Chapter 7
IoT-Enabled Smart Farming: Challenges and Opportunities

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Abstract Internet of Things (IoT)-based technologies, cloud computing, big data analysis and computer vision have redefined every sector including smart agriculture. It helped to achieve low cost, high efficiency and high precision farming by using wireless sensor network and communication interfaces. The increase in population has created a huge burden on food industry and limited portion of earth surface is cultivable due to various limitations such as temperature, climate, soil quality, irrigation requirements and topography. In order to resolve this issue, expert intelligent techniques, robots and artificial intelligence algorithms are integrated with IoT to form part of agricultural automation management. Smart farming goes beyond agricultural management task and streamlines data, monitoring and decision-making based on real-time events to introduce new business models related to food industry. Big data are being harnessed to provide predictive insights in farming operations. IoT helps to automate agriculture growth in several ways such as soil mapping and testing, monitoring health and growth of crops, prevention and control of crop diseases, prediction of crop harvesting period, automated irrigation and fertilization, classification and inspection of agricultural products and monitoring farm using Unmanned Aerial Vehicles (UAVs) equipped with image sensor which provide details of crop conditions. However, there are technological challenges needed to be resolved for implementing IoT in new areas. Demand of professionals to develop and utilize the automated agricultural techniques need to be fulfilled. Also, traditional methods of agriculture must be complemented with sensing and driving technologies inspite of completely modifying the complete farming structure. Inclusion of these technological aspects will promote high quality yield of agricultural products and reduce the labor cost and time expenditure.

Keywords Smart farming · IoT · Big data · UAV · GPS · WSN

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7.1 Introduction to IoT-Based Smart Farming

As per Indian economic survey 2016, agriculture indulges more than 54.6% of the Indian work force and contributed 13.9% to country's GDP. However, this work force reduced to 41.49% in 2020 with increased percentage requirement of crop production. Figure 7.1 shows the report on percentage contribution of various sections in GDP of India for different periods of time (Wagh and Dongre 2016). The limited cultivable land and agricultural resources are the challenging issues which can only be resolved by including smart and automated technology into farming. Internet of Things (IoT) is a crucial technology that has contributed in recent growth of digital market by establishing Machine-to-Machine (M2M) communication. IoT has been versed in different ways depending on its implementation in several application fields such as smart farming, industry, supply chain, retail, healthcare, constructions, energy and transport as shown in Fig. 7.2. Since the global percentage contribution of smart farming-based IoT projects is only 4%, this sector can be more deeply explored to benefit nations' GDP.

One of the definition states "IoT is amalgamation of people, technology and devices with sensors network. The overall integration of IoT with human beings is to achieve communication, technological enhancement and communication to make real-time decisions (Srbinovska et al. 2015). It has found the application in several domains, one of which is agro-industrial sector. The major research in the context of IoT-based smart farming is focused on application domain such as monitoring (62%), control (25%), logistics (7%) and prediction (6%) (Giusto et al. 2010) (The percentage shows the distribution of literature in selected research domains). The literature on IoT is mainly focused on sensors, actuators, power sources, i.e.,

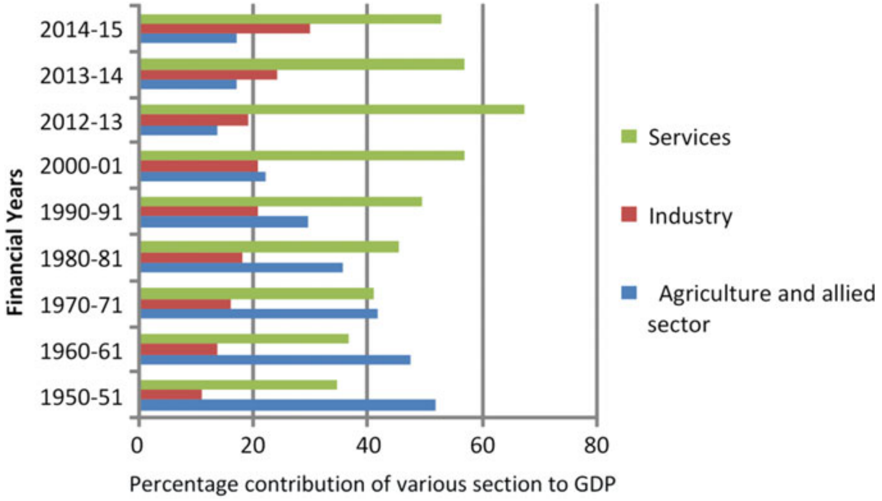

Fig. 7.1 Sector-wise contribution of GDP of India (1950–2015)

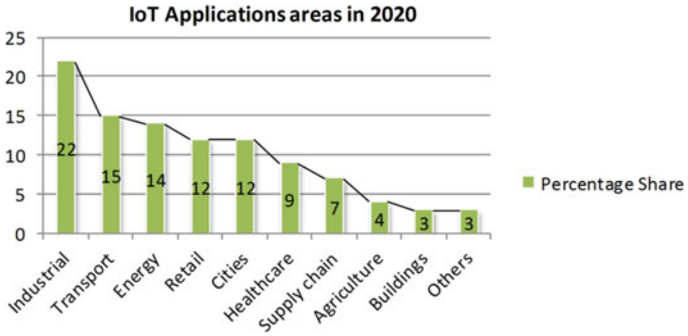

Fig. 7.2 Global share of IoT projects in different sectors

equipment's and edge computing technologies, communication network, big data computing and storage solutions.

The need of continuous monitoring and control of wide areas implemented in agro-industry and environmental sector makes them suitable domain for IoT-based solutions. It provides several advantages in terms of field automation, data collection, machine learning based on prediction, easy decision-making for owners, seamless planning by managers and policy makers. This technology is applicable at different levels of agro-industry sectors. It can monitor field variables such as soil conditions, irrigation, fertilization, atmospheric conditions, harvesting period and product quality. Also, IoT provides information, connectivity, adaptability and better management to rural farming practices. The low cost, low power electronic devices and computation software with internet connectivity can provide better interaction of human being with physical world. IoT is a vital tool to facilitate beneficiaries such as suppliers, farmers, technicians, business enterprises, distributors, consumers and government policy makers in upcoming years.

The recent thrust area of IoT-enabled smart farming has focused on communication network, energy management, monitoring and logistics. IoT application empowered with Low Power Wide Area Network (LPWAN) technologies such as SigFox, LoRA, narrowband IoT, Bluetooth, Zigbee, WiMax are becoming popular because of energy efficiency, wide coverage and low cost (Barrachina-Muñoz et al. 2017). Since Wireless Sensor Network (WSN) work at wide area and remote locations, it requires multisource energy harvesters and battery free solutions such as solar powered devices or self-powered devices. Thus, energy management of WSN is a crucial area of research for successful implementation of IoT-enabled smart farming. Nowadays, environmental monitoring techniques offer purely autonomous, hostile intervention and resiliency in case of node failure or poor connectivity. This IoT-enabled WSN system can monitor wide field parameters and will improve the overall productivity (Shaikh and Zeadally 2016). The agri-buisness is dependent on food safety and quality control. IoT-enabled logistics framework can resolve the challenges faced by transporters such as perishability and expensive logistics. It creates centralized information system among the food supply chain which can make food storage, transport, e-commerce deliveries seamless and effective (Ruan and Shi 2016). Figure 7.3 shows the basic IoT architecture for smart farming framework. It has four basic layers, physical layers which has WSN network (meant for smart sensing, monitoring and control), communication layer for transmitting the collected data from physical layer to service layer. In this layer, the storage, analysis, visualization of collected data is carried out. The inference is then passed to the application layer which implement the data to monitor, control or predict the environmental and crop conditions.

There are some open challenges and limitations in the adoption of IoT technology in agro-industrial sector. These are briefly pointed below (Talavera et al. 2017).

1. *Standardization/compatibility issue*: Compatibility with legacy infrastructure is an utmost important factor for smooth implementation of IoT. Improved compatibility and standardization among different vendors and security measures for entire IoT-enabled WSN network is one of the limitation for IoT technology adoption.
2. *Energy Management*: Using energy harvesters/alternative power storage modules can increase the life expectancy of electronic smart devices modules.
3. *Data privacy*: End-to-end data privacy and physical integrity is required for IoT-enabled agro-industry and environment.
4. *Cost efficacy*: The per unit cost sharply increases for the total module of high quality sensors, actuators, nodes, internet data access and embedded communication technology.

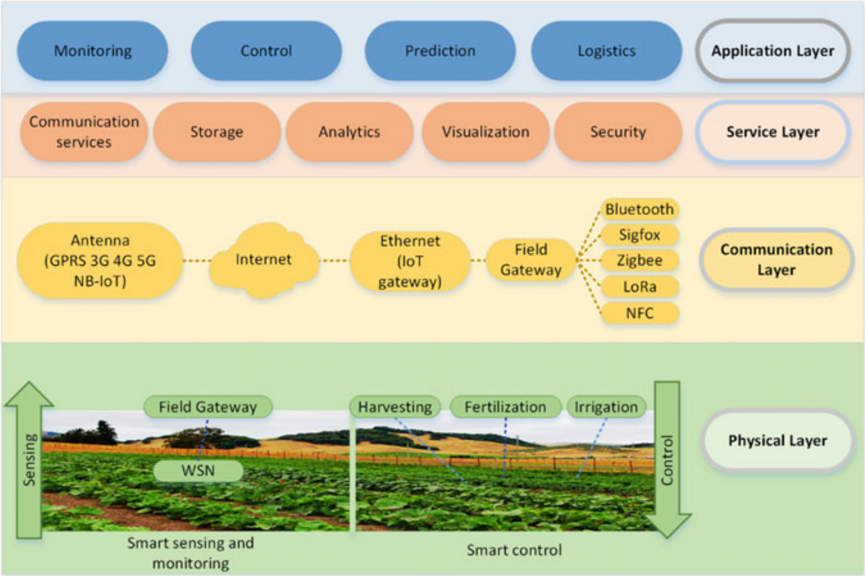

Fig. 7.3 IoT architecture for smart farming framework

5. *Scalability*: Improved data synchronization and data reliability is the prerequisite for large deployment of IoT technologies.
6. *Software professionals*: The implementation and maintenance of IoT and WSN technology requires skilled technicians/software professionals to refine codes, add features and generate data according to the in-field conditions.

7.1.1 Key Drivers of IoT Technology in Smart Farming

IoT-based technology has redefined almost all the sectors including industries, manufacturing, health, energy, climate prediction, digital marketing and agriculture. This revolutionary alteration has created new opportunities along with technological challenges. IoT devices integrated with wireless sensor network and big data computing applications serves various purposes in smart farming such as soil preparation, crop condition, monitoring fertilization, irrigation, pest detection, harvest period prediction and product quality analysis. Thus, it empowers the complete food chain and provides benefits to food industries. In order to feed larger urban community, food production should be doubled by 2050, which creates huge burden on rural community working with traditional agricultural resources and limited cultivable lands.

Considering the traditional farming procedures, 70% of farming time is spent on monitoring and understanding the crop conditions instead of doing proper irrigation, pest detection and fertilization activities. Also, specific crops can be rotated in same field season to season and biologically reach different stages depending on location and temporal difference. To respond to these critical challenges, farmers need remote sensing and communication technologies which can help in producing more yield in less efforts and can continuously observe fields without being present there physically. IoT technology is going to play a huge role in various applications of agricultural domain. They offer capabilities such as remote data acquisition, cloud computing, user interfacing, agriculture process automation, decision-making, logistics and marketing. Such features will modify the agriculture industry. Figure 7.4. summarizes the key drives and challenges faced to implement IoT technology in smart farming (Ayaz et al. 2019).

7.1.2 Challenges Faced to Implement IoT Technology in Smart Farming

Engineers and researchers around the world proposed different framework and architecture to implement IoT and big data computing technologies in agricultural sector to meet up the upcoming food crisis. Despite several benefits offered by technological reforms, the major hurdles in implementation of technology in smart farming still

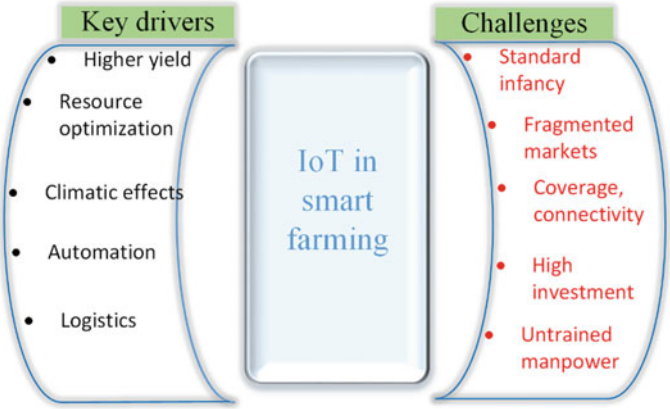

Fig. 7.4 Key drivers and challenges of IoT technology implementation in smart farming

persists. There are different reasons which create obstacles in successful adoption of IoT technology such as:

- *Standard infancy*: Although several IoT platforms are open source, still their infancy, regulations and governance regarding data privacy, ownership, liabilities and security is still in growth phase (Alam et al. 2017).
- *Fragmented markets*: The compatibility with legacy infrastructure, improved smart devices compatibility among various vendors and data privacy measures need to be completely addressed before in-field application.
- *Coverage and connectivity*: The communication layers offers critical functionalities of interaction between physical layer and service layer. These communication technologies such as Bluetooth, Zigbee, LoRA, SigFox, WiMax offer different coverage and speed of data transfer according to basic characteristics of techniques. To choose the best low power, wide coverage and reliable connectivity communication technology is also a major challenge (Zhang et al. 2019).
- *High investment*: Initially, the investment to implement IoT technology with WSN is very high even for monitoring and control of small agricultural field. Also, the power sources are required to operate the WSN network which will incur cost of batteries for remote monitoring applications. Thus, need of energy harvesters or self-powering smart devices is growing in smart agriculture applications.
- *Untrained manpower*: Unlike the traditional agricultural methods, the IoT-based smart farming requires skilled technicians/skilled professionals to refine features, modify codes and generate desired data.

7.2 Major Applications of IoT in Smart Farming

With implementation of IoT technology and wireless sensing network, every aspect of traditional agriculture technique has reformed to gain higher yield, better drought response, land preparation, irrigation, pest control, harvest prediction and production control. The various technological advancements help in different stages of smart farming leading to enhanced overall farming efficiency. The major application of IoT in different stages of agriculture are (Farooq et al. 2019):

- *Soil preparation*: The main goal of soil analysis is to determine the status of soil nutrients, so that appropriate measures can be taken during soil preparation to meet such deficiencies. In order to furnish this detail, comprehensive soil tests are prescribed in different topographical and climatic zones. The soil mapping enables better match of soil properties to different crop varieties. These soil features facilitate precise fertilization, selection of seeds, time to sow and planting depth. Furthermore, multiple crops can be sown in same land making a smarter use of available resources in smart farming. Such soil testing kit tool developed by Agro-Cares facilitate complete lab for soil testing (Accessed 2019). Moderate Resolution Imaging Spectroradiometer (MODIS) sensor can be used to map various soil functional properties to estimate soil degradation risks (Vågen et al. 2016).
- *Irrigation*: Several automated irrigation techniques, such as sprinkler and drip irrigation system, have been opted to reduce water wastage and improve irrigation efficiency unlike flood irrigation method. The crop productivity and quality essentially depend on soil moisture content. The shortage or excess of water may cause reduction in soil nutrients and promote microbial diseases. In order to determine the water necessity of crops, several factors are analyzed such as crop types, soil types, irrigation method, precipitation rate and climatic conditions. Thus, WSN helps in achieving this goal leading to a better productivity efficiency in least physical intervention (Jaiswal and Ballal 2020).
- *Fertilization*: It is a vital step of smart agriculture which helps in precise estimation of required nutrients to be added in the soil to help in crop growth. Fertilization requires site-specific data and depends on several factors like soil types, crop types, fertility rate, absorption rate and weather conditions. Thus, it is not only time consuming but also a quite expensive process. There have been several researches in this domain, NDVI (Normalized Difference Vegetation Index), variable rate technology, geo-mapping, GPS, GPRS and UAVs can be used in IoT-based smart farming.
- *Disease control*: Crop disease control depends on three important components, i.e., sensing system, analyzing system and treatment. The disease detection and treatment is possible by image processing of crop area using field sensors, UAVs or remote sensing satellites. Remote sensing image covers wide range area and offers high efficiency in low cost setup. Field sensors on the other hand offers more functionalities and is expensive in comparison to remote imaging techniques.
- *Crop monitoring and estimation of harvest period*: Crop productivity monitoring is an essential stage of smart farming as it plays important role in crop yield

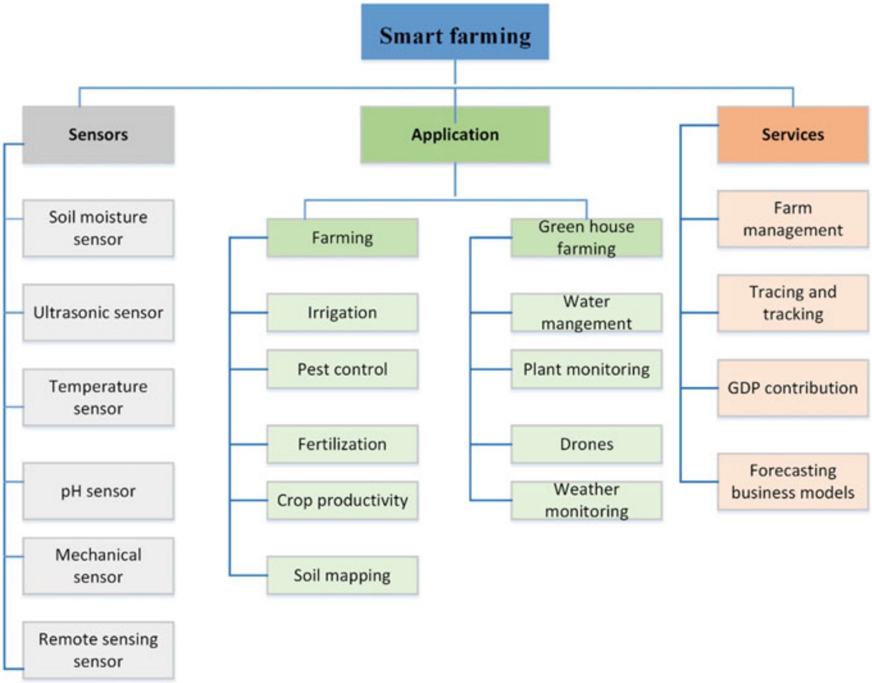

Fig. 7.5 Block diagram of sensors, applications and services in smart farming

estimation. The productivity is largely affected by pollination with good quality pollen grains and climatic conditions. The yield quality and crop maturity are essential parameters which decides the right time of harvesting. Forecasting harvesting period not only maximize the total benefit to farmers but also provide an opportunity to prepare for storage and logistic beforehand.

- *Green-house farming*: Green-house farming is the oldest type of agriculture where indoor grown crops are least affected by outside environment. Thus, the growth of crop is dominated by controlled environment inside such as structure of shed, covering material to protect from heavy wind, ventilation, moisture monitoring and decision-making technique. An IoT-based prototype is depicted for green-house farming to control humidity, temperature and light and is done using MicaZ nodes (Akkaş and Sokullu 2017). Figure 7.5 shows the block diagram of sensor, applications and services in smart farming.

7.3 Equipment and Technologies for Smart Farming

Every domain of agriculture that can be digitalized, automated and controlled will be profited with the implementation of IoT technologies and solutions. Based on this fact, several efforts are made to invent more sophisticated tools such as UAVs and robots that can perform range of operations such as irrigation, weeding, fertilization, harvesting and logistics. The successful implementation of smart farming depends on the accuracy of data collected from two ways, i.e., first through imaging devices with remote sensing satellites and UAVs and second from in-field-based sensors. The collected data can be stamped with precise location information by GPS so that site-specific planning and measure can be carried out for any specific problems.

7.3.1 Wireless Sensors

Wireless sensors are crucial part of smart farming to collect crop condition information. They can be used in standalone mode or further be integrated with advanced data computing tools depending upon application requirements (Navulur et al. 2017).

- *Acoustic sensors*: It performs several purposes including soil preparation, weeding and crop harvesting. It is a portable and low cost solution catering to fast response data transfer (Srivastava et al. 2013).
- *Airflow sensors*: These are capable of accurate measurement of soil permeability and moisture, which helps in distinguishing different types of soil.
- *Electrochemical sensors*: These sensors are used to assess the significant soil characteristics to analyze the soil nutrient level and pH value (Cocovi-Solberg et al. 2014).
- *Optical sensor*: The working principle of these sensors are based on light reflectance phenomena and helps to detect soil organic content, color, presence of soil nutrients.
- *Ultrasonic sensors*: These sensors are economic and have a lot of application in wide areas. They are used in smart farming for tank level monitoring, uniform spray coverage, monitoring crop canopy and weed detection.
- *Optoelectric sensors*: These sensors differentiate in plant type, detect weeds, herbicides and help in better crop productivity (Pajares 2011).
- *Mass-flow sensors*: These sensors are used in crop harvesting and crop yield monitoring as it can measure grain flow when crop passes through harvesters.
- *Mechanical sensor*: These sensors assess soil mechanical properties to indicate the variable level of compaction. These sensor cut through the soil and record the force measured by strain guage.
- *Soil moisture sensors*: These sensors are applicable to categorize hydrological behavior such as flow and water level. It is mostly used to measure water presence in soil, rainfall and stream flow.
- *Remote sensing*: It captures, stores and transmits geographic and spatial data. Agros sensor is one of the leading satellite-based sensor used to collect, process and analyze environmental data from mobile communication platforms worldwide (Rose and Welsh 2010).

7.3.2 Communication Technologies

Communication and data logging are two major functionalities of precision farming. It should be secure, reliable and provide wide coverage connectivity among various smart devices. To achieve the communication reliability, Ethernet, telecom operators and WiFi can play a vital role in agro-industry sector. Based on the availability, application requirement, communication mode and scalability, different communication protocols can be opted.

- *IEEE 802.11 WiFi*: It can accommodate several standards such as IEEE 802.11 a, 802.11b, 802.11n operating at different bandwidths, i.e., 5 GHz, 2.2 GHz and 60 GHz, respectively. Data transfer rate can vary between 1 Mb/s and 7 Gb/s. Coverage range is in-between 20 and 100 m (Xiao et al. 2006).
- *WiMax*: It provides broadband multi-access connectivity including mobile communication through wired or wireless connections. It operates in the range of 1.5 Mb/s to 1 Gb/s.
- *LoRA WAN*: LoRA wide area network is developed by TM alliance and is open source protocol. It assures interoperability between multiple operators specially designed to improve crop yield.
- *Mobile communication*: There exists multiple generation for mobile communication, i.e., 2G/3G/4G/5G. IoT devices communicate using these mobile communication network to monitor field data such as soil, crop growth and climatic conditions (Feng et al. 2019).
- *RFID*: It works on the principle of assigning unique number individually to each smart devices in order to record information. It can be used for low cost smart farming environment for receiving and transmitting sensor information.
- *SigFox*: SigFox is a narrowband wireless cellular network which has low data rate suitable for IoT and M2M communication (Pitì et al. 2017).
- *Bluetooth*: It is suitable for low power and low range personal area network suitable for short range communication (Ruiz-Garcia et al. 2009).
- *Zigbee*: This is used for device-to-device communication with low power data rates. It helps smart farming environment by establishing low cost, bidirectional communication between IoT devices and remote servers (Ray 2017).

Table 7.1 gives the comparison between the above-mentioned communications technologies based on their features.

7.4 Role of Big Data in Smart Farming

The fundamental concepts of IoT and device-to-device communication was stated by Kevin Aston in 1999 (Ashton 2009). IoT is versed as convergence of three visions: things oriented, internet oriented and semantic oriented. It helps in real-time information sharing between wireless networks. IoT generates a tremendous volume of

Table 7.1 Comparison of wireless communication technologies used in smart farming

Parameters	Standard	Frequency band	Data rate	Coverage	Energy efficiency	Cost
WiFi	IEEE 802.11	5–60 GHz	1 Mb/s to 7 Gb/s	20–100 m	Low	High
LoRA	LoRA WAN R1.0	868/900 MHz	0.3–50 Kb/s	<30 km	Very high	High
WiMAX	IEEE 802.16	2Ghz to 66 GHz	1 Mb/s to 1 Gb/s	<50 km	Medium	High
Mobile communication	2G-GSM, CDMA, 3G, 4G-LTE, 5G	865 MHz to 2.4 GHz	40–250 Kb/s	Cellular area	Medium	Medium
RFID	ISO 18000-6C	860–960 MHz	40–160 kbits/s	1–5 m	High	Low
Zigbee	IEEE 802.15.4	2.4 GHz	20–250 Kb/s	10–20 m	High	Low
SigFox	SigFox	200 kHz	100–600 bit/s	30–50 m	High	Low
Bluetooth	IEEE 802.15.124 GHz	24 GHz	1–24 Mb/s	8–10 m	Very high	Low

data called as big data which requires recent trends solutions for data management to provide process insights and decision-making. Big data has different characteristics such as high volume, high variety, veracity and high velocity. IoT framework facilitate with ubiquitous network of WSN, data sources, smart devices with a potential to incorporate existing applications and give a deeper insight for future upgradation and solutions. The exponential growth in variety of sensor and generated data sets makes it complex and difficult for user to extract knowledge by analyzing the data and share it on the cloud. The solution to this issue can be devised by integrating IoT and big data computing environment. Big data tools can collect, analyze and evaluate high volume of data and extract useful information using data mining technique.

Big data technologies in smart agriculture goes beyond the crop production, it affects the entire food chain by transforming the agro-industrial environment. It provides deeper and accurate predictive insight in farming operations, analyzes volume of real-time data to extract decision and redesign business models which can revolutionize food markets. There are several key drivers of development of big data technology in smart farming such as farm process, farm management, data chain and network management. Data chain forms an integral part of big data applications. It refers to sequence of functions originating from data capture to decision-making and data marketing. Data chain consists of technical layer that gathers the raw data and convert it into information and passes it to business layer that makes decision and provides data services to owners. The technical layer and business layer is inter related to form data value chain. Figure 7.6 presents the Schematic diagram of functions performed in data chain for big data applications (Dumbill 2014).

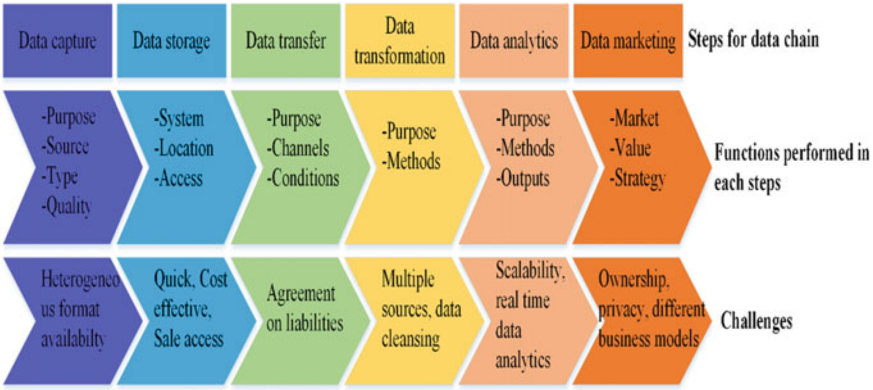

Fig. 7.6 Data chain functions and challenges faced in Big data applications

7.4.1 Big Data Tools for IoT Applications

There are several tools mentioned in the literature which support big data computing for IoT applications. Some of them are discussed below (Hajjaji et al. 2021).

- *Hadoop*: Apache foundation facilitating several open source projects out of Hadoop serves the purpose of distributed storage and processing of massive datasets enabled with big data architecture. The core of Apache Hadoop consists of two subprojects, HDFC for storage and MapReduce for processing.
- *Apache Flume*: This platform provides efficient distribution services to log file and events into Hadoop.
- *Kafka*: It is a distributed, highly efficient and publish subscribing messaging platform. It is used for large-scale message processing and enables data to be implemented in various application software.
- *Spark and Strom*: These open source framework are produced by Apache to analyze massive data like Hadoop. Spark is faster in computation because of its memory capabilities stream processing in comparison with Hadoop.
- *Apache Hive*: Hive utilizes SQL-based interface to poll the data stored at different files and databased to run at the top level of Hadoop.
- *NoSQL database*: As name suggests, not only SQL database system manages large volume of data of unstructured and semi-structured characteristics perfectly which was not earlier possible with traditional databases.
- *Cloud computing*: It is a computing technique which relies on remote server to analyze a large volume of data for fast speed data analysis. Cloud computing ensures the basic layer of computing resources and backing higher layer of big data processing.

7.4.2 Benefits of Integrating IoT with Big Data Tools

There are several benefits of integrating both the recent techniques together to collect large amount of data from smart devices using IoT and analyze and store it using big data tools.

- *Connectivity*: It is the most crucial factor in computing and information exchange by aggregating massive volume of data from multiple sources. The communication network between interlinked nodes and data management system (DMS) caters as the backbone of the complete application layers. Thus, a variety of low cost, wide coverage and efficient communication technologies are now available with distinct communication protocols and security measures to fit the need of smart farming environment (Babar and Arif 2019).
- *Collection of heterogeneous data from multi-source system*: By integration of IoT technology with data mining techniques, multiple sources such as sensors, actuators and other smart devices can deliver useful information and deeper insight to operational modes. Such knowledge can be used to form predictive models (Bandyopadhyay et al. 2011).
- *Data storage*: Storage of unstructured and heterogeneous data using data management system is a challenging task. In order to resolve this issue, big data technologies such as Hadoop, Spark, Strom, No SQL databases have been introduced which helps in collection, storage and preservation of large volume of data (Tu et al. 2020).
- *Data analysis*: Efficient, real-time processing software solutions and technological capabilities enabled processors are required for accurate data analysis for dynamic and demanding situations in order to extract useful information for decision-making and control.
- *Cost efficacy*: Big data technologies are mostly open sourced and offer low cost solution for development and deployment of new applications. It makes implementation of IoT integrated with big data tools easier to be opted by developing countries to benefit rural community (Wolfert et al. 2017).

7.4.3 Key Challenges in Implementation of IoT and Big Data Tools Applications

In order to successfully implement the IoT and big data technologies to upgrade the agricultural environment, the following hurdles need to be discussed and resolved.

- *Security and privacy*: This is a major challenge in implementing IoT since the risk of spoofing, data hacking, manipulation and cyber-attack on confidential information can affect the performance of big data technologies and may result in faulty decision-making (Asghari et al. 2019).

- *Massive volume*: In order to deal with massive volume heterogeneous data, the operational mechanism need to be upgraded with latest technologies for data collection, storage, processing and management.
- *Velocity*: The speed of data access and generation is a crucial issue which also generates a concern for real-time dynamic data analysis.
- *Veracity and variety*: The quality, accuracy and applicability of data is an important concern. The data should be free of noise, biases and abnormalities. The data can be of different variety; structured, semi-structured and unstructured which makes it difficult to organize (Ardagna et al. 2018).
- *Visualization and value*: The visualization technique such as graph and charts should be effectively chosen to highlight the inferences drawn from the data. Also, the amount of data extracted for decision-making decides its cost and benefit ratio. The data which is important only need to be extracted and valued.
- *Knowledge extraction*: Process of extraction of knowledge from heterogeneous data collected from multi-source system having different structures is a difficult task.

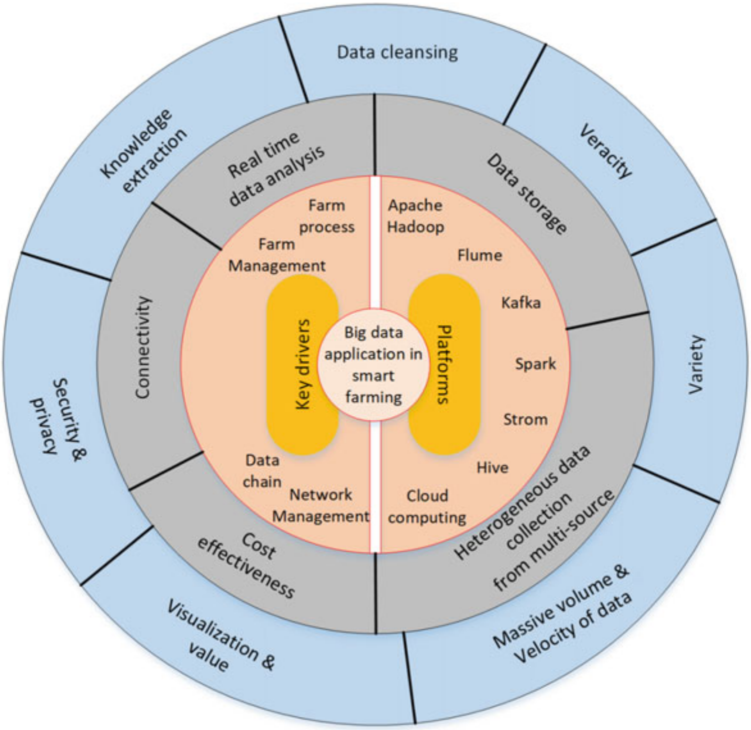

Fig. 7.7 Benefits and challenges of Big data applications in smart farming

Figure 7.7 presents the summary of different aspects related to big data applications.

7.5 Future Opportunities in the Domain of Smart Farming

Researchers around the world are working to reduce the overall cost of hardware and software deployed in IoT applications to farming to maximize the crop yield efficiency. The standardization in IoT application and platforms is important to clear the interoperability and compatibility hurdles faced by service providers and active users. Energy management is also a most crucial issue for IoT-based system implementation. Green computing technologies need to be integrated with IoT, so that the smart devices consumes less amount of power and may increase system life expectancy. Fault tolerance is almost an unaddressed topic in concern of IoT-based smart farming researches. To make flawless system, fault tolerance level of the system should be kept at high priority. Hardware modules may fail due to depleted batteries or other reasons, can incur heavy maintenance cost.

Machine learning algorithms and intelligent techniques integrated with IoT technology may help to access the predictive and behavioral analysis of smart farming activities. Portability of the IoT architecture need to be enhanced to increase its usability in real-time environment. Cloud-enabled computing, storage systems and agro-logistic system are recent research topics that can help to leverage high profit margins to the farmers and make smart farming a seamless experience. Big data analytics and cloud computing web services may be developed to facilitate the knowledge of farmers about the smart farming. Furthermore, government and policy makers should come together to pave new policy for improving agriculture-related big data analytics.

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