Smart Agriculture Management System Using Internet of Things (IoT)

M. B. Abhishek, S. Tejashree, R. Manasa, and T. G. Vibha

Abstract Agriculture is a part of the most significant features in human civilization. In the last two decades, information and communication technology has contributed immensely to this field. Internet of Things [IoT] is an innovation in which actual material items like sensor nodes function together to render a technology-driven and information-based network that maximizes benefits with significantly reduced risks. IoT technology helps to collect online crop-monitoring information about conditions such as weather, humidity, soil, temperature, and fertility. IoT allows farmers to connect with their farms from anywhere at any time. Wireless sensor networks (WSNs) are usually used to monitor farm situation, and the process is regulated and automated with controllers. A smartphone enables farmers to stay up-to-date on the ongoing conditions of their farms from any part of the world. This paper deals with an agricultural system on the principle of Internet of Things monitoring and controlling the production process.

Keywords Smart agriculture · Monitoring and controlling · WSNs · Internet of things · Cloud computing

1 Introduction

The United Nations Food and Agriculture Organization better known as the FAO estimates that in 2025, the world population is estimated to reach eight billion and by the year 2050, the value will be 9.6 billion. There must be a 70% increase in food production globally by 2050, in order to keep pace. India is one of the largest countries in terms of agricultural production, and this has a significant impact on national food security. The farmland area per capita in the developed countries in the world is much lower than the world average level and the production value per capita and land

M. B. Abhishek (✉) · S. Tejashree · R. Manasa · T. G. Vibha
Department of Electronics and Communication,
Dayananda Sagar College of Engineering, Bengaluru, India
e-mail: abhishek.mb@gmail.com

S. Shakya et al. (eds.), *Proceedings of International Conference on Sustainable Expert Systems*, Lecture Notes in Networks and Systems 176,
https://doi.org/10.1007/978-981-33-4355-9_28

yield per unit in the case of India are also much lower. Therefore, it is required to build innovative ways to achieve higher yields with limited natural resources in order to combat the challenges of food production. In most of developing countries, agriculture stands as an essential pillar in the Indian economy and accounts for 22% of gross domestic product (GDP) of the country. More than 70% of Indians live in rural areas with agriculture being the main source of livelihood of most rural residents. Agriculture offers the vast majority of the rural population not only food safety but also employment opportunities. Agriculture is, therefore, an essential part of the Indian economy, but, if asked, "What is the condition of farmers?" the response that comes to our mind first is "They lack Education, Technology, and Capital." These three things are needed to develop and live in this day and age. Indian farmers adopt conventional agricultural practices, including methods of tilling, sowing and planting that involves labor. On the other hand, modern agricultural techniques use mechanized machinery for irrigation, tilling and planting, along with hybrid seeds. Agricultural technology in India is primarily labor-intensive. It makes the work slow and imperfect to do most of the work by hand. Farmers face many challenges in agriculture without crop rotation due to climate change in the environment, inadequate rainfall for crops, and conventional methods. Agriculture is India's backbone. Agriculture is regarded as the production or cultivation of beneficial crops in the appropriate ecosystem. Farm productivity may be augmented by evaluating the variety of crops that produced the highest output under different conditions of soil, fertilization, irrigation, and climate. Agriculture is regarded as the chief source of food grains, raw materials; it is therefore termed the basis of life. It serves a significant purpose in national economic growth. It also offers people job opportunities. Agricultural growth is required to develop the country's economic condition, such as trade. Evidently, conventional agriculture techniques are still being used by many farmers, and this leads to a lower crop and fruit output. Thus, the country's trade declines; hence, the tractor was the first technology introduced into agriculture. It improved productivity and was useful to farmers as a machine. The technology advancement will help farmers boost crop yields. The emerging technologies in agriculture are the IoT, wireless sensor networks (WSNs), and Precision. Internet of things better known as IoT is a system where real-life objects are interconnected, and they appear to form many integrated networks, including fields such as electronics and sensors through which data can be reliably transmitted and received. Precision farming equipment with proper wireless connections to transmit data collected from remote satellites and ground sensors can take crop conditions into account and modify how each portion of a field is farmed. Global ICT Standardization Forum for India described the possible benefits of IoT as

- (i) Enhanced the quality, accessibility, and scalability,
- (ii) Faster and more cost-effective operation,
- (iii) Physical stream clarity and accurate status data,
- (iv) Increased capacity, reliability, flexibility, and automation.

1.1 Precision Farming

Precision farming uses a variety of technologies, e.g., sensors, GPS services, and large data transmission to maximize crop yields. ICT-based systems to facilitate decision-making, supported with real-time data, instead of replacing farmers' capabilities and notions, also give information on all features of agriculture at an unprecedented level of granularity. This makes it possible to make better decisions, leading to less waste and maximum operational efficiency. Scientific solutions, GPS innovations, technological advancements, computer-based image analysis, remote sensing, weather forecasting, ecological controls and more are the specialties and expertise now required for agriculture. Precision agriculture is often referred to as "smart farming," a general word for simpler comparison with other M2M-based applications such as smart towns, smart measurement and so on. It is based on sensor technologies that are well recognized in other sectors, e.g., environmental inspections for pollutants, eHealth monitoring of patients, building management for farm soil monitoring, etc. IT systems retrieve, compile, analyze and present the data for all M2M implementations in order to trigger a suitable response to the information obtained. An extensive range of details on soil and crop behavior, storage tanks condition, animal behavior, machinery condition is presented for action to the farmer from remote sites.

1.2 What is Smart Farming?

To various individuals, the Internet of Things (IoT) implies utilizing or incorporating modern innovations such as Google Glass, Apple watch, or a driverless car. In fact, some of the most revolutionary and effective applications occur in the industrial IoT like smart cities and smart agriculture, factories. Then, as now, IoT is transforming the agricultural sector by allowing farmers and producers to solve the overwhelming challenges they face. In a number of ways, IoT can help farmers. To allow farmers to obtain an abundance of insightful information such as the temperature of stored goods, the number of fertilizers used, the amount of water in the soil, the quantity of seed required to be planted, etc., sensors can be installed across the farm and farming machinery. When IoT is enabled, smart systems are deployed and they can track and make informed decisions on a number of environmental variables on the farm. IoT implementation in agriculture can tackle many challenges and improve the quality, yield, and cost-effectiveness of agricultural products. The Concept of Smart: Typically, a machine is considered to be smart if such a device/artifact or system does something that can only be performed by intelligent person. Any device, process, or domain that follows the six different levels of intelligence is said to be smart.

- Adapting: The term adapting refers to the changes made in order to fulfill certain requirements; in terms of smart agriculture, these changes are said to be environmental.

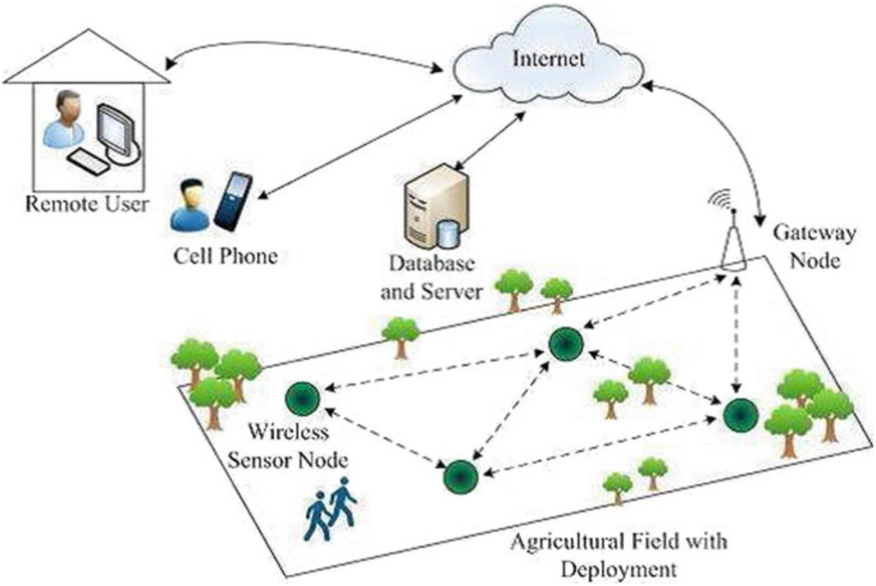

Fig. 1 Basic architecture of Internet of Things in agriculture

- Sensing: This is the ability to feel/detect and perceive any changes in the surroundings.
- Inferring: This simply refers to a conclusion based on results and findings.
- Learning: Once observations and observations have been confirmed, training can be used to consolidate previously used methodologies. It involves various types of information.
- Anticipating: This is all about thinking about something new and innovative that might happen, and it is considered to be the next phase of something.
- Self-Organizing: This level of intelligence is attributed to any device that is capable of sensing and tracking and then modifying its configurations according to the requirements (Fig. 1).

1.3 Process Flow in IoT

- Smart irrigation.
- Livestock monitoring.
- Weather monitoring and forecasting.
- Sensor-based precision farming.
- Remotely monitoring the quality of the soil.
- Smart warehousing, logistics, distribution.
- Greenhouse monitoring and automation system.

Smart farming deals with

- The environment monitoring and control subsystem includes monitoring water quality, regulation of water quality autonomously. Precise fertilization manages fertilizer. Regulate soil constituents and moisture, and also some environmental conditions like light, wind, air, etc. The agricultural asset regulation subsystem includes a smart greenhouse that will automatically adjust the temperature. A water irrigation system
- That will optimally regulate the flow of water automatically in order to conserve water. Monitoring of insects and pests.
- The production process monitoring and control subsystem includes the recognition of individual animals that ensure safe breeding. Monitoring the growth of animals and crops and product sorting ensures efficiency.
- Farm produce and food safety subsystem includes an arrangement of warehouse inventory logically. The traceability program on the farmland encourages the supply chain.
- Agricultural equipment and facility systems include remote monitoring of farm machinery, process tracking of farm machinery. Diagnosis and appropriate maintenance of farm machinery.

Since the computer age, two new concepts emerging are Internet of Things (IoT) and cloud computing. The idea of "Digital India" was put forward by India's Prime Minister Narendra Modi, which primarily stressed the growth of IoT and innovative new companies. IoT is closely linked to cloud computing as it is connected to the Internet. India is a traditional agricultural country with rice, dal, wheat, fruit, and cotton production. In India's socialist modernization, agriculture, rural areas, and farmers are of particular interest. Wikipedia's interpretation of cloud computing is this: Cloud computing is an Internet-based computing program that is used to distribute software and hardware data to computers and other devices in the network. End users don't need to have professional or even basic information about the "cloud," or directly control it. All of them need to know the type of tool they really want and how to get appropriate internet service. Cloud computing represents a modern system of implementing, utilizing, and sharing Internet-based IT services that include using the internet to deliver dynamic, expandable, and mostly virtualized resources.

2 Literature Survey

In papers [1–3], the agricultural implementation of a wireless sensor system for crop field tracking was proposed. There are two types of sensor nodes installed to these systems to determine temperature, humidity, and an image sensing node to compare and contrast information by occasionally taking images of crops. These variables perform a vital function to make good decisions about the crops' health within a period of time. Humidity, temperature, and images are these major parameters. By following these techniques, high sensor stability with low power consumption can be achieved. The agricultural field area can be monitored for a longer period of time.

Paper [4] discussed a greenhouse regulatory system on the basis of agricultural IoT with cloud computing capabilities. Inside a greenhouse, the administrator can effectively track and control various ecological parameters remotely using sensor devices such as temperature sensors, light sensors, soil moisture sensors, and relative humidity sensors. The sensors collect data on the agricultural field area at a regular interval of 30 seconds, and the data is logged and collated online with the aid of cloud computing and the Internet of Things.

Paper [5] illustrates an IoT-based irrigation automation and crop-field monitoring system. In this research, a system is designed to track crop-field using sensors and according to a server's decision based on sensed information, the system of irrigation is automatic. By using wireless communication, sensed data is transmitted to the database of the web server. When irrigation is done automatically, it ensures that the fields of humidity and temperature drop below the potential range. With the aid of a program that shows the user a web interface, the user can remotely track and manage the device.

According to Paper [6], a smart drip irrigation system is recommended. In this system, an application usually by android is used in order to reduce human intervention and for the remote tracking and managing the crop area. With the drip irrigation system, water wastage can be reduced and it works using the data obtained from water quantity sensors. To monitor environmental conditions, some additional sensors can be used.

Papers [7–9] proposed smart irrigation systems with the use of the Internet of Things. Wireless sensors are also needed to obtain the level of soil moisture and humidity. With the use of a gateway known as Generic IoT Border Router Wireless Br 1000, these detected data are transmitted through a network to a smart gateway. The data is then sent via a network to a web service from the gateway.

Paper [10] says an IoT-based smart agriculture system is built to carry out different agricultural operations such as bird and animal scaring, weeding, moisture detection, spraying, etc.

Paper [11] proposed storing the collated data, and only a database management program is required which will hold all the details about the soil. Based on the temperature sensor values, the primary focus is regulating the flow of water to the agricultural field automatically. Weather forecasting is made possible using a sensor to monitor conditions of the weather; this will be monitored via the smartphone of the farmer. In WSNs, data detected from the agriculture field is automatically analyzed with the aid of different intelligent application software, and a decision is made concerning the crops' health which is then forwarded to the farmer.

Paper [12] proposed a farming system that ensured low maintenance and high production using novel sensor technologies that are energy-efficient and eco-friendly. This paper explicitly explains automated irrigation techniques and farm monitoring which include a broad spectrum of sensors to remotely detect and regulate different conditions of the soil like temperature, fertility, and moisture and also regulate the distribution of fertilizer and water to the farmland.

Paper [13] proposed a farming system for monitoring pest insect traps by the application and distribution of image sensors. Imaging devices that use GSM and are run via a network of wireless sensors. Retrieval and relay of images are done by GSM from the trapping region and sent to the remote host station. Feedback about the accumulation of pests is relayed via call or text message to the farmer's smartphone. This technique only determines the presence of pests and doesn't proffer any way of pest control.

This paper identifies a theoretical framework and structure of a system that supports the decision for smart farming with network sensor applications to be able to achieve the desired tasks for farmers with the aid of the Internet of Things (IoT). Recommended is a Smartphone Irrigation Sensor [14]. For use on the crop field is a new invention an automated irrigation sensor and also the digital images are captured by making use of a smartphone, and with this, it can remotely monitor the crop area and also determine the level of water.

Smart Agric [15] depicts a combination of IoT and image analysis approach to evaluate the environmental or the man-made factor (pesticides/fertilizers) that directly impedes plant growth. Its decision-making system is utilized in the transmission of an evaluated framework from collated data of systems in challenging environments and the image of the leaf; it is then analyzed by software such as MATLAB with the aid of histograms for analysis.

In paper [16], the use of a monitoring system based on smart sensors for agriculture to reach decisive results is proposed. To continually monitor agricultural environments, various new technologies are being used. This serves as the gateway (FPGA) that includes various kinds of sensors, for example, soil moisture, relative humidity and temperature sensors, the field-programmable gate array, serial protocol, microcontroller, and the wireless protocol. In the dissemination of collated data kilometers away and also in an area with background noise keeping the sophistication of the network at a low level, TM radio chip is used. With the help of terrestrial microbial fuel cell, the power is supplied to the device in a zero-emission and eco-friendly manner.

Agricultural system is handled with information input, maybe humidity prediction, pH determination, and agricultural field area temperature and multi-processing can be accomplished with cloud computing, Internet of Things (IoT). Mobile computing, sensors, and big data analysis [17] are utilized. In this agricultural system, environment and soil characteristics are detected, analyzed, and occasionally sent to Agro Cloud via the Internet of Things (Beagle Black Bone). Heavy data analysis is done on Agro Cloud data for the required amount of fertilizers, total production, optimal crop cycle analysis, and current stock and market demands. The recommended system is favorable for regulating the cost of agro-products and for improvement in agricultural production with the display characteristics. The collated information is transmitted into a microcontroller in an agricultural environment with the use of the wireless Bluetooth unit.

A wireless transmitter–receiver unit pair is used to transmit and receive the data that is then fed to FPGA with the use of a serial communication protocol UART. A smart, ultra-low-power, inexpensive, and energy-neutral device with microbial fuel cells [18] to track the degree of prelatic aquifers was proposed. In [19] say that IoT technology innovation can be used to improve livestock and plan operational productivity and efficiency. The advantages of IoT and DA have been described and presented in this paper as well as open challenges. IoT is expected to offer the agricultural sector a number of benefits. Nonetheless, to make it affordable for small- and medium-sized farmers, many issues still need to be resolved. Price and security continue to be key issues. The rate of IoT adoption in agriculture is expected to increase as competition in the agricultural sector increases and favorable policies are implemented. The implementation of LPWA communication technology for agricultural purposes is one major area that is likely to attract significant research attention. Among LPWA technologies, the NB-IoT is expected to stand out. This is due to the open standard of 3GPP and telco.companies adoption.

Manishkumar Dholu et al. [20] proposed that in the agriculture domain, cloud-based IoT should be applied. Precision agriculture is essentially a concept that focuses on providing the appropriate amount of resources for the same length of time. Examples of these resources are water, light, pesticides, etc. The advantages of IoT were used in the proposed paper to incorporate precision agriculture. These agriculture parameters include light intensity, temperature, relative humidity, and soil moisture. Appropriate resolution is made on the basis of the reading received from the sensor, i.e., fogger valve (for spraying water droplet) is actuated on the basis of relative humidity (RH) readings, irrigation valve is actuated on the basis of soil moisture readings, etc. This paper suggested the integration of the sensor node to analyze all of these factors and to establish the actuation signal for all actuators. In addition, sensor nodes can also send this information to the cloud. To regulate all these parameters of farming, an android application is also designed. The proposed system is able to locally collate data and regulate the parameter, while at the same time transmit data to the cloud that can be accessed on the smartphone by the user. Such work can be done in the future by enhancing the use of mobile apps such as adding alerts when different parameters are not properly controlled. During the coding of the MCU, the set point for ambient temperature, relative humidity, soil moisture is specified in the proposed framework and to make such design more functional, the mobile app can be assigned the function of regulating the set point.

Prem Prakash Jayaraman et al. [21] proposed that optimizing productivity on the farm is important to improve activity yields profit and meet the ever-increasing food demand driven by rapid population growth worldwide. By interpreting and predicting crop production under a range of environmental conditions, farm productivity can be increased. Currently, crop recommendation is on the basis of the data compiled in field-based agricultural studies capturing plant production under a range of variables (e.g., environmental conditions and soil quality). Nevertheless, the collection of data on crop performance is actually slow, as studies on crops are mostly carried out in secluded and dispersed areas, and such data is generally acquired manually. In addition, the validity of these collated data is very low as it does not consider the earlier conditions that have not yet been encountered by the human handlers, and it is important to discard collated data that will lead to inaccurate results (e.g., solar radiation values in the midday after a short rain or overcast in the morning are inaccurate, and must not be included in the data analysis). Nascent Internet of Things (IoT) innovations like IoT devices (e.g., smartphones, cameras, wireless sensor networks, and network-connected weather stations) is useful in collating extensive amounts of information on the environmental conditions and crop performance, from temporal data retrieved from sensors, to spatial data obtained from cameras, to human observations collated and documented via smartphone applications. This data can now be analyzed to dismiss inaccurate details and evaluate personalized crop recommendations for any particular farm. This paper discusses the development of Smart FarmNet, an IoT-based system that automates the collection of data on the environment, fertilization, irrigation, and soil; automatically coordinate these data and discard inaccurate data to assess crop performance; evaluate crop forecasts and personalized crop recommendations for a specific farm. Smart FarmNet can be incorporated into almost any IoT device; this includes the ones that are available commercially like cameras, sensors, and weather stations, etc., and accumulate the collated data in the cloud for analysis of the performance of crop and also for crop recommendations.

Paper [22] says that to boost output and cost-effectiveness with the latest technologies like the Internet of Things (IoT), it is important to strengthen the efficiency of farming and agricultural operations. In general, by limiting the involvement of humans through mechanization, IoT can make processes in the farming and agricultural industries more effective. The purpose of this study is to examine newly initiated IoT applications in the farming and agricultural sectors in order to give an outline of data collected from sensors, technologies and sub-verticals like crop inspection and water conservation. It was discovered that water conservation is the most examined IoT sub-vertical under potential applications of the Internet of Things followed by crop inspection, smart farming, irrigation management, and livestock management with the same percentage. According to the analysis, the most essential measure in data collection from a sensor is relative humidity, ambient temperature, and some other sensor data are collected for IoT implementation such as soil pH (acidity/alkalinity) and moisture content of the soil. Wi-Fi has the highest demand for use in farming and agriculture, followed by mobile technology. In the farming and agricultural industries, other innovations such as RFID, ZigBee, WSN, LoRa, Raspberry pi, Bluetooth, and GPRS are of lesser interest. The agricultural sector has a higher percentage using IoT for mechanization as compared to the farming sector.

3 Analysis of IoT Hardware Requirement

3.1 Device

An IoT setup makes use of devices that perform an operation in detecting, actuating, regulating, and monitoring [23, 24]. Depending on temporal and spatial limitations (i.e., processing capabilities, memory, speeds, communication delays, and deadlines), IoT devices can share information with other linked devices and applications or collate data obtained from other devices and then send the data to the base station server and from there to the cloud server through a gateway or execute some functions locally and some other functions within the IoT structure. An IoT device can comprise multiple wired and wireless interfaces that are used to communicate with other devices [24]. These include (i) I/O interfaces for sensors, (ii) interfaces for connectivity to the internet, (iii) interfaces for memory and storage, and (iv) interfaces for audio/video.

3.2 Communication

A communication block is used to relay information across the remote servers and devices. IoT communication process typically works with the network layer, data link layer, application layer, and transport layer [24].

3.3 Services

IoT systems can be used to perform functions like device discovery, device prototyping and representation, device monitoring, data dissemination, and data statistics.

3.4 Management

Management block may perform various functions such as governing an Internet of Things system and finds the governance underneath the Internet of Things system.

3.5 Security

Security blocks can be used to provide features such as privacy, encryption, content credibility, message integrity, authorization, and data security. IoT system is also protected by the security block [21].

3.6 Application

For users, the most critical layer is most likely Application layer. This layer gives the essential modules that will manage and track the different features of the Internet of Things system. Users are allowed to view and evaluate the status of the system using applications, often predicting future prospects [22].

4 Challenges and Future Work

While the architectures described in the previous section make the IoT theory technologically conceivable, it still needs further research effort. This chapter deals with technical difficulties related to existing IoT systems. An innovational concept of IoT architecture was later developed to meet all the essential elements that are not present in the current architecture. A thorough understanding and research of industrial features and demands on conditions like privacy, security, cost, and uncertainty must be done prior to the widespread recognition and implementation of IoT in all domains. Let us discuss a few issues in this regard

- Maintaining cost—This is a far more essential variable for farmers. Researchers, therefore, concentrate on developing new IoT architecture for smart agriculture with added benefits to attain this level.
- Currently, the database management system may not be capable of handling information in real time due to the size of the data collected. It is important to idealize the appropriate solutions. Data based on IoT would be initiated at a fast rate. At the receiver end, the current RAID system is unable to handle the data collated. The data based on IoT service-centric system needs to be re-evaluated to address the issue.
- Data is an unprocessed fact that is typically not consistent with non-relevant handouts. Data plays a major role in IoT decision-making. The data value is the data pool. Data can be obtained by orienting mining, analyzing and interpreting meaningful information. A similar architectural framework can be used for mining data and analyzing them and therefore helps with decision-making operations. A large data method is integrated with data mining and analysis.
- Service-oriented architecture (SOA) for IoT is a major challenge in which service-based artifacts can face quality and cost-related problems. SOA is needed to deal with a wide range of system-connected devices with scalability issues. Challenges such as transmitting, managing, processing and storing, data become a challenge of service allocation.
- Service standard and integrity is also a major challenge. A developer needs to focus on QoS parameters to obtain an appropriate range of QoS.
- IoT envisages an unbelievably great amount of nodes. All devices and data attached to the network are recoverable. A distinctive identification is compulsory for the secure initialization of point-to-point connection. IPv4 protocol specifies a 4-byte address for each node. The supply of numbered IPv4 addresses is declining quickly, and it's approaching zero in the next few years, so the ability to identify new policy addressing IPv6 area is the field where the utmost attention is required and the adequacy of architectural skills is compulsory.

5 Conclusion

Through IoT-enabled technology, precision farming can be made more accurate and effective. In different fields of agriculture, IoT can be applied. Energy and water are one of the highly essential resources for agriculture and their prices can boost the agricultural sector or break it down. This means that water wastage has not been curbed as a result of substandard irrigation systems, inadequate field application procedures and sowing crops that require much water to grow in unsuitable farmland. Electrical energy is required for the optimum functionality of boosters, pumps, and lighting, etc. Water for agriculture can be used conservatively by controlling and adjusting the volume of water, location timing, and flow duration. Use of effective electrical energy for boosters, lighting, pumps, and other uses with the aid of IoT; the second one is crop monitoring. Applying pesticides and fertilizers based on crop and soil health and pest control is the major concern in this area. IoT can be used to make a proper decision by installing sensors and imaging systems in the crop field that is connected to the internet. IoT can be used efficiently for fertilizers and pesticides. Finally, it can be concluded that an efficient agri-IoT architecture has to be developed with low cost, the minimal power consumption of devices, optimum performance, improved decision-making action, and QoS service so that farmers can easily understand it without basic knowledge.

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