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# State Of Art Technology And Framework For Iot Based Agricultural Systems

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**Abstract**

*The conventional methods of agriculture have recently undergone a significant modernization, driven by technological breakthroughs such as the Internet of Things (IoT). This transformation aims to enhance crop yields to meet the escalating demands of the global population.*

*This study intends to investigate the state-of-the-art Internet of Things (IoT)-based smart agriculture, clarifying its constituents-smart devices and sensors-as well as various communication protocols. Additionally, the discussion encompasses country-wide policies, prevailing challenges, [1]and unresolved issues within IoT-based agriculture, culminating in the proposal of a comprehensive framework for smart agriculture. Furthermore, the paper delves into the utilization of open-source software for effective agricultural management.*

*To achieve this, a meticulous review of high-quality papers published after 2018 in renowned databases such as Springer, IEEE, ScienceDirect, and Elsevier has been conducted. The selected papers undergo thorough analysis, forming the basis for the proposed IoT framework.*

*In identifying the challenges encountered in smart agriculture utilizing IoT, the research highlights critical concerns. These include technological limitations in communication protocols, data transmission issues linked to the flimsy IoT system architecture, guaranteeing data security while data transmission is in progress, lowered accuracy of locating, and a widespread lack of knowledge about technology among most farmers.*

*The paper underscores the imperative need for extensive education and training initiatives targeted at farmers in rural areas to foster an understanding of the myriad benefits offered by IoT-based smart agriculture. Furthermore, the advocacy for standardized government policies pertaining to IoT-based agriculture at a national level is emphasized as a pivotal step in promoting widespread adoption and success.*

***Keywords-*** *agricultural automation. Communication protocols IoT Smart Agriculture*

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*Wireless Sensor Networks*

## 1. Introduction

The need for food is growing rapidly due to global population growth, and it is crucial to preserve crop quality. Industrialization and advancements in the agriculture sector can help achieve this. The highly advanced Internet of Things (IoT) technology is providing the agriculture industry with a plethora of innovative options. Research centers and scientific associations are always looking for new ways to use IoT to build products and services. Additionally, they are working to find solutions for problems with cost management, productivity, smart irrigation, soil health monitoring, and fertilizer recommendations. Modern IoT technology has pinpointed each of these issues and particular fixes that will boost output while cutting expenses. (Gönüllü, O. 2022)

Recent technological advancements, such as the utilization of the Internet of Things (IoT), have modernized the agricultural industry. With rising demands from the world's expanding population, it aids in raising crop yield. Due to the country's rapid urbanization and growth, many educated villagers are moving to cities, which means that less educated farmers are unaware of technological advancements and do not receive timely aid for their agricultural jobs. Farmers suffer significant financial losses as a result, and their level of emotional stress rises.

An intelligent wireless Internet of Things architecture with sensors is created to increase agricultural productivity and adapt to changing climatic conditions. A multi-protocol, controllable Internet of Things solution for agricultural automation was demonstrated. Some of the characteristics are connection type, data transfer rate, data encoding, latency, coverage, power consumption, and controlled devices. Water is saved via the Internet of Things (IoT)-based system for automating agriculture, which helps with everything from seed sowing to post-harvest activities. Unmanned aerial vehicles (UAVs), cameras, and farm robots can all be added to this system in the future to achieve total agricultural automation and eliminate the need for ongoing human intervention. Numerous commentators stress the significance of farm data analytics and the Internet of Things. The impact of IoT technologies in agriculture on farmers' daily operations has also been examined. (Singh, P. K., & Sharma, A., 2022) (Pathmudi et. al., 2023)

Considering this, the present study focuses on aspects of smart agriculture, including the use of IoT technology, its benefits, and its applications.
Research Objectives:

1. To review the research on Internet of Things (IoT)-based agriculture and present a summary of IoT utilizations in agriculture.
2. To discuss different Internet of Things (IoT)-based agricultural sensors or devices.
3. To draw attention to the unresolved problems and difficulties and offer suggestions based on current circumstances.

### 1.1 Scope of the study

The Internet of Things (IoT) applications in smart/intelligent farming, challenges, and issues in the IoT framework, IoT-based agriculture, and the usage of IoT in agriculture are the main topics of the proposed research. It also covers the use of wireless protocols in smart agriculture.

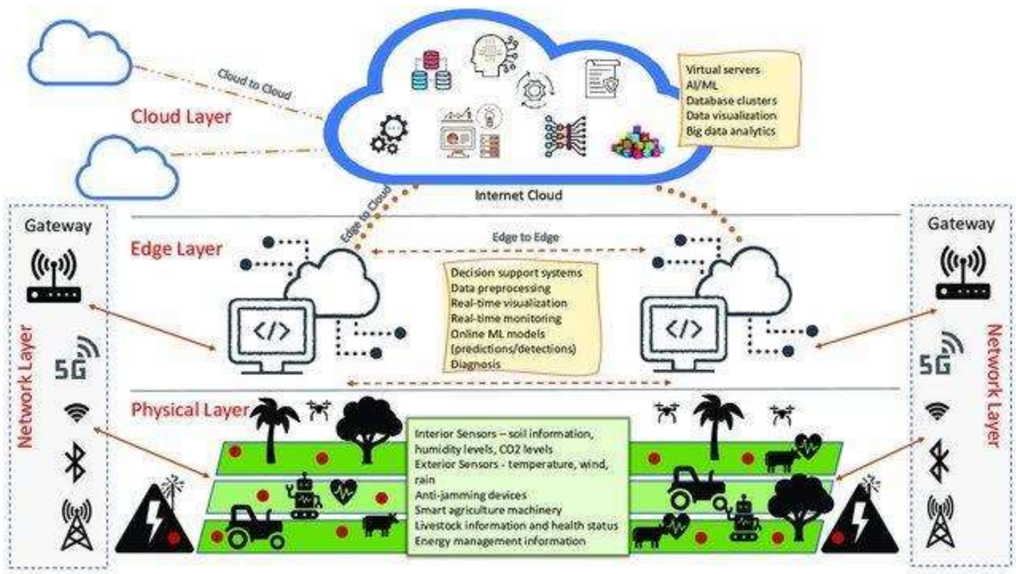


**Figure 1.** Multilayer Smart Farming
Source: https://www.scopus.com/sourceid/19700166503?origin=resultslist
DOI: 10.1109/ACCESS.2020.2975142

The concept of multilayer intelligent farming is shown in Figure 1. In order to gather data and distribute it across the network, sensors, robots, drones, and other devices are affixed to fields, animals, and plants at the physical layer. The information could include the kind of disease affecting the animal and plant, the water level, the ambient temperature and humidity, the condition of the soil, and other factors that need to be kept an eye on. The gathered data is recognized, preprocessed, and fed into ML models at the edge layer to support decision-making. Through the network layer, towers, Bluetooth devices, and wireless networks all offer seamless communication. Lastly, analytical, visualization, and other tools are used to study the data. The user receives the created reports back to aid in future decision-making.

### 1.2 Application of IoT in agriculture

In order to use IoT technology in the agriculture sector, a lot of work has gone into finding smart agricultural solutions. As IoT technology advances, reports indicate that IoT systems will play a critical role in assisting farmers in resolving issues like water scarcity, low productivity, cost management concerns, etc. IoT technologies have identified every problem and provide solutions to increase productivity at a reduced cost. Utilization of Internet of Things (IoT) to agriculture is shown in Figure 1, which shows how smart agriculture can replace traditional agriculture. Wireless sensor-based networks are used to collect and transfer data from several devices or sensors to the main servers. (Farooq, et. al. 2019). With the use of IoT applications embedded in mobile devices, farmers may remotely monitor information relating to crop/plant health, leaf disease, and animals. It will also notify farmers in the event of any unfavorable scenario.

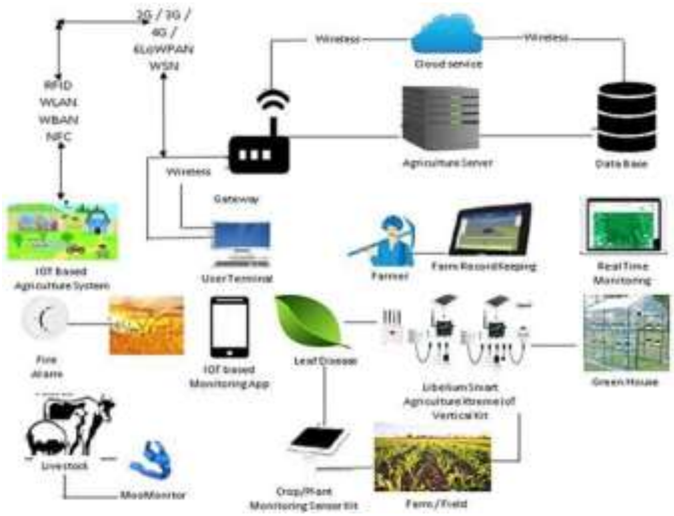


**Figure 2.** Smart Agriculture
Source: Applications of Internet of Things for smart farming – A survey - ScienceDirect

**Related Work**
The writers have screened the following kinds of papers before considering them for this evaluation.

- The Research papers are published in journals, conference papers, technical reports etc
- The papers released from 2019 to 2023

Research/Study articles on the subject, such as those from our study Scopus , Web of Science and publications in journals published by IEEE Access, IEEE Transactions, Springer, Willey, and other journals, are taken into consideration.
Clearly, efforts have been made to integrate Internet of Things(IoT)-based technology inside the agriculture industry., which offers intelligent solutions to challenges related to agriculture. Utilizing the Internet of Things(IoT), traditional agriculture has undergone a considerable transformation that could reduce challenges like productivity issues, budgetary limits, and water scarcity. Wireless sensor networks are connected with The sensing devices, and the primary cloud servers receive the data gathered by these sensors and devices.

**2.1 Use of IoT in agriculture from a farmer's perspective**
Farmers utilize the Internet of Things (IoT) to boost crop quality and productivity. Strict punishments for certain offenses can dissuade farmers from continuing.

1. An organization can employ data from advanced agricultural sensors to improve staff efficiency and productivity, as well as the overall level of intelligence in the country. This data can include information about crop development, animal health, meteorological conditions, and soil quality.
2. Inferior production risks because of improved internal technique switching. If predictions regarding the production process are made, one can plan ahead of time and be better prepared to deliver the things on time.
3. Automation of processes has increased firms' effectiveness. One can learn about

various technologies used in building, like pest control, composting, and drainage, by employing attentive practices.

4. Budget without fully utilizing the elevated controller knowledge of a manufacturer. Being fit can reduce the risks associated with the items.
5. If new building construction is finished, production quality standards are set, and automation is greatly advanced, more capacity and enhanced supremacy can be guaranteed (Gowda et al. 2021).

### 2.2 IoT based devices in Agriculture

Through the analytical console, farmers can assess the state of their farm and make subsequent decisions based on their interpretations. Data from sensors can be accessed remotely to check on crops, environmental factors, irrigation, livestock monitoring, and soil health. If necessary, the corrective actions can be put into action. (Navarro, E., Costa, N., & Pereira, A., 2020) (Ng H.T., Tham Z.K. et al., 2023)

Smart farming relies on the use of Raspberry Pi, WSN-based RF communication for sending, receiving, and monitoring greenhouse data, and fuzzy logic systems for decision-making. (Benyezza, Hamza, Bouhedda, et al. (2023))

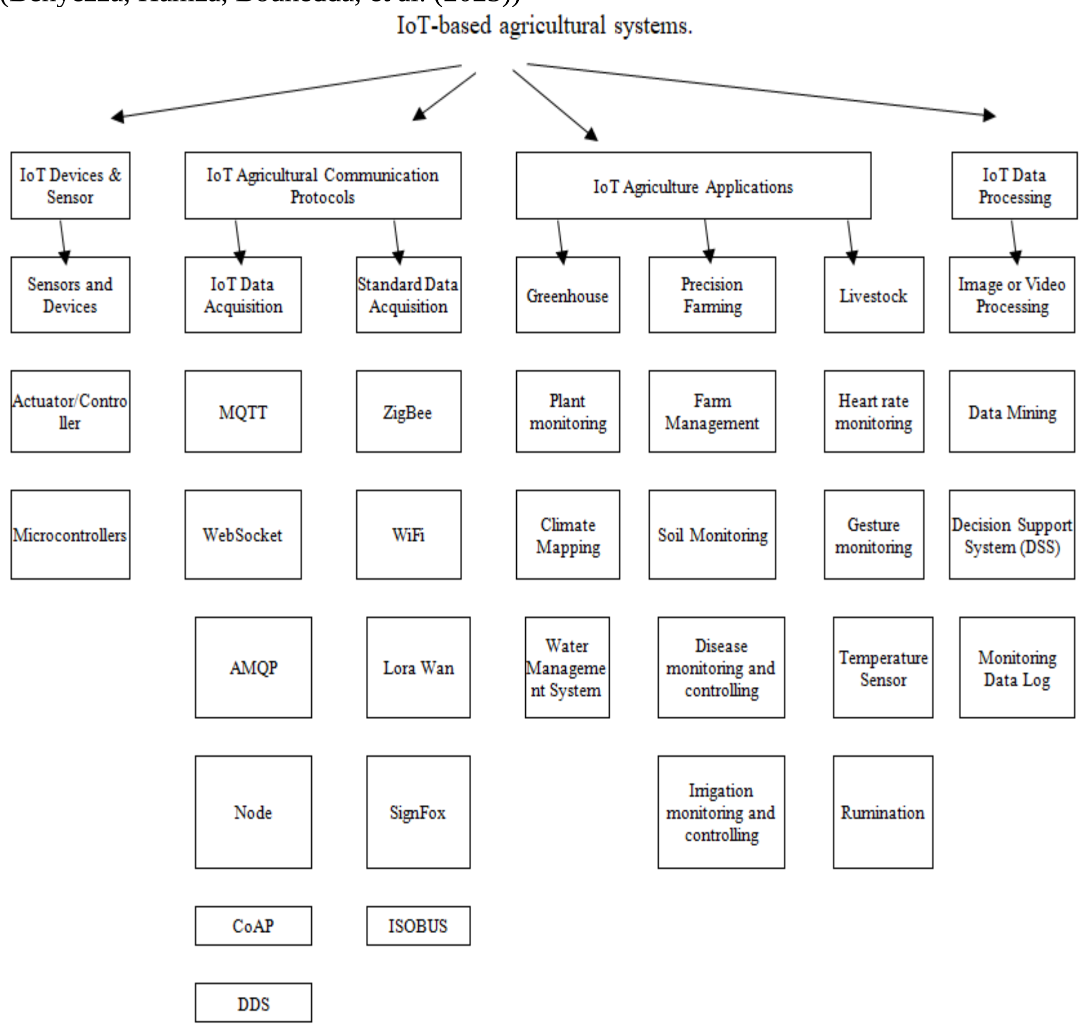


**Figure 3.** Snapshot of IoT agricultural System

The structure of the IoT-based agricultural system is shown in Figure 3. This system snapshot illustrates every element of the system that can be used to apply smart agriculture to efficient national agriculture.

### 2.3 Role of IoT Communication Standards and Protocols in Agriculture

A key component of modern farming is the network, including gateways, sensors, and servers. The sensor nodes are placed near the farm path and linked to the gateways, which coordinate the data storage on the local device with the planned uploads to the internet. To get to the server that collects sensor data, data is delivered from the gateway using the Remote Terminal Unit (RTU). The Transmission Control Protocol/Internet Protocol (TCP/IP) allows a connection to be made between the server and the network sensor.

Since IoT communication technologies are affordable, they are used in the development of IoT applications. They also require a little energy to run. They have a larger coverage area than other long-distance communication techniques. Table 3 displays various systems of communication. It has been determined that the most commonly used technology is WSN (29%) and that WiFi (15%) and ZigBee (10%) are used less frequently. (Dhanaraju et. al., 2022)

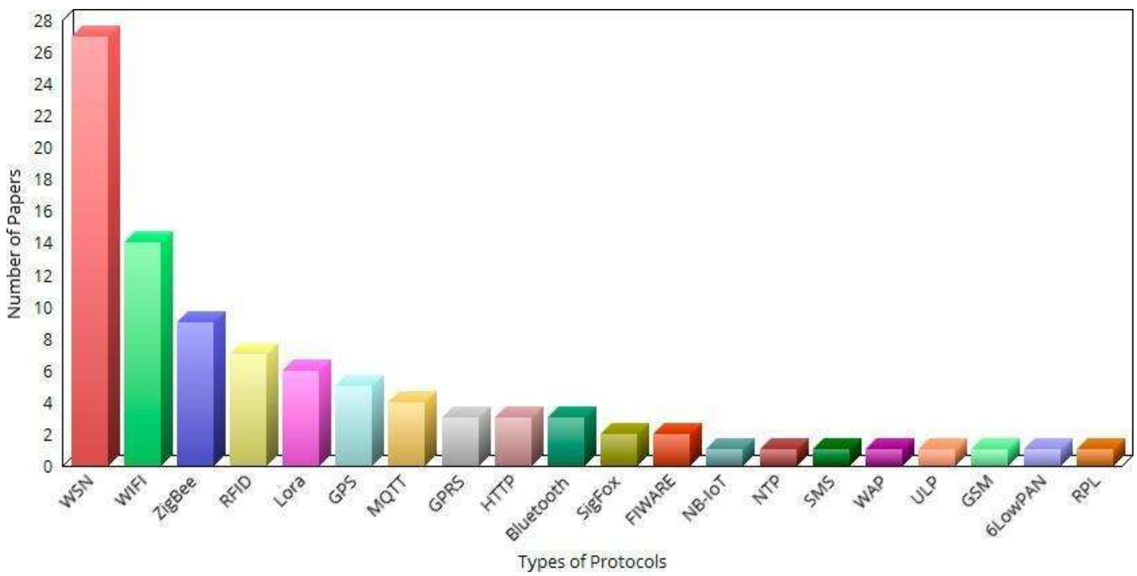


**Figure 4**. Types of Communication Protocols
Source: https://www.mdpi.com/2079-9292/9/2/319

#### 2.3.1 Message Queue Telemetry Transport Protocol (MQTT)

Sensation data is sent and received via MQTT. By regulating water pump motions and sending data about water pump status and soil moisture to user web pages and mobile applications, this protocol also solves the irrigation problem.

#### 2.3.2 Low Range Wide Area Network Protocol (LoraWAN)

The Lora TM Alliance is working on a low-range wide area network protocol. The main goal of this protocol is to enable communication between different operators. A framework is created to raise crop productivity and lower hazards.

### 2.3.3 Radio-Frequency Identification (RFID)

RFID assigns a unique number to every item and tracks its whereabouts. It also establishes atmospheric factors such as moisture content and temperature. RFID tags are used to determine an object's exact location and trace crop information. Farmers may save costs, time, and energy by utilizing RFID technology in conjunction with identifying sensors

The necessary rate, the range or coverage, the implementation cost, the energy consumption, etc., can all be taken into consideration while choosing the communication protocols. Table 1 presents a comparative study of various methods.

**Table 1**. Comparison of Wireless Communication protocols
Source: https://www.sciencedirect.com/science/article/abs/pii/S2542660520300238

| | **Frequency band** | **Range** | **Data rate** | **Cost** | **Energy consumption** |
|---|---|---|---|---|---|
| WiMAX | 2 - 66 GHz | high | high | High | reasonable |
| WiFi | 5 - 60 GHz | moderate | high | High | high |
| Cellular | 865 MHz, 2.4 GHz | high | flexible | reasonable | reasonable |
| Bluetooth | 2.4 GHz | less | reasonable | Less | Very low |
| LR-WPAN | 868-915 MHz, 2.4 GHz | less | less | Less | less |
| SigFox | 868- 920 MHz | high | less | reasonable | Very low |
| NB-IoT | 800-1800 MHz (EU) | high | less | High | less |
| LoRa | 868 - 900 MHz | high | less | High | Very low |

## 2.4 IoT Agricultural Policies implemented in different countries.

Government policies that regulate land reform, telecommunications, irrigation, rural electrical access, pricing regulations, marketplaces for agricultural goods and support for developing technologies all significantly contribute to agriculture. Although the goals of the various policies vary by nation, they always aim to improve the nation's agricultural system and raise crop production and quality. Table 2 enumerates the IoT agricultural policies put into effect in several nations.

**Table 2.** Country wise IoT Agricultural Policies (Farooq, et. al. 2020)

| **Sr No** | **Countries** | **Application Sub-Domains** | **Summary** |
|---|---|---|---|
| 1 | Australia | Enhancement of farming techniques | The Australian government is using precision farming in order to protect the privacy and security of agricultural data. |

| | | | |
|---|---|---|---|
| 2 | China | Environment monitoring | A low cost systems are put in place to monitor the greenhouse's conditions. The technology demonstrated reliability and resulted in labor cost reductions of up to 60% and 80% for pesticides and fertilization, respectively. |
| 3 | Philippines | Measurement of crop heat stress with satellite imagery | The Philippines uses remote sensing and satellite imaging techniques to collect data on many agricultural characteristics. South-eastern Philippines (USeP) and Western Mindanao State University (WMSU) collaborated to build an intelligent system to measure the crop's heat stress using IoT technology. |
| 4 | Brazil | Soil temperature and moisture Monitoring | Low cost forecasting method for soil humidity and temperature measurements. The size and weight of the arugula leaf increased to 17.94% and 14.29%, respectively, after this procedure was applied. |
| 5 | Ireland | Lowering the Cost of Smart Farming Implementation | The Irish Farmers' Association (IFA) created an IoT-based system that lowers costs while improving soil quality. The purpose of the initiative was to teach farmers how to save water and electricity. The enterprises might save up to 47% on soil fertility costs, 10% on greenhouse gas emissions, and 21% on pasture management by implementing the suggested techniques. A Sigfox network is utilized for farm asset tracking. |
| 6 | Africa | Animals location tracking, Animal behavior and Animal pasture grazing. | This animal behavior monitoring system was developed and implemented in Africa. It tracks animal movements and monitors pasture grazing. |
| 7 | China | Gathering Agricultural Data at a Minimal Cost Without Using a Gateway | Huawei introduced NB-IoT application in China, which offers great answers for problems related to agriculture. |
| 8 | India | Light, temperature monitoring, Pesticides, Soil moisture monitoring, Animal CO2. | For bell paper plants, a sophisticated and user-friendly system built on the Internet of Things (IoT) and robotics was used to detect and quantify pesticides, moisture, and animal movement in the soil from a distance. It produced satisfactory outcomes and cut down on labor costs. |
| 9 | Malaysia | Fruit traceability | The Minister of Science, Technology, and Innovation has proposed the My Traceability Sdn Bhd (MTSB) and Mi-Trace IoT-based tracking systems to improve fruit quality. |

| | | | |
|---|---|---|---|
| 10 | France | Agriculture Innovation Project - 2025 | A new initiative called Agriculture Innovation has been launched by the Ministry of Agriculture. This project's main goals are to strengthen the land, improve field conditions, and keep an eye on the weather. Farmers are also given support in developing creative agricultural solutions. |
| 11 | USA | Precision Farming | Water management is one of the agricultural problems that the United States Department of Agriculture (USDA) program helps to resolve. National Institute of Food and Agriculture (NIFA) has started looking into sensing devices to enhance agricultural practices. It is putting effort into the Internet of Things project. The primary goal was to provide precision farming, which includes optimizing the use of organic food, fertilizers, water, and other resources. |
| 12 | India | Internet of Things(IoT) Based Farming | The objective of the Indian government is to keep an eye on the density, temperature, and soil conditions of the planet in order to ward off agricultural diseases and pests. The Ministry of Communication and Information Technology has been recommending the use of IoT in its policies since 2015. These recommendations aim to enhance the agriculture process. |
| 13 | Thailand | Smart Farming for Rural farmers | IoT technology is being used by Thailand's National Electronics and Computer Technology Centre (NECTEC) to enhance IoT-based farming. The principal goal of the Thai government is to facilitate agriculture for farmers in rural areas. Their main goal is to increase rural areas' output of cassava, rice, rubber, and sugar—the four main agricultural crops. |
| 14 | Malaysia | Collecting environmental factor data using WSN and MEMS | The Malaysian Institute of Microelectronic Systems (MIMOS) aims to increase agricultural output while reducing poverty. The Mi-MSCANT PH sensor was included in this system to gather data on weather conditions. This application, which makes use of WSN and Micro Electromechanical System (MEMS) technology, offers a solid foundation for fostering closer relationships between farmers, customers, and merchants. |

## 2. Framework of IoT based agriculture

The effective implementation of an IoT-based smart agriculture environment relies on a foundational structure encompassing key components: report generation, sensing equipment, data collection, data processing,data analysis and decision-making. In the physical framework, various sensors, equipped with microcontrollers, are strategically placed for tasks such as livestock monitoring and measurement of temperature, gas levels, and humidity. The utilization of 5G cellular technology ensures swift data transfer, optimized energy consumption, and efficient network control. Data, ranging from text and images to videos, is gathered through established protocols like HTTP, MQTT, Web socket, Node, or IoT-specific protocols such as SigFox, Wi-Fi, Zigbee Tec and LoRaWan. Subsequent to data collection, advanced tools like Decision Support Systems (DSS), image and video processing, and data mining are employed for data processing. Analytical tools are then utilized for data analysis, enabling the monitoring of agricultural systems, including gas levels, temperature or moisture, and livestock conditions. The outcomes of this comprehensive process are detailed reports that facilitate the implementation of corrective measures aimed at enhancing agricultural yield and achieving additional benefits, such as improved crop quality and economic efficiency. The analysis phase can be executed using any of these sub-components: cloud computing, edge computing, or big data. Within the realm of big data technology, tasks such as image processing, data visualization, prediction, simulation modeling, and statistical analysis are carried out. The controlling functions play a key role in managing agricultural factors such as pest control, fertilization and greenhouse gas emissions. Figure 5 shows the overall Internet of Things(IoT)-based system for agriculture.

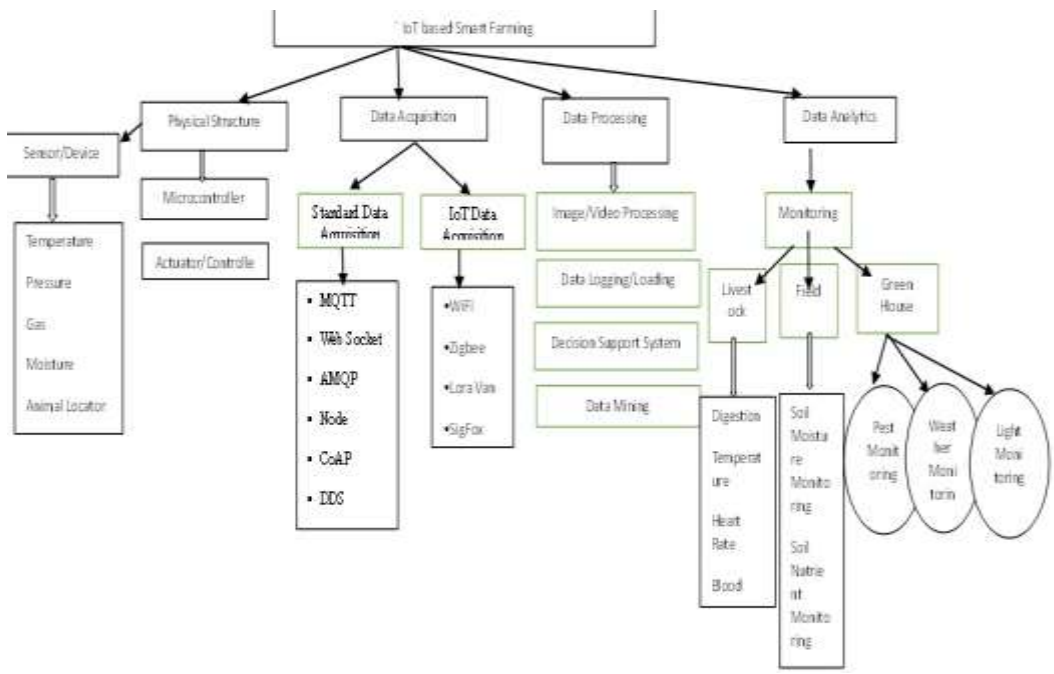


**Figure 5.** Framework of IoT based Agriculture.
Source:
https://www.researchgate.net/publication/339280210_Role_of_IoT_Technology_in_Agriculture_A_Systematic_Literature_Review

## 3. Open- Source Software's for Agricultural Management

An online application that aids farmers in tracking environmental factors, maximizing and conserving resources, and raising productivity. In a more sophisticated form, farmers can even employ AI algorithms to forecast profitability and production. The number of open-source applications for smart agriculture is few (Kassim, M. R. M, 2020).

Here is a discussion of the most popular open-source smart, or intelligent agriculture software.

FarmOS: FarmOS is built using Drupal over a web application architecture.. The application is utilized for agricultural tasks such as customer portals, farm and crop details, and weather forecasts.

Tambero: Tambero is an online tool for agricultural management that assists farmers in efficiently managing their crops. It provides tools for managing cattle, agriculture, and livestock, as well as the weather forecasting system.

Tania: Tania software is licensed under Apache 2.0 and is built on top of SQLite, Vue, Go, and JavaScript. We are able to monitor data from any location and interface with several sensors and devices.

Farmathand: This software offers management for farm tools, sales, and supplies, among other things.

Trimble: With the use of internet connectivity, Trimble collects real-time agricultural data for purposes like crop details, farm data maintenance, and climate monitoring.

FarmRexx: FarmRexx is an agricultural application that tracks data in real time on the movement of cattle, fertilizers, weather patterns and other factors.

There are numerous obstacles to overcome in the installation of IoT applications. The following discusses a few of the ones that were found in the literature.

### 1.1.Security

Effective solutions are required for the security concerns that IoT-based agricultural systems face on multiple levels. Users are affected by inadequate security standards, which can lead to data loss and physical manipulation of on-field devices, such as attacks by predators or animals and location alterations. Moreover, memory limitations and low energy consumption are obstacles to the development of complex algorithms.

### 1.2.Cost

There are numerous cost-related problems with integrating IoT in agriculture. It is made up of running and startup costs. Hardware costs for IoT devices, base station setup and gateway establishment are all included in the setup costs. Moreover, continuing membership fees for information sharing, central services that facilitate data collection, and IoT device management are needed.

### 1.3 Lack of Knowledge/Awareness of Technology

Rural farmers don't know enough about technology. To boost productivity and income, farmers in rural areas need to be properly informed about IoT applications in the agriculture sector through a few training sessions.

1.4.Reliability

Since IoT devices are in direct contact with their surroundings, the harsh environmental conditions act as a barrier to data transmission. To protect IoT-based devices from dangerous environmental conditions, their safety is crucial.

1.5.Scalability

Many Internet of Things(IoT)-based devices and sensors are used in agriculture to monitor various processes, so an effective IoT management system is needed to recognize and manage each sensor node.

1.6.Localization

Since IoT devices are supporting and functioning for the entire world without the need for additional devices with overhead architecture, great care must be given when installing them. The location needs to be selected such that there is no interference with the device's ability to communicate and exchange data.

1.7. Interoperability

The interoperability of IoT devices is dependent on standards and protocols. Syntactic, technological, administrative, and semantic policies all have an impact on this. Semantically interoperable content is understood by humans, whereas syntactically interoperable content uses formats such as JSON and XML. Infrastructure and standards for Internet of Things communication are part of technical interoperability. Information sharing between infrastructures is the main goal of organizational interoperability. Compatibility issues with hardware and software present hurdles for the integration of diverse sensor data.

1.8. Power Consumption

Wireless sensors and devices are used in smart farming because of their wide coverage. Intelligent power-saving management techniques can be used to lower their power consumption.

1.9.Business Process

The food industry's value chain needs to be completely reengineered due to a major shift in how agricultural commodities are sold, to retailers and consumers by farmers. To address the new challenges, agricultural groups and agriculturalists need to be prepared with the information and resources (such e-commerce platforms).

## 4. Comparison of relevant wireless communication protocols

IoT technology uses a variety of wireless communications protocols, such as SigFox, Wi-Fi, and ZigBee. The two most popular Low Power (LPWAN) protocols are Narrowband Internet of Things (NB-IoT) and Long-Range Wide Area Network (LoRaWAN). The non-LPWAN protocols are ZigBee and Wireless Fidelity (Wi-Fi). The data rate, coverage, frequency, and other aspects of the protocols vary. The table below examines the protocols with applications for smart agriculture, including weather forecasting, pest control, water conservation, monitoring soil parameters, and energy harvesting. Among all the protocols, LoRaWAN is becoming more and more popular. This satisfies the three primary metrics: energy, scalability, and coverage or range. (Avsar et al., 2022)

**Table 3.** Wireless Communication Protocols in Smart Agriculture
Source: Ercan Avşar, Md. Najmul Mowla, Wireless communication protocols in smart agriculture: A review on applications, challenges and future trends, Ad Hoc Networks, Volume 136, 2022, 102982, ISSN 1570-8705, https://doi.org/10.1016/j.adhoc.2022.102982 .

| **Wireless Protocol** | **Data Rate** | **Frequency of operation** | **Range** | **Security** | **Power Consumption** | **Cost** | **Battery Lifetime** | **Limitations** |
|---|---|---|---|---|---|---|---|---|
| Wi-Fi | 150 kbps | Sub – 1GHz | 6-1000 m | Low-High | Moderate, Medium, 1 W | Low-High | 3 + years | High Power Consumption and Long access time |
| | 11-54 Mbps | 1-60 GHz | | | | | | |
| | 150 Mbps | | | | | | | |
| | 6.75 Gbps | | | | | | | |
| | 1 Gbps | | | | | | | |
| ZigBee | 50–100 m | 868/915 MHz | 20/40 kbps | High | Low | Low | 1+ years | The coordinator node and sensor node need to have a clear line of sight. |
| | 10 m | 2.4 GHz | 250 kbps | | | | | |
| | | 2.4/2.483 GHz | | | | | | |
| NB-IoT | 170-250 kbps | Cellular Bands | 1-40 km | High-Very High | Low | $ 8 -12 | 7-10 years | Medium data rate |
| | 0.1 – 1 Mbps | Licensed LTE | | | Medium | | | |
| LoRaWAN | 50-100 kbps | Various sub-GHz | 5-15-45 km | High | Extremely low | Low Cost | 8 - 10 Years | Network size rate of data transfer and message size. |
| | 290 bps - 50 kbps | 869/915 MHz | | Medium | Low | | | |
| | 0.3-50 | | | | | | | |
| | 50 – 100 kbps | | | | | | | |
| Sigfox | 10-1000 bps | Sub GHz | 3-50 km | Low | Low | Medium | 2 -10+ years | Low Data Rates |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100-600 bps | <1 GHz | | | | | | |
| | 8 Bytes | 433/915 MHz | | | | | | |
| | | 868/915 MHz | | | | | | |

## 5. Discussion

Farm data collection from multiple farm nodes is being revolutionised by remote sensing. Wireless sensor networks are used in Internet of Things (IoT)-based remote sensing to gather data from sensors placed next to farms, such as weather forecasts, and send it to data analysis tools.

Farmers can monitor crop status and take appropriate action based on insights gained from using the analytical tracker. High-caliber research articles on IoT-based agriculture are surveyed in this research.

### 6.1 Open Issues and Challenges

Because of issues with temperature variations, topography, low soil quality, climate, and the non-uniformity of most of the cultivable land, agriculture is not possible on our entire planet. The current agricultural land's fragmentation due to political, financial, and urbanisation factors is another barrier to the availability of arable land (Figure 3). In general, less land has been used for food production recently. Key attributes of any agricultural area that are assessed in terms of quantity and quality regarding a certain crop include the type of soil, water availability, nutrient content, and insect resistance. Using yearly crop rotation, farmers may maximize agricultural output on the same land. There needs to be both temporal and spatial heterogeneity. When the deep reinforcement learning algorithm was used, both the model's design and algorithm's training significantly improved. Nonetheless, it was unable to outperform humans in terms of adapting to dynamic environments and completing challenging tasks. (Bu, F., & Wang, X. , 2019)

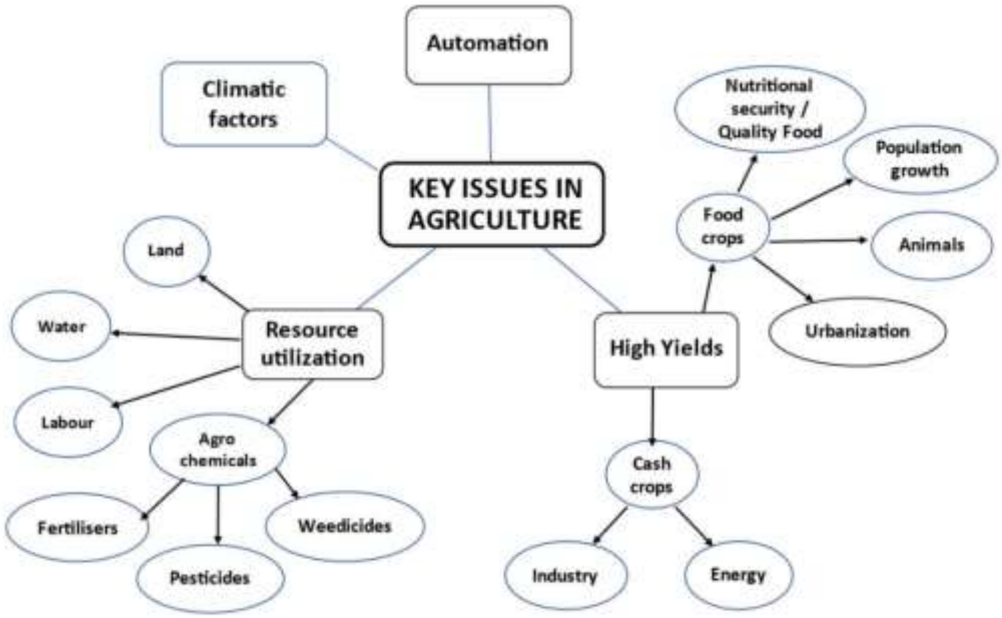


**Figure 6. Key Issues in Agriculture**
Source: https://www.mdpi.com/2077-0472/12/10/1745

**Table 5**. Summary of Literature on IoT based Agriculture.

| **Author(s)** | **Year** | **Domain/parameters** | **Algorithm Methodology/ Algorithm used** | **Limitations or challenges** | **Future Scope** |
|---|---|---|---|---|---|
| Ayaz et al. | 2019 | Agriculture and conventional farming methods make use of wireless sensors. | **Systematic literature review (SLR)** | Energy intensive applications based on the Internet of Things (IoT) and power issues | NA |
| Wu et al. | 2022 | Internet of Things(IoT)-based crop growth monitoring system | Fuzzy theory | NA | Monitoring the environmental factors influencing crop growth requires research. |
| Shi et al. | 2019 | Traceability of the food and agricultural product supply, plant management, and animal husbandry. | **Systematic literature review (SLR)** | The gadgets are exposed to extreme greenhouse conditions, including high temperatures, high humidity, intense sun radiation, vibration, and other | Improved food safety monitoring, improved crop and animal management, and the creation of cutting-edge sensor technology, data processing algorithms and communication protocols. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | dangers that can harm end devies and sensors. | |
| Quy et al. | 2022 | End-user applications, big data, wireless sensor networks, cloud computing | **Systematic literature review (SLR)** | Economic efficiency and Technical problems | Security aspects for IoT devices |
| Farooq et al. | 2020 | IoT devices and sensors for use in communication protocols, agriculture, etc. | **Systematic literature review (SLR)** | Security, gaps in technology understanding, cost, reliability and scalability of IoT applications. | NA |
| Farooq et al. | 2019 | Automated Maintenance and monitoring of farms. | **Systematic literature review (SLR)** | IoT agriculture platforms, networking challenges and hardware issues. | NA |
| Alrowais et al. | 2022 | Images captured by Internet of Things devices can be used to automatically identify weeds. | **(Hybrid Leader-based Optimization in IoT-enabled Smart Agriculture with DL-driven Weed Detection).** | NA | Designing intelligent herbicide sprayers. |
| Lydia et al. | 2022 | Grain quality and weight are greatly impacted by warehouse variables that must be monitored and managed, including motion, grain level, temperature, CO, humidity, vibration. | Through the use of the GSM module and the PIC microcontroller , sensor data is transmitted to the cloud. | NA | NA |
| Lakshmi, G. P., et al. | 2022 | Ielf-sufficient irrigation scheduling and tracking system that uses information from soil moisture sensors to adjust watering schedules to tomato and aubergine plant requirements.. | A LoRa-based machine learning (ML) and Internet of Things(IoT) approach | It only focused on two different plant locations for testing and calibration. This limited breadth may make it difficult to fully capture the diverse requirements and conditions of | The accuracy of irrigation frequency estimates could be increased by obtaining additional weather data, or information other than temperature and time, such as cloud percentages, wind gusts, wind direction, and |

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| | | | | different agricultural locations, which could affect how broadly applicable the recommended smart irrigation system is. | rainfall. Adding these components to the smart irrigation system would enable more accurate and efficient water management for precision farming. |
| Vani et al. | 2021 | Montering of Water Supply | **Internet of Things(IoT)** | Hardware Restrictions: Arduino Uno microcontroller's capabilities and future growth potential may be limited. | With the use of an integrated Wi-Fi module, the Raspberry Pi 3 microprocessor can enable remote monitoring and expansion for a variety of contemporary agricultural facilities and may overcome hardware complexity |
| Li et al. | 2020 | Efficient data transmission and processing in real time. | The maximum distance-based k-means algorithm is used for data mining, and it optimizes data processing and storage for large agricultural production datasets. | According to the paper, there have been opportunities to get significant insights from the huge amount of agricultural big data that has been collected, but the data's full potential has not been fulfilled yet. | Neural networks and other classification technologies help improve agricultural product analysis and prediction. |
| Mohammed, M., et al. | 2021 | Management of Irrigation | Advanced subsurface irrigation systems with cloud IoT solutions. | The study's relevance to other types of fruit plants and soil was limited because it only looked at date palms in arid places. | To investigate the effects of the planned CSIS on different soil types and various fruit tree cultivars |
| Forcén-Muñoz et al. | 2021 | Water supply management and Crop Monitoring | Cloud Computing | While the Region of Murcia has successfully adopted the Irriman Platform, more research may be necessary to determine its suitability and efficacy in other geographic areas with | More sophisticated data analytics and predictive modeling features could be added to the platform, enabling stakeholders to make more proactive and knowledgeable decisions about crop management and irrigation. Investigating scalability |

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| | | | | diverse soil types and temperatures. | and cost-effectiveness options will help farmers and agricultural communities around the world utilize the platform more widely, promoting more efficient and sustainable farming methods. |
| Siddiquee et al. | 2022 | An Internet of Things-powered intelligent agricultural monitoring system that uses many algorithms to identify, measure, and assess the ripeness of vegetables contaminated with pesticides. | Convolutional Neural Networks (CNN). The optimal process for integrating this agricultural monitoring system was determined by contrasting traditional methods with CNN, which was simulated in MATLAB. | Study centered on tomatoes, a single vegetable. | In order to properly assess the economic value of damaged tomatoes, in an effort to identify tomatoes with surface characteristics beyond just black dots, scientists are analyzing shape changes and the amount of water in the outer skin. |
| Awan et al. | 2020 | The recommended routing technique reduces energy consumption, shields the network against IoT architectural assaults, and eliminates unnecessary data. | The suggested protocol selects a route to the Base Station by use of smart contracts that operate across many IoT networks. | The challenges and requirements of different farming environments or crop types are not taken into account. | It is possible to validate recommended energy-efficient solutions in the real world with geographical differences. and varying farming conditions |
| Doshi et al. | 2019 | Monitoring of temperature, humidity, UV index, and soil moisture in real time | The model makes use of an ESP8266 Node MCU, a SI1145 digital UV Index/Visible light/IR sensor, a DHT11 temperature and humidity sensor, and LEDs for the | The budgetary limitations of the current prototype have hindered the development of additional models for larger farms and diverse crop varieties. | In the future, numerous such prototypes linked to one another using Bluetooth can be placed on huge farmlands in a local network. These nodes' data can be gathered by a main node, which can subsequently be uploaded to cloud for analysis and decision making. Artificial |

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| | | | soil moisture sensor. The goal of the Blyank mobile app is to keep an eye on live data. | | intelligence can also be added to systems to enhance it even further. This will allow the network of nodes to make judgments on their own and initiate the appropriate activities in response to particular circumstances. |
| Ullo et al. | 2021 | The major goal of this effort was to use remote sensing, namely, for tasks like measuring soil quality and meteorological conditions. | Examining the most recent advancements in the Internet of Things (IoT) and smart sensor technologies. | The current scarcity of agricultural sensors with remote sensing capabilities hinders the development of innovative, trustworthy monitoring and control systems. | To enhance remote sensing applications, a clear IoT architecture must be established and a greater number of dependable sensors must be installed. The processes for gathering data and documenting it will consequently become more effective and successful. |
| Chakravarthy, R. | 2022 | Agriculture Intrusion Detection System | The Message Queue Telemetry Transport (MQTT) protocol facilitates data exchange between devices connected to the internet. | It concentrates on utilizing only a specific set of topologies (STAR, P2P, MESH and BUS) to link and analyze the nodes. It's likely that other topologies that would offer better performance or alternative trade-offs were not investigated in this study. | There is potential for improving intrusion detection systems through future testing of the mesh topology module using various application layer protocols. This protocol research could result in improved system functionality, higher security, and more efficient data sharing. There may be advantages to looking into the mesh topology's scalability for larger agricultural regions and real-world implementation scenarios. |
| de Araujo Zanella et al.’ | 2020 | Smart farm security systems identify significant challenges, deal with present security problems, and suggest future | A comprehensive analysis of smart agricultural security, | Security is a key concern because of the substantial volume of data generated by a small number of devices | Future research in smart agriculture should primarily focus on developing more sophisticated security techniques to protect data |

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| | | directions for development. | emphasizing open-field farming. | and transmitted to the cloud or gateways. However, a lot of agricultural systems lack robust security mechanisms to shield data from threats, unwanted access, and discovery. | at every stage of the farming system, from data collection to storage and decision-making. |

### 6.2 Gaps, issues, and challenges

The Internet of Things is currently organised into three layers: perception, transport, and application. While the research on a single layer is detailed, the research and discussion regarding the overall structure of IoT systems are a little lacking. This results in inconsistent data transmission, difficulties distributing data, possible communication safety hazards, and decreased placement accuracy and consistency, all of which reduce IoT's capacity to send data rapidly.

Installing more sensors for different agricultural applications makes things more challenging because each sensor node requires a unique communication interface and an incompatible protocol, demanding the employment of specialized software in addition to hardware to execute IoT-based programs. Many of the IoT's embedded gateway middleware applications are still in the early stages of development, so more study and application are needed.

Research on how agricultural IoT is perceived primarily focuses on data gathering and processing on a single machine; research on complete self-contained application systems are scarce.

Networks of wireless, high speed sensors are used by IoT devices to transmit data. High-speed data transfer is not feasible due to the weak wireless connectivity signal in isolated rural environment. Therefore, for real-time performance, increasing day coding efficiency is necessary.

## 7 Future Scope

The following areas of future development and research are identified based on the review that was conducted regarding Internet of Things(IoT) based agricultural research.

5G networks and improved connection will allow Internet of Things (IoT) technologies to exchange real-time data fast, improving performance and responsiveness. By processing data locally, edge computing integration helps cut down on latency and reliance on centralized cloud resources. IoT data analysis can be improved with the use of artificial intelligence and machine learning which provide accurate forecasts, anomaly detection, and personalized insights.

Using blockchain technology will improve transparency across the agriculture supply chain by verifying the quality and origin of products. For sustainable agriculture, energy-efficient Internet of Things devices must be created. Encryption and authentication, along with more powerful security measures, can protect a farm's privacy and data. New legislation will regulate data sharing and technology use to ensure the ethical implementation of the Internet of Things.

## 8 Conclusions

Applications of the Internet of Things (IoT) in agriculture, its significance,communication protocols employed, problems, and unresolved issues are all covered in detail in this study.

There is also discussion of the national policies pertaining to smart agriculture. There is a great deal of room for improvement in communication protocol development because different protocols have different restrictions related to things like frequency, cost, power consumption, coverage, etc. Furthermore, these protocols' compatibility is not always effective. Rural farmers require education regarding the use of IoT technology and its benefits because they have a limited understanding of it. IoT-based agriculture is an effective way to increase crop yield and accommodate the increasing demand for food and both urban and rural areas should support this approach. Small-scale farmers will be empowered by IoT-based agriculture, which will transcend national borders and benefit rural communities.

**Conflict of Interest**

The authors confirm that there is no conflict of interest to declare for this publication.

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