A Novel Framework for Smart Crop Monitoring Using Internet of Things (IOT)

Kamal Kumar Ghanshala
Graphic Era University
Dehradun, India
kamalghanshala@gmail.com

Rahul Chauhan
Graphic Era Hill University
Dehradun, India
chauhan14853@gmail.com

R.C Joshi
Graphic Era University
Dehradun, India
rcjoshi.geu@gmail.com

Abstract- Agriculture is one of the area which required urgent attention and advancement for high yield and efficient utilization of resources. In this paper an approach of smart crop monitoring is presented through Internet of things (IOT). A 4 level framework is proposed namely sensing devices, sensor data level, base station level, edge computing and cloud data level for smart crop monitoring. Method proposed here focuses on analysing the soil nutrients (eg. NPK), soil moisture, temperature and humidity through a sensor node designed using arduino. Sensor node also consists of a wireless Zigbee module, metos NPK sensor, motor and water sprinklers. LAN of sensor node is designed using Zigbee and LEACH routing protocol is used for hopping. Collected data at gateway is being uploaded to cloud using an ESP8266 Wi-Fi module. An experimental setup was made in the field. Various data collected, analyzed and necessary information was sent to farmers for appropriate action. The data collected at cloud is analysed using machine learning technique and available to the farmers through soil nutrient index to monitor their soil nutrient requirements and ensure better crop yield.

Keywords- Crop Monitoring, IOT, Soil nutrients, NPK, Metos, Zigbee, LEACH, REST, ESP8266

1 INTRODUCTION

Agriculture is the science of farming, which involves crop cultivation and rearing of animals. India is an agricultural country, agriculture being the one-third source of income in the country. Traditionally, agriculture in India was seasonal i.e. crops were grown in two seasons, rabi season and kharif season, wheat-rice were the two crops grown alternately, no pulses or vegetables were grown . With the advancements in farming technology, HYV (high yielding variety) seeds were used for a better crop yield with an increased use in fertilizers, insecticides and pesticides. The Agriculture sector is in a phase of transformation from traditional methods to modern methods [1]. Agriculture is the backbone of Indian economy and contributes for about 16.5% of the GDP. Although several new methods have been implemented in agriculture sector which has shown improvement in crop yield, some farmers still practice traditional methods. Modern technologies broadly involve the use of wireless sensor networks that collects data from various sensor nodes and the information collected helps in monitoring of crops and automation of monitoring system of crops reduces physical labour. The recent technology of sensors, sensor nodes and IoT may play a major role in crop monitoring and can be implemented at every level of agriculture. IoT or "Internet of things" is a heterogeneous, distributed network of communicating or non- communicating devices, connected in a network, using internet for communication and management. IoT has evolved from wireless sensor technology and various mechanical and electronic devices [2] [3]. In IoT the basic element is unique identification of things through sensing technology which uses sensors or sensor nodes, collecting of data through these sensors with the help of a processing element like arduino or raspberry-pi. The data is collected at a sync node, called a gateway which may have both transmitter and receiver and is further uploaded on cloud and this information can be subscribed and using the information various factors can be controlled and monitored. IoT is the present and future of agriculture where using the sensors and processing elements data can be collected about fields, soil nutrients, weather, humidity, rain and these factors could be monitored and controlled for modernization in agriculture[8]. In the table below, the countries and their wheat production in the current years have been shown [15]. The wheat production in India may have declined approximately 6 million metric ton according to this data during 2014-15. This shows that our agricultural sector needs serious upgradation. Agriculture trends in India have several issues. Major issue include stagnation in production of major crops and soil exhaustion, which makes soil either infertile or devoid of certain nutrients. Also, traditional methods are often inefficient and do not focus on requirement of soil. These problems can be addressed with the help of technology integration in agriculture.

TABLE.1 WHEAT PRODUCTION PER YEAR IN MILLION METRIC TONS

Country	2015-16	2014	2012	2008
India	90.6	95.9	94.9	78.6
China	130.9	126.2	125.6	112.5
Russia	53.5	59.6	37.7	63.7
EU	156.4	157.2	134.5	150.3
USA	56.8	55.4	61.7	68.7

Various methods have been presented that help in modernization of agriculture based on sensors, IoT and wireless sensor network technologies. Some of the existing methodologies are like Kalaivani et.al [9] presents applications of WSN (wireless sensor network) in agriculture and how the WSN improved agriculture and crop monitoring etc. Liqiang et.al [1] implements two types of sensor nodes for collecting meteorological and soil nutrients data like temperature, rainfall, soil PH etc for crop growth and monitoring. This system monitors crop growth and agricultural conditions monitoring.

Manijeh et.al [11] presented a wireless sensor network which comprise of sensor nodes with two basic topologies based on IEEE 802.15.4 network architecture. It is used mainly in precision agriculture for real time measurement of details which help in agriculture crops development. Lima et.al [12] proposed wireless sensor network as a technique for precision agriculture and developing applications for monitoring soil moisture, humidity and temperature. Nodes are connected using protocols and standards in the network.

Bencini et al.[13] shows a case study related to wireless sensor network application in real world. The major focus was on growth of crops in stressful conditions in rural areas. The paper suggests farmers for application of specific pesticides and insecticides in stressful conditions.

The above proposed methods mainly focused on the use of wireless sensor networks for crop monitoring, growth and measurement of meteorological factors. There was no focus on soil nutrients, the level of soil fertility, and the requirements of a particular crop for the soil to maintain its fertility and monitor the crop growth or suggest the crop for the next season. The solution to the issues in agriculture trends and advancements to the WSN technologies is proposed in this paper. The proposed solution to these issues involves the fuse of IoT with WSN technologies. The solution involves a system implemented on agricultural fields that includes sensor nodes, cloud technology, wireless sensor network and internet.

The sensor nodes have a humidity sensor, temperature sensor, potassium sensor, nitrogen sensor, calcium sensor and moisture sensor embedded with a processing element Arduino. The data is collected on a sync node designed on a wireless sensor network and the information is collected, analysed and used to control the crop monitoring and growth. The crop monitoring is necessary for a better crop yield and sensing technology help us achieve this aim [2].The paper is detailed as follows: The introduction about smart crop monitoring is discussed and in next section problem statement is formed. Proposed system is explained with the help of flowchart and design of sensor node is given. Herein the 4 level framework is proposed for different level of data and finally the advantage and conclusion of the system.

II. PROBLEM STATEMENT

The Agriculture sector in India is one of the major employment sectors. However, the traditional methods followed by farmers for cultivation of crops are inefficient. It doesn't utilize all the resources properly. The traditional methods often lead to soil nutrient degradation and soil exhaustion, as the main focus is only on productive crop. The soil is exhausted by growing only specific crops with the use of particular nutrients making it deficit in some nutrients and over increase in level of other nutrients. The agriculture sector is the source of income for 53% of the population in the country; hence there is a requirement for more modernization in this field. The area under agriculture is sinking and population is increasing. Until and unless efficient resource management & utilization is done the food needs cannot be fulfilled.

III. PROPOSED SYSTEM

The previous systems are centric to irrigation automation in agriculture; they do not focus on soil nutrients level, its analysis and soil exhaustion.

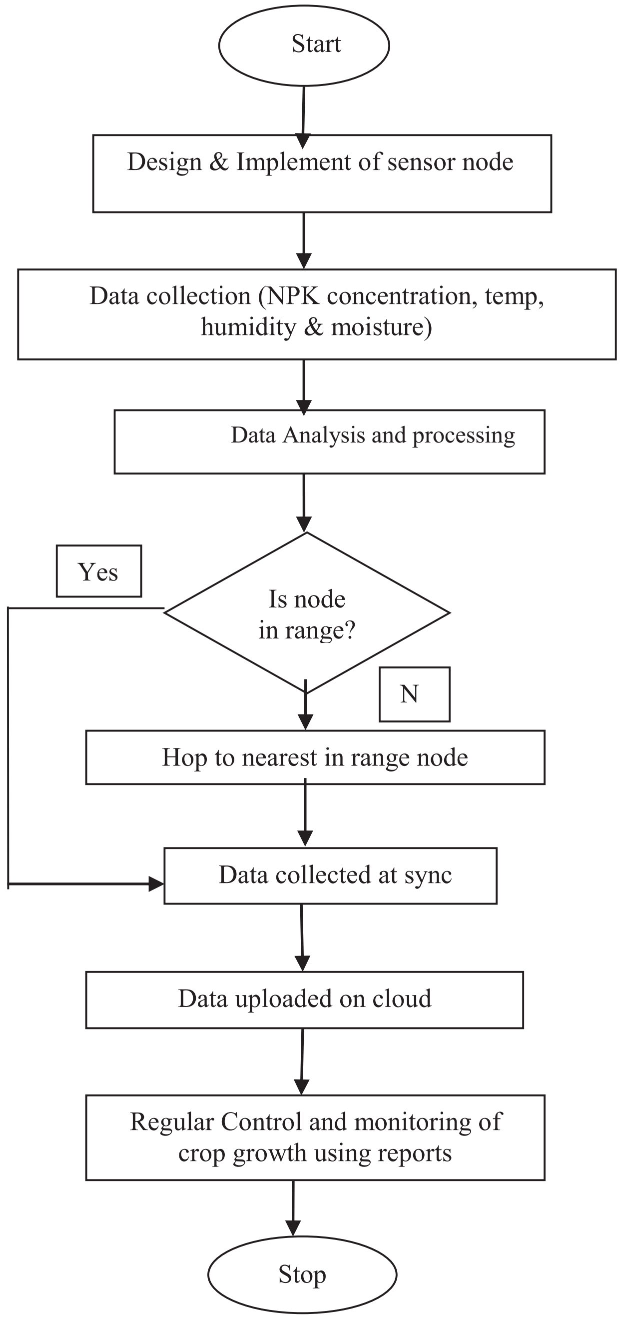

Fig.1. Flowchart of System

Also, power consumption is a neglected factor. The proposed system focuses not only on automation in irrigation for agriculture but also on analysing the soil nutrients, soil moisture , temperature and humidity in the air for better crop yield. The proposed system consists of solar panels, sensor nodes, metos NPK, and arduino processing element, a wireless Zigbee module, motor and water sprinklers. The entire network is wirelessly connected using an ESP8266 Wi-Fi module. Each sensor node is a collection of temperature sensor, humidity sensor, moisture sensor, soil pH sensor and a metos NPK sensor with Arduino as the processing unit. The solar panels power the sensor nodes and collect data from the soil. The data is then sent to the sync node or the gateway. If a sensor node is near to the gateway it can easily send data to the sync node, else hopping is required to send data. Therefore, a Zigbee transceiver is present on every sensor node. As mentioned in figure 1 the collected data from the sync node is sent to cloud using the internet. On the cloud the data is analysed and is subscribed by the farmer's through an android application. Based on the reports, the farmer can monitor his crop growth, soil nutrients level and monitor his cultivation accordingly.

A. Sensor node Design

A sensor node can be defined as a network of sensor nodes that can gather data, has a processing unit and communicate with other sensor nodes in network. All the sensor nodes collect data from soil and are powered by solar panels. Figure 2 shows the design of the node.

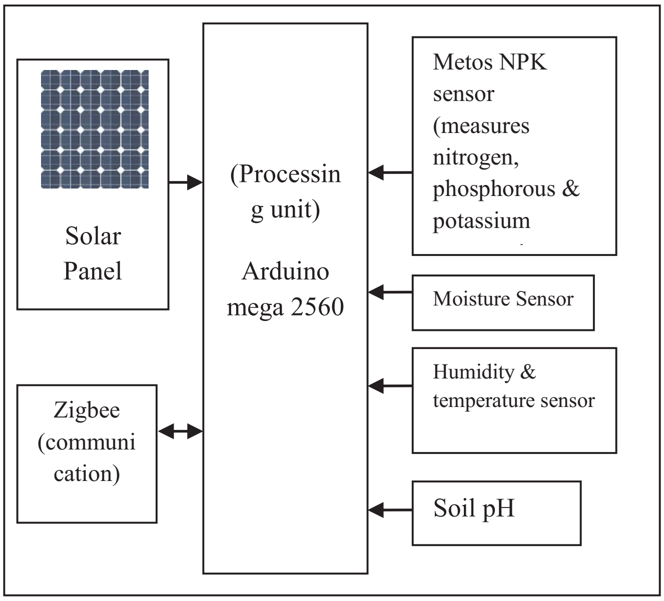

Fig.2 Sensor node Design using Arduino and sensors

The sensor node for the proposed system consists of the following:

- A solar panel to power the sensor node.
- Arduino processing unit (mega 2560) which connects the sensors on its pin that read data from the soil, which is present in discrete values.
- A Zigbee transceiver for wireless communication.
- Moisture sensor (SKU: SEN0114), Humidity sensor and temperature sensor (DTH 11) and soil pH sensor to read the respective values from soil.
- A metos NPK sensor to measure samples of nitrogen, phosphorous, potassium contents in soil. The reading is in ppm (parts per million) [14].

The proposed system consists of the above such sensor node deployed one per field. The sensor nodes are powered by solar panels, thus making it energy efficient. A solar panel is a panel that takes energy from sun to generate electrical and heat energy. A photovoltaic module is attached in the panel, it is a solar cell which absorbs light energy and converts it into heat and electrical energy due to photovoltaic effect. The average power of the solar panel implemented is 4.1W. The maximum average current I_{max} is 8 Ampere. The maximum voltage required is V_{max} 5 V. The processing element is arduino mega 2650 on which sensors are connected. All the sensors collect data in discrete values and the sensors are connected to each pin of arduino. It operates on 5V and has 54 input/output pins which are digital and 16 analog pins. The sensors in the sensor node are:

- Metos NPK sensor [14] is a soil macronutrient analyser based on capillary electrophoresis to give indication of NO_3, NH_4, K and PO_4 i.e. nitrogen, ammonia, potassium and phosphorous. A single chip is used to analyze multiple samples. When the soil samples are extracted, they are injected in the capillary tubes to which high electric charge is passed. The extracted electrically charged compounds start to migrate in the electric field. Each molecule when separated travels at individual speed and reaches its destination sites in different times where the concentration of each compound is measured separately. The data is related to GPS coordinates and is sent to the web cloud where it can be accessed by multiple users. The measurement range is 5-1000ppm, resolution is 0.5 ppm. The accuracy is +15% to -15% for soil concentration [14]. The duration of measure is 5 minutes. A person with no laboratory knowledge can also operate on it to find the concentration. Figure 3 shows a Metos NPK sensor.

- Moisture Sensor is the sensor that measures the volumetric content of water in the soil. SKU: SEN0114 is a sensor compatible with Arduino to measure the soil moisture. It works on a 3.3V or 5V power supply and 35mA current. The moisture of the soil is checked every 3 days i.e. moisture sensor takes the reading of soil moisture every 3 days.

Fig.3 Metos NPK sensor

- Humidity and temperature sensor is used for measuring the humidity and temperature. The DTH 11 sensor has a 20-90% range for the measurement of relative humidity. It measures temperature between 0-50 degree Celsius. The accuracy of the measurement of Relative humidity readings is -5% to + 5% and the temperature reading accuracy is between -2% to +2%.

- Soil pH sensor is used to measure the acidity or basicity of the soil. Crop cannot grow in too much acidic soil neither in too much basic soil. pH is the measure of hydronium ions(H_3O^+) in the soil. The ideal pH for most crops is between 5.5 to 7.5. A soil pH sensor gives us the pH value of the soil.

All these sensors operate on low power and give efficient results. All these components are present on a single sensor node and there is one sensor node per field. These sensor nodes are connected to each other on a wireless local network. Each sensor nodes collects the readings from the soil. All the readings are in discrete values as all the components have some standard units in which they are measured. These sensors are having an arduino processor for value collection. The data collected is sent to the gateway or sync node. Since, the sensor nodes are connected wirelessly; some nodes which are near to the gateway can easily transmit data. Other nodes which are out of range make use of routing or hopping algorithms to transfer its data to the gateway. A Zigbee transceiver is at each sensor node to fulfil this purpose only, of both sending and receiving data. Zigbee is an IEEE 802.15.4 communication module for wireless (PAN) personal area networks. Zigbee works on low power; low data rate and is suitable for a closed personal area network. Zigbee operates on 868 MHz, 902-9028 MHz and 2.4GHz frequencies. The physical range of Zigbee is 10-20 meters [9].

The switch turns on the motor which starts pumping water in the fields. The water sprinklers thus sprinkle the field with water. Hence, irrigation is also automated.

B. Case Study of proposed system

The working of the above system is as follows:

Consider an example of 10 fields. Each field has a sensor node implemented in it with a motor and its water sprinklers. All the sensor nodes are connected through a wireless local area network. In the below diagram four sensor nodes are connected wirelessly to the main gateway. Figure 4 below shows the connection of sensor nodes on the field to the common gateway or sync node.

Fig.4 Node 1, 2, 3 and 4 connected to the sync node

These nodes are connected over the wireless Zigbee Wi-Fi module. The ESP8266 is the Wi-Fi module. It is a Wi-Fi chip with microcontroller unit capabilities built with TCP/IP stack. It follows the IEEE 802.11 b/g/n protocol for wireless communication. The sensor nodes in range can transmit data directly. Other nodes make use of hopping algorithms. Figure 5 below shows the peripheral nodes and in range base station called the sync node.

The protocol that can be used for routing in the network is LEACH. It is a proactive protocol that is used in wireless sensor network routing. Routing is the technique by which data packets are sent from sensor nodes to base station. The protocols based on mode of functioning and type of target application are classified as proactive, reactive and hybrid. LEACH is low energy adaptive clustering hierarchy protocol, it is a proactive protocol. The proactive protocols are protocols in which nodes switch their sensor nodes and transmitters, sense the environment and transmit the data to the base station on a predefined route. LEACH is a self-configuring cluster formation protocol, which is adaptive and randomised also it is a minimum transmission energy protocol. It is a low energy media access control protocol. The data is collected at base station also called as sink, is transferred to the edge cloud as well as the central cloud. If a low latency is required then data is directly sent to the edge cloud and from there a message is sent to the farmer for emergency action. If data has to be analyzed for a longer duration then cloud data analytics can be done using machine learning to predict soil nutrient requirement. There are various protocols that send data from sensor nodes to cloud like Simple Object Access Protocol (SOAP) and Representational State Transfer (REST). REST is used for this communication [7] [16].

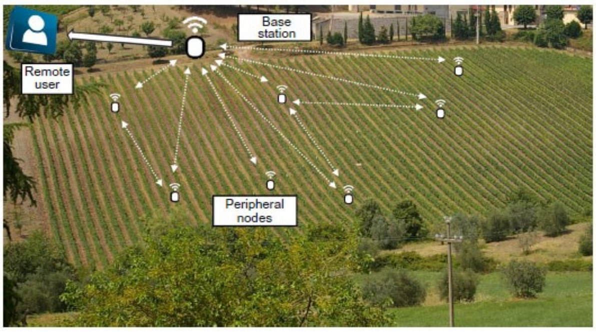

Fig.5 Sensor nodes on Wi-Fi network

C. Proposed Framework

As the sensor nodes have limited computational and storage capability, it is proposed to design a framework for monitoring, control of various time series data. Analyse the data and actuate, control and manage various parameters using 4 level architecture namely sensing devices, sensor data level, Base station level, edge server and cloud level.

Various sensing devices (temperature, humidity, soil nutrients etc) sense the data and send it to the sensor level. This data is measured, validated and processed at this level. Access control is designed so that only authorised person can access relevant data. An efficient energy consumption technique is also applied at this level. At the next level (base station level) routing, congestion control and traffic scheduling is performed. Data which require low latency is send to edge server for storage and computing. Data which do not require low latency is directly send to cloud. The edge server increases the reliability of the system. Finally the cloud computing layer ensures data analysis and fusion using machine learning techniques. The cloud security is also introduced in this layer. From there a report of soil nutrients is generated and it can be accessed by the farmer for better crop yield.

i. *Edge computing*: Smart crop monitoring systems were based on wireless sensor networks, though provided efficient information of soil moisture and humidity but the latency factor continued to be a problem. So the concept of Fog Computing is proposed which is also called as edge computing. Fog computing is basically an extension to cloud computing to provide cloud services to the edge users. Like if the moisture content is too low in any field then it has to be communicated quickly to the farmer for necessary action [18]. Some systems cannot afford latency, thus implementing fog at local level improves security of private data and improves experience for end user. The overhead of sending the data to the cloud server and then informing authorities often increase latency.

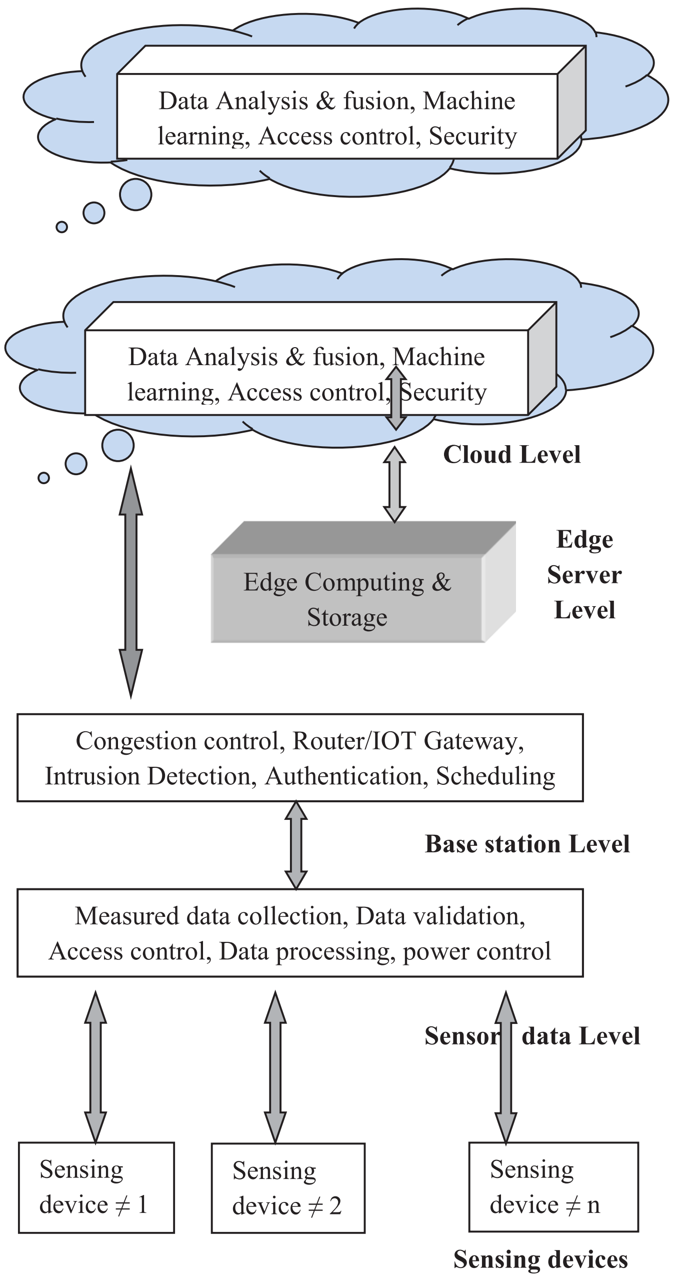

Fig.6 Proposed Framework for different level of data

ii. *Machine learning for generating soil nutrient index:* In the proposed framework data from sink node or gateway is not only transferred to edge cloud, it also transferred to central cloud. On regular interval the sensors reading uploaded and stored in the cloud. With the help of machine learning algorithms a soil nutrient requirement index can be made on regular basis. Support vector machine, k nearest neighbour, decision tree, linear regression and logistic regression [23] are some of algorithms used for prediction. So depending upon the amount of data generated and linearity of data, one can choose the best algorithms. Here logistic regression is proposed because comparatively it is more robust to other algorithms and can be applied for non- linear data which is possible in the proposed framework.

When the data is sent to cloud, it is in a user understandable form. The data reports are about soil nutrient contents, the required quantity of nutrient according to the crops and seasons, the status of motor switch (on/off) etc. This data is subscribed by farmers on their phones and the crops can be monitored efficiently keeping in mind the soil requirements. The switch is used to power the motor and in turn water sprinklers which irrigate the fields whenever required.

III. ADVANTAGES OF THE SYSTEM

The proposed system is not centric to irrigation or moisture factors of soil that contribute in crop growth instead it covers all the major factors which are important in crop growth. The proposed system focuses on soil nutrients and its content monitoring, because the requirements of soil for every crop are different and changes often. The monitoring of soil nutrient requirements helps in maintaining the fertility of soil. Most of the systems earlier were mainly focused on automation in irrigation or monitoring the moisture content of soil, ignoring the fact that soil plays a crucial role in crop development. The quantity of the nutrients required by the soil is also fixed. An overdose of nutrients can harm the soil or change the pH level. Therefore, it is necessary to monitor the pH levels of soil and add the nutrients in required quantity. Further, the moisture level of soil is measured every 3 days and according to the fields is watered as required. The update to the farmer is given on his mobile phone which can be easily accessed and interpreted. Therefore, the proposed system broadly covers all the major aspects which can assist in crop growth and monitoring of the soil for crop growth.

IV. FUTURE WORK

The project can be implemented on broader area of fields with a wider network. Also, skill based training can be provided to farmers for the technical support and operation of sensor nodes so that it is easier to maintain. The sensor nodes for various soil and crop types can be developed according to the requirement. The further works may include monitoring of crop diseases using sensors and implementation of a system to predict crop growth.

V. CONCLUSION

In this paper a 4 level framework for smart crop monitoring is proposed. Unlike the traditional agricultural trends followed in India, this system mainly focussed on the soil nutrients and its adequate utilization. Earlier most of the crop monitoring techniques were based on temperature and humidity and limited to user end only but proposed system is based on soil nutrients and based on IOT. Thus increase the reach and use of edge computing and cloud computing make it globally accessible for data analytics. Cloud data analysis can be easily done for generating the soil nutrient requirement through machine learning techniques. Thus this system ensures that access is available to the farmers and ultimately fertilizers can be efficiently utilized for high yield.

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