Agriculture Monitoring with Lora Based Wireless Sensor Networks

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Abstract— Nowadays the Internet of Things (IoT) is one of the maximum promising areas in information generation for future products and services. Smart farming is one of the application of IoT to monitor agriculture field and to automate irrigation system, the wastage of water is reduced. Most wireless communication technologies have high power consumption and short transmission distances and costly, therefore farmers are not able to adopt IOT in agriculture This paper proposes smart Agricultural monitoring System using LoRaTM is low power wide area wireless network (LPWAN) protocol for Internet of Things (IoTs) applications. LPWAN has been enabling technology of big scale wireless sensor networks (WSNs). Less cost, long range and energy efficiency of LPWANs make them most suitable for smart agriculture and irrigation system.

Keywords: LPWAN, IoT, WSNs

I. INTRODUCTION

Agriculture happens to be the economic backbone of the developing countries like India. The traditional methods of farming practiced in India are inadequate in fulfilling the ever increasing demand for agricultural products due to the increasing population. As a result, farmers are in tremendous pressure, even in spite of putting efforts, resources, labour, farmers are not getting fruitful results. One way to overcome this problem would be to develop a cost effective means by which the wastage of resources and labour requirement could be cut down and at the same time the agricultural productivity would be improved not only in quality but also in quantity.

Now-a-days cultivating crops are becoming a very hectic task for the farmers because of the unpredictable climate and expense cost of the seeds. Due to the unpredictable and sudden change of the climate the damage ratio will be high and even the loss rate will be high. So in order to overcome this scenario have to adopt a design procedure which should be effective. The solution for this problem is by following the techniques of precision agriculture. Precision Agriculture is a process of giving a correct set of inputs to the crops or lands according to the environment changes. Precision Agriculture follows a defined set of rules. They are collecting the data, processing the data, sending the data to the centralized machine and according to the data received the decisions will be taken by the expert. It is due to the recent advancement in the technologies, in particular the semiconductor and Micro Electro Mechanical Systems (MEMS) technologies that the sensors are being developed in the sub-nano or particle sizes with reduced manufacturing costs.

II. WIRELESS SENSOR NETWORK

In the present scenario, Wireless Sensor Network (WSN) is an emerging technology to be deployed at an accelerated pace. WSN combines sensing, computation and communication into a single tiny device. A typical WSN mostly consists of gateway, router and end devices. End devices are spatially distributed nodes which work independently and collect required data which is then sent to the central analyzing center i.e. gateway where the data is collected and analyzed for sending back data to the sensor node for actuation. The newly emerging technology i.e. Wireless Sensor Networks spread rapidly into many field's like medical, habitat monitoring, bio-technology etc. The relevance of WSN are tremendous. The utility of WSN is for collecting the sensed data, storing or processing the sensed data and the transmitting data to the appropriate central station. Agriculture is one of the field which have recently averted their scrutiny to WSN. By taking help of WSN, one can transmit the real-time data quickly with in no time. Precision agriculture is nothing but applying right inputs at the right time to get more cultivation with less power and work. The real-time data is based on the several characteristics of weather like temperature, humidity etc.

A. Internet of Things

Now is the era of connected objects. IoT (Internet of Things) is gaining much importance in almost every field such as business, industry, consumer electronics, automotive and much more. Every object in today's world is well connected to each other in one way or the other. We can control the lights and equipment in our homes sitting in our office. In industries and other fields activities are regulated and controlled from a remote location. Controlling street lights from a remote distance, smart food order system, etc., is no longer a dream. Gone are the days where the presence of the person on the spot was necessary for the monitoring and control. Technology has advanced to an extend where everything can be made possible sitting in your house or in your office cubicle. IoT plays a major role in this. IoT connects various objects such as sensors, actuators, electronics and network connectivity that enable the objects to exchange data between them and stay connected. It is a network of physical objects.

In IoT-based smart farming, a system is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, etc.) and automating the irrigation system. The farmers can monitor the field conditions from anywhere. IoT-based smart farming is highly efficient when compared with the conventional approach. The applications of IoT-based smart farming not only target conventional, large farming operations, but could also be new levers to uplift other growing or common trends in agricultural like organic farming, family farming (complex or small spaces, particular cattle and/or cultures, preservation of particular or high quality varieties etc.), and enhance highly transparent farming.

It is a network of physical objects .The IoTs supports the development of a wide range of applications. Most

wireless communication technologies have high power consumption and short transmission distances and therefore do not meet the requirements of IoTs applications for connections Consequently, LoRa technology has been proposed. It is battery-powered and operates for several years without the need for a battery replacement, so it can be used outdoors. For example, it can be used to collect agricultural information traffic signals in smart cities [1].

B. Objectives and Goals

The primary objective of this thesis involves designing, implementation and analysing long range communication protocol in agriculture system which should be capable of:

- Low-cost devices for low-cost network deployment
- Low power consumption
- Easy to deploy network infrastructure nationwide
- Secure
- Extended coverage

III. SOME OF THE COMMUNICATION PROTOCOL

A. Bluetooth

Bluetooth is a wireless personal area network (WPAN) technology based on IEEE standard 802.15.1. It was launched in 1994 by Ericsson. There are many wireless technologies one of them is Bluetooth technology, it is for short range distance which works for point to point data transfer. It consumes low power and covers range within 10-100 meters. Here one device acts as Master and the devices connected as slaves.

Various sensors are connected to Bluetooth module via a microcontroller. It consists of packet delivery service in network layer which is capable of spreading data across the network. Information is received and compared in the application layer, then climate data from the sensors are gathered by control layer and suitable decisions made for the control of the agriculture environment. And information is interfaced to user. Bluetooth technology which puts limitation in terms of range and energy efficiency of sensors

B. GPS (Global Positioning System)

GPS technologies enable the user to get a real-time data collection with correct position information, leading to the efficient manipulation and analysis of large amounts of collected sensed data. Using GPS farmer can accurately navigate to specific locations in the field to collect their requirements such as Soil samples or monitor crop conditions. GPS allows farmers to work during conditions like dust, fog, rain and darkness. .But adopting this technology is costly and also can limit in connectivity.

C. GSM

The another emerging technology is GSM.GSM can send SMSs to the Farmer about their field conditions. It serves as an important part as GSM is responsible for sending sensed values from the sensors and controlling the irrigation on field and sends them to the receiver through coded signals. It operates through SMSs and is the link between ARM processor and centralized unit. Using GSM, user can get to know about the exact field conditions. In the form of SMS information is sent to the requested user.AT (Attention) commands are used to control GSM modem. Majority of the functions of GSM modem are controlled by these commands. The main concept behind the GSM technology in precision agriculture is receiving the sent SMS and processing it further as required to perform several operations. The system allows the remotely located user to effectively monitor and control the motor via the mobile phone set by sending commands in the form of SMS messages and receiving appliances status. This technology limits in connectivity and band range.

D. Wi-Fi

Wi-Fi (Wireless Fidelity) is a wireless technology, this technology uses radio frequency to send data via air. Wi-Fi has data rate of 1 mbps to 2mbps and sends information in the frequency band of 2.4 GHz and the range is 40-300feet. Various sensors with analogue outputs in the field are connected to chosen Wi-Fi module via multiplexer. The data from various sensors namely temperature, pressure, humidity, pH etc., parameter is collected by the sensors. Then data is sent from sensor nodes to the base station via a sink node. By using user interface the farmer can access the data .Also it is user-friendly for an Indian farmer. With moderate cost, serving large number of nodes with the flexibility of mobility, it can be a sought after alternative. Adopting this technology may be costly.

E. ZigBee

The IEEE standard 802.15.4 commonly known as ZigBee is most popular choice in Low Rate Wireless Personal Area Networks (LR-WPAN) and WSNs. IEEE standard 802.15.4 has only defined the characteristics of physical (PHY) layer and Medium Access Control (MAC) layer ZigBee based wireless network can adapt star topology and/or peer-to-peer topology.

ZigBee are low power and low complexity wireless sensor technologies, but they have some limitations, such as low data rate, short range, and less penetration across obstacles.

It is clear from the above Overview that there are some drawbacks in monitoring and irrigating agriculture field. Some systems are extensively wired which makes it difficult to implement and also implementing for larger fields increases the cost of implementation and maintenance as well. Power cuts are common in villages that shut down the entire system which can result in improper irrigation of the field which affects the crop production. So it is necessary to build a system which consumes low power low cost and long range connectivity which is help full for user to improve their crop production.

IV. INTRODUCTION TO LORA TECHNOLOGY

LPWAN is the rapidly growing area of the communication industry. Amongst the recently introduced low power and long range technologies, the semiconductor manufacturer Semtech has introduced extensive utilization of advanced spread spectrum. LoRa is a designed specifically for long range, low-power communications[1]. In general, a LoRa Wide Area Network (LoRaWAN) can cover 20 km in rural area and around 8 km in urban area, which can ensure the high coverage of the irrigation system. Because of low power consumption, the LoRa device can operate up to ten years on

battery. In the long term, it brings great benefits, such as water-saving, lower costs of maintenance and deployment.

A. Basic concepts of LoRa Technology

There are numerous technologies in today's world that is used in IoT applications. Every technology has its own features, merits and demerits. One technology cannot serve all the applications of IoT. Different applications will have different requirements. No technology can be said as the best technology. Each technology differs from other in different aspects. Applications also differ from each other in their requirements and their usage. Based on the requirement we can only choose a technology that is best suited for the specific application from the existing technologies. Wi-Fi is the most popular technology that has been recently evolved and is used in long distance communications. We have Bluetooth, ZigBee, etc., for short distance as well and these can and are being used in various IoT applications. But in all of this battery is a major concern. LoRa enables secure bi-directional, low cost and mobile communication for IoT, smart city, machine to machine (M2M) and industrial applications[2].

LoRa is a long range low power wireless technology platform that uses unlicensed radio spectrum in the industrial, scientific, and medical radio band (ISM band). LoRa aims to eliminate repeaters, reduce device cost, increase battery lifetime on devices, improve network capacity, and support a large number of devices. It is a physical layer used for long range communication LoRa or LPWA (Low Power Wide Area) is a generic term for a group of technology for wide area communication. LoRa is rapidly gaining high popularity and is a preferred technology for IoT embedded systems because of its Long Range, high capacity of nodes in network, long battery life, bi-directional, secured and efficient network.

B. What is LoRa?

- LoRa is the physical layer or the wireless modulation scheme utilized to create long distance communication link.
- LoRa is based on chirp spread spectrum modulation, which is similar to FSK (Frequency Shifting Keying) modulation but it increases the communication range significantly.
- The biggest advantage of LoRa over other communication technology is its long-range capability. A single gateway or base station can provide service to an entire city or hundreds of square kilometers.
- LoRa has better link-budget greater than any other standardised communication technology

C. LoRaWAN

The LoRaWAN protocol is relatively new and became the focus of several research centers across the world. LoRa (Long Range) is a modulation technique that enables the long range transfer of information with a low transfer rate. The LoRa modulation has been patented by Semtech Corporation. LoRaWAN uses star topology as it increases battery lifetime when long-range connectivity is used[4].

LoRaWAN protocol is a wireless communication protocol developed by LoRa Allience to serve for challenges faced with long-range communication faced with IoT. It specifically deals with long range, low power consumption at a low bit rate due to its LoRaWAN-based system architecture. The protocol and its network architecture have a great influence in determining a node battery lifetime, network capacity, quality of service(QoS), security, and a variety of applications served by the network[5].

The Low Power Wide Area Network (LPWAN) type and encompasses battery powered devices that ensure bidirectional communication. The LoRaWAN specification ensures the perfect interoperability between the IoT objects, without the need for complex local implementations[4].

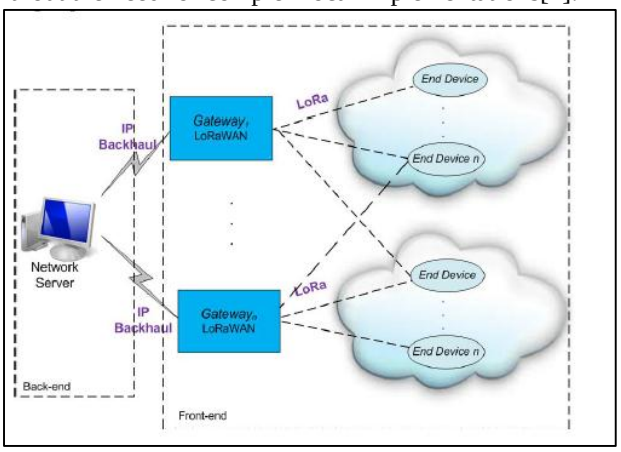

Fig. 1: LoRa architecture

Fig. 1 presents the LoRa architecture. The LoRa network is implemented by using the star network topology. The structure of a LoRa architecture can be separated into a back-end and a front-end part. The back-end part consists of the network server that stores the information received from the sensors. The front-end consists of the Gateway modules and the end-device nodes. The Gateway modules act as a bridge between the end-device nodes and the network server. The information between the network server and the Gateway modules is sent through the IP connection.

The advantage of LoRa lies in the technology's longrange capability. A single base station can cover hundreds of square kilometers, but the range is highly dependent on the environment or obstructions.

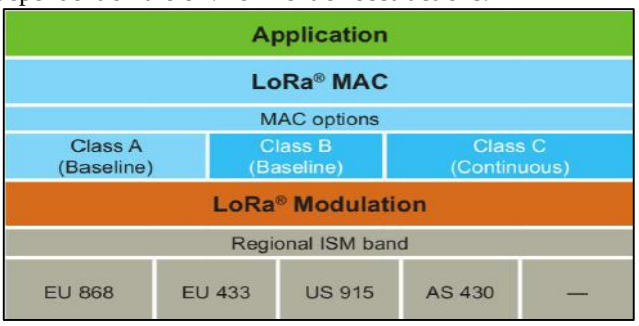

Fig. 2: The communication protocol and system architecture of LoRaWAN[6]

Fig2 represents the system architecture of LoraWan LoRa modulation is based on spread spectrum techniques and a variation of the chirp spread spectrum (CSS) with integrated forward error correction (FEC). It operates in the lower Industrial, Scientific, and Medical (ISM) bandwidths (USA: 915MHz, EU: 433MHz and868MHz). The LoRa modulation can be utilized by many different protocol architectures such

as Star, Mesh, and 6lowPAN. Furthermore, the LoRa Alliance has standardized the MAC protocol called LoRaWAN. LoRaWAN (Fig. 2) defines the communication protocol and system architecture for the network while the LoRa physical layer enables the long-range communication link. The edge nodes of the LoRaWAN network can transfer data to multiple base stations. LoRaWAN is an open standard governed by the LoRa Alliance and the first version, 1.0, of the LoRaWAN specification was released in June 2015. Version 1.1 of the LoRaWAN specification was published in 2017.

LoRaWAN ensures data rates from 0.3 kbps up to 50 kbps, which are considered acceptable for transmitting real-time sensor data in the IoT, Machine-to-Machine (M2M), smart city, and industrial applications. However, transmission of real-time image data, or anything that requires high bandwidth that may not be suitable on LoRa networks. This low data rate ensures the low power consumption of the edge node devices, therefore enabling the usage of battery for a seamless deployment. Edge node devices can be configured with different features. LoRaWAN defines three classes of devices. These device classes can negotiate network downlink communication latency versus the battery lifetime.

These classes are shown in Fig. 2 and, depending on the application needs, A, B, or C class can be chosen. Battery-powered devices in "Class A" are intended for low powered devices such as sensors. These are the most energy efficient class but have the biggest latency time. It also includes devices that do not need to transmit data all the time. All the LoRaWAN-capable devices must support the functionalities of this class.

The B Class is focused on battery-powered devices, such as actuators and sensors. These are energy efficient but with a latency-controlled downlink. The communication is slotted, synchronized by an external beacon, which allows the server to know when the end device is listening.

The C Class is used by bi-directional end devices with maximal receive slots. The end devices of Class C have almost continuously open receive windows, which are only closed when transmitting. These devices should be used with external power source, are capable of listening to the air interface the whole time, registering no latency over the receive or transmit mode. LoRaWAN network protocol security is based on IEEE 802.15.4, and is also extended by using two session keys: a network session key and an application session key. Each LoRaWAN edge node device also has its own 128-bit AES key, known as the AppKey.

V. Features of Lora technology

A. Long Range of Lora

As the name implies LoRa is a long-range protocol. It is capable of transmitting data over long distances. A single gateway can cover hundred-kilometer square of area. The long range of the LoRa technology is due to its link budget and the chirp spread spectrum modulation that it employs.

B. Battery lifetime

The most important criteria of an embedded device is its battery lifetime. Most of the embedded devices need to communicate with other devices near or far. This consumes high power. The embedded devices are all mostly battery operated. Thus, the essential requirement of these embedded devices is its battery lifetime. Most of the protocols or techniques used to create IoT embedded device now-a-days consumes very high power thus reducing the battery lifetime. LoRa optimizes the battery consumption in a device and is most suited for battery operated embedded device. LoRa consumes the least power when compared to all the existing technologies.

C. Network Capacity

Star network is used in Lora network. The LoRa network gateway receives data from large number of nodes.For this the gateway must have high capacity. This is achieved by adaptive data rate and multichannel multi-modem transceiver at the gateway.

D. Security

AES encryption and IEEE 802.15.4/2006 Annex B is used in this technology for security and authentication. While most technologies incorporate single layer security, LoRa network incorporate two layers of security: network security and application security. The network security is used for authenticating the node in the network while the application security protects the end user application data from the network operator. The LoRa technology uses two keys for the security and authenticity: NwkSKey (Network Session Key) and AppSKey (Application Session Key). For the end device to participate in a network it must be activated and authenticated. The technology has two methods of authentication and activation

- Over the air activation (OAA)
- Activation by personalisation (ABP)

E. Quality of Service (QoS)

Quality of service is the account of overall performance of a network. It is based on various parameters such as data rate, immunity, throughput, packet loss, etc. The LoRa technology which is based on chirp spread spectrum technology offers fairly good quality of service. It is immune to interference, multipath and fading. In a wireless network, as the distance between the devices increases the signal strength decreases. These are usually avoided by installing repeaters or by having additional nodes as in mesh topology. But the cost of having more repeaters or nodes in between is very high. But for LoRa, those signal with different sequence will be treated as noise at the network coordinator. The nodes near the coordinator can transmit at a higher data rate and ones far away from the coordinator can reduce the bandwidth.

F. Cost

Various cost aspects need to be considered such as spectrum cost (license), network/deployment cost, and device cost of LoRa are more cost-effective compared to other technologies.so farmers can afford it and take advantages to increase yield and increase profit.

1) Advantages of LoRa in Agriculture Monitoring

- Long battery life for devices and sensors due to low power consumption

- Low cost implementation due to low cost hardware and unlicensed spectrum
- Long range coverage
- Less complexity in programming
- Offers a secure transmission network
- Scalable network to support future upgrades
- Ease of access and connectivity to the cloud applications
- Remote management and control access
- Highly intelligent architecture

VI. IMPLEMENTING OF AGRICULTURE MONITORING SYSTEM WITH LORA BASED WIRELESS SENSOR NETWORKS

By implementing a precision farming solution comprised of sensors and gateways embedded with LoRa Technology, and a low power wide area network based on the LoRaWAN™ protocol, farmers can help improve crop yields, animal health and farm operations.

LoRaWAN uses star topology as it increases battery lifetime when long-range connectivity is used.

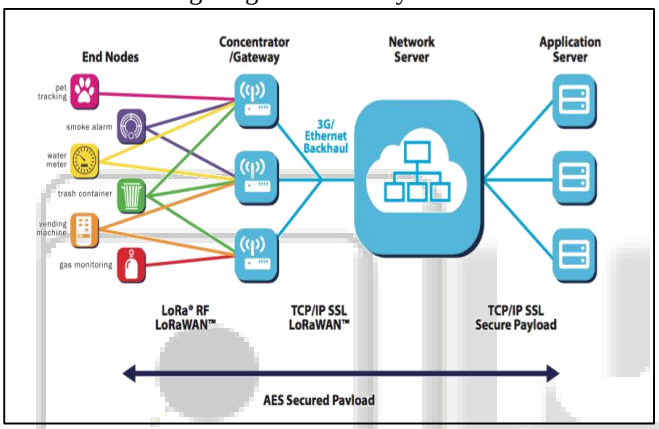

Fig. 4: explains the LoRa network which consists of several elements.

A. LoRa Nodes / End Points:

LoRa end points are the sensors or application where sensing and control takes place. These nodes are often placed remotely. Examples, sensors, tracking devices, etc.

B. LoRa Gateways:

Unlike cellular communication where mobile devices are associated with the serving base stations, in LoRaWAN nodes are associated with a specific gateway. Instead, any data transmitted by the node is sent to all gateways and each gateway which receives a signal transmits it to a cloud based network server. Typically the gateways and network servers are connected via some backhaul (cellular, Wi-Fi, ethernet or satellite).

C. Network Servers:

The networks server has all the intelligence. It filters the duplicate packets from different gateways, does security check, send ACKs to the gateways. In the end if a packet is intended for an application server, the network server sends the packet to the specific application server.

Using this type of network where all gateways can send the same packet to the network server, the need of hand-off or handover is removed. This is useful for asset-tracking application where assets move from one location to another.

VII. SYSTEM DESIGN FOR AGRICULTURE MONITORING USING LORA TECHNOLOGY

The complete system is divided into three modules as shown in following diagram

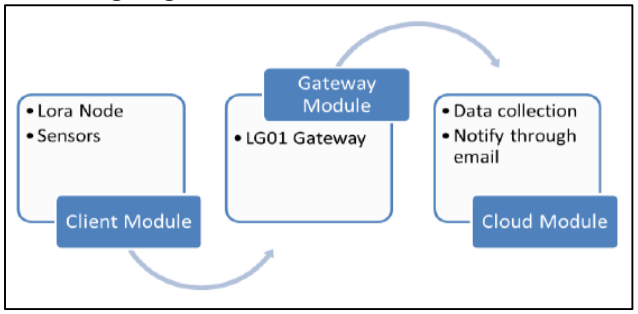

Fig. 5: System Design

Figure 5 explains the system design to implement LoRa technology

A. Client Module

Client module consists of LoRa node along with atmega128 controller and is connected with sensors which are used to collect condition of soil such as its moisture and also nutrients present in soil like nitrogen(N), phosphorous(P) and potassium(K). Humidity and temperature of the field is collected at regular interval to provide information regarding water requirement in the field. NPK sensor is used to collect the information regarding amount of N,P,K present in the soil and suggest the crop that can be grown in such soil and also suggest if extra quantity of fertilizers is required in soil for the suggested crop. Soil moisture sensor is used to calculate the moisture of soil. DHT11 sensor is used to collect humidity and temperature of field. This data collected, was analyzed to pro-vide information regarding water requirement in the field.The same setup as explained above is done with another LoRa node and experimented to get data from multiple nodes to gateway.

B. Gateway Module

Gateway module acts as a link between the LoRa nodes and cloud. Gateway collects the data from the LoRa nodes and gives it to cloud to analyze the data. LoRa gateway can communicate with the LoRa nodes placed at almost 1-3kms distance in open field as their range is higher than the any present technologies. Basically, gateway uses two technologies to communicate one is Lora technology to collect information from LoRa nodes placed in fields and second one is WiFi, which is used to up-load the data collected into the cloud. It uses HTTP protocol to communicate between gateway and cloud.Thus gateway has to be placed as per the requirements. receive data from LoRa nodes through LoRa communication and upload data to cloud through HTTP protocol.

C. Cloud Module

To store the data collected in gateway to cloud, one has to create an account in cloud with specific user name and password. Once account is created one must give the API keys of specific channel of the account to make the HTTP communication from gateway to cloud. Once the connection is established between cloud and gateway, the data from gateway will be stored in the cloud. Data collected in the cloud is analyzed in MATLAB to notify user through email

about water and fertilizer requirement in field. Even the data collected in cloud can be displayed in mobile through mobile widget

VIII. CONCLUSION

Agriculture plays a very important role in growth of Indian significant role. The above work helps one to monitor the agriculture field parameters such as temperature, moisture level in the soil and humidity. Thus, above work provides a solution to increase the yield of crops using current technology of sensors and LoRa. The information obtained from sensors is analysed and information regarding amount of water required by crops is given to end user using email and mobile. The use of LoRa Technology helps to cover large geographical land with low power consumption. Thus, increasing the efficiency of operation. This work aids remote monitoring of fields to farmers as well as assists increase in yield.

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