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Comprehensive Review of Modern Computing Paradigms Architectures for Intelligent Agriculture

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Abstract

Background and Objectives: With the increase in population in the world along with the decrease in natural resources, agricultural land, and the increase of unpredictable environmental conditions, causes concerns in the field of food supply, which is one of the serious concerns for all countries of the world. Therefore, the agricultural industry has moved towards smart agriculture. Smart agriculture uses the Internet of Things, which uses different types of sensors to collect data (such as temperature, humidity, light, etc.), a communication network to send and receive data, and information systems to manage and analyze data. Smart agriculture deals with a huge amount of data collected from farms, which has fundamental challenges for analysis using old systems such as lack of storage space, and processing delay. The Computational paradigm is a key solution to solve the problems of time delays, security, storage space management, and real-time analysis. Computing paradigms include cloud, fog, and edge computing, which by combining each of them in smart agriculture has caused a great transformation in this industry. The purpose of this article is to provide a comprehensive review of the architecture of computing paradigms in smart agriculture applications.

Methods: To achieve the goals of this article, the methodology is divided into two parts: article selection and review of the selected articles. The computational paradigms used in the selected articles are from 2019 to 2022. Each selected paper is then reviewed in detail in terms of categories of computing paradigms, architectures, key points, advantages, and challenges.

Results: Computational paradigms have significant advantages. Combining these paradigms in a complementary way covers many challenges. The architecture based on the combination of edge-fog-cloud computing is one of the best architectures combined with smart agriculture.

Conclusion: By combining computing paradigms and smart agriculture, the challenges based on traditional and old systems are overcome. Combining these paradigms complement each other's challenges.

Introduction

Agriculture plays an essential role in the global food supply chain, which is the basis of human survival. According to the prediction of the World Health Organization, the population will reach 10 billion people by 2050 [1]. Therefore, if these predictions happen, the production of agricultural products in the universe should increment by about 60% annually [2]. In the last two decades, with the expansion of the Internet, there have been unlimited changes for organizations and citizens around the universe [3]. The appearance of the Internet of Things, which is defined as a network of objects in which instruments, sensors, software, machines, and people are used through the Internet to communicate, exchange information, and interact between the real and virtual universe [4]. Internet of Things (IoT) systems also use various technologies such as Wireless Sensor Networks (WSN), cloud computing, and artificial intelligence. The Internet of Things is used in different scopes such as intelligent homes, healthcare, traffic, intelligent cities, and agriculture. Therefore, farmers, scientists, and agriculture industries have turned to intelligent agriculture, which uses methods and technologies at distinct levels and scales in the production of agricultural products.

In last years, intelligent agriculture has become very popular. Intelligent agriculture uses new technologies to maximize the use of wellsprings and minimize environmental impacts. Wireless Sensor Networks are one of these technologies that help farmers in the accumulation of information [3]. In intelligent agriculture, different sensors are used to accumulate data such as temperature, humidity, light, pressure, etc., which uses a correlation network to send and receive information, and finally, by analyzing the obtained information, it increments productivity and Minimizes waste is done at the right time and place [5]. Fig. 1, shows an example of IoT applications in intelligent agriculture. Existing sensors provide the complete status of agriculture products with accurate measurements. Based on the provided values, actuators manage agriculture processes related to beasts, crops, irrigation, etc. This can lead to predicting crop harvest, increasing production, reducing operating costs, remote monitoring, and accurate evaluation of farms [5].

Intelligent agriculture deals with plenty of heterogeneous information wellsprings.

Heterogeneous instruments and sensors accumulate agriculture information such as temperature, humidity, soil conditions, etc. Next, different actuators such as ventilation instruments, water supply systems, etc., adopt operations based on the information. With the development of science and technology, new methods and technologies have been presented in agriculture. An emerging trend is the use of the Internet of Things and Modern computing paradigms such as cloud, edge, and fog [5]. Computer-based agriculture systems have challenges such as processing acceleration, infrequent storage space, reliability, scalability, etc., which are unable to meet today's needs [6]. To solve these problems, services based on cloud services are used. Information captured by sensors is analyzed and processed using cloud services to make better decisions. Fog computing can also lead to declined network load and computing and storage in cloud servers. The purpose of this paper is to revise the existing investigation in the scope of computing technology architecture based on edge, cloud, and fog in intelligent agriculture. The structure of this work is as follows: In the second section, an overview of the concepts of computing technologies such as edge computing, fog computing, and cloud computing is presented. In the third section, the introduction of intelligent agriculture and its distinct scopes and the protocols used for correlation in it are examined.

In the fourth section, we review new investigations and describe the architecture of each of them. In the fifth section, the benefits and challenges of computing technology in intelligent agriculture are reviewed. Finally, the conclusion is given in the sixth section.

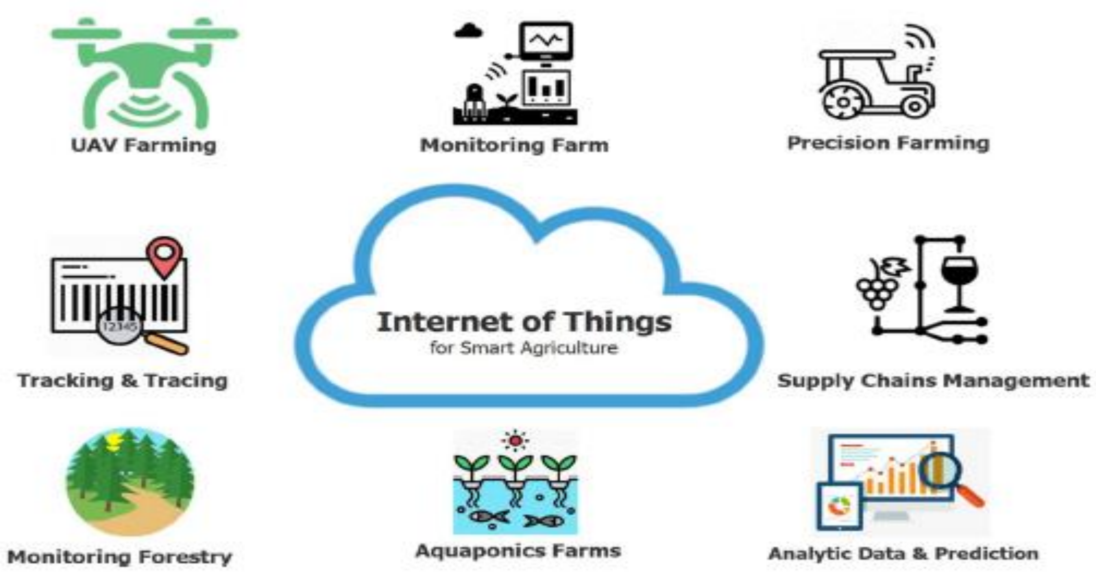

Fig. 1: Internet of Things applications in intelligent tillage [4].

An Overview of Modern Cloud Computing Technologies

A. Cloud Computing

In last years, cloud computing is becoming a principal technology in the scope of data technology. The phrase cloud computing was first used by Google and Amazon in 2006 [7]. Cloud computing is a model for easy access to computing wellsprings such as networks, servers, storage wellsprings, programs, and services through the Internet to provide access quickly and with minimum directorship requirements. Cloud computing includes five basic features, three service layers, and four distinct deployment models. The five necessary characteristics of the cloud consist of On-demand self-service, broad network access, wellspring pooling, Rapid elasticity and scalability, and measured service. A cloud must contain all five characteristics. The three service layers refer to the services provided by cloud providers and the user chooses them based on their needs. These three layers include infrastructure as a service (IAAS), software as a service (SAAS), and platform as a service (PAAS). Four cloud deployment models are also divided into Public Cloud, Private Cloud, Community Cloud, and Hybrid Cloud [8]. Clouds are formed by centralized servers that are also called information centers. Its advantages include fast deployment, cheap maintenance cost, and availability of stored information anywhere in the universe, simultaneous information analysis, and high computing power. But when dealing with big information, it has challenges such as time delay, internet bandwidth, real-time analysis, information directorship, and security [9].

B. Fog Computing

The new method of fog computing was proposed by Flavio Bonomi in Cisco in 2012 [10].

In fog computing, processing, and storage instruments are located close to every other and provide computing and storage services between end instruments and cloud computing information centers. Therefore, the basic idea is that the user's processing operations are performed in the nearby cloud and then sent to the cloud information centers. Fog computing is used for applications that require real-time processing with very infrequent time delays. Fog computing is distributed on a large scale and deployed where edge instruments perform processing [11], [12].

Fog nodes are an accumulation of nodes that receive information from IOT instruments in real-time. These nodes process the received information in less than a few milliseconds and periodically send analytical information to the central cloud. Every cloud node is equipped with internal computing wellsprings, information storage, networking, and information directorship and acts as a bridge between the central cloud layer and the edge layer [13]. The advantages of the fog node include infrequent delay, real-time interaction, mobility support, improved security, efficiency, and maintaining network bandwidth.

C. Edge Computing

Edge computing is a distributed architecture that enables computing at the edge of the network. In other words, computing is closer to the wellspring of information generation, that is, information is captured at the place where computing instruments perform analysis on them. Finally, the information extracted from the analysis is sent to the central cloud using the Internet. One of the principal advantages is that critical processes are monitored in real-time and operations are executed accordingly.

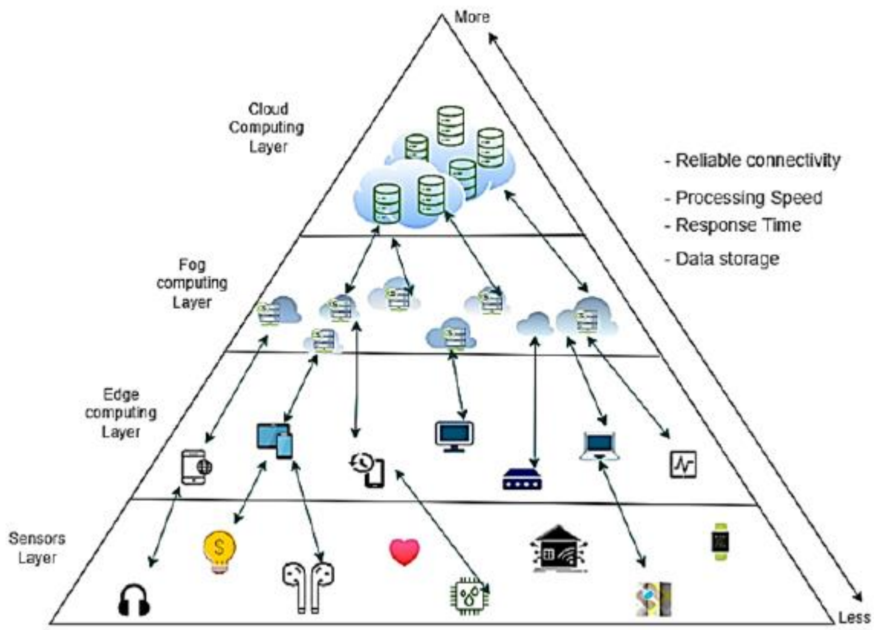

Fig. 2: Viewpoint of hybrid solutions for cloud, fog, and edge computing [14].

The advantages of using edge computing include very infrequent latency, high processing speed, and wide bandwidth.

These three computing concepts can be used in a complementary way. Fig. 2, shows an example of hybrid solutions for calculations. For instance, we can transfer easy processes to the edge nodes and assign a higher level of burdensome processing to the fog nodes and assign the processing of huge information to the cloud. The composition of these three clouds, fog, and edge computing creates maximum productivity in operations and applications [14].

An Overview of Intelligent Agriculture

A. Intelligent Agriculture

Intelligent agriculture is based on the knowledge and principles of agriculture, which uses a new method of planting, harvesting, and maintaining products and livestock products based on intelligent technologies. The purpose of intelligentization is to create a system to help decision-making in farms, which has advantages such as increasing production, saving energy, reducing manpower and increasing the efficiency of wellsprings, and improving the quantity and quality of products, etc. In intelligent agriculture, different technologies such as sensors, robots, and software are used, which provide farmers with positioning and information analysis. Farmers can monitor the ongoing activities anywhere in the universe and make the best decisions about farm activities with the information obtained from the intelligent system. Combining modern technologies with agriculture can lead to increment efficiency, and sustainability, which can have a significant impact on the universe's agricultural economy.

In last years, IoT applications have been used in different scopes of agriculture. These programs are mainly classified as agriculture programs such as crop directorship, greenhouse directorship, soil and water directorship, and livestock agriculture programs such as beast monitoring and livestock disease monitoring. In 2021, [5] categorized the main areas of intelligent agriculture into six categories, including crop directorship, beast directorship, irrigation directorship, soil directorship, climate directorship, and greenhouse directorship, which we will briefly describe below.

• Agriculture directorship: This directorship includes all the activities that are used to improve the growth and development of crop performance. Using sensors, drones, and intelligent robots, products can be managed and in case of pests and diseases, lack of water, the risk of harmful insects, etc., farmers can be informed about these harmful risks. To make the necessary decisions for better productivity of products [5].

• Beast directorship: Beast directorship includes all activities such as health, breastfeeding, breeding, which are done by farmers to raise farm beasts. To control the situation by installing distinct sensors on the beasts, their performance is checked at any moment based on specified factors, and if there is a threat, a warning will be sent to the farmers [15].

• Irrigation directorship: Irrigation directorship includes all activities that are used for proper planning and optimal use of water wellsprings. For water directorship, additional irrigation costs can be avoided by installing multiple sensors in appropriate places and leading to saving water wellsprings [5].

• Soil directorship: Soil monitoring is one of the environmental issues that have a great impact on crop production. For soil directorship, soil patterns such as humidity, temperature, deal of fertilizer, etc. are monitored. Suitable soil increments crop production [15].

• Weather directorship: Continuous weather monitoring is one of the most principal functions in agriculture. In this regard, tools are used to obtain weather parameters such as temperature, humidity, wind direction, air pressure, etc. The obtained information is used to improve agriculture productivity [15].

• Greenhouse directorship: Plants are grown in a greenhouse under controlled conditions. This directorship includes all the activities that are carried out to accurately control the environmental conditions suitable for growing plants [2].

B. Correlation Protocols in Intelligent Agriculture

In intelligent agriculture, many wireless correlation protocols are used based on the situation and available features. The instruments in the intelligent agriculture system can interact, switch data, make decisions for monitoring, control agriculture conditions, and amend performance and efficiency by using protocols. These protocols can be divided into short-range and long-range based on the correlation range. Short-range protocols include Bluetooth, ZigBee, and Radio Frequency Identification, and long-range protocols include Long Range (LoRa), SigFox, and Narrowband IoT (NB-IoT).

• Bluetooth: It is one of the wireless protocol technologies known by the IEEE 802.15.1 standard. This technology is infrequent cost and infrequent consumption and is used for transmission in a short range of 8 to 10 meters. Bluetooth acts in the 2.4 GHz frequency band [16]. Information transfer speed in distinct versions is from 1 to 24 Mbps.

• ZigBee: It is an IEEE 802.15.4 standard for wireless correlation designed for sensors and controls. This technology has a long battery life and is used for transmission up to a distance of 1 km [17].

• Radio Frequency Identification (RFID): This technology is suitable for long-range correlation. In this technology, every object has a unique identifier separately and tracks and records the location of each of them [18].

• Universe Wide Interoperability for Microwave Access (WiMAX): It is an IEEE 802.16 standard that can cover a range of 50 km radius. The information transfer speed in this technology can increment up to 1 Gbit/s [19].

• Wireless Fidelity (WiFi): It is one of the local wireless network standards that use the Internet to transmit information wirelessly. This technology is known by IEEE 802.11 standard. Currently, it is one of the most widely used wireless technology in different instruments such as mobile phones, laptops, and tablets. Its coverage range is from 20 to 100 meters. The information transfer speed of this technology can be up to 700 Mbps. Of course, in distinct Wi-Fi standards, the coverage area and speed are distinct [19].

• SigFox: It is one of the wireless cellular networks that is suitable for long-distance correlation. This is an inexpensive network technology with infrequent power consumption and limited information rate and operates in a frequency band between 860 and 920 MHz. Its coverage range is from 10 to 50 km and the information transfer speed in this technology is up to 600 bits per second.

• Long Range (LoRa): It is a long-range wireless correlation technology that has very infrequent energy consumption and operates in an unlicensed band. Its coverage range is about 20 km and the information transfer speed in this technology is up to 100 kbps.

• Narrowband IoT (NB-IoT): It is an infrequent-power and infrequent-consumption long-range correlation technology introduced by the 3GPP standardization organization. This technology acts in infrequent bandwidth and covers a range of up to 35 km. The speed of information transfer in this technology is up to 250 Kb/s [20].

• Cellular correlation: It is one of the principal correlation technologies in the applications the Internet of Things that can transmit multimedia. These technologies include 3G, LTE, 4G, and 5G versions, which have wide cellular coverage, high throughput, and infrequent latency. This technology operates in the frequency band of 865 MHz and 2.4 GHz. The information transfer speed in this technology is distinct in distinct versions, for example, in 4G, the information transfer speed varies from 100 Mbps to 1 Gbps [21].

Types of Computing Technology Architecture

In the last halls, the vast investigation has been carried out in the scope of intelligent agriculture with edge, fog, and cloud computing technologies. These investigations have distinct combinations of computing technologies that can be divided into 4 categories including intelligent agriculture and cloud computing, intelligent agriculture and a combination of edge and cloud computing, intelligent agriculture and a combination of fog and cloud computing, intelligent agriculture and a combination of edge computing- Fog - the cloud split. In the following, we will examine every of these categories in the last investigations, which can be seen in Table 1, a summary of the reviewed investigations.

A. Architecture Based on Cloud Computing

In [22], an infrequent-cost intelligent system for monitoring environmental parameters using drones and cloud computing technology is presented. In this system, it periodically gathers information using a soil moisture sensor; these sensors forward data to the gateway. Then, using a drone equipped with long-range network technology, the obtained information is sent to the cloud. Finally, in the cloud, the operation of accumulation and storing remote user information, information processing and displaying the outcomes to the user, analyzing the information obtained from the sensor, and making decisions are done. Fig. 3, shows the architecture of the suggested system. This intelligent system based on cloud computing can help farmers analyze the information on environmental conditions in large farms, leading to increment crops, better directorship, and time-saving.

In [23], an Internet of Things system based on long-range network and cloud computing is suggested for intelligent farms. According to Fig. 4, the suggested system consists of four portions namely sensor nodes, control equipment, clouds server, and a web application platform. Sensor nodes are distributed across the scopes and accumulate information about the state of the scope and send it to cloud servers for information storage and directorship. Cloud server communicates with sensors and warehouse control network using long-range network. In the warehouse control network, a Programmable Logic Controller (PLC) is used to control the process and drive instruments. The cloud server receives sensor information using long-range network gateways and stores it in databases. Farmers can remotely monitor the system using any intelligent instrument such as mobile phones and laptops through the monitoring program on the cloud server using a Web browser, control as well as review captured information. This design has outcompeted in high scalability, increment number of sensors for monitoring, increment efficiency, and remote directorship. In [24], a Wireless Sensor Network system based on cloud computing is suggested for monitoring farm beasts. This system stores the locations of livestock movements in real-time. The monitoring system includes three parts: Wireless Sensor Network, cloud platform, and user interface, as shown in Fig. 5. The Wireless Sensor Network segment includes sensors for beast monitoring. Every sensor obtains location information at a specific time using the Global Positioning System (GPS).

Table 1: Review of investigation acts based on computing technologies

Reference	Year	Suggested method	Architecture			Protocol
			Edge layer	Fog layer	Cloud layer	
[27]	2022	Monitoring system based on the Internet of Things and edge and cloud computing for intelligent farm	Sensors, Edge Gate	-	Cloud server	WSN, Wifi
[23]	2022	Internet of things system based on long-range network and cloud computing in intelligent tillage	-	-	Cloud server	LoRa
[24]	2021	Wireless Sensor Network system based on cloud computing for beast monitoring	-	-	Cloud services	WSN, 3G
[22]	2021	Intelligent system for monitoring environmental parameters in intelligent tillage	-	-	Cloud server	LoRa
[5]	2021	Cloud-fog-edge computing model for intelligent tillage	Sensors, Actuators, Tractors	Fog node	Cloud server	LoRa, ZigBee, SigFox, Bluetooth
[30]	2020	Monitoring system for fire prediction combining cloud and fog computing for environment and tillage	-	Fog node	Cloud server	ZigBee
[32]	2020	Intelligent knowledge system architecture based on edge-fog-cloud computing	Edge node, Edge gate	Fog node, Fog gate	Cloud services	-
[28]	2020	Architecture based on fog computing and long-range network technology in intelligent farm	Sensors, Actuators	Fog node	Cloud	LoRa
[29]	2020	A deep learning method to fog nodes in cloud-based intelligent tillage	-	Fog node	Cloud server	-
[26]	2020	Information accumulation method using edge computing in intelligent greenhouse	Sensors, Edge servers	-	Central Cloud	ZigBee, wifi
[25]	2019	Home edge computing architecture	Sensors, Home edge computing, Multiple Access	-	Central Cloud	LoRa
[31]	2019	Advanced system for remote tillage monitoring using long-range network and edge-fog-cloud computing combinations	End instrument, Edge gates	Fog gates, Repeaters	Cloud server	LoRa

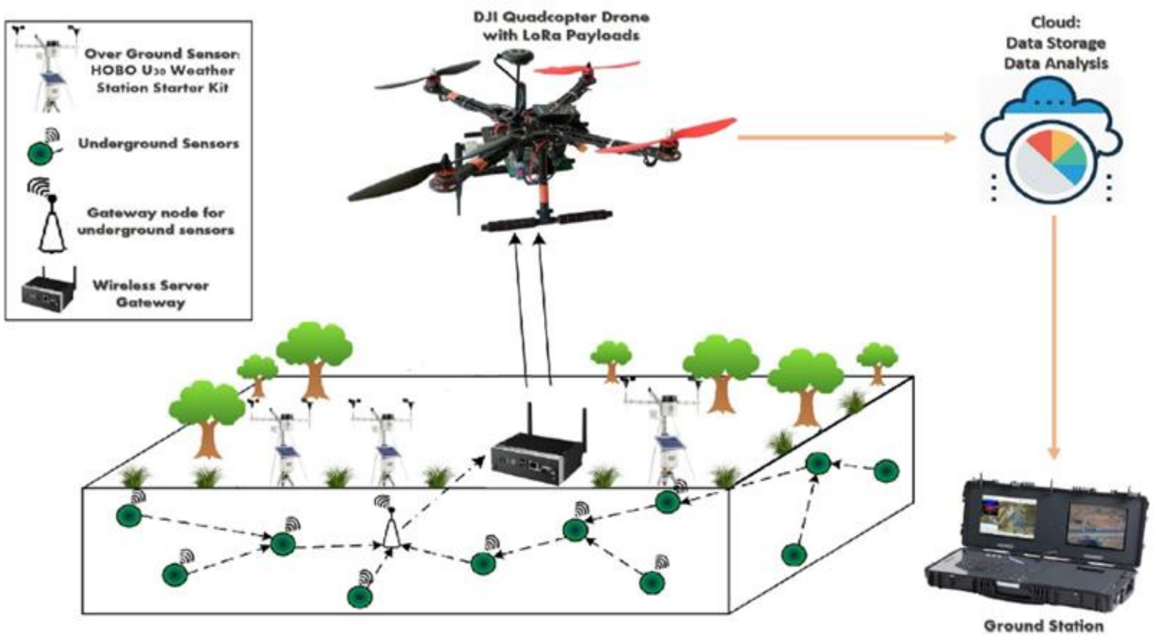

Fig. 3: Infrequent-cost intelligent system architecture for farm monitoring using UAV and cloud computing [22].

Then the information generated by the sensors is captured and sent to the second part for information storage, directorship, and processing. In the second part, processing is done on the information in cloud services, and uploads the obtained information on a web page. Cloud computing platforms provide computing power, information storage, and applications. In the third section, the user interface provides the current system status and processed information. Farm managers can check the estate of every beast through website pages and analyze the comportment of each of them using this system.

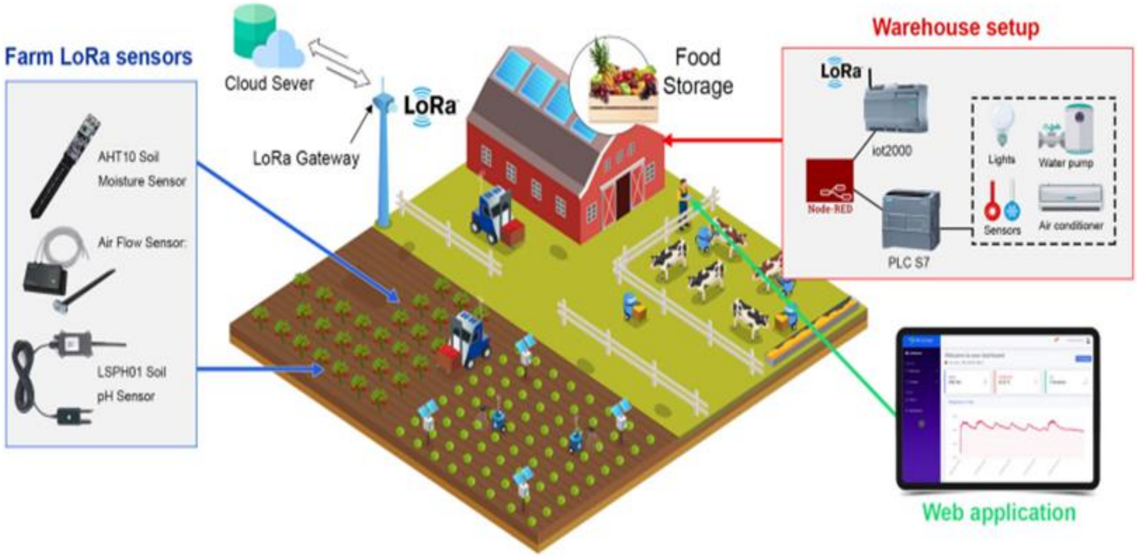

Fig. 4: Internet of Things system based on long-range network and cloud computing for intelligent farm [23].

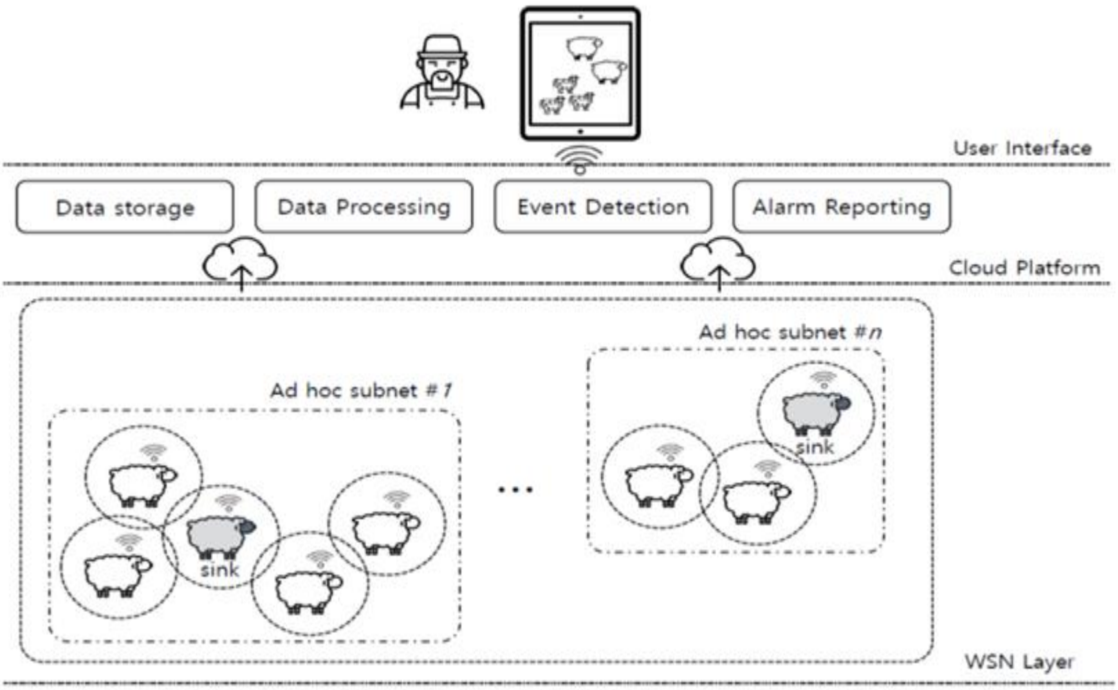

Fig. 5: Architecture based on cloud computing for monitoring beasts [24].

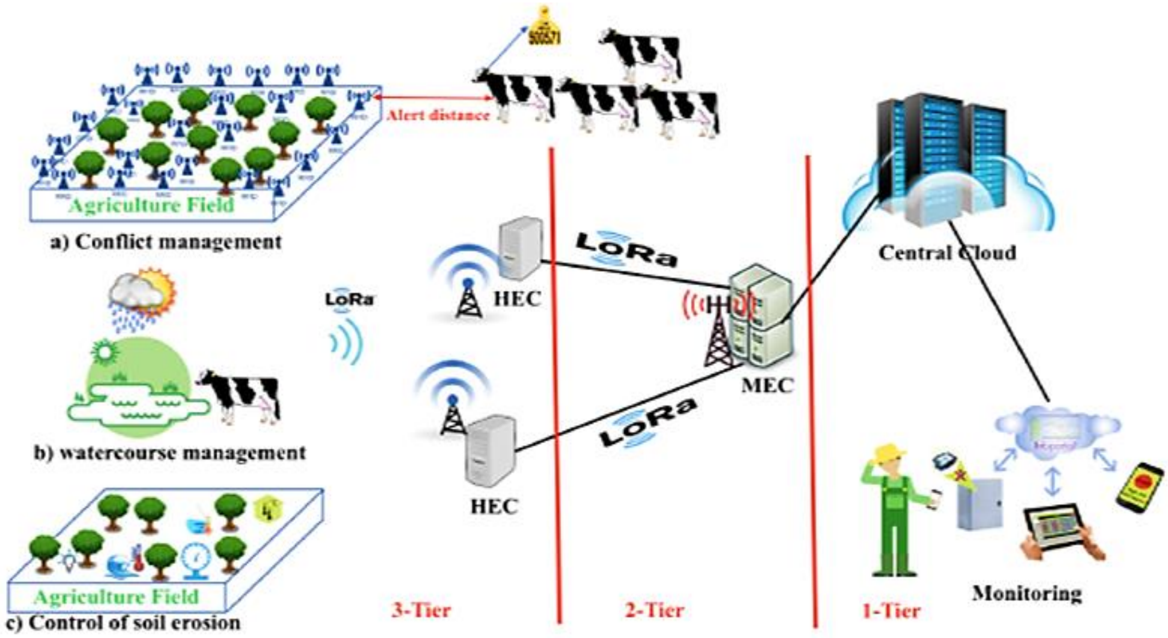

Fig. 6: Three-layer architecture of home edge computing in intelligent tillage [25].

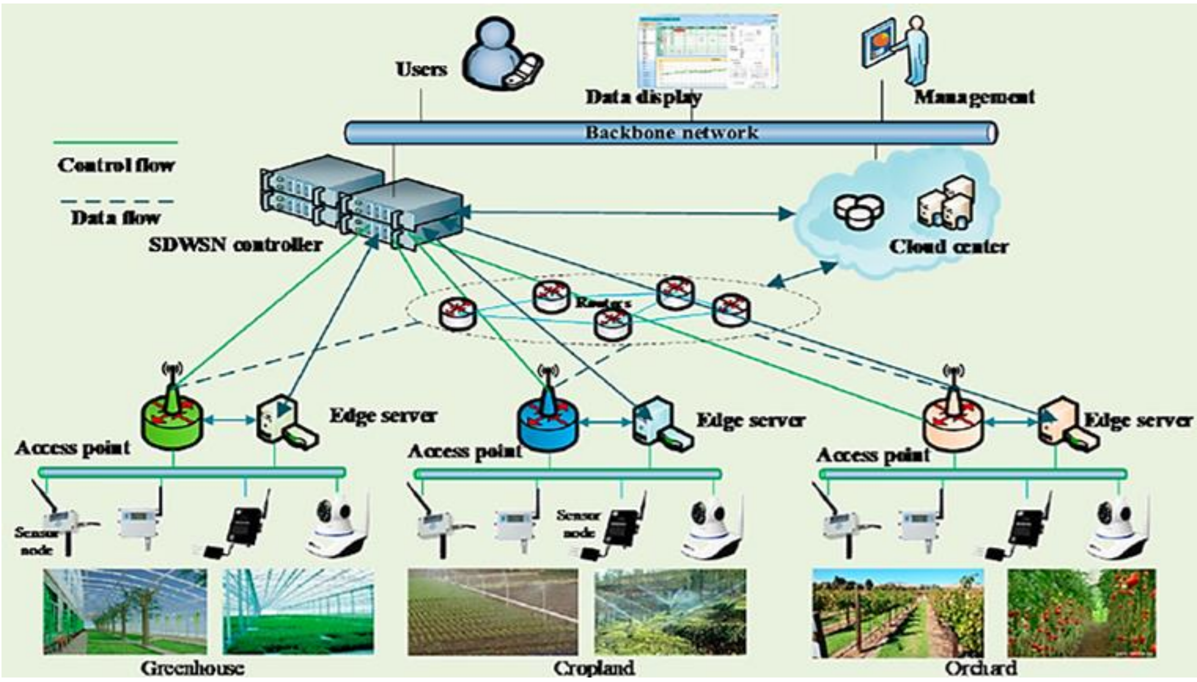

Fig. 7: The architecture of information accumulation method with the help of edge computing in intelligent tillage [26].

B. Architecture Based on a Combination of Edge and Cloud Computing

In [25], a Home Edge Computing (HEC) architecture for intelligent and tolerable agriculture and breeding is suggested. This architecture consists of three layers and is based on home edge computing. Fig. 5, shows the architecture related to home edge computing in intelligent agriculture.

This architecture includes three levels of cloud which are local cloud or home server, edge cloud, and central cloud. This architecture is suggested to solve the latency quandary in Multi-Access Edge Computing (MEC) for certain kinds of applications that require too high availability of wellsprings and must be processed with very infrequent delays. According to Fig. 6, in the third level, sensors and instruments related to intelligent agriculture are located in this layer, which is connected to a local information center called home edge computing. Home edge computing performs local information processing and acts as a gateway to higher levels. The duty of this gateway is that if further wellsprings are needed, it transfers the traffic to higher levels, i.e., multi-access edge computing at the second level and central cloud at the first level. If the distance between the two sites of multi-access edge computing and home edge computing is far, they can be connected to every other through a point-to-point radio correlation using a long-range network protocol. This architecture leads to the reduction of delay in the network.

In [26], an information accumulation method with the help of edge computing for principal events and reducing information redundancy in intelligent agriculture is suggested. This method consists of four parts including Wireless Sensor Network, Software-Defined Wireless Sensor Network (SDWSN) layer, edge computing layer, and application layer. Fig. 7, shows the architecture of this method. The Wireless Sensor Network layer includes different sensors in the scope of agriculture and access points. The function of access points is to create effective links between sensors and edge servers in the cloud. Software-Defined Wireless Sensor Network layer has been used to increment the flexibility of the system for information accumulation. By using cloud computing, information processing, and storage capacity are provided for the application layer. Cloud-based applications are also divided into categories of information visualization, user demand analysis, and system directorship. The overall method as shown in Fig. 7, is that the cloud server obtains the characteristics of principal events by analyzing and processing the information. Then, the edge server determines the information received from the sensors and the feature value of principal events and performs optimization on the information based on the features of the principal event, and the corresponding information is sent to the Software-Defined Wireless Sensor Network. In the next step, the sensor nodes receive the information related to the measured information and the correlation parameters considering the principal events from the Software-Defined Wireless Sensor Network. In the next step, the Software-Defined Wireless Sensor Network sends control streams including information accumulation commands and principal parameters to the access points. Next, this information is sent to cloud centers for directorship. Finally, by checking the information on the clouds, the outcomes are sent to the application layer. This method leads to a reduction in correlation time and infrequent delay in the information accumulation system.

In [27], a hybrid monitoring system based on the Internet of Things and edge and cloud computing is suggested for an intelligent farm. This system has 3 main layers including an accumulation layer, a decision layer, and an application layer as illustrated in Fig. 8.

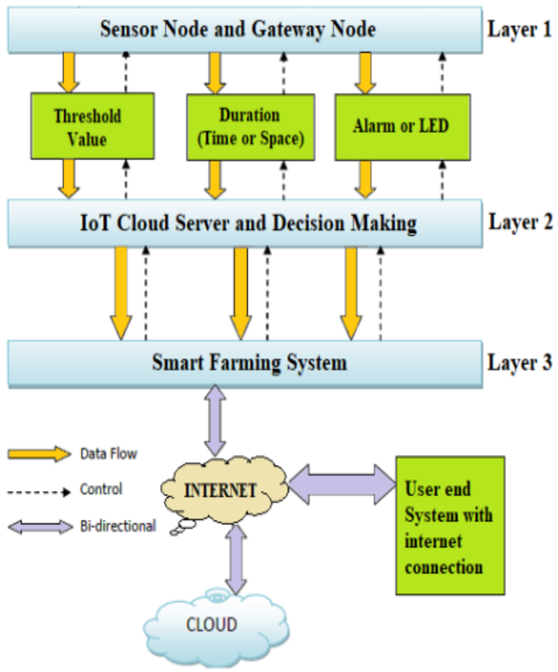

Fig. 8: Architecture of hybrid monitoring system based on edge and cloud computing [27].

In the first layer, sensors are deployed in distinct monitoring locations. All sensing data from distinct scopes in the scope is captured and stored using wireless network gateway nodes at the edge. Then the sensor information is sent to the second layer for decision-making and storage in the cloud server. In this layer, values are defined as threshold limits for all types of sensors. At a certain time, this layer examines all the obtained data using threshold values and makes appropriate decisions. Finally, in the application layer, related decisions for different scopes are communicated to the end user through SMS, email, and website. The user can access the website anywhere in the universe and make an effective decision to monitor the farm. This system leads to increasing production, increasing productivity, reducing the cost of producing products, and increasing the speed of processes.

C. Architecture Based on a Combination of Fog and Cloud Computing

In [28], an architecture based on fog nodes and long-range network technology is proposed to optimize the number of sensors deployed in an intelligent farm. Fig. 9, shows the architecture based on fog nodes and long-range network technology. According to Fig. 9, the sensors and actuators in the smart farm are connected to fog nodes.

The role of the fog node in this architecture is to create a bridge between the sensors and the network and is located as a local server near the data source. It also manages data collected from sensors. Then, in the next step, the fog nodes transmit only the important information to the cloud via the Internet. In this proposed architecture, the fog nodes process and store the generated data of the sensors locally and prevent all the information grown from the sensors from moving to the cloud. This action reduces network delay and information processing can be done in real time. The use of fog computing in this architecture has improved real-time processing, reduced latency, and saved bandwidth.

In [29], a deep learning method for fog nodes in intelligent agriculture based on cloud computing is suggested. The target of this technique has been to minimize the response latency and further processing of deep learning tasks for intelligent agriculture applications. This method consists of several layers and every layer deal with the input information from the prior layer to extract features and produce an outcome to deliver to the subsequent layer.

The lowest layer handles the incoming pure information and the highest layer provides the processed data at the output. Every layer declines the information volume for delivery to the subsequent layer. Fig. 10, shows the general picture of the deep learning method in intelligent agriculture. A cloud server assigns several layers of the deep learning model to fog nodes and maintains the remaining layers. Every instrument has information related to the fog node close to it, and at the request of applications, it transfers the captured information to the corresponding fog node. By receiving raw information from instruments, a fog node performs the defined layers of the deep learning model corresponding to an application. After the deep learning layers process is completed in the fog node, the outcomes are sent to the central cloud server, which performs the remaining deep learning layers for the outcome. As further layers are assigned to the fog nodes, the deal of information sent to the cloud through the network decreases, and eventually the network congestion and computing load on the cloud are declined.

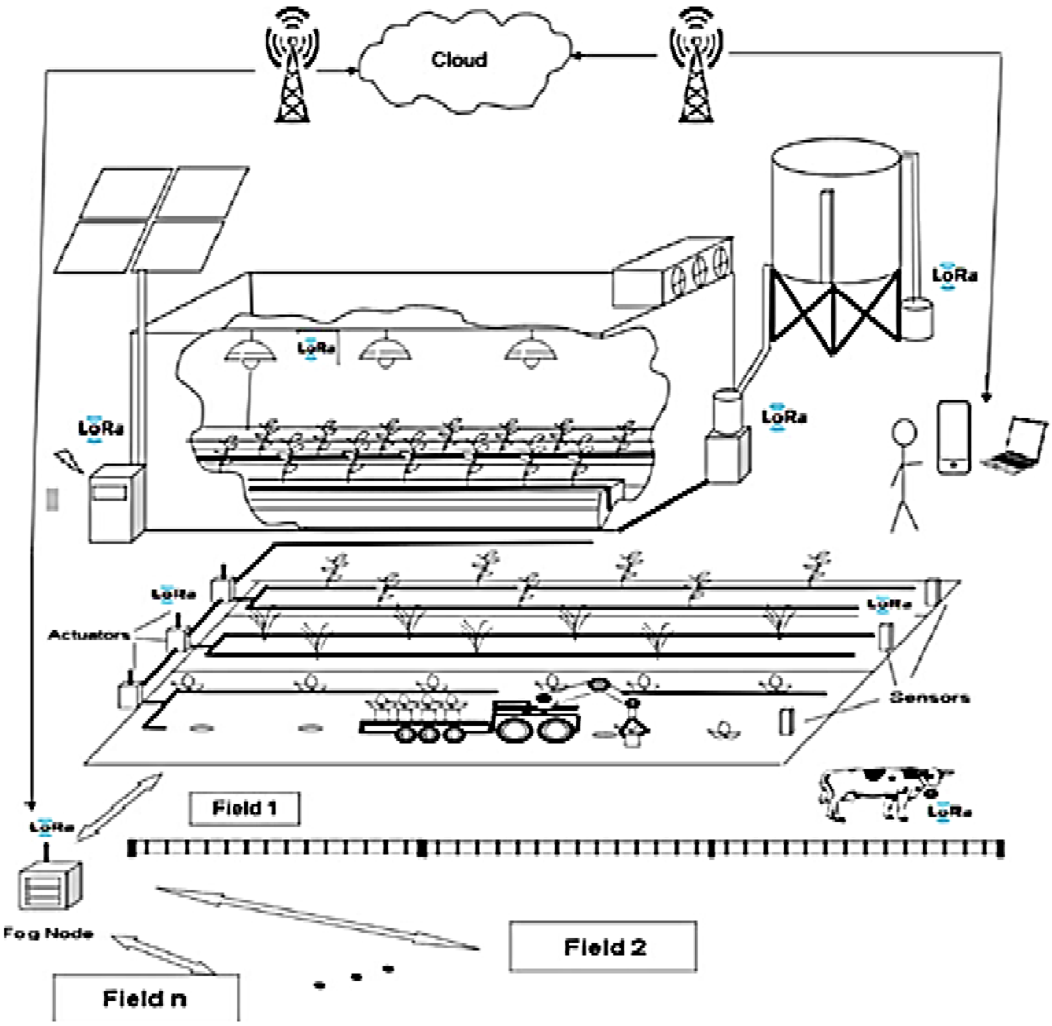

Fig. 9: Architecture based on fog node and long-range network technology in the intelligent farm [28].

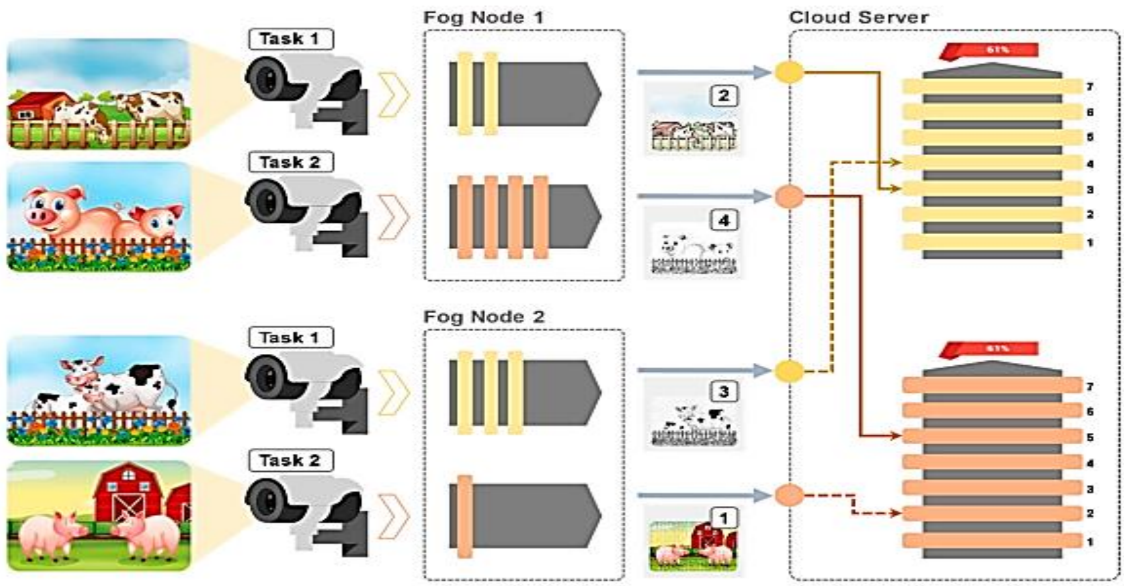

Fig. 10: The overall pcture of the deep learning method to fog nodes in intelligent tillage [29].

In [30], an Internet of Things system based on a Wireless Sensor Network with a combination of cloud and fog computing is suggested for fire prediction and early detection in the environment and agriculture sectors. This suggested system has 3 layers as illustrated in Fig. 11. The first layer consists of a cloud infrastructure formed by information centers that are dynamically allocated facilities and wellsprings based on user's requests. The services of this layer include information storage and processing. At the second layer is cloud computing, which can work as small information centers that are more inexpensive and more accessible, extending service delivery to the edges of the network. This act declines the computational load, frees up wellsprings, prevents network traffic, and increments system capacity. In the third layer, fire directorship events are addressed using agriculture and environmental monitoring programs. For example, there are instruments called sensory nodes that monitor environmental factors such as temperature and humidity. Next, using a sink node accumulations information from sensors and transmits them to higher layers for more calculations. Finally, end users such as farmers, fire services, etc., through graphical user interfaces, intelligent instruments, or mobile phones, perform the necessary actions in emergencies. Using fog nodes can decline latency, increment throughput, and control energy consumption.

D. Architecture Based on a Combination of Edge-Fog-Cloud Computing

In [31], an advanced long-range grid-based system using a mixture of edge, fog, and cloud computing is suggested for remote agriculture, which is also applicable for use in remote areas that are developing.

The architecture of this system includes five layers, including the sensor layer, edge layer, fog layer, cloud layer, and final layer, as shown in Fig. 12. This system should be used for situations that have infrequent power transmission and long-range with limited information rate. The sensor layer includes several groups of sensor nodes and actuator nodes. These nodes are deployed in distinct areas of the farm according to their applications. The sensor nodes send the captured information to the edge gateways at the edge layer, while the actuator nodes receive commands from the edge layer for control. In the second level, the edge layer consists of edge gateways and is responsible for receiving information from sensor nodes. Then, after processing the information in this layer, the processed and compressed information is sent to the fog gateways in the fog layer. The edge layer has many benefits including fast notification, channel categorization, and security. The edge layer and the fog are connected to every other through broadband network technology, which can transmit information at an infrequent speed of 10 to 20 kilometers. On the third level, the fog layer, includes two parts, repeaters, and fog gates. In this layer, the information sent from the edge gateways is received and sent to the fog gateways. The section of repeaters is used to maintain the correlation link so that packets are not lost to transmit information over long distances. The fog gateways section is also used to share sensor information. The advantages of this layer include advanced services such as distributed information storage, information fusion, information processing, and security. At the fourth level, it consists of the cloud layer, which includes cloud servers and their services, such as global information storage, major information analysis, and information processing with complex algorithms. The final layer, also called the end-user layer, includes mobile phone and web browser applications that are used to access real-time information and provide input commands for remote farm control.

In [32], an intelligent knowledge system based on a combination of edge, fog, and cloud computing is suggested for farmers to use in intelligent farms. This system helps farmers in making decisions to increment the production and profits of crops. Farmers can connect with this system using mobile applications and web applications and receive the required information from expert experts. Fig. 13, shows the architecture of the intelligent knowledge system. This system includes five layers, including the agriculture surroundings layer, edge computing layer, fog computing layer, cloud computing layer, and intelligent user interface layer. In the agriculture environment layer, sensors are used to monitor environmental parameters. This layer accumulates information from sensors and sends it to the node in the edge computing layer. The edge computing layer, also includes an edge node that accumulates the information sent by the sensor node and processes them. Using this layer in the network has the advantages of reducing delay and reducing traffic in the cloud network. The fog computing layer, it includes fog nodes, which are in the appearance of servers and storage instruments. This layer has three operations of information accumulation, information display for analysis, and knowledge generation for farmers.

The task of this layer is to classify and filter information so that the deal of information transmissive to the cloud is declined and information processing is close to knowledge production. Then the information is sent to the cloud computing layer. In this layer, different information of the sent information and agriculture land are stored, which are performed on them and stored in it. Finally, the intelligent interface layer, is an interface between farmers and the intelligent agriculture system. Users can act with the intelligent farming system using web pages or intelligent phones to get comprehensive data about the agricultural land under observation. The suggested system by using the combined computing of edge, fog, and cloud has brought advantages such as increasing efficiency, reducing delay, reducing cost, high scalability, and increasing speed and security in intelligent agriculture.

In [5], a computing model based on cloud fog edge is suggested for intelligent agriculture. In this model, the cloud layer is used to store information, analyze information in huge volumes, and upload algorithm and information analysis tools to the fog node, storing backup information for future analysis. On the second level are fog layers that are installed on local farms. This layer is responsible for real-time information analysis, decision making, and information reasoning. After analyzing and processing the information, it is sent to the cloud layer for more analysis and backup. The third level, which is the edge layer, consists of end instruments, tractors, sensors, and actuators. In Fig. 14, the architecture of this computational model is shown.

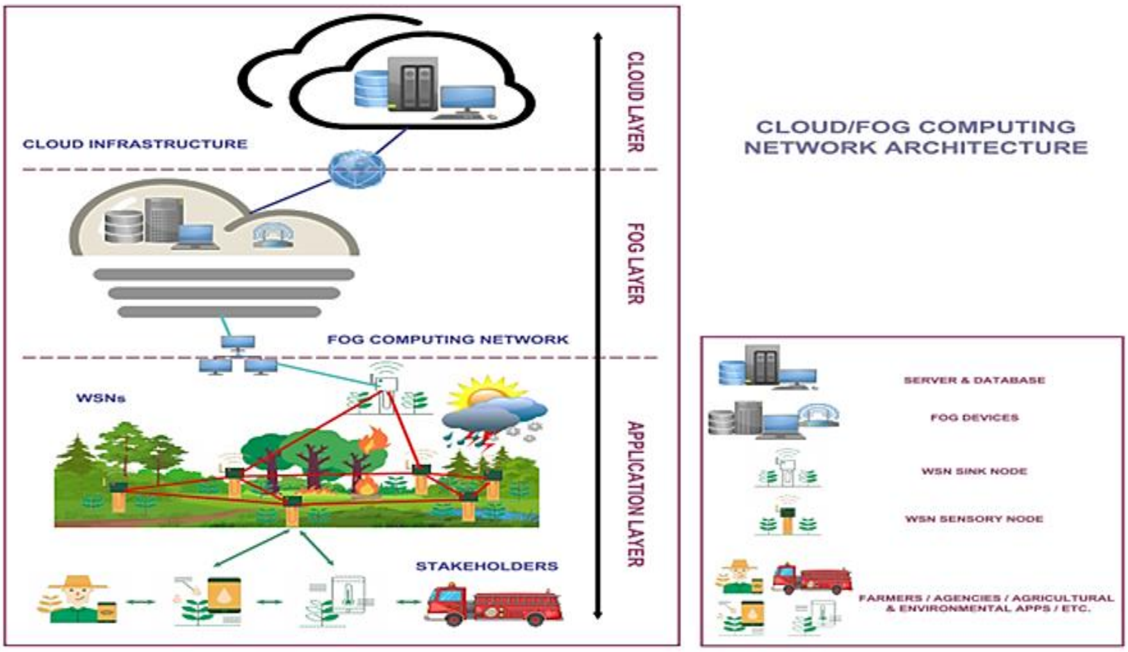

Fig. 11: Architecture of the Internet of Computing Objects with the combination of cloud and fog for environmental and tillage monitoring [30].

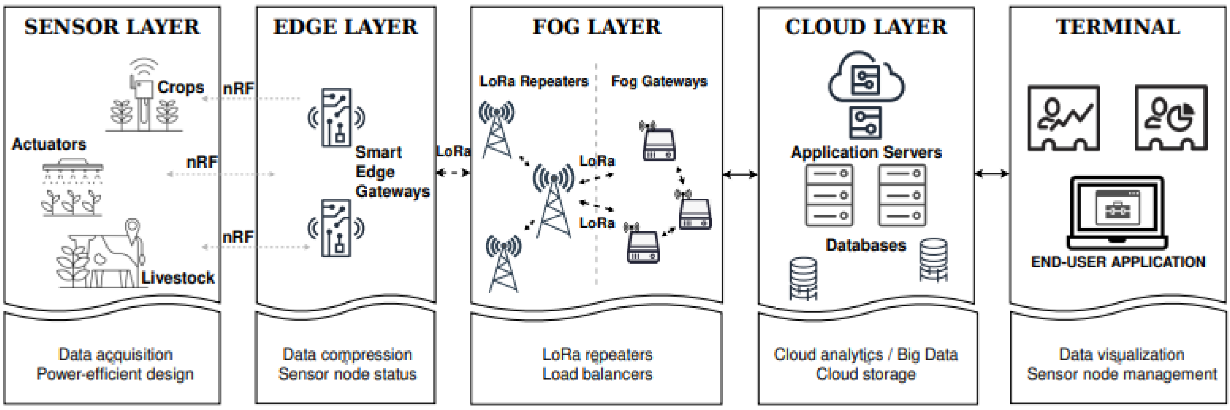

Fig. 12: Advanced system architecture based on a long-range network with a mixture of edge, fog, and cloud computing [31].

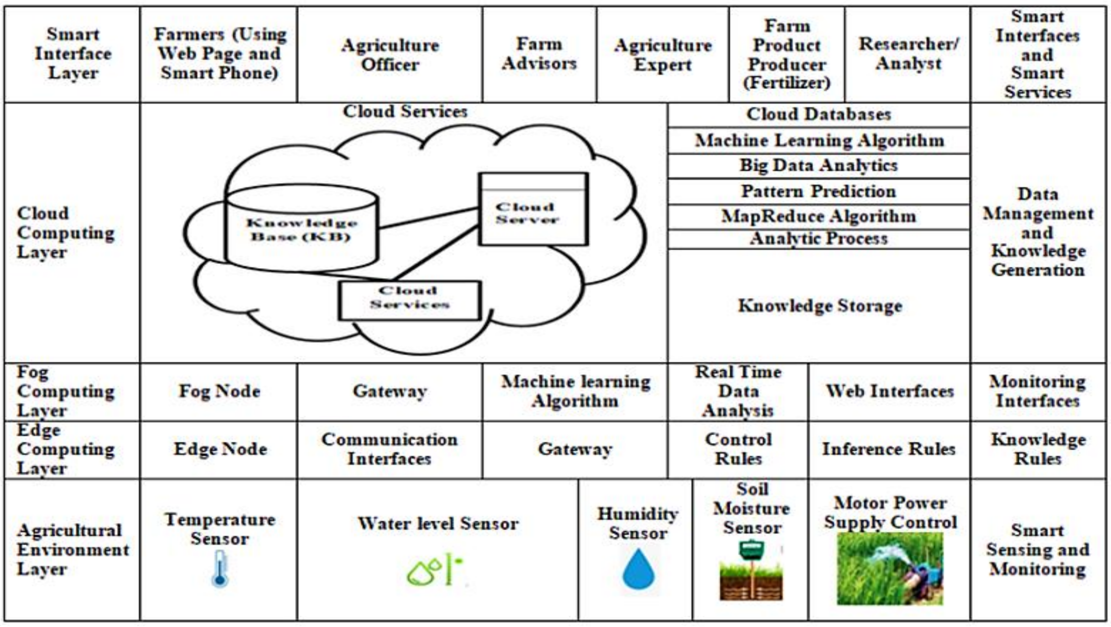

Fig. 13: Intelligent knowledge system architecture based on edge, fog, and cloud combinations [32].

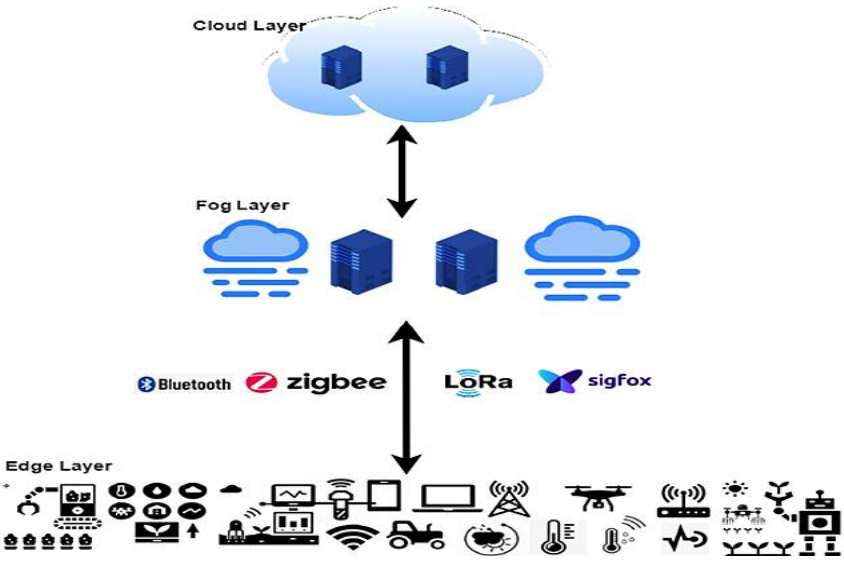

Fig. 14: Three-layer architecture based on cloud-fog-edge calculations in intelligent tillage [5].

Advantages and Challenges of Computing Technology in Intelligent Agriculture

Edge, fog, and cloud-based technologies have significant advantages in the agriculture sector. Some of its advantages are 1- the improvement of information directorship which is done by the service provider and categorizes the information in an organized manner, 2- users can access the information at any moment and position, 3- the user is free from repair and Infrastructure maintenance is safe because service providers are responsible for technical issues, 4-building and improving the supply chain of agriculture products, mentioned [33]. In contrast, these technologies also have significant challenges. Among these challenges are 1-security and privacy, which may cause great economic losses to farmers and industries if the information stored in the cloud servers is transferred outside. 2- intelligent farms should not go to the cloud for information analysis depend because it is not suitable for real-time information processing, 3- Intelligent farms need fast support and real-time information processing to be able to accumulate more information from farms, which is not possible just by connecting to the cloud, 4- Poor internet is one of the main challenges are in intelligent farms, because it can cause information loss, delay in information processing, decrease the speed of information loading, he pointed out [5]. Using fog and edge computing, problems caused by real-time processing, reducing delay and increasing bandwidth, increasing information security, and local information processing can be solved.

Conclusion

Agriculture is one of the principal parts of the universe's economy and human life. Intelligent agriculture using the Internet of Things tries to decline the problems of traditional agriculture and increment the production of agriculture products and accumulate information about the current situation for farmers. With the emergence of new technologies such as computing technologies and their combination with intelligent agriculture, the challenges of intelligent agriculture based on old systems will be overcome. In this article, the architecture of edge, fog, and cloud computing technologies, advantages, and challenges of this technology were investigated. These computing technologies can complement every other and cover many challenges. Smart agriculture can solve the challenges of traditional agriculture, but it faces many challenges, including the energy of sensors and the challenges of deploying sensors and data security. In this article, the challenges of smart agriculture were examined and the work that can be done in the future to solve these challenges was explained.

Author Contributions

Mojtaba Farmani, Saman Farnam and Zahra Shirmohammadi contributed to the idea, review, writing and editing paper. Mohammad Javad Khani writing and editing paper. Zeinab Torabi and Zahra Shirmohammadi edited/reviewed the paper.

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Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

Abbreviations

IAAS	Infrastructure As A Service
SAAS	Software As A Service
PAAS	Platform As A Service
SDWSN	Software-Defined Wireless Sensor Network
PLC	Programmable Logic Controller
HEC	Home Edge Computing

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