Agricultural Monitoring And Management Based On Internet Of Things, Data Analytics And Artificial Intelligent Technologies: Review

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Abstract - *The increase in productivity of agricultural processes is essential to improve yields and cost-effectiveness using new technology like Internet of Things(IoT) and Artificial Intelligent (AI). The improvement of agricultural sensor, machine learning, wireless communication, Big data and Cloud computing technologies, stimulates the IoT in agriculture. IoT is playing a vital role in innumerable areas of protected agriculture. This study aim to analyze the recently developed IoT technologies applicable in agricultural industries. Data for this study were mined from 40 recently peer-reviewed scientific publications (2015-2019) targeting on the frequently of use of the mentioned technologies in agricultural industry. Results from the reported studies reveals that Bluetooth and LoRaWAN technologies were the most useful technologies among the reviewed technologies with (15%) followed by Mobile cellular and ZigBee technologies at about (13%) of application. However, NB-IoT technology comes the most applicable technology after ZigBee technology with about (12%). From the data collection, SigFox seems to be the next most applicable technology among the reviewed studies in agricultural industry after NB-IoT with about (11%). Wi-Fi were found the most useful technology after SigFox with an application rate of about (8%). The least applicable rate of technologies from the reviewed studies were found to be 6LowPAN and NFC with similar application rate of about (7%). The study also reveals that Machine Learning technologies were the most useful computational technologies in farm monitoring among the reviewed technologies with the application rate of (32%) followed by Edge Computing with the application rate of 24%. Cloud computing technology was happened with an application rate of 23% followed by Big data computing technology with the application rate of 21%. However, results also reveals that Big data analytics were the most useful computational technologies in animal health monitoring among the reviewed technologies with the application rate of (29%) followed by Cloud computing with the application rate of 27% and Edge computing with an application rate of 26%. Machine Learning technology were found with the application rate of 18% as expressed in section VI of the study.*

Keywords - *Internet of Things (IoT), Smart farming, Sensor data, Agriculture, Data analytics (DA).*

I. INTRODUCTION

The recent development of information and communication technology (ICT) results into emerging of the IoT notion with expectation of an intense expansion in the near future. The IoT interconnect the physical objects (i.e. devices, vehicles, buildings), which are instrumented with embedded electronics, sensors, software, and networking connectivity allowing these objects to gather and exchange data [1].

When the environmental factor change away from the fixed threshold, IoT can automatically alert for the removal of the hidden threat. The environmental factors such as temperature, humidity, soil nutrients concentration and weather can also be controlled based on the state of crop and animal growth in real time. In particular, IoT can make agricultural and farming industry processes more efficient by reducing human intervention through automation [9].

With IoT objects can remotely be detected and measured across accessible network infrastructure, producing chances for more direct integration of the real world objects into computer-based systems, and resulting in enhanced efficiency, economic advantage and accuracy on top of reduced human involvement [7]. Everything is distinctively identifiable under embedded computing system and it is able to interoperate in existing Internet infrastructure. Typically, IoT is expected to offer progressive devices connectivity, systems, and services that goes beyond machine-to-machine (M2M) communications and covers a numerous protocols, applications and domains [2].

IoT for agriculture uses sensors to collect big data from the agricultural field. It discovers analyses and deals with models built upon big data to make the development of agriculture more sustainable [6]. IoT in agriculture focus is on automating all the aspects of agricultural methods to make the process more efficient and effective [2].

This review intend to gain insight into of IoT applications technologies in protected agriculture and to detect the rate of application of different applicable technologies in particular environment. Therefore, the methodical literature review of IoT research and deployments in secured agriculture over the past years and evaluate the impacts made by different technologies in agriculture. Selected references were clustered into two technological domains corresponding to IoT based agricultural monitoring and management. Furthermore, the study focus on the characteristics along with future research forecast, to help new researchers of this area understand the research progress based on IoT technologies in agricultural industry and to suggest more innovative ideas in the future.

This study can be considered as a reference for members of the agricultural industry to improve and develop the use of IoT and corresponding applicable technologies to enhance agricultural production efficiencies. This study also provides recommendations for future research to include IoT system's scalability and system architecture, size or scale of the perceived land or agricultural domain where, IoT security, operational technology, data storage, cloud platform, risk solutions/protocols, and power supplies.

This review also provides an overall picture of the current development trends of concerned technology in agricultural monitoring and farming management based on IoT, in agriculture and farming between 2015 and 2019. IoT is the network of things which identifies elements clearly with the help of software intelligence, sensors and ubiquitous connectivity to the Internet. In IoT, the data that collects from Internet-connected items or things contains with gadgets, sensors and actuators [16].

The agriculture sector in many countries especially in developing countries is facing a lot of challenges in recent years due to the need to diversify its economy and the population growth. The key gaps facing the agriculture sector in most of these countries are inability to meet domestic food requirements and the inability to export at quality levels required for market achievement [21].

The low quality farm products are considered as the results of poor monitoring and farming management. IoT has penetrated persistently most aspects of human life everywhere such as health care, smart home, smart city, industrial control and so on. Agriculture is an ideal candidate for the deployment of IoT solutions because it occurs in global areas that need to be progressively supervised and controlled [11]. IoT transforms the agricultural industry and enables farmers to overcome different challenges. Innovative applications can address these issues and therefore increase the quality, quantity, sustainability and cost-effectiveness of crop production [34].

The IoT equips the objects of interest to be detected and measured remotely over existing and coming network infrastructure, which creates various opportunities to integrate physical objects with computer-based systems. The main goals of IoT include improved efficiency, accuracy, economic gains, and healthier quality of life [38].

The IoT is the key to agricultural production expected to contribute 70% of global food production, meeting the food needs of estimated population of 9.6 billion in 2050 [8]. To attain ever increasing quantity and quality demands in modern agricultural industry, technological innovations must be sightseen. The traditional practices can be combined with modern technologies as IoT and Wireless Sensor networks (WSNs) to enable numerous applications in Modern Agriculture Domain [2].

Among these are bacterial and fungal crop diseases. Weather control and monitoring of the soil contents of the soil are also the major factor to be measured for best growth [4]. The automation process of agricultural and farming based on IoT reduce human interaction and improve the efficiency since every country population depends on agriculture thus available agricultural resources needs to be utilized optimistically [10]. IoT is pushing the future of agriculture industry to the next level and enabling farmers to cope with the massive challenges they face. New innovative IoT applications are addressing the matters in agriculture by increasing the quality, quantity, sustainability and cost efficiency of agricultural production [9].

Among the benefits IoT brings is its ability to innovate the scene of current farming techniques. IoT sensors are capable of providing farmers with information about crop yields, rainfall, pest invasion, and soil nutrition are invaluable to production and provide accurate data which can be used to advance farming techniques over time [40].

Prospering on this unlimited build-up of the IoT in agriculture, smart farming applications are gaining momentum with the guarantee deliver of 24/7 visibility into soil and crop health, machinery in use, storage conditions, animal behavior, and energy consumption level [6]. IoT will grow into an important tool in the next few years to involve people in embedded agriculture which comprises suppliers, farmers, technicians, distributors, consumers and government representatives [11].

With the improvement of agricultural sensor, wireless communication, cloud computing, machine learning and Big Data technologies, IoT technology has developed and is gradually being encouraged and applied in the secured agricultural field [13]. The IoT is a technological revolution that represents the upcoming of computing and communications, and its progress depends on dynamic technical innovation in a number of significant fields, from wireless sensors to other technologies [9]. Figure 1 below is a reviewed sample of 3-tiers IoT framework which seems to work under agricultural environment.

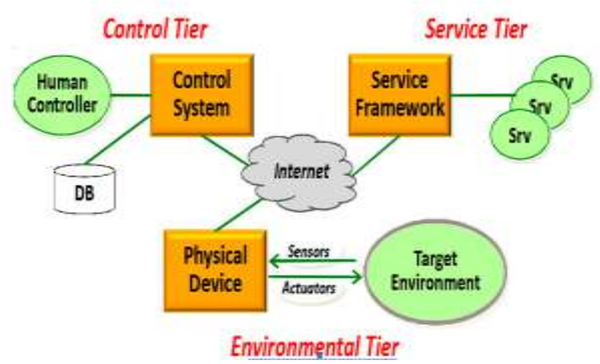


Fig. 1 Three Tiers IoT framework [12].

The remainder of this paper is organized as follows: Section II includes data acquisition technologies gathered from the reviewed studies. Section III discuss the raw data collection for the study while Section IV discuss the appraised data transmission technologies. Section V discusses the reviewed data analytics technologies. Results for the study are discussed in Section VI.

II. DATA ACQUISITION TECHNOLOGIES

Data acquisition (DAQ) is the integration of several components within the signal conditioning module, the sensing module, the output module and sometimes the control module that leads to store, manipulable digital data representations of the sensor measurement [27]. Technologies involved in data acquisition according to the reviewed studies includes the following:

A. Radio Frequency Identification (RFID) Technology.

RFID technology is a simple, unremarkable and cost effective technology of item identification that can be used to link any objects and devices to large databases and networks, and undoubtedly to the network of networks (internet) [13]. RFID technology using radio waves to recognize items is considered as the essential enablers of the IoT. Although it has sometimes been labeled as the next generation of bar codes, RFID systems offer much more in that they can track objects in real-time to produce vital information about their location and status. Early applications of RFID include supply-chain management, pharmaceuticals and e-health for patient monitoring of some vital parameters. RFID readers nowadays are being embedded in mobile phones [29]. It can work in parallel with sensor technology in collection of data and detection of changes in the physical status of things [24]. Embedded intelligence of the things themselves can enhance the power of the network by devolving information processing capabilities to the edge of the network. Finally, developments in these technologies results into the ability to interact and connect objects of related and different properties together in the so called IoT which nowadays used to change static objects of today into newly dynamic things. It also embed intelligence in our environment and stimulating the creation of innovative products and entirely new services [37]. The IoT will motivate the functionality offered by all of these technologies to realize the vision of a fully interactive and receptive network environment [19].

B. Sensor Technology

Sensor plays a vital role in capturing environment, crop and animal information and it also one of the practical bottleneck under the progress of IoT. Nowadays sensor technology has quickly developed with the coming out of new resources and techniques [12].

Three major types of sensors are extensively used in researched agricultural sensors which are physical property type sensors, biosensors, micro electro mechanical sensors. The physical property type sensor recognize the signal conversion during the physical change of the sensitivity of the material of the sensor itself, which is generally humidity, temperature and gas sensor [17]. The biosensor employ the organism itself as an insightful component to send out information due to the reaction of the organism to the outside world and includes enzyme sensor microbial sensor, adaptive sensor etc., which is mostly used to sense pesticide residue, heavy metal ion, antibiotic residue and toxic gas [22].

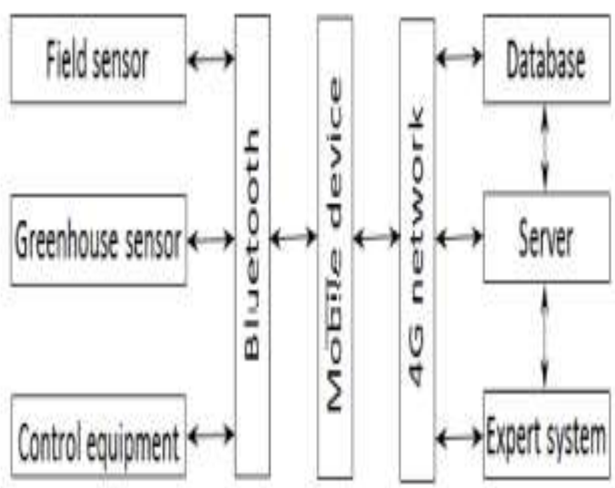
Soil pH sensor is the device that senses the pH of the soil as we need to maintain a good pH for a particular type of crop. This pH sensor keeps track of the soil pH and sends the data to server where the user can see the collected data and can use chemicals to maintain the right pH for that crop [38].

Soil Moisture Sensor works similar to soil pH sensor. The collected data is then sent to server and server will then perform required action like if the moisture is less than needed then spray pumps will be used to moisturize the soil and if the moisture is more than needed than server will adjust the temp inside the poly house to make the moisture level normal. [30].

Air temperature sensor is an IoT device that senses the temp inside the poly house and the information is then sent to the main server and the server can perform necessary operations like Switching on the Air conditioner, exhaust fans etc and spray water if needed. This will help to maintain an ideal temp inside the poly house [33].

C. Bluetooth Wireless Technology

Bluetooth technology is a wireless standard used for range transmission of data. Its working frequency range is 2.4 to 2.485 GHz. Bluetooth's data transfer rate is IMbps, using time division duplex (TDD) transmission scheme to realize full duplex transmission [28]. It can link various devices and solve problems of synchronization. It is controlled by the Bluetooth Special Interest Group (STG), with more than 25,000 member companies in the field of electronics and telecommunication, computing, networking, and electronics users. Bluetooth technology is suitable for being applied in the Internet of things in agriculture system because of its low power consumption and low latency, The 4th Generation mobile communication technology and Bluetooth technology were applied in this agriculture loT system. The Application model is shown in Figure 2.



D. Wireless Sensor Network

Fig. 2 Application of B1uetooth Technology and 4G Network in Agriculture

The WSN comprises of a numerous sensor nodes that are commonly powered by battery and it is a multi-hop self-organizing network system designed by wireless communication to collectively sense, capture and process several information of the real object in the network coverage area [12]. It can be terrestrial WSN or wireless underground sensor networks (WSN). The agricultural Sensors are normally planted into soil and lower frequency wireless technologies are selected due to low attenuation in WSN. Moreover, antenna size and energy consumption in WSN is greater than terrestrial WSN [39]. With development of LPWAN, IoT do not require a mesh-style WSN with power-based routing, from which one node forwards packets of other nodes.

III. RAW DATA COLLECTION

The whole process of collecting data for the study involves identifying some important criteria from reviewed research articles on the Internet of Things (IoT), Computational analytics (CA) and artificial intelligent (AI) in the agricultural industry. Table I summarize these essential criteria that were used to analyze relevant research papers. In particular, 40 peer-reviewed scientific publications on IoT and AI in agricultural industry published in scientific journals between 2015 and 2019 were used.

The data for this study were collected from 40 recently peer-reviewed publications (2015-2019) that were collected from different international publication journals. All these publications have different data applications that have been studied and analyzed in this survey. The attributes compared were data collection measurements, used technologies to overcome some issues, challenges in current approach, benefits and drivers of IoT. Table 1 below show the raw data collected from 40 recently peer-reviewed publications used in this study.

TABLE 1. The Raw Data Collected from 40 Recently Peer-Reviewed Publications Used in this Study.

Paper No	Year published	Technologies used	Measures	Applications
1	2016	▪ Raspberry pi ▪ RFID ▪ Bluetooth ▪ ZigBee	▪ Environmental temperature ▪ Humidity ▪ Soil moisture	In crop monitoring and management
2	2017	▪ ZigBee ▪ RFID ▪ Mobile technology ▪ Wi-Fi. ▪ Biosensor	▪ Body Temperature ▪ Body weight ▪ Positioning ▪ pH, Cl, Na. ▪ Lactate, Zinc ▪ Stress, ▪ Body weight, ▪ Toxins, Glucose, Heart rate.	In animal health monitoring and clinical management.
3	2016	▪ Wi-Fi ▪ Arduino ▪ WSN	▪ Temperature ▪ Respiration ▪ Humidity ▪ Heart beat ▪ Rumination	In animal health monitoring
4	2015	▪ Mobile technology ▪ Sensor technology	• pH level • Moisture • Temperature	In crop monitoring and management
5	2017	▪ Wireless sensor network. ▪ Mobile technology	• pH, Cl, Na. ▪ Body Temperature ▪ Body weight • Positioning • Lactate, Zinc. • Stress, • Body weight, • Toxins • Glucose, • Heart rate.	In animal health monitoring and clinical management.
6	2019	▪ Wi-Fi ▪ Mobile technology ▪ Biosensor	• Body Temperature • Body weight • Positioning • pH, Cl, Na. • Lactate, • Zinc, • Stress, • Toxins, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
7	2015	▪ Raspberry pi ▪ Mobile technology ▪ Wi-Fi. ▪ Biosensor	• Humidity • Environmental temperature • Nitrogen quantity	In crop monitoring and management
8	2016	▪ Mobile technology ▪ Sensor	• pH, Cl, Na. • Lactate	In animal health monitoring and clinical management.

		technology ▪ Wi-Fi. ▪ Biosensor	• Zinc. • Stress • Body weight, • Toxins. • Glucose, • Heart rate.	
9	2018	▪ Raspberry pi ▪ Mobile technology	• Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
10	2018	▪ Bluetooth ▪ Wi-Fi ▪ Biosensor	• Leaf diseases • Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
11	2019	▪ Wi-Fi ▪ 6LowPAN ▪ Wi-Fi ▪ ZigBee	• pH, Cl, Na. • Lactate, • Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
12	2016	▪ Mobile Technology ▪ ZigBee ▪ Wi-Fi ▪ 6LowPAN	• Fungal diseases • Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
13	2016	▪ Raspberry pi ▪ Mobile technology	• Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
14	2016	▪ Raspberry-Pi ▪ Wi-Fi ▪ Blue tooth	• Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
15	2018	▪ Wi-Fi ▪ ZigBee ▪ 6LowPAN ▪ Mobile cellular	• pH, Cl, Na. • Lactate • Zinc • Stress • Body weight. • Toxins • Glucose • Heart rate.	In animal health monitoring and clinical management.
16	2019	▪ ZigBee ▪ Raspberry Pi ▪ Wi-Fi. ▪ Biosensor	• Soil moisture • Temperature • Water level • Moisture	In crop monitoring and management
17	2019	• Wireless Sensor Network	• pH, Cl, Na, • Lactate,	In animal health monitoring and clinical management.

		• Radio Communication • Biosensor	• Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	
18	2018	• LoRaWAN • Wi-Fi • 6LowPAN • Biosensor	• pH, Cl, Na, • Lactate, • Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
19	2017	▪ Wi-Fi ▪ ZigBee ▪ 6LowPAN ▪ Mobile cellualr ▪ Biosensor	• pH, Cl, Na, • Lactate, • Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
20	2019	▪ ZigBee ▪ Wi-Fi ▪ 6LowPAN ▪ Mobile cellular	▪ Leaf diseases ▪ Soil moisture ▪ Temperature ▪ Water level ▪ Moisture	In crop monitoring and management
21	2019	▪ Android ▪ Wi-Fi ▪ 6LowPAN	▪ Soil moisture ▪ Temperature ▪ Water level ▪ Moisture	In crop monitoring and management
22	2017	▪ Raspberry Pi ▪ Wi-Fi ▪ Mobile Technology ▪ 6LowPAN	• pH, Cl, Na, • Lactate, • Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
23	2019	• ZigBee • Mobile cellular • Wi-Fi	▪ Soil moisture ▪ Temperature ▪ Leaf diseases ▪ Water level ▪ Moisture	In crop monitoring and management.
24	2017	▪ RFID ▪ Sensor technology ▪ Microcontroller	▪ Soil moisture ▪ Temperature ▪ Water level ▪ Moisture	In crop monitoring and management
25	2018	▪ Mobile technology ▪ Sensor network ▪ Wi-Fi	▪ Soil moisture ▪ Temperature ▪ Water level ▪ Moisture	In animal health monitoring and clinical management.
26	2017	▪ Biosensor ▪ Microcontroller	• pH, Cl, Na,	In animal health monitoring and

		▪ Raspberry pi ▪ Bluetooth ▪ ZigBee	• Lactate, • Zinc, • Stress, • Body weight, • Toxins, • Glucose, • Heart rate.	clinical management.
27	2017	▪ Raspberry pi ▪ RFID ▪ Bluetooth ▪ ZigBee	• Body weight • pH, Cl, Na, • Lactate, • Zinc, • Stress • Toxins, • Glucose • Heart rate.	In animal health monitoring and clinical management.
28	2017	▪ Raspberry Pi ▪ Wi-Fi ▪ Mobile Technology	▪ Soil moisture ▪ Temperature ▪ Water level ▪ Moisture	In crop monitoring and management
29	2017	▪ Raspberry pi ▪ RFID ▪ Bluetooth ▪ ZigBee ▪ Biosensor	• Glucose, • Heart rate. • pH, Cl, Na, • Lactate, • Zinc, • Stress, • Body weight, • Toxins,	In animal health monitoring and clinical management.
30	2016	▪ Mobile technology ▪ Sensor network ▪ Wi-Fi ▪ Biosensor	• Body weight, • Toxins, • pH, Cl, Na, • Lactate, • Zinc, • Stress, • Glucose, • Heart rate.	In animal health monitoring and clinical management.
31	2019	▪	•	
32	2018	▪ Wi-Fi ▪ 6LowPAN ▪ Biosensor	• Body weight, • Toxins, • pH, Cl, Na, • Lactate, • Zinc, • Stress, • Heart rate.	In animal health monitoring and clinical management.
33	2018	▪ Raspberry pi ▪ RFID ▪ Bluetooth	• Temperature • Soil moisture • Water level • Fungal deseases	In crop monitoring and management
43	2015	▪ Biosensor ▪ Microcontroller ▪ Raspberry pi	• Body weight, • Toxins, • pH, Cl, Na,	In animal health monitoring and clinical management.

			• Lactate, • Stress, • Glucose, • Heart rate.	
35	2018	▪ Mobile technology ▪ Sensor network ▪ Wi-Fi	• Water level • Moisture • Soil moisture • Temperature	In crop monitoring and management
36	2017	▪ ZigBee ▪ Wi-Fi ▪ 6LowPAN	• Temperature • Water level • Moisture • Soil moisture	In crop monitoring and management
37	2016	▪ RFID ▪ Bluetooth ▪ ZigBee	• Temperature • Soil moisture • Water level • Moisture	In crop monitoring and management
38	2016	▪ Mobile technology ▪ Sensor network ▪ Wi-Fi ▪ Biosensor	• Body weight, • pH, Cl, Na, • Lactate, • Zinc, • Stress, • Heart rate.	In animal health monitoring and clinical management.
39	2019	▪ Raspberry pi ▪ RFID ▪ Bluetooth ▪ ZigBee	• RFID • Bluetooth • ZigBee	In crop monitoring and management
40	2018	▪ Mobile technology ▪ Sensor network ▪ Wi-Fi ▪ Biosensor	• pH, Cl, Na, • Lactate, • Body weight, • Toxins, • Stress, • Glucose, • Heart rate.	In animal health monitoring and clinical management.

IV. DATA TRANSMISSION TECHNOLOGIES

Detail for data transmission technologies are discussed in this section. These technologies are basically for real-time dynamic data acquisition of agricultural information. Unlike industrial application, agricultural information acquisition is not demanding in timelines and have minor delay in the transmission process with slight effect on agricultural production. [12].

Compared with guided transmission technologies like field bus, wireless communication technology takes an advantages of low construction and maintenance cost, low power consumption and exceptional extensibility. For the time being, most organizations, manufacturers and researchers opt to build up their WSN in environmental monitoring of automatic irrigation and remote control [17]. As shown in Table 1, popular wireless technologies are summarized and the basic parameters were presented. Several vendors and research institutions have developed their private wireless devices from these wireless protocols, which has somehow increased the heterogeneity of IoT. However, wireless signals from different protocols positioned in the same band can result into mutual interference such as ZigBee, Wi-Fi and Bluetooth [22]. Wi-Fi has high communication speed with high power consumption, which is appropriate for sensor network deployment at fixed points. Bluetooth offers high security with short communication distance and high power consumption.

This makes it suitable for short time short range networking. ZigBee has advantages of low power consumption, low cost, and self-organization. Each node can under ZigBee can be used as a relay station for conveying data of adjacent nodes [31]. 4G mobile phone has a data transfer rate between a few Mbps and 100 Mbps. Users can conveniently and securely use personal communications, information systems and agricultural Internet applications through the 40 core networks. The core technologies used in 4G include orthogonal frequency division multiplexing (OFDM), software radio, smart antenna technology, multi input multi output (MIMO) and lP-based wireless networks. TD-LTE-Advanced and FDD-LTE-Advance from China are also 4G international standards [33]. Sensor data acquisition, remote control of agriculture and Agricultural disaster warning appliances are some of the possibilities in the country through the 4th generation mobile communication technology [18].

TABLE 2. Summary of the most common wireless technologies used for data transmission applied in agriculture as revealed from the study.

Wireless technology	Wireless standard	Frequency band	Network type	Transmission Range	Power	Frequency of use	Data rate
Wi-Fi	IEEE802.11a/c/b/d/g/n	2.4GHz -5-60GHz.	WLAN	20-100m	1W	14	1Mbps-6.75Gbps
Bluetooth	Formally IEEE 802.15.1	2.4GHz	WPAN	10-300m	1W	25	1Mbps-48Mbps
6LowPAN	IEE 802.15.4	908.42MHz-2.4GHz	WPAN	20-100m	1mW	10	20Kbps-250Kbps
SigFox	Sigfox	908.42MHz	LPWAN	<50Km	N/A	19	10-1000bps
LoRa WAN	LoRa WAN	Various	LPWAN	<15Km	N/A	24	0.3-50Kbps
NB-IoT	2GPP	180KHz	LPWAN	<15Km	N/A	19	0-200Kbps
Mobile Cellular	2G, GSM,GPRS,3G, UMTS, CDMA-2000,4G LTE	865MHz-2.4GHz	GERAN	Entire cellular area	1W	22	2G:50-100Kbps 3G:200Kbps 4G:0.1-1Gbps
ZigBee	IEE 802.15.4	2400-2483.5MHz	MESH	0-10m	1mW	21	250Kbps
NFC	ISO/IBC13157	13.56MHz	P2P	0.1m	1-2mW	11	424Kbps

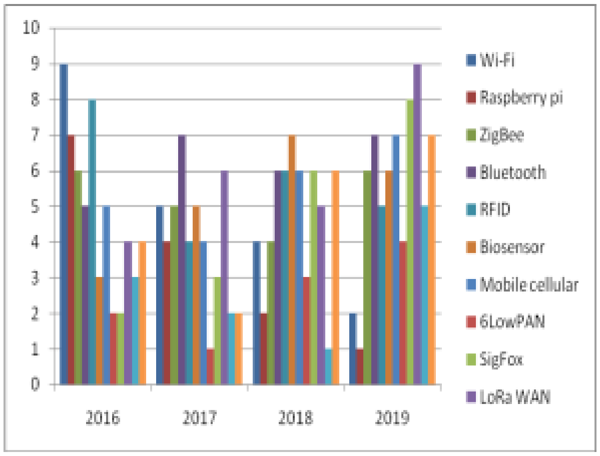


Fig. 3 Reviewed frequency of use of wireless transmission technologies from the study

Currently, the Low Power Wide Area Network (LPWAN) becomes one among the best IoT hotspots considered as a novel technology with high improvement potential indorsed to its huge benefits like very long communication distance. This can be used as a vital supplement of the traditional wireless local area network (WLAN) and cellular communication technologies like GSM and GPRS [37]. LPWAN offers a lot of technical standards classified into two groups as proprietary patented technology working under unlicensed spectrum like LoRa, Sigfox, RPMA and cellular communication technology which works under a licensed spectrum like EC-GSM and NB-IoT. Because of the use of dedicated frequency bands and unified deployment by operators, licensed spectrum technology seems to have a carrier-class security and low interference features, which produce a full network coverage and operation [29], [38].

The benefits of IoT deployments under LPWAN in agricultural environment includes the large connection distance of the LPWAN terminal device to the base station varying from numerous kilometers to tens of kilometers, overcoming the challenges of setting up and preserving routing devices. Bluetooth operates at 2.4 GHz band compared with LPWAN which adopts the sub-1GHz band to attain less attenuation and multipath fading due to obstacles and other dense surfaces such as concrete walls [19], [21]. Additionally, the sensitivity of LPWAN receivers spreads as low as –130 dBm because of modulation techniques involved like narrowband and spread spectrum. Operating at a very low power is another advantage of LPWAN achieved by duty cycling mechanism and lightweight medium access control protocols with complex tasks [23], [28].

Many LPWAN technologies also support more number of device networked by adaptive channel selection, diversity techniques, and data rate technologies [22]. It also incorporates a large number of end devices besides keeping the purchasing cost of hardware at very low [19]. LPWAN technologies also target a various set of publications with different necessities in protected agriculture and hence it should deliver some kind of quality of service (QoS) over similar underlying LPWAN technology.

V. COMPUTATIONAL ANALYTICS TECHNOLOGIES

A. Cloud Computing Technology

Cloud computing arise from dispersed computing, grid computing and parallel processing. It is an Internet-based computing system which offers software services, hardware services, platform services, infrastructure services and storage services to several IoT applications [36].

It is a vital system for dynamically deploying and redistributing a dynamic monitoring of virtualized computing as well as storage resource pools, thus providing users with platforms for computing, data storage and services that satisfy the QoS requirements [21], [27].

Cloud computing plays a vital role of promoting the improvement of agricultural IoT by providing farmers with low cost data storage services for all agricultural information such as text, image, video and others with minimum storage costs of agricultural creativities [32]. It is not easy to make straight use of these captured raw data for making decisions due to the low technical understanding of farmers. Therefore agricultural experts can make accurate decisions and give recommendations centered on quantitative analysis [24], [26]. Cloud computing can support intellectual large-scale computing systems and offer a secured platform for the development of numerous IoT applications like crop and animal health monitoring [25]. Clouds can be deployed as public, private, or hybrid to implement a private IoT cloud platform that can be used for the precision agriculture and ecological monitoring of sustainable agriculture, crops, forest and water ecosystems and the development of techniques for analysis and standardization of food products, controlling and reducing pollution, controlling of land quality, and enhancement of the public health [40],[23].

B. Edge Computing technology

Edge computing becomes a unique computing model that executes calculations at the edge of the networks [26]. In this technology, the downlink data of the edge denotes the cloud service while the uplink data represents IoT service. The edge computing technology stands to any computing and network resources between data source and the cloud computing center [30].

Since the computing tasks are partially roamed to the network edge devices, the performance on data transmission can be improved to ensure processing on real time while keep on reducing the computational load of the cloud computing center [29]. Furthermore, edge computing protects data at a very high quality because processing happens very close to the source comparing to that of cloud computing [17],[22].

C. Machine Learning Technology

Machine learning (ML) is now a smart technology for computers to simulate the learning activities of the people, continuously improve performance, attain new knowledge and put their own perfection into practice [20]. Recently ML has attained a great achievement in algorithm, applications and theory [29] and have been joined with other agricultural technologies to maximize crop yield while minimizing the applied costs [10], [13]. The most common ML algorithms are K-nearest neighbor, naïve Bayes, support vector machine (SVM) and discriminant analysis, K-means clustering, artificial neural network (ANN), fuzzy clustering, Gaussian mixture models, deep learning, decision tree algorithm etc [22].

ML can find out the internal connection between disordered, modeless and complex agricultural data, resulting into perfect predictions and deliver a theoretical foundation for agricultural decision-making. ML technology is playing an important role in crop breeding, crop disease monitoring and identification, pest and disease prediction, knowledgeable irrigation planning and agricultural expert systems [34], [37].

ML can analyze historical farm data, including the growth progress of crops under various climatic conditions and the birthright of a particular phenotype. ML technology can also discover the association procedures and then figure out the probability model to forecast genes that are most likely to take part in the appearance of a certain good quality of the plant. It can also help the breeding expert to conduct a practical breeding experiment [28], [30].

According to [19], a method for identifying the maturity of a particular intact tomato-based ML can consist of three steps which are blob-based segmentation, pixel-based segmentation and distinct fruit detection. The first two steps can consider decision trees based on the features like texture, color, shape, and size and image segmentations. Finally, the automatic detection of individual fruit in multiple tomatoes were attained by X-means clustering method. The results of the tomato detection image test reveals that, their method succeeded a recall of 0.80 over the threshold precision of 0.88.

On the other hand deep learning architecture was proposed by [22] for counting fruits based on convolution neural networks. Synthetic images was used to train the neural network so as to save time-consuming to collect and interpret relevant data. The network was trained for three periods on 24,000 synthetic images based on Adam optimizer and 100 randomly selected images were examined. The experimental results reveals that their method had higher degree of average accuracy as comparing with methods.

D. Big Data Technology.

Big Data technology can find out the internal links of captured data through data mining and other means, determine new information and offer data support for the coming operation [25]. The most frequently applied techniques to deal with Big Data technology are image processing, ML, Simulation and modeling, statistical analysis as well as Geographical Information Systems (GIS). Nowadays, with the improvement of technologies like cloud computing, ML, etc., IoT based solution can easily attain smart data processing and low cost analysis of these data in a appropriate way with higher degree of accuracy[27].

Wireless communication terminal is to capture the sensor signal transmitted through the wireless communication network to the standardized production of agricultural monitoring platform [7].

Wireless communication terminal is a GSM device that supports GPRS with a packet switching technology for GSM networks. GPRS modems do not involve a constant connection to the Internet like standard modem, since it just uses the network only at a time when there is data to be sent. GPRS provides faster data transmission and immediate connections similar to radio coverage. The GPRS Modem fully allows desktop internet applications via the mobile network. It also offers an applications like file transfer and home automation [7].

TABLE 3. Frequency of use of computational technology

S/No	Technology	Frequency of use in crop monitoring	Frequency of use in animal health monitoring
1	Cloud computing	18	22
2	Machine learning	25	15
3	Big data	16	24
4	Edge computing	19	21

VI. RESULTS AND DISCUSSION

The review was focusing to give insight in IoT, AI and CA technological trends in agricultural and farming particularly in crop and animal health monitoring and management. The gathered results from the reviewed studies are summarized in Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 of this section.

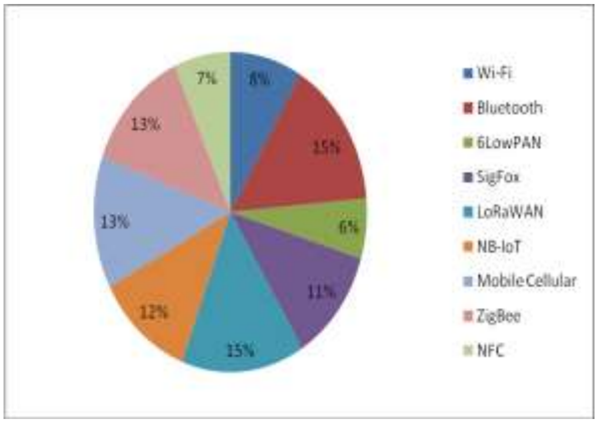


Fig. 4 Rate of use of reviewed wireless IoT technology in Agriculture

Results from the reported studies reveals that Bluetooth and LoRaWAN technologies were the most useful technologies among the reviewed technologies with (15%) followed by Mobile cellular and ZigBee technologies at about (13%) of application. However, NB-IoT technology comes the most applicable technology after ZigBee technology with about (12%). From the data collection, SigFox seems to be the next most applicable technology among the reviewed studies in agricultural industry after NB-IoT with about (11%). Moreover, from the study Wi-Fi were found the most useful technology after SigFox with an application rate of about (8%). The least applicable rate of technologies from the reviewed studies were found to be 6LowPAN and NFC with similar application rate of about (7%).

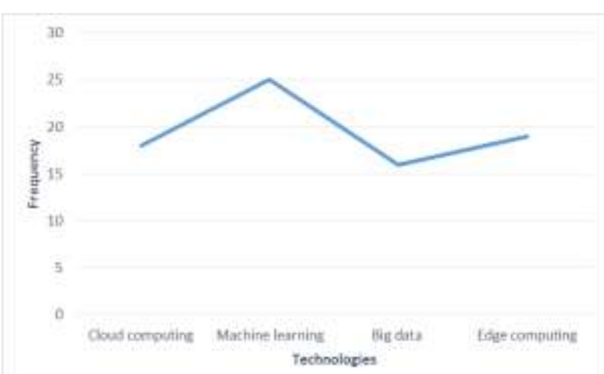


Fig. 5 Frequency of use of computational technologies in crop monitoring

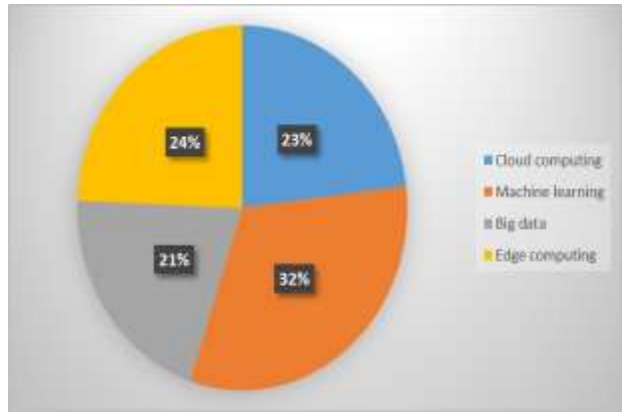


Fig. 6 Frequency of use of computational technologies in crop monitoring

Results from the reported studies also reveals that Machine Learning technologies were the most useful computational technologies in farm monitoring among the reviewed technologies with the application rate of (32%) followed by Edge Computing with the application rate of 24%. However, Cloud computing technology was happened to have an application rate of 23% followed by Big data computing technology with the application rate of 21% as expressed in figure 5 and figure 6 above.

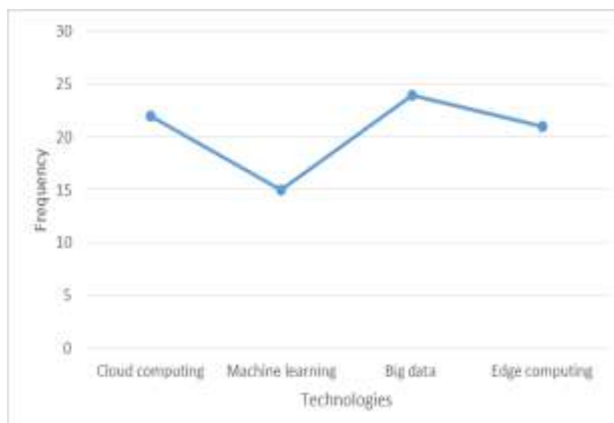


Fig. 7 Frequency of use of computational technologies in crop monitoring

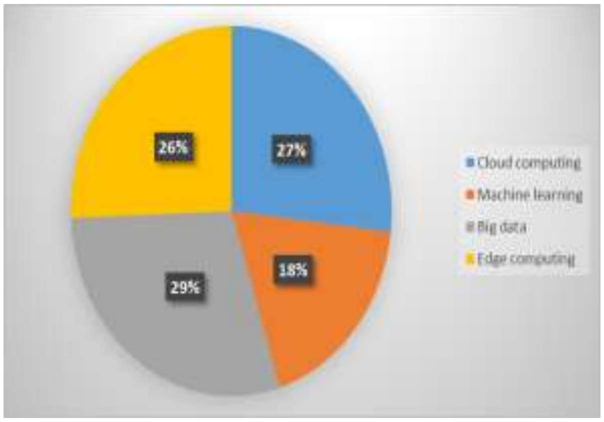


Fig. 8 Frequency of use of computational technologies in crop monitoring

Nevertheless, results from the reported studies also reveals that Big data analytics were the most useful computational technologies in animal health monitoring among the reviewed technologies with the application rate of (29%) followed by Cloud computing with the application rate of 27%. Edge computing technology was found the next after cloud computing with an application rate of 26% followed by Machine Learning technology with the application rate of 18% as expressed in figure 7 and figure 8 above.

VI. CONCLUSION AND FUTURE WORK

This study has identified some vital attributes to analyze the research findings in agriculture and farming technologies. Data were collected and analyzed based on 40 recent scientific studies. The result generally reveals that, most investigated technologies were used for the monitoring of soil nutrients, soil pH and soil moisture contents. However, adoption of these technologies on the detection of the crop and animal diseases as well as weather forecasting is not suitable for sustainable agriculture particularly in developing countries. This might be due to some identified challenges during the study. Therefore, the future research needs to be conducted on the IoT device compatibility and interoperability. Durability and lifetime of the sensors are also the key challenges to address in the future. High-speed internet connection was also discovered as a challenge especially in developing countries, the situation which hinder the adoption of these technologies in agricultural industries. More studies are also recommended on computational technologies and infrastructure to reduce computational load from the cloud and makes the accessibility of the information easier especially in constrained IoT infrastructure. However, the diverse techniques for fog computing structure, decision making using prediction or pattern analysis and big data databases should also be considered for the future study.

REFERENCES

[1] Milija Bajčeta, Petar Sekulić, Božo Krstajić, Slobodan Djukanović, and Tomo Popović, Senior "A Private IoT Cloud Platform for Precision Agriculture and Ecological Monitoring", 2016.

[2] Meenakshi .M, and Snehal. S. Kharde " Advance Cattle Health Monitoring System Using Arduino and IOT" ,2016.

[3] Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C. and Nicole, H. " Farm management systems and the Future Internet era. Computers and electronics in agriculture"2015.

[4] Yun Shi, Zhen Wang, Xianfeng Wang, Shanwen Zhang "Internet of Things Application to Monitoring Plant Disease and Insect Pests" ,2015.

[5] Olakunle Elijah ; Igbafe Orikumhi ; Tharek Abdul Rahman ; Suleiman Aliyu Babale ; Stella Ifeoma Orakwue "Enabling smart agriculture in Nigeria: Application of IoT and data analytics", 2017.

[6] A. A. Raneesha Madushanki1, Malka N Halgamuge, W. A. H. Surangi Wirasagoda and Ali Syed "Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: A Review" , 2019.

[7] Ji-chun Zhao, Jun-feng Zhang; Yu Feng ;and Jian-xin Guo "The Study and Application of the lOT Technology in Agriculture" ,2015.

[8] T.Vineela,, J. NagaHarini, Ch.Kiranmai, G.Harshitha, and B.AdiLakshmi " IoT Based Agriculture Monitoring and Smart Irrigation System Using Raspberry Pi ", 2018.

[9] Rahul Dagar, Subhranil Som and Sunil Kumar Khatri, "Smart Farming – IoT in Agriculture" , 2018.

[10] Xiaojie Shi , Xingshuang, Qingxue Zhao, Huimin Liu, Lianming Xia, Xia Sun and Yemin Guo;" State-of-the-Art Internet of Things in ProtectedAgriculture ", 2019.

[11] Karandeep Kaur, "The Agriculture Internet of Things: A review of the concepts and implications of implementation" , 2016.

[12] F Bing, "The Research of lOT of Agriculture based on Three Layers Architecture", 2016.

[13] Xiaojie Shi, Xingshuang An, Qingxue Zhao, Huimin Liu, Lianming Xia, Xia Sun, and Yemin Guo "Review State-of-the-Art Internet of Things in ProtectedAgriculture", 2019.

[14] George Suciu, Cristiana-Ioana Istrate and Maria-Cristina Dițu "Secure smart agriculture monitoring technique through isolation", 2018

[15] Pallavi S., Jayashree D. Mallapur and Kirankumar Y. Bendigeri "Remote Sensing and Controlling of Greenhouse Agriculture Parameters based on IoT", 2017.

[16] Monishanker Halder, Ananya Sarkar and Habibullah Bahar "Plant disease detection by image processing: Review", 2019.

[17] A. A. Raneesha Madushanki, Malka N Halgamuge, W. A. H. Surangi Wirasagoda and Ali Syed "Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: A Review" ,2019.

[18] Christian Dimkpa, Prem Bindraban, Joan E. McLean, Lydiah Gatere, Upendra Singh, and Deborah Hellums " Methods for Rapid Testing of Plant and Soil Nutrients" , 2017.

[19] Rolf A. Kjellby, Linga R. Cenkeramaddi, Anders Frøytlog , Baltasar B. Lozano, Soumya J and Meghana Bhange "Long-range and Self-powered IoT Devices for Agriculture & Aquaponics Based on Multi-hop Topology" , 2019.

[20] Keerthana, Nivetha P, Boomika M, Mathivatahni M and Niranjanaa "Literature Review on IOT Based Smart Security and Monitoring Devices for Agriculture" , 2018.

[21] Tejaswinee A. Shinde and Jayashree R. Prasad "IoT based Animal Health Monitoring with Naïve Bayes Classification",2017.

[22] P.Keertana and B Vanathi "IoT Based Animal Health Monitoring and Tracking System using ZigBee " ,2017

[23] T.Satish T. Bhavani and Shameena Begum "Agriculture Productivity Enhancement System using IOT", 2017

[24] Milija Bajčeta, Petar Sekulić, Božo Krstajić, Slobodan Djukanović, and Tomo Popović, "A Private IoT Cloud Platform for Precision Agriculture and Ecological Monitoring", 2016.

[25] Abdul Salam and Syed Shah "Internet of Things in Smart Agriculture: Enabling Technologies", 2019.

[26] Manishkumar Dholu and K. A. Ghodinde " Internet of Things (IoT) for Precision Agriculture Application " , 2018.

[27] Mohan C. Nikam, Suraj Wagh, Priyanka Mahajan, Devayani Waghmare, and Ketan Padewar "Animal Welfare Monitoring Using IOT : A Review", 2018.

[28] Santosh Reddy, Abhijeet Pawar, Sumit Rasane and Suraj Kadam "A Survey on Crop Disease Detection and Prevention using Android Application" , 2015.

[29] Olakunle Elijah , Tharek Abdul Rahman, Igbafe Orikumhi, Chee Yen Leow , and M. Nour Hindia, "An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges", 2018.

[30] T.Satish1 T. Bhavani and Shameena Begum "Agriculture Productivity Enhancement System using IOT", 2017.

[31] Meenakshi .M and Snehal. S. Kharde "Advance Cattle Health Monitoring System Using Arduino and IOT", 2016.

[32] K. A. Patil and N. R. Kale "A Model for Smart Agriculture Using IoT", 2016.

[33] Ravi K and Archana S "An IoT based soil moisture monitoring on Losant platform", 2016.

[34] Foughali K Fathalah K and ali Frihida "Monitoring system using Web of thingsin precision agriculture", 2017.

[35] Mahammad S and Viswanathan P "A survey: Smart agriculture IoT with cloud Computing", 2017.

[36] Rahul D, Subhranil S and Sunil K "Smart Farming – IoT in Agriculture", 2018.

[37] Mahammad Shareef Mekala , P. Viswanathan, "A Novel Technology for Smart Agriculture Based on IoT with Cloud Computing" ,International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC 2017).

[38] Dolui. K and Datta, S. K. "Comparison of edge computing implementations: Fog computing, cloudlet and mobile edge computing," Global Internet of Things Summit (GIoTS), 2017.