



Review on improving Services in Agriculture Using Internet of Things (IoT) with Fog Computing

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ABSTRACT

Smart farming management systems that are based on Internet of Things have emerged as an outcome of the growing availability of affordable IoT devices. Smart Agriculture is a rigorous strategy that uses communication and information facilitated by technology to keep an eye on farms. With the current advancements in fog computing, the IoT, and information and communication technology (ICT), tiny, intelligent devices are becoming a part of people's everyday lives to improve their quality of life by minimizing labour-intensive tasks. A smart agricultural system that makes use of the IoT facilitates intelligent and seamless communication between agricultural devices and computing components, thereby modernizing agriculture. Cloud resources are typically used to process the sensing data from agriculture equipment in order to assist smart agriculture systems. However, the unreliable and lengthy connections between cloud data centers and agricultural devices pose a challenge to the high quality-of-service (QoS) of farm systems. Beneficial data collecting, extremely accurate control, and automated monitoring techniques are all provided by the smart agriculture technology. The IoT-assisted fog-based concept that promises to deliver an affordable smart agriculture system was the main focus of this study. Fog platforms enable the effective processing of data generated by IoT devices across smart agricultural systems by bringing compute and storage closer to the network's edge.

1. Introduction

Agriculture contributes significantly to the global food supply chain in addition to being a significant source of revenue. It is necessary to ensure human survival. However, a number of issues, including population expansion, increased industrialization, and climate change, impede agricultural progress [1]. According to UN estimates, there will be a population of 9.7 on the earth by 2050. If these prognoses are exact, once a year worldwide crop production will need to increase by over 60% over 2010 and 2050. To address this requirement, agriculturalists, experts, agronomists, and the cultivation sector employ cutting-edge technologies including drones, IoT, big data, AI, and cloud computing. Recently, the terms "smart farming," "smart agriculture," and "precision agriculture" have become more common [2, 3,4]. Because both concepts are commonly seen as equivalent, the phrases are comparable. Astute farming optimizes resource adeptness while reducing ecological impact by utilizing state-of-the-art agricultural technologies. Currently, sensors are capable to offer tremendously accurate yield condition measurements. Based on those values, actuators can regulate agricultural operations involving crops, cattle, orangeries, moisture, soil, and climate. Harvest forecasting, weather prediction, increased output, water conservation, real-time data collection and production, lower operating expenses, accurate farm and field appraisal, equipment monitoring, and remote monitoring are all possible outcomes of this. Smart agriculture is continuously linked to a wide variety of data sources, such as self-directed tractors, threshers, robots and drones, sensors, and actuators. Assorted sensors and other devices amass soil parameters, pH, humidity, and other relevant agricultural data. In a similar vein, it takes into account the use of different actuators, including irrigation

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sprinklers, airflow systems, lights, automatic windows, and pumps for water and soil feeding that react in line with the information. An increasing number of cloud-based physical and autonomous agricultural systems are serving to attain a variety of monitoring and analytical ideas [5]. Smart agriculture, which uses information and communication technology (ICT) to effectively address problems in rural areas, such as the labor shortage, has been used in many countries in the past. More recently, smart agriculture has attempted and implemented total automation, utilizing other contemporary technologies like big data, the IoT and AI, cloud, and fog to improve farmers' quality of life [6, 7].

This work offers a summary of how integration of IoT with Fog computing enhance the services of agriculture. Also present a compressive survey related to traditional way of agriculture facing various challenges. Paper divided in to sections. Section I is the introduction related to importance of agriculture and with technology. Section II overview of IoT and Fog Computing. Section III Literature review. Section IV discussed challenges faced in agriculture and at in the last section V discussed about the applications.

2. Internet of Things

Essentially Internet of Things also known as IoT is the network of physical objects these objects are considered as devices, appliances, vehicles, edifices, and other items—that are united with integrated circuit technology, software, sensors, and network connectivity to consent them to collect and disseminate data. By making it conceivable to identify and oversee substances at a distance using the existing network substructure, the IoT produces openings for more unswerving incorporation of the physical world into computer-based systems, subsequent in boosted competence and accuracy. An expressly designed Coke machine at Carnegie Mellon University was the first appliance to be allied to the internet when the idea of a network of smart devices was primarily explored in year 1982. It could give details about its portfolio and if anew filled drinks were cooled. The phrase "the Internet of Things" was lay claim to by British technical pioneer Kevin Ashton in 1968 to mention to a system in which ubiquitous sensors connect the Internet to the physical world. Kevin Ashton expresses the Internet of Things as a network of interconnected, uniquely identifiable items that make use of radio-frequency identification (RFID) technology when he at first introduced the idea in 1999. The specific definition of IoT, nevertheless, is still up for debate and depends on the viewpoints used.

The IoT denotes to the next generation of the Internet in which actual objects can be accessed and identified via the Internet. The definition of the Internet of Things changes depending on the different technologies used for its implementation. Nonetheless, the foundation of the Internet of Things suggests that items can be exceptionally identifiable in virtual representations. Everything in an IoT can communicate data and, if necessary, process it using pre-established protocols.

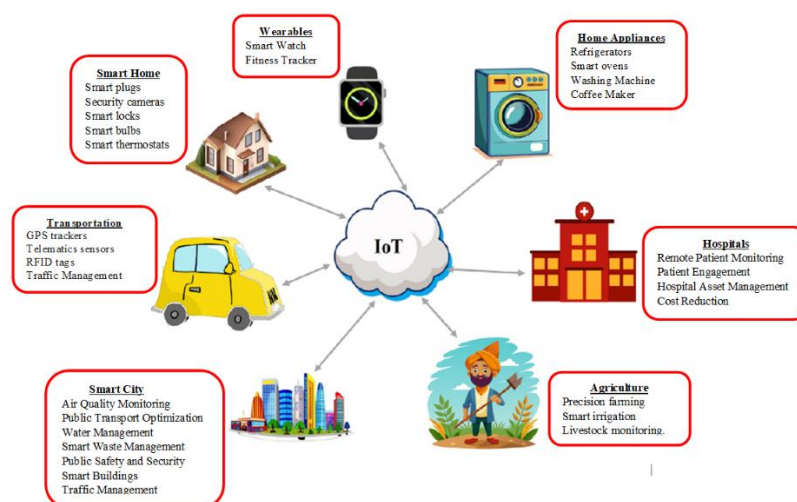


Fig1: IoT Devices and their uses in different Areas

3. Fog Computing

Cisco realises fog as an extension of cloud computing from the network's core to its edge. Networking, storage, and computation amid endpoints and traditional cloud servers are made laid-back by this extremely virtualized architecture. "A set-up where a enormous quantity of assorted pervasive and distributed devices interconnect and possibly collaborate among themselves and with the network to achieve storage and processing tasks deprived of the mediation of third parties" expresses fog computing. These duties could be associate new facilities and apps that operate in a sandboxed environment, or they could be supporting.

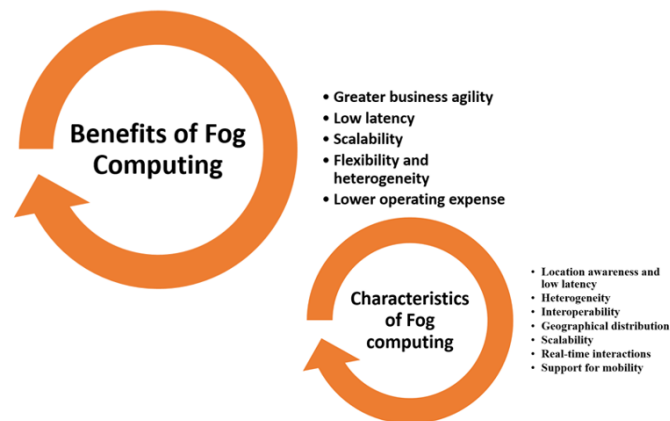


Fig2: Benefits and features of Fog Computing

fundamental network functions. Incentives are given to users who lease a portion of their devices to host these services. In order to overcome the drawbacks of cloud-centric designs, which include latency and bandwidth inefficiencies, fog computing has emerged as a revolutionary option for real-time data processing in IoT-based agricultural systems.

A technique called fog computing moves some of a data centre's processes to the network's edge. Beyond end devices and the traditional cloud technology data centers, the fog offers restricted networking, compute, and storage capabilities in a scattered way. Providing low and foreseeable latency for time-sensitive Internet of Things applications is the main goal of fog computing. The structural design of fog is characterized by its close proximity to data sources, mobility support, real-time data processing capabilities, and capacity to function in a heterogeneous environment with a diverse array of devices and applications. Fog computing makes use of these characteristics to enable a scalable, responsive, and context-aware infrastructure that can satisfy the needs of contemporary IoT services and applications, where prompt decision-making and local data processing are essential[9].

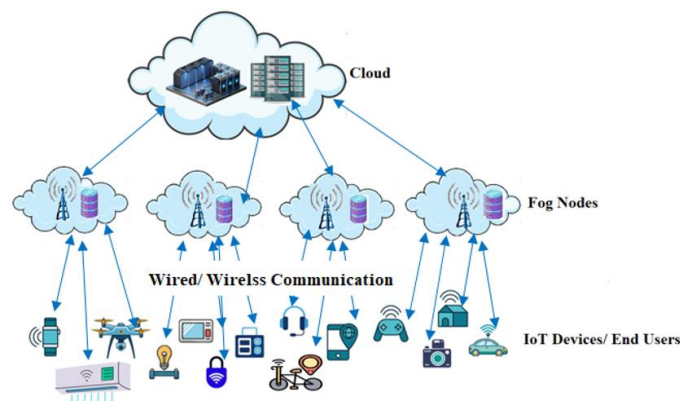


Fig3: Fog Architecture

4. Cloud Computing

Cloud computing is the expansion of a number of technologies, including disseminated computing, hardware, internet-based technologies, and system administration. Cloud provide various services according to the

requirement to access computer resources, such as real or virtual servers, storage space as per demand, software, networking, various development tools, AI-based platform and many more services [8]. Cloud-to-IoT integration, has numerous advantages. For example, it facilitates the management of IoT resources and offers more economical and effective IoT services. The CoT standard is not simple; it correspondingly presents new issues for IoT systems that the conventional centralized cloud computing architecture cannot handle, including latency, volume limitations, devices with limited resources, and network failure with sporadic connectivity, and increased security. For Internet of Things applications with time-sensitive operations or insufficient Internet connectivity, the centralized cloud architecture is inappropriate. To address these issues, a sophisticated cloud computing architecture that enhances capacity and latency limits is needed. To solve the majority of these issues, Cisco proposed a novel technology known as Fog computing.

5. Integration of IoT with Fog Computing

IoT applications are posing noteworthy difficulties to the existing centralized cloud computing infrastructure. For example, it cannot support augmented reality and other time-sensitive IoT applications, gaming, and video streaming. Furthermore, as it is a centralized slant, it lacks location alertness. Multiple problems can be solved by fog computing due to its distributed nature. Table 1 lists the distinctions among fog and cloud computing.

Table 1: Comparison between Cloud and Fog Computing

Factors	Cloud Computing	Fog Computing
Latency	High	Low
Location Awareness	Low	High
Geographical Distribution	Centralized	Disseminated
Bandwidth Requirement	High	Low
Number of Nodes	Few	Large

Fog is the middle layer in the middle of IoT devices and cloud that connect of them. Fog computing, according to Cisco, is a component of the cloud standard that moves the cloud nearer to the network's edge [10]. It offers an extremely virtualized method of networking, storage, and processing capabilities among endpoints and traditional cloud servers. The majority of the data produced by these IoT items and devices requisite be processed and evaluated in real-time in order to boost the effectiveness of IoT applications [11]. By bringing cloud networking, computation, and storage capabilities to the network's edge, fog will solve the real-time problem of IoT devices and offer safe and effective services [12].

6. Literature Review

Fog computing can help a wide range of IoT applications by enabling large-scale sensor networks, a significant problem caused by the growth of IoT devices. A comparison between fog computing with cloud computing has been presented by K. Saharan and A. Kumar [13] they talked about fog computing's features, motivation, and Internet of Things applications. A review of assimilating IoT with fog computing was given by Chiang and Zhang [14], who addressed new concerns in IoT systems and how the existing system models are unable to meet them without fog computing. IoT-integrated fog computing offers a number of benefits. It can address issues with flight finance trading, automotive application control, and carrying out end-to-end latency of roughly milliseconds among the control mode and the sensor. Networks, systems, and end-user apps can all be managed with its assistance. Puliafito et al. [15] examined potential challenges and demonstrated the mobility sustenance matter in the fog-based IoT system, focusing on mobile IoT devices that use fog computing. Additionally, the necessity of mobility assistance was highlighted and three distinct scenarios based on IoT integration with fog computing were given. A number of research avenues were proposed for the future to address the mobility issues, including proactive and reactive service migration, appropriate virtualization and migration strategy selection that might result in improved efficiency, and mobility support employment. In order to highlight fog-based mobility support systems, the incorporation of 5G mobile networks was too investigated and shown to be a feasible investigation route. In their analysis of IoT-based fog computing applications, Khan et al. [16] revealed that, notwithstanding security being a crucial part of the system, most programs place an advanced priority on usefulness than security. This makes various fog-based platforms vulnerable. In order to afford future security-based fog computing tactics, the analysis mainly concentrated on evaluating the significance and influence of security challenges and potential outcomes; however, system-level matters related to fog computing, such as resource management and service-oriented computing, were omitted. A QoS- and service level agreement aware optimization approach was presented by Toghiani et al. [17] to enhance IoT facility placement in fog-cloud settings, where resource

fluctuation can impair application recital. In order to proactively lower SLA violations, the authors suggested a resource reservation technique based on both historical data and real-time device status. This study by Hashemi et al. [18] provides a structured summary of strategies for effective resource management and energy conservation in fog. It draws attention to optimization techniques, simulation tools, and difficulties unique to IoT-based fog settings. Mahajan et al. [19] author offers a thorough examination of fog structures, deployment models, resource scheduling techniques, and security concerns and draws attention to the variations and interdependencies between fog and cloud computing systems. Patel et al. [20] focuses on how computing paradigms have changed from cloud to fog and they explain real-world applications, simulation tools, and fog's potential to address latency and bandwidth issues in IoT-heavy systems. Costa et al. [21] by moving processing power closer to the network's edge, fog computing improves conventional cloud services and supports applications that require low latency and real-time response. Orchestration mechanisms are used to control the fog infrastructure in order to guarantee efficient service delivery and maintain both Service Level Agreements (SLAs) and Quality of Experience (QoE). Among the many interrelated tasks involved in these processes, monitoring is crucial. Additionally, S. Yi et al. [22] have offered an overview of fog computing by going over several fog computing application scenarios and potential problems that could occur during the implementation of such systems. The key features of fog in healthcare systems have also been covered by Y. Shi et al. [23]. By analysing important facets of fog and in what way it enhances and expands cloud computing, F. Bonomi et al. [24] looked into the incorporation of IoT with fog. They also suggested a design for the fog that was spread hierarchically. They outlined scenarios for use for smart traffic light systems and wind farms. In order to test the features of their architecture. A framework for realising, measuring, and modelling A. Yousefpour et al. have suggested delays in service in IoT-fog-cloud situations [25]. To diminish service delays for IoT nodes, they recommended a delay minimization strategy for fog nodes. In order to thoroughly assess the service latency in IoT-fog-cloud situations, the authors additionally created an analytical model and carried out comprehensive simulation tests to bolster the model and the suggested policies. Similarly, V. Gazis et al. [26] identified the primary permitting skills pertinent to the fog standard and addressed the major issues posed by the industrial IoT.

These are some papers which present the contribution of Fog computing in enhancing services of Internet of Things.

7. Internet of Things in Agriculture

The Latin words "Ager," which means "land," and "Culture," which means "cultivation," are the source of the word "agriculture." It is one of the benchmark fields and the pivotal sector of human civilization. This industry is resilient to the economy of different countries. The Food and Agricultural Organization of the United Nations (FAO) estimates that 12% of all land is used for agricultural production and that over 60% of the world's populace hinge on agriculture for existence. Due to the usage of biomass, machinery, and fertilizers derived from fossil fuels, farming is also the second-largest source of greenhouse gas emissions. The agricultural sector is the foundation of the economies of some developed and developing countries. This sector significantly contributes to the expansion of developing nations' GDPs. Currently, demand exceeds supply, and as the population grows, this curve will show more erratic outcomes in the years to come. The agricultural sector will be under tremendous pressure to preserve the demand-supply curve. Climate change and global warming are other significant factors that need to be taken into account. In recent decades, this field has seen a slow but steady transition from traditional ways to the most cutting-edge technology-driven approaches due to increased demand and strain on the field's general structure. The agricultural sector is under duress because to the employment of conventional technologies and traditional approaches, as well as conservational variations.

Issues facing the agriculture trade:

- Time and cost optimization are hampered by the use of conventional farming methods.
- Inundations and storms that deposit contaminants such as gravel, nitrates, and phosphates induce topsoil depletion, which results in eutrophication and soil runoff.
- The soil becomes deficient in vital nutrients when the same crop is planted after every harvest.
- Climate change-related water scarcity reduces groundwater levels for irrigation, upsetting the water cycle.
- The devastation of tropical jungles and other vegetal species in agriculture causes global climate change, which raises levels of carbon dioxide and additional greenhouse gases.

- Unable to accurately identify the specific plant species.
- There is no effective way to identify the illness in its early stages so that preventative actions can be implemented.

In order to effectively employ water, land, minerals, and other resources, it is therefore necessary to develop new techniques and intensify agricultural operations.

The use of fields like IoT, Machine learning, and big data, etc. have undergone a paradigm shift in recent years. Consequently, it is constantly necessary to review the present positions and capabilities of the modern IoT concepts based on the developments of these data sets. It is necessary to meet the contemporary demands, the corrective alternatives in the sphere of agriculture, and the precise modifications to the prospects grounded on the principles of IoT. We conducted a study that covers current difficulties regarding the use of IoT in agriculture because of its contribution to the area and specific gaps in resource utilization. It is anticipated that technological advancements, particularly in the field of IoT, will greatly strengthen agriculture. The phrase "precision agriculture" has been added to the agricultural field, and it refers to the use of technology to follow, address, and mimic all procedures. By connecting things together, the internet has begun to transform this industry; this is now known as the Internet of Things. The expression "Internet of Things," which first came into use in 1999 by British modernist "Kevin Ashton," depicts a group of connected objects [7]. Wireless sensor networks, RFC, NFC, long-term evolution, and other communication devices and technologies are used to connect the equipment to the internet.

Table 2: Findings and research gap in IoT with Fog Computing

Author	Year	Findings	Research Gap
Charania, et al. [27]	2020	IoT's use in detecting maladies and pests Garnering robotics	Issue of Real time monitoring system and lack of resources
Chouhan, et al. [28]	2020	IoT and UAV roles are concentrated on areas like the process of fertilization water distribution, and identifying diseases.	Not discussed on data collection, Issues and challenges are not discussed.
Farooq, et al. [29]	2020	Discussed about various sensors and protocols used in farming,	Not focused on real time working and enhancement of services
Virupaxappa, et al. [30]	2021	Discussed about sensors, actuators, wireless technologies, architectural layers, , along with the interplanetary of IoT in agricultural	Challenges in deployment of IoT. Real time monitoring
Farooq, et al. [31]	2022	IoT-based livestock systems with pertinent technologies and communication protocols were discussed.	Security issues, Issues in livestock management , monitoring, controlling, and predicting solutions
Mishra et al. [32]	2023	Discussed about on the use of technology and equipment, farm animal health and welfare, and digital twins in livestock farming and precision livestock farming (PLF).	Challenges in Security, Real time monitoring, Real life case study
Benti, et al. [33]	2024	This paper provides perceptions into the existing state, obstacles, and potential forthcoming developments of ML, DL, and IoT integration in agriculture.	Challenges in data quality, Connectivity issues, Issue of technical skills, Financial issues
Miller, et al. [34]	2025	The paper emphasized the potential of autonomously platforms for field-level digitalization, block chain systems for dispersed information governance, and Edge AI for local inference. These challenges include high infrastructure costs, limited interoperability, connectivity limitations in rural areas, and principled concerns about clearness and data privacy.	Resilience of the system, model accountability, and data privacy

8. Enhancement of services of IoT in agriculture using Fog Computing

Fog computing and cloud computing have different but complementary features. By enabling computations and processing activities within fog nodes, fog is an extension of cloud servers that seeks to reduce the workload on

these servers. In order to decline the traffic load on networks, fog nodes are essential. This makes it possible to send lower capacities of data to cloud servers by filtering, cleaning, or compressing raw data. This guarantees quick reaction times and reduces bandwidth usage. However, for complex processing activities, fog computing depends on cloud servers. To supplement the necessary processing capacity, cloud servers provide extra computational resources. Fog nodes are essential to the system because they store photos and data from IoT sensors with low latency. Large amounts of sensor data and photos gathered are filtered and compressed at the fog nodes across the duration of the day. in order to maximize network traffic. This procedure greatly lowers bandwidth consumption and boosts overall system efficiency by extracting only the most important information and sending a minimal quantity of processed data to the cloud. Our system's fog nodes are made up of a database and web server. They serve as a central location for field photos and IoT sensor data, handling functions including data transmission, compression, and storage. The fog nodes' primary functional modules are a local analysis module, an IoT sensor data management module, a data encoding, transmission module, and an image processing module. These modules are in charge of data compression and broadcast management, picture processing and storage, sensor data gathering and display, basic data analysis, and alarm production, in that order. System adaptability and scalability are guaranteed by the fog nodes' modular design. It is simple to incorporate new sensor types or analytic techniques, and the system can be simply modified to adapt to variations in farmstead size or needs. The deployment of this fog system significantly improves the operative effectiveness of smart farmsteads by facilitating quick decision-making and real-time monitoring.

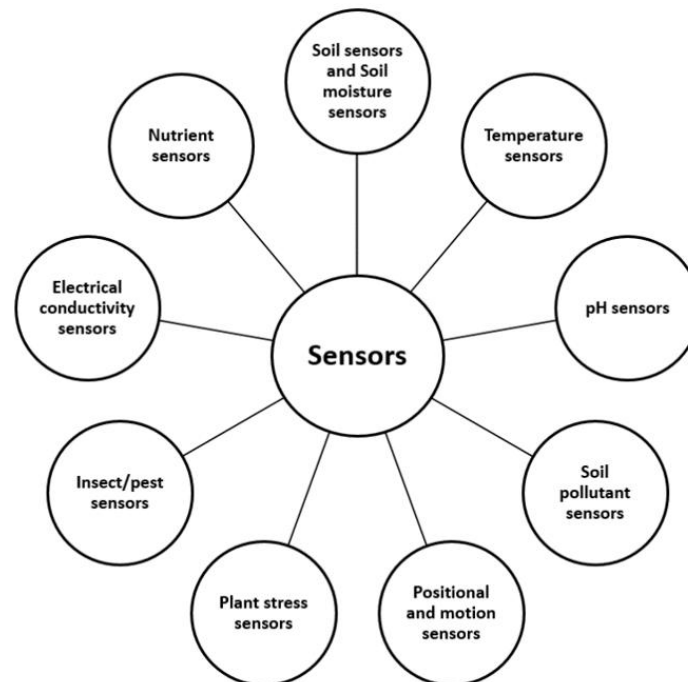


Fig 4: Types of Sensors

Table 3: Sensors with their working [36]

Sensor/Device	Type	Function	Application
DHT11	Temperature/Humidity Sensor	Monitoring Temperature & Humidity	Crop monitoring and environmental control
Capacitive Soil Moisture Sensor	Soil Sensor	Measuring Soil Moisture	Irrigation management and soil health
BMP180	Pressure Sensor	Weather Monitoring	Weather prediction and climate analysis
LM35	Temperature Sensor	Measuring Temperature	Crop health monitoring
SI1145	Light Sensor	Measuring UV Light & IR	Plant growth monitoring
GPS Module	GPS Sensor	Location Tracking	Precision farming
MQ-135	Air Quality Sensor	Air Quality Monitoring	Pest detection and environmental monitoring
Raspberry Pi	IoT Platform	Data Processing & Communication	Data aggregation for multiple sensors
Arduino	IoT Platform	Data Acquisition	Custom sensor
LoRaWAN Module	Communication Device	Long-range Data Transmission	Remote data transmission for farms

By facilitating more sophisticated resource management and increasing productivity, the Internet of Things is transforming agriculture. Intelligent sensors are used by IoT-based systems to track field conditions in real time. Data is then transmitted to fog platforms over wireless networks for accurate irrigation changes. Farmers can use mobile applications to remotely monitor and control agricultural systems thanks to IoT connectivity with mobile internet. Intelligent farming techniques are advanced when IoT and agricultural robotics are combined. Robots may carry out duties like sowing, fertilizing, and pesticide treatment on their own.

By facilitating real-time data processing, the cultivation of precision crops and effective resource management right at the network's edge, fog advances agriculture.

1. In lieu of transmitting data to remote cloud servers, fog enables local processing of data gathered from IoT sensors, including temperature, humidity, light intensity, and soil moisture. This lowers latency and permits minute-to-minute monitoring and management of agricultural parameters, enabling farmers to react quickly to shifting conditions, like modifying lighting or irrigation systems for the best possible crop development.
2. Fog computing facilitates precision agriculture, which uses resources like water, fertilizer, and energy effectively, by processing data locally. For instance, real-time soil health monitoring reduces waste and increases crop yields by precisely determining the amount of water or nutrients required. Additionally, this strategy reduces operating expenses and the impact on the environment.
3. Fog technology act as middlemen between cloud platforms and edge devices. Fog nodes aggregate, pre-process, and analyse data locally while edge devices gather it, transfer solitary relevant perceptions to the cloud for long-term storage and sophisticated analytics. In smart agriculture systems, this hybrid architecture guarantees scalability, data accuracy, and prompt decision-making.



Fig 5: Application of Fog Computing in Agriculture

9. Prospective Insights and Suggestions

The way farmers monitor crops, improve irrigation, and reduce risks associated with insect infestations and climate variability has been completely transformed by the quick development of IoT and fog technologies in agriculture. However, resolving technical, financial, and policy-related obstacles is necessary for the smooth changeover to copiously automated and AI-driven smart agricultural systems. The development of advanced smart sensing technology, the integration of dispersed models, the improvement of sustainability, and the establishment of explicit legal frameworks to guarantee ethical execution are all critical to the future of IoT and fog in agriculture.

Conclusion

Both academic institutions and business groups have become interested in the Internet of Things in recent years. It is starting to play a crucial role in our lives. It can link nearly everything in our surroundings to everything else. IoT devices are flexible and have partial processing and storage size. Two of the numerous concerns with the traditional centralized cloud are network downtime and high delay. To improve these issues another technology came in the scenario known as Fog. This technology an extension of the cloud that is nearer to IoT devices, has been settled to address these problems. All data processing will take place at fog nodes, which will condense latency, particularly for real time applications. The incorporation of fog will be very advantageous for numerous IoT applications. This study covered the most advanced in fog computing, as well as its features, architecture, and welfares. There was also discussion of the several IoT applications that will profit from the fog. In conclusion, this paper's objective was to deliver an overview of recent research on fog, the IoT, and practical applications. It also sought to draw consideration to unresolved problems and potential avenues for future study in fog with the Internet of Things.

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