climatic predictions by farmers; it varies from time to time. Labour problem is the major limitation in agriculture. Costs for labour is also get increased in recent times. The major limitation is the limited signal range (Butun, Pereira, and Gidlund 2019). The range of Wi-fi can approximately extend up to 50 m. But this range cannot be used in agricultural farms, because of its larger surface area. Data transmission speed in most wireless networks is far slower than the wired networks. Another protocol called Zigbee, also having a limitation of short-range, low complexity, low transmission and low data speed. Maintenance cost is somewhat high that makes it a step back when compared to other protocols.

2. Methodology

In this paper, the agricultural autonomous system is designed where it will sense the conditions in real time and analyse the field parameters such as temperature, soil moisture and humidity. The soil moisture sensor monitors the moisture level in the field and the temperature sensor monitors the temperature level. These data will be given to the LoRa Gateway. The LoRa Gateway performs the dual function of both receiving and transmitting the data to the cloud server via Wi-fi or Ethernet. At the transmitter side, the soil moisture, temperature and humidity of the soil are measured using sensors and it is processed using Arduino. The processed data are transmitted to the user side via LoRa technology. When any of the parameters falls below the optimum level, the Arduino send the command to motor for the operation to attain the level. The block diagram of the LoRa-based smart agriculture methodology is shown in Figure 1.

3. LoRa technology

LoRa, an upgraded data communication technology in wireless technology, was patented and developed originally by Cycleo of Grenoble, and later it was take over by Semtech (Zourmand et al. 2019). Spread spectrum modulation technology is used, which is derived from Chirp Spread Spectrum technology. This technology having the uniqueness of low power area network and wide area network is designed to connect wirelessly to the Internet of Things by providing end-to-end localisation services. Security is the major concern in all wirelessly transmitted data modules. A unique 128-bit network session and application session provides the security between end device to application and network server.

3.1. Comparison of LoRa with other technology

Today numerous technologies have used the world for IoT applications. Each and every technique has its own merits and demerits. Wi-Fi, Zigbee, Bluetooth were used for a short distance and used for various IoT applications, but the battery is a major drawback. LoRa acquires high recognition by providing low cost for IoT modules and equipments, M2M and other industrial needs (Queralta et al. 2019) (Table 1).

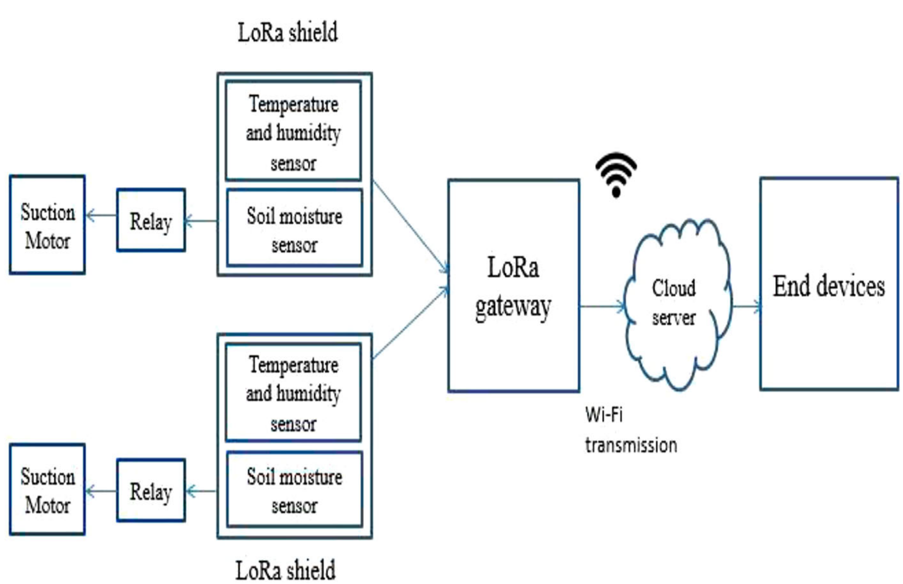

Figure 1. Block diagram of LoRa-based smart agriculture.

Table 1. LoRa with other technologies – a comparison.

Features	LoRa	Wi-fi	Zigbee	Bluetooth
Standard	IEEE 802.15.4g	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.11
Modulation	Chirp spread spectrum	Quadrature phase shift keying	Direct-sequence spread spectrum	Frequency hopping spread spectrum
Frequency	ISM 868/915 MHz	2.4 GHz	2.4 GHz, 868, 915 MHz	2.4 GHz
Topology	Star topology	Tree topology	Mesh topology	Tree topology
Range	2–5 km in urban5 km in rural	35–70 m for indoor 100–250 for outdoor	1–75 m and more	> 1–10 m
Battery lifetime	Extended battery life	0.1–5 (in days)	100–7000 (in days)	1–7 (in days)
Cost	Low cost	Average	Low cost	Low cost
Power consumption	Power consumption is low	low–high	Also low power consumption	Very low

4. Results and discussion

In this approach, several readings were taken for '*n*' number of days for plotting accurate graphs. The sensor data were collected and continuously updated in the cloud with the refresh rate of the 30 s. Below figure shows the graph of humidity, soil moisture readings at different environmental conditions over the surrounding. It concludes whether the sensors are working or not. And it contains all non-zero readings, i.e. the temperature and humidity sensor work continuously. Graph showing variation in temperature collected from field sensors is represented in Figure 2.

Graph showing variation in humidity collected from field sensors is shown in Figure 3. The *Y*-axis shows the different values of

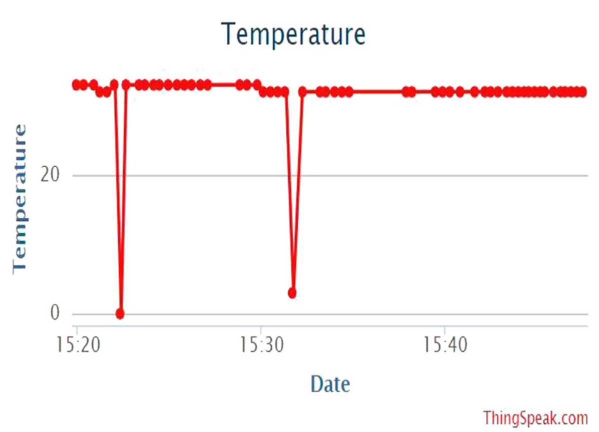

Figure 2. Graph illustration of temperature data.

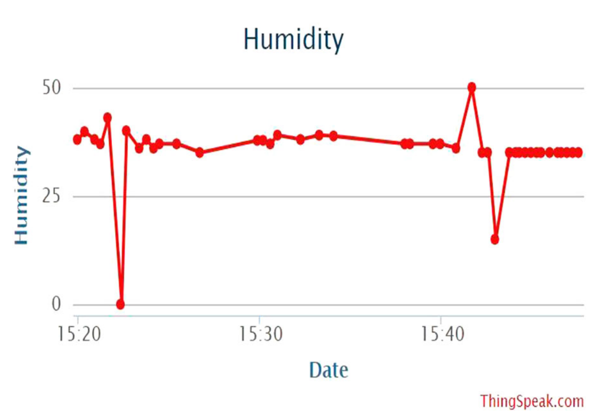

Figure 3. Graph illustration of humidity data.

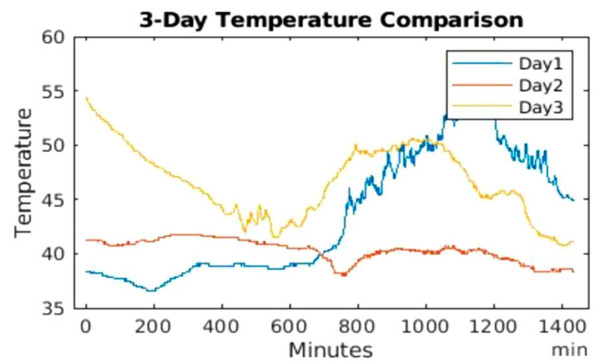

Figure 4. Graph illustration of temperature comparison.

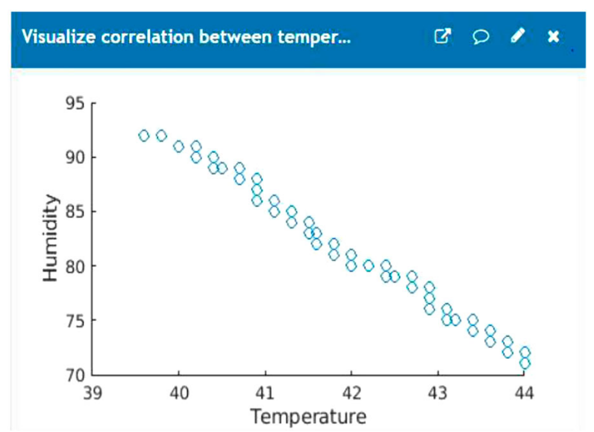

Figure 5. Graph illustration of correlation between temperature and humidity.

temperature and humidity and *X*-axis shows different readings concerning time in seconds.

The comparison of temperature for the data collected from field sensors for the three consecutive days is shown in Figure 4. The colours indicate the readings taken for each day. The graph is non-linear according to variation in time due to temperature in day scenario.

The visual correlation between temperature and humidity data collected from field sensors is shown in Figure 5. This graph clearly illustrates that when the temperature is high, humidity goes low and vice versa. Water molecules and relative humidity are inversely proportional to each other. If temperature increases, air possesses more water molecules, and hence the relative humidity decreases. When the temperature decreases, relative humidity gets increased gradually.

5. Conclusion

The LoRa-based wireless sensor networks provide the way for building smart agricultural monitoring system with lower power consumption and long range transmission. WSNs have the ability to provide low cost end devices, by making it as very attractive for smart agricultural systems. Moreover, most of the work focuses on LoRaWAN as the networking protocol of choice for deploying LoRa-based sensor networks, specifically for the applications. Dissertation work focused on design, development and application of LoRa and IoT technology using low-cost solution available for agriculture platform. The work measures to determine sensor accuracy, select sensor and design a long-range (up to 10 km) low power (66 mW per hour) communication platform. To reduce communication failure and save energy to enhance the efficiency of agricultural management by designing the LoRa network transmission interface. Experimental work aids remote monitoring of fields to farmers as well as assists to increase in yield. This monitoring setup can be further made headway by analysing the sensor data using an unsupervised clustering algorithm to build an automatic agricultural system for monitoring parameters like temperature, humidity, flame, soil moisture and controlling agriculture automatically with improved sensor nodes to increase the yield and to enhance the efficiency of nodes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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