**IOT-BASED SMART AGRICULTURE WITH CLOUD COMPUTING**

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**ABSTRACT**

IoT is a revolutionary technology that represents the future of computing and communications. Most of the people over all worlds depend on agriculture. Because of this reason smart IT technologies are needed to migrate with traditional agriculture methods. Using modern technologies can control the cost, maintenance and monitoring performance. Satellite and aerial imagery play a vital role in modern agriculture. Precision agriculture sensor monitoring network is used greatly to measure agri related information like temperature, humidity, soil PH, soil nutrition levels, water level etc. so, with IoT farmers can remotely monitor their crop and equipment by phones and computers. Internet of things is the most advanced concept in the modern internet era. It provides support to probably all the domains on the Globe. Agriculture is one of such domains, which makes use of the IoT for making the agriculture smart. Several applications of IoT are evident in the field of Agriculture for the unimaginable benefits of farmers which in turn for the successful development of the nation.

**Keywords**— Internet of Things (IoT); Cloud Computing; LiFi; Gprs; Agriculture Monitoring, Irrigation, Routing Protocol.

**INTRODUCTION**

Farming is the backbone for the advancement of the nation. India is called as an Agricultural country for its remarkable agricultural lands and its other resources. In recent days, the temperature and soil moisture factors affect the growth of agriculture such as productivity, diseases, and yield production. Agriculture based issues has been the barrier for the development for the nation. There is a need for Modernization of the current standard techniques for Agriculture. Around 60-70 %( predicted value) Indian population directly or indirectly depends on agriculture. That effects on food security and economic growth of India. With help of Precision, agriculture process can easily monitor or observe of crop growth based on collected information (soil condition and weather information) from a crop field. This mechanism also called as satellite farming or site-specific crop management (SSCM) [1], manually can’t able to collect environmental information because it is a tuff task. New farmers are coming out without knowledge of soil characteristics because insufficient soil testing labs properly not available in the states of the country New trends in Agriculture are required in managing crops in a controlled environment. Eg. Green houses. The Internet of Things is the recent advancement in the Internet field. The ideas facilitate to interconnect physical objects equipped with sensing, actuating, computing power by lending them the potential to collaborate on a task, by remaining connected to the internet, termed as the “Internet of things” IoT. With the assistance of detector, actuators and embedded microcontrollers the purpose of creating good object is accomplished. These good objects collect knowledge from the surroundings of development, process them, and initiate appropriate actions. Thus, the Internet of Things can bring wonderful support and helps humans in leading a wise and smart Agriculture. With IoT, farmers will simply get a timely cultivating guideline relating to the parameters such as pesticide usage, seasonal plant diseases and additionally regarding natural disasters and recovery methods. Main advantage of synergizing agriculture with IoT, is elimination of human-to-human interaction and human- to-computer interaction. So now what is the importance of IoT in agriculture? The solution is Manual data collection; absolutely it is a risk for farmers and also to processes from the crop field. So it is difficult for farmers to get optimal levels of efficiency. To solve this difficulty, IoT (Internet of Things) is only the solution. It plays vital role in collecting information. IoT has been already in raising with novel multiple techniques. Connecting Agriculture to the internet is one of the important activities of the proper operation of IoT device. It presumes the connection to be wireless, which are classified based on energy consumption, uplink data rate & downlink data rate, packet size, device per access point, topology, frequency band range and channel width.

# IOT ENABLING TECHNOLOGIES

Internet of Things has the following technologies:

# Wireless Sensor Networks (WSN)

WSN consists of number of sensors or nodes, that are connected together to track the various sort of data.

# Cloud Computing (CC)

It is termed as on-demand computing that shares the system resources and data among the requested users. It can be represented in various forms such as IaaS, PaaS, SaaS.

# Big Data Analytics

It is the concept of processing large data sets that have various forms of data types.

# Communication Protocol

Communication protocols are the backbone of IoT systems. They enable connectivity of various applications and also data exchange over the network.

# Embedded Systems (ES)

It is a combination of hardware and software,that are intended to do a specific task. It supports the connection of various sensors over IoT.

# APPLICATIONS OF IOT IN SMART AGRICULTURE

Although the use of smart agriculture is not popular in India, still it shows dynamic capabilities for supporting agriculture. It supports the plant growth and development in many ways. Some of such applications are listed below to enhance plant growth:

# Monitoring of Climate Conditions

Climate and weather conditions are the primary factors to be noted during agriculture. Smart agriculture using IoT makes use of several sensors for monitoring the climate conditions of the surroundings. the task of the sensor is to collect the data across the field send it to the cloud. the cloud is loaded with some basic measurements which will then be compared with the sensed data. Based on the comparison, we will be able to map the climatic conditions and choose the required crop for cultivation. Some examples of such agriculture IoT devices are all METEO, Smart Elements, and Pycno.

# Agriculture Drones

One of the best applications of IoT in agriculture are Drones. Drones provide pictorial and aerial maps about the plants, thus making the farmer understand that which crop is in need of immediate attention. Drones also evaluate the health state, irrigation, monitoring of progress, spraying, and planting of each crop. Drones are helpful in saving time and effort. The drones are comprised of two types: ground-based and aerial based drones. Both are used for crop health assessment, irrigation, planting, and soil & field analysis. Farmers have to choose the height or ground resolution of the field for which the Drones have to be used. Then the Drones take the pictures of the crops and helps the farmer to give immediate assistance for the required crops.

# Livestock Monitoring

Livestock Monitoring is the way of tracking the state of the herds. The health of the animals is tracked using the IoT device and monitored for the signs of disease. The sensors connected to the animals will collect data about the location and well-being of the animals. The sensors can even track the state of pregnancies of cattle and intimate the state of the cattle which is about to deliver.

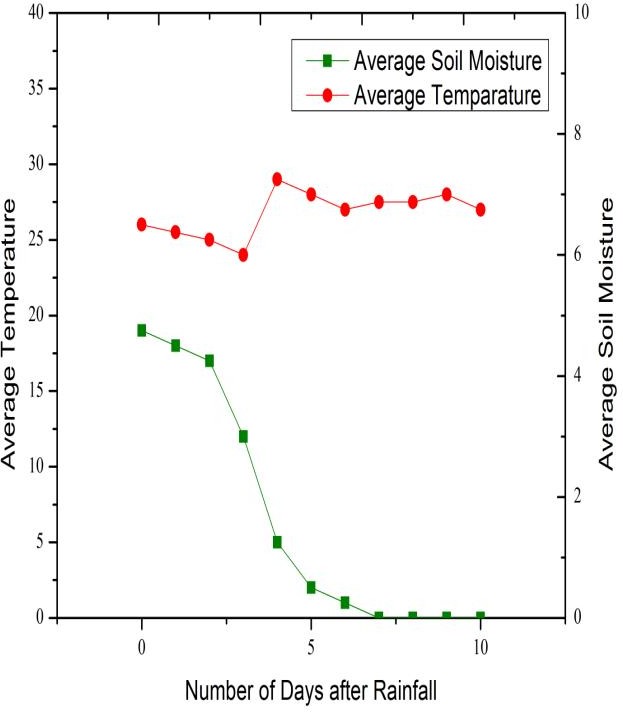
# Smart Greenhouses

Greenhouse farming is a technique that boosts the yield of crops, vegetables, fruits etc., Environmental parameters are controlled by Greenhouses in two ways; either through manual intervention or a proportional control mechanism. However, since manual intervention has disadvantages such as production loss, energy loss, and labor cost, these methods are less effective. A smart greenhouse through IoT embedded systems not only monitors intelligently but also controls the climate. Thereby eliminating any need for human intervention. Different sensors that measure the environmental parameters according to the plant requirement are used for controlling the environment in a smart greenhouse. Then, a cloud server creates for remotely accessing the system when it connects using IoT.

# Crop Water Management

Water is the essential resource for performing agriculture. All the agricultural activities are based on the adequate supply of water. Hence it is necessary for the farmer to ensure adequate supply of water to the crops. This technique uses the Web Map Service (WMS) and Sensor Observation Service (SOS) for ensuring proper water supply for the irrigation of the crops. Thus this IoT reduces water wastage.

The following graph shows the variation of temperature and soil moisture with the increase in the number of days of rainfall. Arduino Mega 2560 is used in the research. DS18B20 sensor is used to measure the temperature of the soil. Also, a soil moisture sensor is used for measuring the soil moisture. From the analysis made, it is seen that as the temperature increases the soil moisture decreases.



# Fig.1 Variation of temperature and soil moisture with the increase in the number of days of rainfall

# SENSORS USED IN IOT FOR SMART AGRICULTURE:

* Location sensors use the GPS satellite signals to find latitude, longitude and altitude within the feet. It requires three location sensors to be fixed, since for triangulating the position.
* Optical sensors are used to measure the clay, organic matter and moisture content of the soil. these sensors are generally fixed to the drones.
* Electrochemical sensors provide the essential information about the pH and soil nutrient level.
* Mechanical sensors are used to find out the mechanical resistances of the soil.
* Dielectric soil moisture sensor measures the moisture level of the soil, by using the dielectric constant.
* Parrot sensors are used to monitor the plant’s temperature, moisture, soil salinity. The information is sent to the farmers’ mobile phone.

Spruce is a sensor device, which is used for irrigation control. The data is saved in the cloud server and the user can access it at anytime and anywhere.

* Koubachi is used for sprinkling water to the plants in the garden. It acts a node that collects data from multiple sensors like air temperature, soil moisture, sun light etc.

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| **S.No** | **Applications of IoT** | **Sensors used** | **Measures** | **Uses** |
| 1 | Monitoring of Climate Conditions | Temperature sensor, Light Dependant Resistor, sound and CO sensor | Rainfall, Wind speed and direction, Temperature, relative humidity, light intensity and CO level | Reduces labor costs, Effective decision making, Ease of time, Utilization of resources |
| 2 | Agriculture Drones | NDVI Sensor, Phantom 4 Pro V2.0 Drone, Matrice 210 Drone, Zenmuse XT2 Thermal Camera, AGRAS MG-1S Drone | Irrigation problems, soil variation, and pest and fungal infestations | Increase crop production and crop growth |
| 3 | Crop Water Management | Ultrasonic sensors for water level, Temperature and relative humidity sensor, Soil Moisture sensor, | Focus on climatic circumstances | Understand the soil properties, Demand of water supply for various plants, Control the water wastage, |
| 4 | Smart Greenhouses | Temperature Sensor, Arduino compatible Mini Luminance Sensor, light sensor and actuators | Temperature, humidity, Water content, Light level, CO2 level, Soil water potential | Efficient plant growth, Controlled temperature |
| 5 | Livestock Monitoring | Connected sensors | Measures the heart rate, blood pressure, respiratory rate, temperature, digestion, and other vitals of the livestock | Saves time, prevent health issues of cattle at earlier stage, Track the location of livestock |

**Table (1): Sensors used in IoT for Smart Agriculture**

# BENEFITS OF IOT IN SMART AGRICULTURE

* IoT enables the large amount of data to be collected over the sensors and thus providing better control over the internal processes and, as a result, lower production risks.

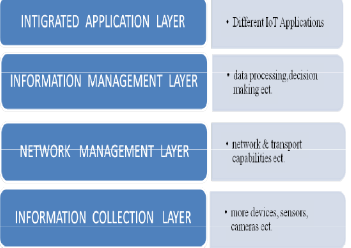
With IoT efficient monitoring of the farming environment is ensured.

* IoT helps the farmers to monitor the fields at multiple locations by enabling remote monitoring. Decisions can be made in real-time and from anywhere.

IoT guarantees increased crop production by keen tracking of planting, watering, pesticide application and harvesting.

**FOUR LAYERS IOT-AGRICULTURE ARCHITECTURE**

A conceptual model for smart agriculture is proposed by analyzing the literature survey. Before that, let us know the overall structure of IOT. Constituting many physical devices in practice IOT basically has a three-layer structure. The first layer is the integrated application layers which in agriculture related applications are operated because it is considered as user interface layer. It is user free and it includes farmer’s cell phones and personal devices are takes place to monitor the agriculture area. According to with this layer the farmers can take a decision to protect their crop as healthy and get better food production output. The second layer is information management layer which contains some responsibilities like formation and classification of data, creating, monitoring, decision making etc. These roles are maintained and performed in this layer. The third layer is network management layer which represents the communication technologies like Gateway, RFID, GSM, Wifi, 3G, UMTS, and Bluetooth Low Energy, Zigbee etc. The fourth layer is information collection layer which contains all types of sensors, cameras etc. These are used to collect information of crop for better and easy field monitoring of agriculture area.



**Fig.2 The four layers IoT structure**

In every method by default, a process is, several sensors are deployed in the crop field for measuring various parameters like temperature, humidity, soil PH, light intensity. Each device in the network will be assigned with an IP address for identification purpose. For example, the temperature sensor in the network will be addressed with object ID T1 within the communication Network. Addressing methods of IoT objects include IPV6 and IPv4.Identification methods are used to provide a clear identity for each object within the network. IoT sensors can be smart sensors, actuators or wearable sensing devices. The sensed data‘s from crop field are sent to a cloud through a gateway which is connected to the internet via Wifi or any other communication network. From the cloud, the data’s are sent to farmer‘s smartphones or computers. By analyzing this data farmers can take appropriate decision.

**ANALYSIS AND COMPARISION OF IOT HARDWARE REQURIEMENT**

**Device:** An IOT system uses devices which provide sensing, actuation, control, and monitoring activities. Based on temporal and space constraints (i.e. memory, processing capabilities, communication latencies, and speeds, and deadlines IOT devices can exchange data with other connected devices and application, or collect data from other devices and that collected data sends to base station server and from it to cloud server by using gateway or perform some tasks locally and other tasks within IOT Infrastructure). An IOT device may consist of several interfaces for communications to other devices, both wired and wireless. These include (i) I/O interfaces for sensors, (ii) interfaces for Internet connectivity, (iii) memory and storage interfaces, and (iv) audio/video interface.

**Communication:** communication between devices and remote servers is done by the communication block. Data link layer, network layer, transport layer, and application layers generally work with IOT communication protocols.

**Services:** Functions such as device modeling, device control, data publishing, data analytics, and device discovery can be done by IOT system.

**Management:** Different functions like to govern an IOT system& to seek the underlying governance of IOT system can be done by management block.

**Security:** providing functions such as authentication, authorization, privacy, message integrity, content integrity, and data security can be done by security block. Security block also secures IOT system.

**Application:** For users, the Application layer is the most important layer. This layer provides necessary modules to control, and monitor various aspects of the IOT system. Applications allow users to visualize and analyze the system status at present stage of action, sometimes prediction of futuristic prospects.

Some of the wireless sensors are listed out below and explained briefly

**i. 802.11 – Wi-Fi**

IEEE 802.11 is a collection of Wireless Local Area Network (WLAN) communication standards. For example, 802.11a operates in the 5 GHz band, 802.11b and 802.11 g operate in the 2.4 GHz band, 802.11n operates in the 2.4/5 GHz bands, 802.11ac operates in the 5 GHz band and 802.11ad operates in the 60 GHz band. These standards provide data rates from 1 Mb/s to 6.75 GB/s. the communication range of Wi-Fi is in the order of 20 m (indoor) to 100 m (outdoor).

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|  | **WIRELESS TECHNOLOGIES** | | | | | |
| **PARAME**  **TERS** | **Li-Fi** | **Wi-Fi** | **WiMAX** | **LR-WPAN** | **Bluetooth** | **LoRa** |
| Standard | IEEE 802.15. 7(out of date) (for  VLC) | IEEE 802.11a/b/c | IEEE 802.16 | IEEE 8205.15.4 | IEEE 802.15.1 | Lora WA N R1.0 |
| Frequency band | 10\*1000 times frequency of radio(3KHZ- 300GHZ) | 5-60GHZ | 2-66GHZ | 2.4GHZ | 2.4 GHZ | 868/900MHZ |
| Data rate | 224Gb/s | 1Mb/s- 6.75 Gb/s | 1Mb/s-1 Gibb/s | 40-250  Kb/s | 1-24 Mb/s | 0.3-50Kb/s |
| Transmission  range | 10 m above | 20-100m | <50Km | 10-20m | 8-10m | <30Km |
| Energy consumption | Low | High | Mediu m | Low | Medium | Very Low |
| Cost | Low | High | High | Low | Low | High |

**Table (2): comparisons of wireless communications**

**ii. 802.16 – WiMax**

IEEE 802.16 is a collection of wireless broadband standards. Data rates from 1.5 Mb/s to 1 GB/s provided by WiMAX (Worldwide Interoperability for Microwave Access) standards. Data rate of 100 Mb/s for mobile stations and 1 GB/s for fixed stations is provided by (802.16 m). On the IEEE 802.16 working group website (IEEE 802.16, 2014) specifications are readily available.

1. **802.15.4 – LR-WPAN**

IEEE 802.15.4 is a collection of Low-Rate Wireless Personal Area Networks (LR-WPAN) standards. High level communications protocols such as ZigBee are formed by

802.15.4. Data rates from 40 Kb/s to 250 Kb/s are provided by LR-WPAN. Low cost and low-speed communication to power constrained devices is provided by LR-WPAN. The low frequency data rate of LR-WPAN is 868/915 MHz and the high data rate frequency of LR-WPAN is 2.4 GHz.

**iv. 802.15.1 – Bluetooth**

IEEE 802.15.1 is the Bluetooth standard. For a short range (8- 10 m) data transmission between mobile devices is provided by Bluetooth. Bluetooth is a low power, low cost wireless communication technology. The Bluetooth standard defines a personal area network (PAN) communication. It operates in

2.4 GHz band. Bluetooth data rate ranges from 1 Mb/s to 24 Mb/s. Bluetooth Low Energy (BLE or Bluetooth Smart) is the ultra low power, low cost version of Bluetooth. BLE was merged with Bluetooth standard v4.0 in 2010.

**v. 1.5.6. Lora WAN R1.0**

The LoraTM Alliance which is an open and non-profit association recently developed long range communication protocol called Low Power Wide Area Networks (LPWAN) standard protocol to enable IOT. The main aim of this protocol is interoperability between various operators in one open global standard. LoRaWAN data rates range from 0.3 kb/s to 50 kb/s. LoRa operates in 868 and 900 MHz ISM bands. LoRa communicates between the connected nodes within 20 miles range, in unobstructed environments according to post capes. Battery life for the attached node is normally very long, up to 10 years.

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| **IOT Platforms** | **Real time data captur**  **e** | **Data Visuali zation** | **Cloud service type** | **Data analyt ics** | **Developer cost** |
| Ubodots [(http://ubidots](http://ubidots/).com/) | Yes | Yes | Public | Yes | Free |
| Thing Speak (https://things  peak.com/) | Yes | Yes (Mat  lab) | Public | Yes | Free |
| ThingWorx (www:thingwo  rx.com/) | Yes | Yes | Private (IaaS) | Yes | Pay per  use |
| Xively (https://xively.com/) | Yes | Yes | Public (IoTaaS) | No | Free |
| Plotly (https://plot.ly/) | Yes | Yes (Mat  lab) | Public | Yes | Free |
| Nimbits (www.nimbits.com/) | Yes | Yes (Mat  lab) | Hybrid | Yes | Free |
| Connecterra (www.Connect  erra.io/) | Yes | Yes | Private (IaaS) | Yes | Pay per  use |
| Axeda [(www.ax](http://www.axeda.c/)e[da.c](http://www.axeda.c/)om) | Yes | Yes | Private (IaaS) | Yes | Pay per  use |
| Phytech (http://www.phytech.com/) | Yes | Yes | Private (IaaS) | Yes | Pay per  use |
| Aekessa (www.arkessa.com) | Yes | Yes | Private | Yes | Pay per  use |
| Yaler (https://yaler.net) | Yes | Yes | Private | Yes | Pay per  use |

**Table (3): Comparison of the IOT cloud platforms may be used for agricultural domains: a case study.**

**MATHEMATICAL EXPLANATION FOR HIGH YIELD PROCESS**

Most of the mathematical explanations are carried out for better yield production. For instance, rice and wheat formula is

Yield = no. of plants/m2×no. of effective fillers/plants× no. of grains/plants×% of filled grains × test weight/1000× 10,000/1000.

Where yield analysis is done with two parameters. The relation between Biological yield and economic yield is

Biological yield× K = economic yield

A crop which produced a dry matter is called Biological yield and a fraction of biological yield which is used by man is called economic yield.

In order to get high production yield, two important parameters are involved. Temperature and soil moisture. The temperature and soil moisture must within 18-25˚ c and 15- 60% respectively.

Y = T×M×A×100

T = temperature optimal range 18-25˚ c M = soil moisture optimal range 15-60%

A = area of crop field

This equation is used to finalize the yield of the crop field. When these values are increased or decreased (violating the optimal range) means, there is a chance of minimal production yield. It seems must be within optimal range only.

A large research effort is still required although the architectures described in earlier section make IOT concept practically feasible. Technical problems associated with current IOT architectures are reviewed in this section. To meet all necessary parts that are missing in existing architecture, later on, a novel concept of IOT architecture was developed. Before the IOT will be widely accepted and deployed in all the domains, a sufficient understanding of industrial characteristics and requirements on factors such as cost, security, privacy, and risk has to be discussed. Let us discuss a few problems in this regard:

1. Maintaining cost- is a more important parameter in case of farmers. So on order to reach this point, researcher concentrate on developing new smart agriculture IoT architecture with added advantages.
2. Current database management system may not handle in a real-time manner because the originated data may be too much large in size. Proper solutions need to be idealized. In a rapid speed, IOT based data would be generated. Current RAID technology is incapable of handling the collected data at receivers end. To handle this problem IOT based data service-centric architecture need to be revised.
3. Data is a raw fact that generally does not conform to non-relevant handouts. Data play the massive role in decision making in IOT. The value of data is the pool of data. By orientation of mining, analysis, and understanding meaningful information of data can only be obtained. For handling similar regression Big data problem is sufficient. Data mining, analytics, and hence decision-making services can be done by a relevant architectural framework. With data mining analytics Big Data approach could be aggregated.
4. The design of Service-oriented Architecture (SOA) for IOT is a big challenge where service-based objects may face problems from performance and cost related issues. To handle a large number of devices connected to the system which phrases scalability issues, SOA needed. Challenges like: data transfer, processing, and management become a matter of burden over headed by service provisioning.
5. The quality of service is also a big issue. To achieve an optimal range of QoS, a developer needs to concentrate on parameters of QoS.

An incredibly high number of nodes are envisaged with IOT. All the attached devices and data shall be retrievable. For efficient point-to-point network configuration, unique identity is the must. IPv4 protocol identifies each node through a 4-byte address. The availability of IPv4 numbered addresses is decreasing rapidly by reaching zero in next few years, so new addressing policy named IPv6 is developed. to pursue device naming and identification capability IPv6 area is the area where utmost care is needed and appropriateness of architectural proficiency is a must.

# CONCLUSION

Various technologies supported by IoT, applications of IoT in smart agriculture are reviewed in this paper. This paper reveals about the benefits of IoT in agriculture. IoT is the emerging concept in the Globe, and a clear understanding of its concepts is more essential. A brief assistance for the farmers in increasing agriculture yield and take efficient care in agriculture has been revealed. Precision agriculture can be made more accurate and efficient with IOT enabled technologies. IOT can be applied in different domains of agriculture First one is the Water and Energy: for Agriculture, Water and energy are the most important inputs and their costs can improve or break the agricultural business. Due to leaky irrigation systems, inefficient field application methods and the planting of water- intensive crops in the wrong growing location water wastage is done. For its operation Pumps, boosters, lighting etc need electrical energy. Water use can be made smarter for agriculture by monitoring and change water volume, location timing and duration of flow can be done with IOT. With the help of IOT, use of effective energy for pumps, boosters, lighting and other purposes also done the second one is the crop monitoring: the major concerns in this area are an application of fertilizers, pesticides based on crop and soil health, pest control. By deploying sensors and image capturing devices in the crop field which is connected to the internet for an appropriate decision can be taken with IOT. Efficient use of fertilizers and pesticides can be made with IOT. Finally conclude that need to develop on optimal Agri-IoT architecture which is enclosed with low cost, low power consumption of devices, better decision making process, QoS service, optimal performance and it is easy to understand the farmer without knowledge. All the above discussed applications show 98% accuracy. This can help the farmer to enhance the crop yield and thus improving the wellbeing of the nation.

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