Survey on Internet of Things and its Application in Agriculture

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Abstract. The Internet of Things (IoT) is empowering the field of agriculture. The IoT application helps the farmer and makes him aware about all the latest information which is related to agriculture. In this study, authors have found that the implementation of IoT is very important in the field of agriculture that makes farming smarter. IoT applications make farmers smarter with the latest information about the crop and weather. By using the IoT application the farmer can prepare a plan for next season's crop. With the help of IoT based agriculture application the farmers already know the information about the weather, soil, wind speed and direction, relative humidity, and temperature. The farmers know about the disease of crops and then consult the expert and get an appropriate solution to the disease. The experts may advise the farmer how farmers can protect the crop from the disease. The IoT agriculture application helps to increase the production of crops and reduce the loss of crops from the disease. The IoT based agriculture application is like a friend of a farmer because the IoT based agriculture applications are helping the farmer at every moment of agriculture activities. India has set a food grain production target of 298.3 million tonnes for the current fiscal year 2020-21 which is 2.5% higher compared to previous fiscal year’s targets. Agriculture sector contribution to Indian economy is 17%. To empower Indian farmers and in turn to empower Indian economy, IoT based agriculture applications are essential for the farmers.

1. Introduction

The Internet of Things (IoT) is a new universal network model that provides transparent services. The IoT based applications are vitally used these days. The IoT devices are connected with the help of a wireless sensor network and communicate with each other. Every device is connected through the internet and each device can transmit the data any time anywhere without any human intervention. IoT based applications are playing an important role in every field of life. There are various types of IoT based applications where IoT techniques are playing an essential role. The IoT based applications are such as smart homes, smart energy, smart city, connected car, smart agriculture, and health care, connected buildings, industry and logistics, and other various domains [1]. The IoT applications are identifying the disease of crops and insects that are harmful to the crops. This application informs the farmers about the disease and gives an appropriate solution too. In earlier decades, various types of techniques were used for solving the agriculture-related problem. The IoT smart devices are used to collect the data and store it to the servers or databases for analysis purposes. After analysis of data, such applications provide a useful result that is better for crops. There are more than 50 billion smart devices in the world according to the IDC report [2]. As mentioned in the survey article [3], “In 2017 Sensor Network market was valued at $34.26 billion and is expected to reach $93.86 Billion by 2023.” A large number of smart devices are being used in agriculture also. This is a big challenge these days on how to monitor and control the complex situation of the real-life agriculture-related problem of the human being.

The internet of things is defined as a system that is interrelated with a computing device, mechanical device, digital component, and object. That uniquely identifies the object and devices which are connected with IoT applications. The uniqueness of each object is important in the transmission of the data between the objects. In this paper, authors have analyzed the analytical survey of IoT based agriculture applications. The IoT based agriculture applications full-fill the large demand for food and essential eating items to the people. Because the population of India and other countries are increasing very fast, due to this reason IoT based agriculture applications are required in the field.
of agriculture[4]. The IoT based agriculture applications inform the farmers about the unexpected weather condition and protect the crops, plants, and foods. Nowadays most of the countries are using the IoT based agriculture application with data analytics. In the IoT application, the collection of data is done by using the sensors and other IoT devices then the data is stored in the server database and processed. After completing the processing of data the IoT applications are taking the right decision for increasing the production of crops. The wireless sensor network (WSN) is organized in the field of agriculture for monitoring the environment, to care for agriculture, and control the process with the help of automation. The WSN is capable of self-configuring and diagnosing the problem. It also helps in taking the appropriate decision that will better for agriculture activity [5].

The smart agriculture application is empowering the farmer to make the right decision and self-analysis about the crop and its environment. Now the farmers are doing qualitative agriculture for growing the production of crops. The IoT based agriculture applications provide valuable knowledge related to the farms, breeds, weather, and environmental effect. The figure 1 given below describes the block diagram of the IoT system. The IoT system has four sections. The first section collects the data, the second section transfers the data by using the IoT devices. The third section analyses the data and images and section four visualizes and manages the operation via IoT application.

This paper has five sections. The first section covered an introduction about the role and need of IoT and its application in agriculture. The second section contains the details of architecture of IoT application in agriculture. The third section describes the details of IoT based agriculture application and the fourth section has explains the data analytics of IoT application. The fifth section gives open issues and future challenges and the sixth section concludes the survey. Against 291.95 million tonnes in 2019-20 and 285.20 million tonnes in 2018-19. Share of agriculture sector in Indian economy is 17 per cent, which is higher than the manufacturing sector, and agriculture alone will give more than 0.52 per cent to the growth rate of Indian economy as markets are intact and prices have not crashed.

2. **IoT System in agriculture**

In this section, authors have discussed the IoT based agriculture system in detail. This system contains four essential components that are important for IoT systems. The components are IoT devices, communication technology, Internet, data storage and processing that is depicted in figure 2. These components are necessary for every IoT application and described as below which are described in the sub-section given below.
2.1. **IoT Components**
The components of IoT based applications are described in this section. There are various types of components used in this section. The components are like a wireless sensor and actuators that are interconnected with the wireless sensor network. The detailed architecture of this device is described in figure 2. This system consists of a programmable gateway, a microprocessor, a communication module, memory and input, output components. The sensors are used to monitor and measure the value of soil nutrients, weather-related data that affect the production of crops. There are various types of sensors that are used in IoT based agriculture applications. The types of sensors are; location sensor, optical sensor, mechanical sensor, electrochemical sensor, and airflow sensor [6]. These sensors are used to collect the information related to the weather, air temperature, soil temperature and rainfall, leaf wetness, chlorophyll and wind direction, relative humidity, solar radiation and atmospheric pressure [7].

2.2. **IoT Communication technology and standard**
Communication technology is playing an essential role in the field of IoT application. All the devices deployed in the IoT based agriculture application communicates with each other through communication technology. Communication technology is categorized based on standard, spectrum, and application consequences. The communication standard is a combination of short-range and long-range communication standards and the communication spectrum is grouped into the licensed and unlicensed communication spectrum. The IoT based applications are based on the wireless sensor network and deployment scenario [8-9].

2.2.1. **Spectrum:** The unlicensed spectrum is used to make the industrial scientific and RF band which is known as the ISM band. This spectrum has some drawbacks which are security, cost, and interference issues. The licensed spectrum is allocated to the cellular network that manages the traffic, less interference, and increases the quality of services.

2.2.2. **Standard:** Various types of standards that are being used in the wireless sensor network. These standards are in the form of short-range and long-range standards. The short-range standard is managed by RFID, Bluetooth, and IEEE 802.15.4/ZigBee [10-11]. The range of short-range standard is 100 meter. The long-range communication standard range is up to 10 km. This standard is categorized
based on a low power wide area (LPWA). Lora, Sigfox, and NB-IoT are examples of long-range communication standards [12-14].

2.2.3. **Application Scenario:** Communication technology communicates IoT devices in the agriculture application. The IoT based agriculture applications are used in different topologies for connecting the devices and transferring the data from one device to another device in the WSN [15]. The detail of the communication band spectrum is described in table 1. That is given below.

**Table 1.** Represents the band spectrum of communication technology all with availability of bidirectional communication link

| Type                  | Spectrum         | Transmission Distance | Type of Network | Frequency Band       | Data Rate       |
|-----------------------|------------------|-----------------------|-----------------|----------------------|-----------------|
| 802.11a/b/g           | Unlicensed       | 6-50 m                | WLAN            | 2.4GHz               | 2Mbps – 7 Gbps  |
| 802.11ah              | Unlicensed       | 100 m                 | WLAN            | 1 GHz                | 78 Mbps         |
| SigFox                | Licensed         | 30-50km in Rural and 3-10km in Urban | LPWA | 902 MHz            | 100bps          |
| 3GPP NB-IoT           | Licensed (Cellular) | <35 km               | LWPA            | 450MHz-3.5GHz        | 250kbps        |
| EC-GPRS               | Licensed (Cellular) | <5km                 | WWAN            | GSM Licensed bands | 240kbps        |
| WiMAX                 | Licensed and Unlicensed | Up to 50-80 km       | WWAN            | 2-11 GHz and 10-66GHz | 70 Mbps |
| Bluetooth             | Unlicensed       | <100 m                | WPAN            | 2.4 GHz              | 2 Mbps-26 Mbps |
| IEEE 802.15.4 / ZigBee| Unlicensed       | <1km                  | WHAN/WPAN       | 2.4 GHz              | 250 kbps       |
| Z-Wave                | Unlicensed       | <100 m                | WHAN            | 900 MHz              | 100 kbps       |
| Wireless HART         | Unlicensed       | 228 m                 | WFAN            | 2.4 GHz              | 250 kbps       |
| NFC                   | Unlicensed       | <20 cm                | P2P             | 13.56MHz             | 424 kbit/s     |
| ANT+                  | Unlicensed       | <30 m                 | WAPN            | 2.4 GHz              | 60 kbit/s      |
| MiWi                  | Unlicensed       | <50 m                 | WAPN            | 2.4GHz               | 256 kbps       |
| Enocian/ISO/IEC 14543-3-10| Unlicensed | <30 m                | WAPN            | 900mHz               | 125 kbps       |
| Thread                | Unlicensed       | <30 m                 | WHAN            | 868/915/2450 MHz     | 250 kbps       |

2.2.4. **Internet:** The internet is a core network that defines the path to carry information and exchange data between multiple sub-networks. With the help of the internet, the sensor objects transmit the data anytime from anywhere to the objects. The internet is a way for cloud computing that collects and stores a large amount of data and process. Cloud computing is used to manage the user interface and coordinate the network node that computes and processes the data. The Internet has established connectivity to a heterogeneous system over the internet. The IoT middleware has developed the protocols. The service-oriented architecture (SOA) is an example of IoT middleware. The SoA is a multilayer architecture for an IoT based agriculture application [16].
2.2.5. **Data storage and execution unit:** Data storage and processing unit are used to store the agriculture-related data that is enormous, complex data in processing. The structured and unstructured data are complex in the processing. The structured and unstructured data are in the form of text, image, audio, and video. These types of data are stored in the database that is in the form of historical data, sensor data, business data, and market-related data. The cloud technique is used to collect data with the help of the sensor and the data are stored in the cloud. The fog computing techniques are used where IoT devices and gateways are used to carry the data for computation and analysis in respect of latency for the processing of complex applications [17]. In this era there are several types of smart agriculture applications being developed that monitor the various types of agriculture-related activities. Various types of platforms are used to store data on agriculture. There are some examples of IoT agriculture applications such as the On-farm system, Cox, Farmx and Easyfarm system, etc. The IoT based agriculture application has been described in the next section.

3. **IoT based agriculture application**

There are several types of IoT based agriculture applications in the field of agriculture. The IoT based agriculture applications are used for crop and livestock, machinery, irrigation, and water quality monitoring, soil monitoring and weather monitoring, disease and pest control, and automation and precision application. IoT based agriculture applications are described based on the following function: Monitoring, agriculture machinery, and precision agriculture [18].

3.1. **Monitoring:** Monitoring is necessary for managing the various factors in agriculture activity. The crop farming management is used to monitor the environment and weather which affects the production of crops. There are several types of data required to understand the patterns of farms for growing crops. These data are like sensor data such as rainfall, relative humidity, atmospheric temperature, and direct solar radiation and soil moisture, climate, etc. Based on these sensor data, the farmers can increase production and reduce the risk. Aquaponics is a term used to monitor aquaculture and hydroponics. Which means providing the essential nutrients to the plants. This is important to monitor the water level, water quality and temperature level of water, health of fishes, pH level, and humidity in the aquaponics. If we monitor the forestry where the carbon cycle and harbour play an important role. There are many factors such as soil temperature, moisture, and different levels of gases like carbon monoxide, carbon dioxide, and toluene, methane, hydrogen and isobutene, ammonia, and nitrogen oxide that farmers need to monitor. [19-21].

3.2. **Agriculture machinery:** The IoT based agriculture machinery that helps to improve productivity and reduce the loss of crops. The GPS is being used to operate the device in autopilot mode. The robotics machine is used to control the device remotely based on available information. This information is collected by the IoT system. The agriculture machinery is used to collect the data that help the farmer to map the plan of next season crops such as fertilizing, irrigation, and nutrition. The UAV sensor is to provide wind speed, air pressure, and other parameters to the farmer [22-23].

3.3. **Greenhouse production:** The greenhouse is a technique where the plants are grown under a controlled environment. This technique provides a suitable environmental condition that is responsible to grow any plant in any place that means the farmer can grow the plants in any environment according to his requirement with the help of this technique. The IoT based agriculture application can reduce human resources, save energy, and effective green-house production.

4. **Data analytics in IoT based agriculture application**

Data analytics is very important in the IoT based application. After collecting the data from the server, the analytics techniques are used for analyzing the data. After analysis, the IoT system takes an appropriate decision related to the crop. There are several types of analysis performed by the IoT
application that is based on the requirement of IoT application. There are different levels of analytics. Such as real-time analytics, off-line analytics, memory level analytics, business intelligence level analytics, and massive level analytics. The sensors are used to collect the data and stored in the server database for analysis purposes. Most of the image data are used in the IoT based agriculture application because the image can easily detect the leaf, stem disease, and root disease, fruit disease and detect the quality of fruit and weed detection and irrigation [24-25]. There are various types of techniques used for data analytics. These techniques are machine learning and deep learning. Machine learning and deep learning techniques are used for data analysis purposes. The machine learning technique is classified into classification, prediction, and clustering methods that are used in the IoT application. The machine learning models that are used in data analysis are such as support vector machine SVM, Linear regression, Random forest, and k-NN, Artificial Neural Network (ANN), and clustering. RNN and CNN models are deep learning techniques. These techniques perform better analysis in the IoT application [26-28].

5. Open issues and future challenges

The main challenges are in the deployment of devices that save energy and secure data in IoT applications. Many other challenges have pointed out that it is data convergence, privacy, and lack of interoperability, heterogeneity of IoT devices. Some points of issues have given below:-

- **Interference:** The deployment of IoT devices in the field of agriculture and all other purposes face an interference problem. The IoT devices that are unlicensed of the spectrum like a ZigBee, WiFi that is given in above table 1 [29].

- **Security and privacy:** In the IoT based application security and privacy is a big challenge and with these issues, the data can be accessed by an unauthorized person. In the IoT based agriculture application the hackers are to change the physical address of IoT devices and then access and destroy the data [30].

- **Reliability:** The IoT devices can be deployed in the out-door environment. Due to environmental harassment, the IoT devices are lost. So the need to protect the devices from the flood, weather conditions [31].

- **Localization:** In the deployment of IoT devices the localization problem can occur. The location of devices is very important for establishing communication with each device. So the exact location of devices is necessary [32-33].

- **Optimization resources:** The optimization of resources is necessary to determine the mechanism of IoT devices, transmit and store the data in the cloud. The farm size is different, so the various types of sensors are needed to monitor the specific crops [34].

After the study and analysis of this survey, authors have found these future challenges are-

- **Deployment of LPWA technology:** The LPWA technology is very important in the field of IoT because the devices need to consume less energy and establish communication for a long time with the device [32].

- **Universal platform:** The platform needs to develop a universal, not a crop-specific platform in agriculture, where the farmer can get the solution of any crops. With the help of the universal platform, the farmer can protect crops and sell the product in the local market. Due to this reason the universal platform is required [34].
• **Security**: Security is a very essential feature of IoT based agriculture application. The end-to-end encryption and decryption technique is necessary for the IoT application to secure the data in the network [30].

• **Energy efficiency**: The consumption of energy is a very challenging task in IoT devices. It needs to research how to save energy in the collection of data and the data can be transferred on time at the long-range [32].

• **Quality of services**: The quality of services that ensure the quality of data that transmit to the IoT devices. This is the big challenge for the open research area [23].

• **Data compression**: The compression technique is useful for transferring the huge amount of data in the communication network. The compression technique is used to compress the large amount of data that has exchanged the data to the receiver device (sensor) in the network. The multiplexing techniques help to solve this problem [15].

• **Real-time monitoring**: In the IoT application there are various types of sensors used for monitoring all IoT devices at the same time. This is a very complex task in real-time applications. The network management protocol that supports the communication between the IoT devices (Sensor) and server database. This is the challenge of IoT applications [28].

### 6. Conclusion

The IoT based agriculture application which is most important to solve the problem of farmers related to their crops, climate, and weather, all environmental impact on the crops. In this survey, authors have discussed in detail IoT and its components and described how IoT applications can be useful in the field of agriculture. With the help of this survey author has shown the work of IoT technology and how IoT technology is increasing productivity of crops and reducing the loss of productivity in the field of agriculture. Author has also discussed the open challenges and future direction of IoT application. With the help of IoT applications, the farmers are aware of agriculture-related information. That shows the advancement of agriculture. The farmer can also make the plan for next season's crop. LPWA communication technology is important for the IoT based agriculture application.

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