IoT in Agriculture- Smart Farming

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***Abstract*— Over time technology has come a long way and many innovations have been carried out over the time. The IoT, which is one of the most revolutionary technologies, is the future of communication and computing. Nowadays, the applications and usage of IoT are seen in every field like smart homes, smart schools, smart cities etc. The administration of IoT is very vast and can be easily deployed into every field. Thus, this paper is about deploying IoT technologies in agriculture. IoT technologies enhance crop management, cost efficiency, resource management, field monitoring, disease detection and crop monitoring. A rigorous discussion on the basic architecture of IoT in agriculture, sensors used to fetch the real time data, connectivity through LPWAN, challenges faced in current farming practices and measures to increase the farm produce by implementing models that increase efficiency and monitor the life cycle of crop growth.**

Keywords— IOT: Internet of Things, agriculture, sensors, protocols, communication, end-user, LPWAN: Low Power Wide Area Network)

I. INTRODUCTION

With the increasing population, it would be difficult to feed the world population after a certain period and with increase in population there will be a decrease in the agricultural land due to various reasons like construction of residential buildings, commercial markets, and other industries. To overcome this and to save the world from the scarcity of the food, implementation of smart farming is necessary. Smart Farming will not only enhance the crop growth but also will increase its quality as well.

The Internet of things helps various devices and sensors to communicate with each other and send real time data over the internet. This real time data can be used by the computer systems to analyses data and make predictive analysis on it to improve the efficiency. With the help of IoT technologies a model can be created in a closed environment to monitor over all the environmental conditions of the farm. In the current practices, the farmers are not satisfied with their crop yield and that is due to various reasons like spread of diseases on the plants, attacks by insects and not having proper knowledge about the practices that involve in the production of the crop. All these reasons can highly impact the production of the crop yield and to solve this problem the proposed model is Smart Farming which will typically use technology to solve the problems faced by farmers to increase the efficiency and quality of the crop

Smart Farming uses technologies like the Internet, IoT devices, sensors, and concurrent assessment of various factors that determine the best conditions required by the plant like nutrients, soil quality, water quality, etc. Smart farming not only makes farming easy but also economical by reducing the labor cost involved and hence improving the crop yield and quality.

II. OVERVIEW

IoT in Agriculture (Smart Farming):

Deployment of IoT technologies enables the moderator to access the real-time data of that environment. IoT uses the access of the Internet for the exchange of data from sensors to the end-system destination. Implementation of IoT Technologies in the agricultural environment is a vigorous task but is achievable. With the implementation of IoT in agriculture we can achieve various advantages that tend to enhance the productivity and quality of the crop and increase the net profit of the farmer. Smart Farming has various applications which can be used to improve and enhance the way of farming. The major responsibilities that are to be carried out by Smart Farms are Crop monitoring, Disease detection, Monitoring environmental factors like pressure, gas, soil, water, and air. To implement these responsibilities, a proper architecture must be created which connects all the nodes and provides us with the reliable transfer of data.

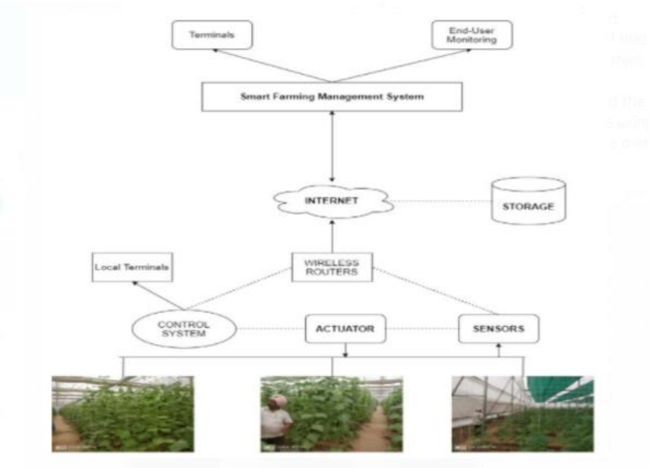
Smart Farming systems make use of sensors to monitor the conditions that can influence the growth of the crop. This real-time data is continuously monitored by an intelligent system that already has a predefined model to detect changes that can potentially lead to the deterioration of the crop. With this predictive analyzer, we can monitor various components of a plant that can lead to any problem in the life cycle of its growth. The Intelligent system uses technologies like machine learning, deep learning, and computer vision to make an appropriate decision on the input given to it. In the current practice with the help of computer vision, we can detect the potential of infection on the plant by just scanning the plant leaf and deciding the percentage of potential infection by deep learning algorithms.

The main obstruction that comes forward in the deployment of IoT technologies in agriculture is the initial capital investment. While the IoT provides us various advantages by using different technologies, all of that comes with huge capital investment and not all farmers can afford to build that infrastructure. Second to that comes communication, while all the farms are in remote locations, it is difficult to provide high-speed internet connectivity in that area. In the coming times, 5G technology can overcome this as well but at the present time, it is difficult to provide high-speed internet connectivity. Thirdly, the biggest challenge is illiteracy, using advanced technology and analyzing data is not possible for everyone. And teaching the farmer this high-level technology is another big task.

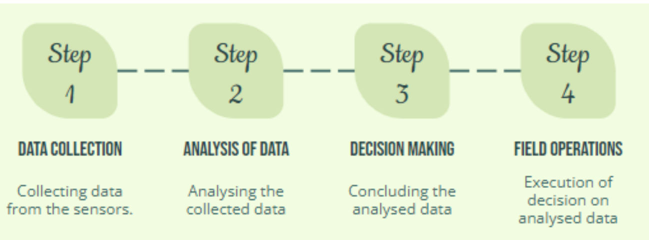
There are various advantages of turning traditional farming into smart farming, not only it will save a lot of labor work but also will be cost-efficient and beneficial. The main advantages of implementing IoT in agriculture are disease monitoring: the system monitors the condition of the plant components in real-time and then accordingly analyses and makes a decision, the other benefit is to improve the production quality and take countermeasures to increase the production quantity as well. It also saves money by reducing the labor cost and increases efficiency by monitoring the crop life cycle and providing the end-user with visualized infrastructure.

Architecture:

The architecture of an IoT system incorporates many devices like actuators, sensors, cloud services, wireless routers, control systems, intelligent management systems and end-user monitors. Every IoT system has a different architecture according to the components in that system. The IoT in agriculture typically has 3 main components, the applications that run on the end-user level and are used for the visualization and analyzation of data, the IoT devices that transmit real-time data and the cloud services storage that stores the raw data transmitted by the IoT dev ices, connected over the internet.

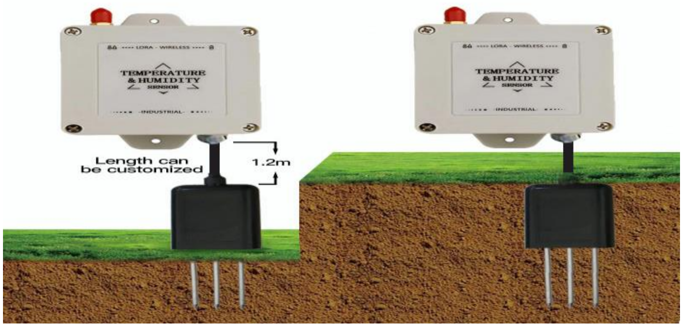


The architecture of the Smart farming system consists of various components like Actuators, Sensors, Storage (Cloud Services), Wireless routers, Smart farming management systems and end-user monitoring systems. All these components are incorporated together to form a smart farming IoT system, which is connected with each other with the help of the Internet. The rudimentary workflow of the system starts from the sensors which send the data to the smart farming management system via the wireless routers using the internet. The Smart Farming Management System then performs its own operations like predictive analysis and visualization algorithms for the understanding of the end-user.



Sensors:

The sensors play an important role in every IoT system, as these are the building blocks of IoT technologies. The main role of the sensors is to capture the real-time data and send it to the control system. The control system then monitors the data and sends it to the intelligent system for its analyzation. There are several sensors involved in IoT in agriculture like pressure, gas, imaging, thermal, soil, water, temperature and humidity.



Temperature and Humidity

Soil Moisture Sensor

Actuators:

An actuator is a system that moves or controls the system on the call from above or the control system. The actuator basically takes an electrical signal as input and turns that into an appropriate physical action associated with it. There are several types of actuators: Linear actuator, Hydraulic actuator, Electric actuator, Mechanical actuator and Thermal actuator.

Storage:

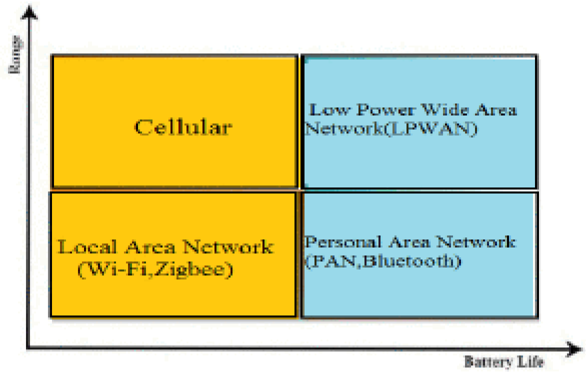
The storage or the database is used to store the data transmitted by the sensors and is used for manipulation or predictive analysis by the intelligent system. This time-series data must be accurate for Internet of Things applications.

If the order of data is not completely aligned and accurate, then it points to potentially different results when analyzed. Time-series data can be created as events take place around the device and then sent. There are several services provided for storage of the IoT devices like Google cloud platform, Microsoft Azure and Amazon Web Services.

Smart Farming Management System: The Smart Farming Management System (SFMS) is the brain of the architecture as all the mathematical computation, predictive analysis and visualization of data happen here. It takes the real-time raw data from the sensors which are stored in the cloud storage, then sorts and segregates the data and cleans the data for the analysis. After the data has been fragmented and segregated, it focuses on feature extraction and hence it analyses the data and combines data to extract important features from the sorted data. After everything, it trains the data and applies appropriate algorithms on the data which gives us the desired results. Once the results have been generated it creates a user friendly, visualized version of the data which is easily understood by the end-user of the monitoring. On the backend it monitors the environmental conditions, associates trigger with every condition and once that trigger is generated it informs the end-user about the scenario.

Connectivity:

There are many methods used in connectivity. But the major issue is farming mostly happens in remote area where there are certain constraints. The LPWAN is the efficient approach in which it utilizes less power and works in wide range. This method also maintains good connectivity, main methods used are NBIoT and LORAWAN.



The LORAWAN is Long Range technology, they are less secure that NBIot.The latency is more. The NBIoT is a radio added LTE platform used for low end of the market. They are basically used in low power sensors. This method provides wide coverage with indoor penetration. It uses license protocol that gives better experience to customer. They are more secure network than LORAWAN. Low latency. Both support geolocation to same level. The cost of LORAWAN is less than that of NBIoT because it uses unlicensed spectrum. The LORAWAN has more mature chipsets, cloud service and gateway can be used well in agriculture. The connectivity is at regional or global level they are used in organization but can be used in green house farming. LORAWAN devices register with network sever not with the gateways so it can move easily between the gateways. But there is possibility that they might go in a bind spot when mobile. NBIoT are stagnant they cannot be register or setup again without consumption of more power. Our is to use LORAWAN for agriculture and monitor of the other sections like delivery where mobility is key and accept some loss of data. But using NBIoT for faming will be best option where it more secure and reliable.

The major task in implementing the IoT technology in any infrastructure is the establishment of a connection between the intermediary nodes. The challenge is to provide low powered and long-range connectivity over the network without any delay or congestion. The reliability of data matters a lot as data is the building block of the IoT systems and hence providing a service that offers this has to be implemented. There are several technologies that offer connectivity and have their own advantages and disadvantages. In IoT in agriculture, the main focus is on providing a connectivity service that has long-lasting battery life, low cost and provides fast transmission of data over a long-range. The technologies that are currently used in connectivity are Cellular Networks(5G, 4G), Local Area Network(Wi-fi, Zigbee), Low Power Wide Area Network(LPWAN), Personal Area Network(Bluetooth).

In Smart Farming infrastructure, there are three main areas that have to be considered in choosing a connectivity technology, namely long-range, low power and low cost. The closest to this type of technology is the LPWAN, which provides all the services that are required in long-range areas like agricultural fields. There are several services that LPWAN provides, which are Long range, Low cost, Low Power, Quality of Service, Security and scalability. There are mainly three types of LPWAN: SigFox, NB-IoT and LoRaWAN.

NarrowBand-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services. NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, especially in deep coverage. Battery life of more than 10 years can be supported for a wide range of use cases. The initial cost of the NB-IoT modules is expected to be comparable to GSM/GPRS.

Sigfox is a long-range cellular wireless communication that offers custom solutions primarily for low-throughput Internet of Things (IoT). Low power consumption ensures that remote devices run for long with minimal battery charging or maintenance. Sigfox enables IoT communication over long distances making it possible to transmit with minimal base stations.

LoRaWAN is the radio modulation technology that is used for the transmission of data over a long-range. It is another category of LPWAN technology that is proprietary and works on RF technology. It works on the unlicensed spectrum hence because of that it does not have a high deployment cost.

NB-IoT	LoRa, Sigfox
Guaranteed QoS	No guarantee about quality of service.
Compared to traditional it has lower cost.	Deployment costs are very low.
It will work on LTE and GSM	Unlicensed spectrum
Operates are target customers.	Target customers are cities, operators
Operates and equipment vendors are backers	Operates are backers

Messaging:

Iot devices basically communicate through telemetry messages with the messaging hub. There should be some protocols used by each and every node. The basic protocol is TCP.

The nodes are connected to the each other using methods like WIFI, Bluetooth, ZigBee, Lora WAN etc.
There is some type of the protocols:

1. Message queue Telemetry Transport (MQTT)
2. Advanced Message Queue Protocol (AMQP)
3. Data Distributed Service (DDS)
4. Extensible Message and Presence Protocol (XMPP)
5. Constrained Application Protocol. (CoAP)

They have their own benefits and each protocol can be used according to the requirement of the system. Below is the comparison between the benefits of each protocols.

MQTT	AMQP	DDS	XMPP	CoAP
Lightweight protocol because push method is used	Transfer data through TCP and UDP	Scalable and effective	Easy to identify or locate device on network	Quick setup
Support low power usage	End to end encryption	Efficient utilization of bandwidth	No Encryption	Small Packet size.
Small Data packets	Application layer protocol is binary	Reliable data transfer	Quality of Service not available.	No broadcasting
Quick Results		Heavyweight protocol difficult to incorporate with embedded system		
Lack of Encryption		Can't use with web pages		
Works over TCP so high-power consumption	Uses large amount of power and memory	More bandwidth usage than MQTT		

After reviewing the benefits MQTT and AMQP are best fit. MQTT is utilized in most of the present system, as AMQP is new in market and less famous implementation AMQP with agriculture is not them according to our research.

III. LITERATURE SURVEY

Smart Farming – IoT in Agriculture:

Sunil Kumar Khatri et al, has stated that the main objective is to design an efficient smart farm for crop management and monitoring, better resources management and improved quality and quantity of crops. This is done using the different sensors such as air sensor, soil pH sensor, soil humidity sensor etc. In this survey the proposed model is a simple Iot architecture which collects information and send it over the Wi-Fi network to the server. Depending on the information the server can act.

Cloud Service Oriented Architecture (CSoA) for agriculture through Internet of Things (IoT) and Big Data:

R Venkat et al, has stated that the producers are not gaining profit due to the obstacles that come up in the process of farming. So, the proposed work makes use of various technologies such as IoT, cloud computing etc., which makes agriculture profitable and enhances the GDP.

A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming:

Muhammad Shoaib Farooq et al, presented this survey paper by keeping in mind the basic architecture of the agriculture farming to reduce dependency on manpower. They focused on the network architectures, layers, topologies, and protocols. And use of modern technologies such as cloud computing, big data and Analytics. They shared about the security breaches that occur while using smart farming. The involvement of government in promoting smart farming.

IoT in Agriculture: Designing a Europe-Wide Large-Scale Pilot:

Christopher Brewster et al, has stated that the implementation of IoT can transform the agriculture sector. The aim is to gain good yield of crop, security, and privacy to monitor the data and to control the cultivation of crop from the collected data using different sensors and IoT technologies such as image sensor, water sensor, fertility sensor etc.

A Survey of LPWAN Technology in Agricultural Field

Liya M L et al, has created this survey paper to help spread smart farming in the remote area. They have highlighted the basic issue faced in deploying smart farming in rural areas. They face poor connectivity and power. LPWAN technology has suffice all the drawbacks. LPWAN technology provide devices with low power and long range. Some of the technologies are LoRa, Sigfox, NB-IoT and LTE-M. They concluded that LORA and NB-IoT suffice most of the requirement generated to deploy in rural areas.

Investigating Messaging Protocols for the Internet of Things (IoT)

Eyhab Al-Masri et al, there is large amount of data generated and to transfer this data from source to a destination where a data can be used for future predictions. This generates certain constraint of reliable data transfer, lightweight, scalable, and secure. So, certain protocols are needed. They have examined six protocols HTTP, CoAP, MQTT, AMQP, DDS and XMPP and investigate the distinctive approach of each.

Security and Privacy in Smart Farming: Challenges and Opportunities

M. Mittal et al, believe that IOT devices play an important role in Smart Farming from knowing the status of crops and soil moisture content to deploying different sensors such as drones to monitor crops or spray pesticides. However, such an exposure also paves path for lot of cybersecurity threats and vulnerabilities. As a solution to this problem authors suggested a lightweight device authentication solution in which session keys and public keys are combined to carry out the encryption/decryption tasks.

A Feasible IoT-Based System for Precision Agriculture

Vesna Maraš et al, has specified about low cost IoT based monitoring system for precision agriculture. A field data is collected by self-powered station and is then transferred to remote controllers such as home or office via the Wi-Fi or open IoT servers for visualization, analysis and react back. By using this process people who have mobile, or gadget can monitor the data.

A Demo of the PEACH IoT-based Frost Event Prediction System for Precision Agriculture

Ana Laura et al, has stated that farmers loose lot of crop production due to frost and to overcome that the PEACH project was started. With the use of sensors to detect the temperature and weather the frost density was predicted ahead than it could also take place. With the collected data from the sensors the farmers can control the damage on the crops and the production can be increased.

IoT Agriculture to improve Food and Farming Technology

Gunaseelan.K et al, has stated that with the use of propel in agriculture we can keep track of the farm and its cultivation. It gives information which can be shared on the cloud storage which will be useful for the IT to maintain the data and its production growth. With the help of this technique, we can maintain the information about the grown of the crop in means of snapshot and using the sensors we can calculate the soil texture, pH value, fertility etc.

FarmBeats: An IoT Platform for Data-Driven Agriculture

Vashisth et al, proposed that data driven techniques help to get more agricultural yields, reduces loss, and cuts down cost of inputs. But are limited due to factors such as limited power connectivity, data connectivity, and sensor outputs. Here authors have suggested systems to generate and conserve power by using solar power and duty cycling the components, for data connectivity using TV White Spaces (TVWS) and for drone sensors to leverage Assisted Yaw Control using wind to increase flight duration.

An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges

Nour Hindia et al, Member, IEEE has concerns regarding the depletion of natural resources so to produce abundantly and efficiently is the main goal. The two factors' analytics and IoT help in achieving these two goals. In this paper they have review various challenges and benefits of IoT and suggests future trends. There are many benefits by incorporating Iot in agriculture, but the only issues are the cost of deployment. The research on LPWA technology and NBIOT is stand out from the LPWA type according to this paper.

Smart farm and monitoring system for measuring the Environmental condition using wireless sensor network - IOT Technology in farming

Tharindu Madushan et al, has cited that as the amount of IoT devices continue to grow, the amount of data being generated continues to increase rapidly. IoT systems depend mainly on using messaging protocols for exchanging IoT data and there are several protocols or frameworks that support different types of messaging patterns. Since IoT devices generally have limited computational resources and processing power, choosing a lightweight, reliable, scalable, interoperable, extensible, and secure messaging protocol becomes a difficult task.

Interoperability among existing messaging protocols will play an important role in simplifying the development and deployment of IoT systems. Hypertext Transfer Protocol (HTTP), Message Queuing Telemetry Transport (MQTT), Advanced Message Queuing Protocol (AMQP), Constrained Application Protocol (CoAP), Extensible Messaging and Presence Protocol (XMPP), and Data Distribution Service (DDS) are commonly used communication protocols in IoT devices. IoT devices produce data at a high velocity and require lightweight communication protocols. It would be desirable in this case to use a lightweight messaging protocol such as Message Queuing Telemetry Transport (MQTT). MQTT is good for cloud based IoT applications (D2C), a lightweight protocol and works well over constrained networks, provides an adequate level of QoS support.

Smart Greenhouse Management System based on NB-IoT and Smartphone

Tao Zheng et al, they are using cloud for storage and UI based application for end user for real time monitoring the environment and many other factors. They have conducted test on the packet transmission. And observed the success rate. They achieved their aim of intelligent management of greenhouse. The sensor node integrates the NB-IoT module, which implements data upload and down through the NB-IoT network, and effectively reduces communication power consumption. They concluded that data packet successfully transmitted rate from the node to the cloud server and the smartphone APP is 99.9008% and 99.7044%, respectively. The use of system application is also convenient.

IV. COCLUSION

The IoT in agriculture is one of the most recent topics under which several researches are being carried out in order to make farming smarter and provide maximum yield with minimum resources for the farmers. Several findings in this area have provided farmers or end users with improved yields by incorporating smart sensors, low cost, unlimited power options, better connectivity on farms etc. Along with these factors several messaging protocols like MQTT have been studied and better ones were suggested like AMQP. Major challenges in smart agriculture like power has been dealt with duty cycling of components and using solar power backed devices which include weather aware base stations. For Security and privacy issues lightweight multi-factor authentication protocols is required. Low power devices, with limited power, memory and storage cannot be considered as feasible solution.

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