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Review Article

Deep Insight into IoT-Enabled Agriculture and Network Protocols

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In recent years, research has combined the connection of agricultural equipment to increase crop growth rates and lower planting costs by refining the entire planting process. IT-enabled agriculture has beneficial effects on this industry and is yet a source of debate in academic circles. Trending network technologies like WSN and IoT have never been easy to develop and use in agriculture. The growth rate was not increased using outdated, conventional methods and technologies. Additionally, the rapid population expansion cannot meet human demands and expectations. *Survey Methodology*. The existence of IoT in agriculture was investigated and reported in this review. The paper describes the different IoT-agriculture network protocols. This study clarifies how the Internet affects agriculture and its underlying mechanisms. It also discusses how the growth rate is boosted when both sectors work together. This study intends to explore a platform that offers an infrastructure to link devices using the network protocol used in agriculture. In this study, several contemporary network difficulties relating to agriculture are also covered. *Conclusion*. The results of this study can be used as a guide for creating particular network protocols for the agriculture industry.

1. Introduction

In the economic development of a region, agriculture plays a crucial role. Agriculture is an essential profession [1]. In India, almost 70% of families survive on the income generated by agriculture [2]. The protection and improvement of agriculture are therefore necessary. Keeping in view the importance of agriculture, smart farming was introduced. Agriculture and information technologies check the production of different crops [3]. Several problems are yet to be solved in agriculture as the most critical portion of farmers' strategies is obsolete and does not reach an acceptable yield [4]. Humidity, air temperature, and farmland significantly affect plant development and the agriculture industry, which are crucial for sustainability [5]. Sustainable agriculture and intelligent farming have drawn widespread interest in academia and industry, which is seen as a modern way of achieving food development, including crop monitoring in a real environment, smart greenhouse, disease detection in crops [6], and smart city management [7], among others. Other challenges, including data collection and recording, are the primary steps toward fundamental analysis and intelligent farming applications [8]. Data has become more ubiquitous with the exponential growth of mobile and wireless networking technology. An IoT (Internet of Things) system consists of low power, small in size, and sensor nodes operated using batteries [9], which also leads to wireless sensor networks (WSNs) [10]. To sense the environment continuously in remote geographical areas, a network of inexpensive nodes is deployed, a typical IoT application. The IoT draws much interest due to high demands for creative operation, performance, and productivity enhancement [11]. Cloud computing and the Internet of Things perform elementary management jobs, manage visual data related to crops, and observe the growth environment [12]. The projected market size of smart farming worldwide in 2017 and 2022 as smart agriculture global market size is projected to rise from around US$ 9.58 billion in 2017 to US$ 23.14 billion by 2022 [11]. Smart farming increases agricultural productivity, solves agrarian challenges like food demand, and makes farmers more connected and intelligent. By 2023, the market size of smart agriculture worldwide is expected to hit around United States (US) $ 26.76 billion. Precision farming is poised to become the most influential agricultural trend in developing countries. It is also projected that the market size of precision farming will rise from US$ 730 million in 2015 to US$ 2.42 billion by 2020. Figure 1 shows IoT projects' global share and trends [13].

With the growing development in mobile and wireless networking technologies and the ever-increasing amount of data and related resources distributed via heterogeneous networks, the Internet of Things (IoT) has transformed the concept of a more interconnected society into reality [14]. The IoT, also known as the Internet of Things or the Modern Internet, is a modern technology model designed as a global network of computers and machines capable of connecting, delivering innovative activities, and improving production and productivity [15]. The IoT is now generally known as a product that already has a significant impact on industrial markets. Current innovations rely mainly on managing and tracking diverse operations, increasingly growing to satisfy human requirements. Most of these innovations are based on efficient management and control of various processes. Several remote health tracking system sensors can screen variables and transfer data to a personal computer or an online storage website [16]. This device can resolve patients' concerns by continuously recording data on their mobile phones, PC, or various remote gadgets, which may influence their procedures. Sensors allow patients to self-screen, monitor, and survey human physiological information while supplying healthcare providers with interfaces and a dashboard. These sensors are efficiently tracked for patient consideration and eventually become accurate and robust. Incorporating the wearable integrated sensor [17] is used to assemble physiological and development information to enable the status checking of patients. The medicinal use of intrigue represents sensors. Using wearable frameworks, health tracking systems often use multiple sensors periodically organized into a sensor that is either confined to body-wearing sensors or incorporates a network of sensors. The use of wearable sensors and systems that are important to the restoration field includes well-being and health observation, safety control, home recovery, adequacy of treatment assessment, and early identification of disorders [18].

The relationship between the Internet of Things (IoT) and agriculture is highlighted in this research. For doing this, different communication protocols have been discussed in this paper. Similarly, the network protocols are further divided into subprotocols, and each protocol's specific purpose is elaborated. After that, the relationship between agriculture and IoT is discussed, including the function of network protocols in agriculture and their problems.

The remaining parts are arranged as follows: Section 2.1 examines existing literary approaches and protocols, followed by Section 2.2 on communication protocols. Section 2.3 then discusses the purpose of distinct protocols in a network; Section 2.4 then discusses agriculture and the significance of computer networks in agriculture; Section 2.5 then discusses the analysis of computer network protocols in agriculture; Sections 2.6 and 2.7 then illustrates potential research and technologies used in agriculture, and Section 2.8 discusses network issues in agriculture. Section 2.9 provides the discussion based on research questions, and Section 3 concludes the paper.

2. Survey Methodology

Based on the discussion mentioned in the introduction section, the proposed work focused on three research questions and targeted them as:

Q1. What network protocols have been utilized in the literature for agricultural digitization?

Q2. Which protocol is the best in IoT?

Q3. What challenges existed in agricultural networks?

We investigated the role of IoT in agriculture and network protocols in depth. A review approach was used for the deep investigation. This aided us in integrating previous work and defining our strategy in a broad sense. The resources are connected to IoT methods in agriculture and network protocols. Other sources include books, research papers, and review articles. The primary goal of our research is to give all users information so they can pick which protocols will best fulfill their needs. Table 1 provides the detail of the gathered research.

2.1. Literature Review. Discuss the constraints that are used to reduce the risk level in farming. The author highlighted that many farm areas with the ownership of that land could increase the expectations of a high growth rate due to freehand decision capability and can determine adoption pace. Moreover, it is mentioned that developing countries use two successful technologies in agriculture. First, technology is for affordability and availability of resources, and second, technology is used to profit by minimizing risk levels in farming decision-making. The profit maximization depends on the number of laborers, the farm size, and the agricultural resources [19]. In [20], the authors introduced a blockchain method as the central spine where IoT devices worked to collect data from the field along with smart contracts, responsible for communication among all the contributing parties. In [21], the authors predicted whether the area is suitable for harvesting or growing a specific fruit tree using high-level protocols. The research discusses the network's strategy used in the business's functionality. The authors examined the protocols and services from a high level and highlighted data transport mechanisms in a continuous communication stream. That data stream was assigned from one company to another and performed transit of message.

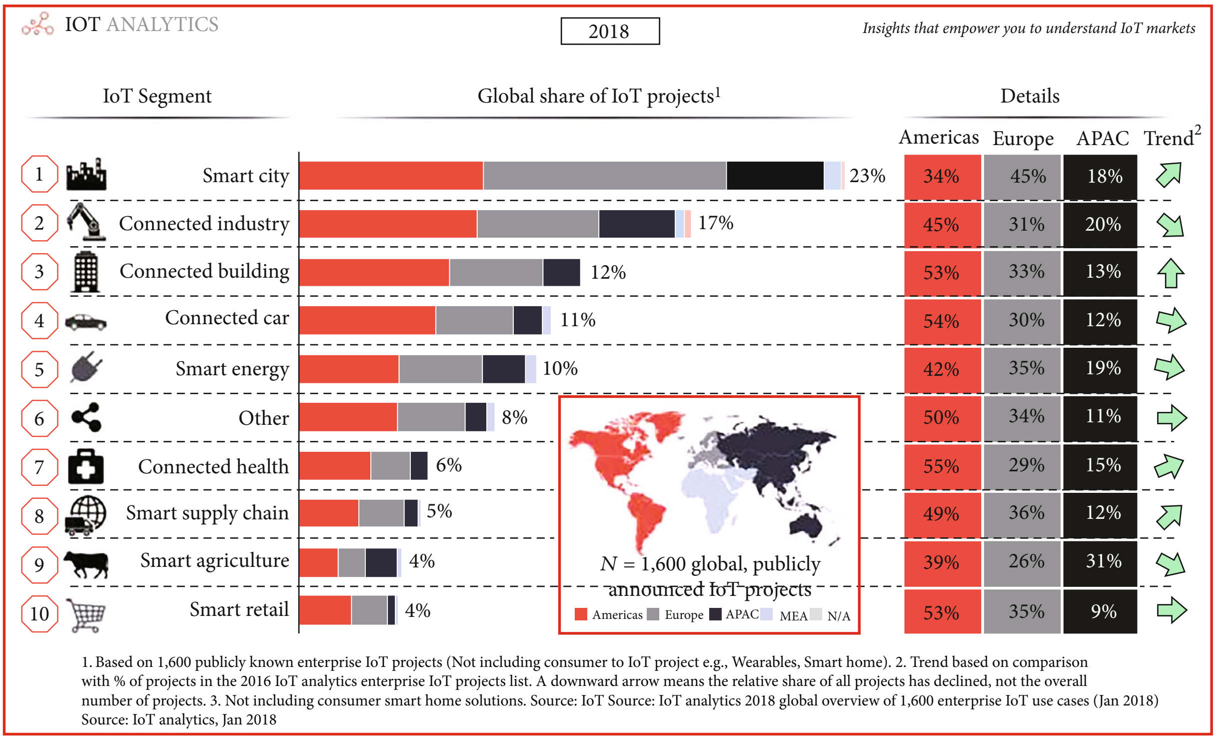

Figure 1: Globally IoT projects trends [13].

Table 1: Methodology and content adoption mechanism in the literature.

Review questions	Q1. What network protocols have been utilized in the literature for agricultural digitization? Q2. Which protocol is the best in IoT? Q3. What challenges existed in agricultural networks?
Research selection criteria	(i) Book, journal articles, conference papers, reports (ii) Research published during the period between 2011 and 2021 (iii) Research must provide the answers to the research questions (iv)Research also contains the title, year, and source (v) Literature targeted the IoT-agriculture along with network protocols
Research exclusion criteria	(i) Summaries of events and seminars (ii) Research published before 2011 (iii) The publication is not in English (i) Source: IEEE, Springer, Hindawi, peerj, and Scopus (ii) Search equations: IoT, agriculture, IoT in agriculture, network protocol, network protocols in IoT, network protocols in IoT-agriculture, communication protocols
Targeted area (no of studies) [reference]	(i) Background and statistics (18) [1–18] (ii) IoT in agriculture (34) [19–52] (iii) Communication protocols (13) [22, 23, 41, 53–62] (iv) Computer networks in agriculture (2) [63, 64]

The main focus is on Hypertext Transfer Protocol (HTTP) applications, and the method used is Hypertext Markup Language. The research claims that the Internet Protocol (IP) or Transmission Control Protocol (TCP) is easier to handle. Furthermore, the paper discusses appropriate HTTP security methods [22].

The research uses Address Resolution Protocol (ARP) to answer the queries of mapping from a logical address to a physical address. ARP protocols are preferred to save denial-of-service (DoS) and man-in-the-middle (MITM) attacks. So, through this, sensitive data can be exchanged without any flaws. After analyzing that no solution is feasible, the author discussed many solutions and generated a statement. Also, a secure and efficient ARP version is provided through this research. The proposed version is viable for all attack types and provides a more reliable solution. The authors claim that the designed ARP is more efficient and can solve entries related to storing in the ARP cache [23] using particle swarm optimization (PSO). The selection parameters have an objective function in node degree, intracluster distance, residual energy, and several optimal CHs. Compared to routing protocols, the model works best in terms of complex network metrics [24]. The research highlighted performance and security issues. Secure Sockets Layer (SSL) is used to discuss security issues. The claim is that SSL is a specific protocol to facilitate user communication. Through SSL secure authentication, data encryption, and data decryption can be done. This protocol provides excellent security service but is less efficient in performance than other protocols and services. Now we combine both the terms "data" and "communication" as "data communication (DC)." DC deals with an encoded movement of information by using an electronic transmission system. Data is sent from one point (known as a source) to another point (known as a destination) [25]. Ahmed et al. [26] introduced fog computing and WiFi-based Long Distance (WILD) networks in present WSN-based solutions to cover long range with minor delays. Also, a cross-layer-based media access control (MAC) is adopted to observe traffic nature and lead to an assigned duty cycle that improves delay and throughput. In [27], the researchers demonstrated the consequences of increasing the overall processing time and decreasing the number of bytes available in memory. The researchers claimed that SSL has a higher impact on real processing time when taking the percentage of the bytes available in memory. The primary function of any sensor network is to route the sensor-assembled information and forward it to the BS. The simplest way to transmit data is direct transfer, where the nodes have to direct their data to the base station or sink node. However, suppose the distance between the sink and the network is high. In that case, the node will die out quickly due to unnecessary energy consumption. The clustering algorithm eliminates wasteful energy consumption when delivering data to BS by grouping the network into clusters. Each cluster is assigned a cluster head (CH), which sends data to base station (BS). Choosing CH, which should ensure a uniform energy distribution between the sensors, is crucial in the clustering algorithm [28]. The selective identity attack model is often considered in identity-based encryption, which means the identity to attack should be announced before the attacker requests the necessary information. The attacker could first pick multiple identities to expose, known as the selective multi-ID attack, for various receivers Strategic Management and Innovations Division (SMID) [29]. Using optoelectronic components and a polydimethylsiloxane (PDMS) microfluidic device, a colorimetry-based miniaturized device for accurately assessing two soil, nitrogen, phosphorus, and macronutrients was constructed. A microcontroller and Bluetooth-based module are adopted to find the remote location and monitor the data. Moreover, an android application is also developed to monitor data transmission [30]. A blockchain-based optimization technique is used for the system of greenhouse. However, the proposed method performs three primary tasks (prediction, optimization, and controlling), whereas the Kalman filter is utilized to predict the greenhouse sensory information. Similarly, for indoor greenhouse climate, the optimal parameters are calculated. Finally, these improved parameters are used to activate and control the actuator with the help of the control module. The proposed optimization strategy reduced energy consumption by 19% compared with prediction-based techniques and 41% compared to the baseline scheme [31]. An IoT multiagent precision irrigation approach enhances water usage in irrigation systems. Irrigation is supervised and regulated in each field with the help of an intelligent irrigation agent that prescribes and applies the amount of water based on agronomical parameters in the proposed system. The results showed that irrigation levels were administered accurately on the fields, resulting in increased water efficiency [32]. Data exchange can be done through a wireless or wired transmission medium from one device to another. In simple words, digital information transferring from one place (source) to another (destination) is known as data communication (DC) [25, 33]. Smart agriculture consists of several parameters such as soil nutrients, business, security, profit, storage, and communications. However, the soil is an essential parameter to enhance business in agriculture. Measuring soil capability first and then investing in it is necessary [30]. Similarly, the greenhouse method can improve or accelerate agricultural progress. As a result, a blockchain-based technique [31] exists in the literature that efficiently monitors greenhouse performance using sensory information. However, this method can be implementable after measuring the soil's capability.

Similarly, other methods [32] are also used to manage or monitor other agriculture components like water and honey. Furthermore, because a large number of sensors are operating at the same time, security is an essential aspect of intelligent agriculture. Security may be improved by addressing vulnerabilities and employing attack-prevention tactics. Many methods [21–23, 25, 26] may be used to enhance network security and performance. The summary of literature is summarized in Table 2.

The IoT integrates the Internet with intelligent devices and objects, becoming an omnipresent network. Messages from the satellite must also be stored until they can transmit to the device. The satellite IoT gateway should eventually be fitted with store-and-forward functionality [34]. Besides, the gateway could also store the data received from the smartphones when traveling beyond the satellite contact range to avoid data loss and vice versa. Moreover, because of BLIP's smaller footprint, Berkeley IP (BLIP) makes it simple and straightforward to build network apps. We performed testbeds on actual WSN consisting of TELOSB and MICAZ hardware systems to discover the characteristics of LowPAN in (BLIP). It is important to note that BLIP can only use the IPv6 unicast address that is part of the network shared from the edge router and its interface identifier derived from the interface's MAC address [35]. WSN provides a platform for data processing and networking to map and navigate the natural environment and strengthen society [36]. Wireless technology transfer drains more electricity than machines designed to receive or stay idle. In [37], the authors developed a routing mechanism using a memetic algorithm that elevated the performance of IoT-based WSAs in regards to throughput, stability period, the actual number of nodes, end-to-end delay, and network lifetime. The rising

Table 2: Brief descriptions of literature review.

Authors	Approaches	Methodology	Remarks
Pranto et al. [20]	Blockchain (BC) method	Collection of data using the intelligent contract Prediction of suitable area for harvesting or tree growth	Robust and secure characteristics of BC in agriculture
Kumar and Venkata [22]	HTTP	Discussion of security methods of HTTP and working mechanism	The researchers claim that IP or TCP are easier to handle
Ataullah and Chauhan [23]	ARP	Discussion of network attacks and prevention swarm particle optimization is used to	It keeps all of the ARP's advantages while removing its security flaws
Gupta [25]	SSL	Secure authentication, data encryption, and data decryption	Less efficient in performance
Ahmed et al. [26]	Fog computing and WILD networks	WSN-based solutions to cover long-range with minor delays	Improves delay and throughput
Pal et al. [30]	Microcontroller and Bluetooth-based module	Monitoring the location and data	—
Jamil et al. [31]	Blockchain-based optimization	Perform three significant operations such as prediction, optimization, and control. First, this model predicts the sensory information, then calculates the optimal parameters, and finally improves the parameters used to initiate and control the actuators	Reduced energy consumption by 19% compared with prediction-based techniques and 41% compared to the baseline scheme

number of smart devices connecting to the Internet has made energy efficiency an excess parameter in the IoT architecture. Setting up energy-efficient methods for integrating sensor networks has always been difficult for researchers. Once combined with the IoT, control becomes a more critical concern due to the number of computers [38].

Technologies such as Automatic Identification and Data Capture (AIDC), barcode, QR code, and near-field communication (NFC) are used to identify warehouse organizations. Using NFC technology is the opportunity to use it as an NFC tag reader on a cell phone. Barcodes can provide fast and accurate data transmission that ensures monitoring of products/pallets/packages and enhances service quality for end-users [39]. In multilinear maps setting MPHF parameters, a new ID-MRPKE scheme based on MPHF is built. In the basic model, we illustrate the security of the suggested method. Our plan is only formulated concerning a standard multilinear level map. Using the improved noisy cryptographic multilinear maps of Gu's work is necessary to construct our scheme, which proved contrary to the attack [40]. The main research focused on HTTP, highlighting that protocol is the critical and essential data communication protocol. He discusses the TCP/IP model in detail and OSI layers. He highlights the message traveling from sender to receiver or client to server. He discusses the packet tracer's monitoring and simulating mechanism [41]. A wide variety of applications, including smart cities, traffic congestion, waste management, systemic health, defense, emergency services, logistics, retail, industrial control, and healthcare, are enabled by the Internet of Things (IoT) [42]. IoT is mega technology that can build links on a website and any network with something, anybody, at any time, location, or operation. It has a massive effect on the entire blockchain of heterogeneous network connectivity-enabled organizations, intelligent objects and applications, networks, and services built as an intellectual, ubiquitous framework of smart devices. IoT devices operating in several areas attach to dynamic devices and communicate with hostile environments [43].

The Burrows-Abadi-Needham (BAN) logic approach was used to test the system. Cryptanalysis finds that our scheme can solve the security vulnerabilities of previously published techniques. The result reveals that our scheme's security features are quantitative and can increase authentication performance in IoT environments. Notably, it has excellent performance reliability, low cost of computing, frugal electricity consumption, and low communication cost [44]. The traffic route between the heads of the zone and the base station is distance-centered and designed to eliminate data packet loss at one hop and dual-hop speeds at the site's leaders. Each site is planned by uniform random deployment to own approximately 1/4 percent of the deployed sensor node count like network energy usage, sensor node average energy consumed, packet distribution ratio, percentage of packet loss, and network throughput [45]. With SWIPT, we have a modeling system for sustainable cellular mass IoT. Under functional conditions, the advantages of spatial beamforming provided by the multiple-antenna BS improve information transformation and energy harvesting (EH). To mitigate the effects of adverse variables, we propose two robust beamforming algorithms to optimize the weighted sum rate, minimize the overall power consumption for the cellular IoT, and prove that the proposed algorithms apply to functional SWIPT systems with low complexity and high analytical and simulation robustness [46]. Nowadays, we see many apps that make our lives easy, such as smart cars, smart houses, intelligent traffic control, intelligent workplaces, innovative medical consultation, smart cities, etc. All such services are beyond an average citizen's control to improve information and communications technologies. The vision of the word Internet has continuously spread its wings in all facets of life over the past few years. Identifying the optimum capacity of the Internet use has been a difficult challenge for researchers. Over time, items have been correlated with the word Internet and are not known as IoT [47]. As the name suggests, Radio Frequency Identification (RFID), wireless sensor networks (WSN), Bluetooth, near-field communication (NFC), Long-Term Evolution (LTE), and numerous other intelligent communication technologies are related through the Internet [48].

Communication is not only between humans in science, but it can also be between devices or computers. The exchanging of information between two (or more) bodies is known as correspondence, while knowledge is used in a well-formed or ordered manner as information about someone. Data can occur in several ways, such as text (SMS) or device data in a text file or image, or a signal, such as cell phone data. The "digital-analog signal" or "digital bit" is known as data in electronic science. Specifically, data is a plural form that describes a single piece of knowledge [49]. WSNs have been an integral part of applications, such as environmental surveillance, military, and medical surveillance, through feasible connectivity, practical inspection, and application efficiency. Many sensor nodes are composed of WSNs that are thinly deployed and wirelessly communicated to transmit and receive environmental data. At least one or more sensors, a radio transceiver, a processor, and a power supply portion are fitted for each sensor node. Due to the sophistication of such structures, developing WSNs is a very demanding task [50]. In accumulation, some essential specifications, such as the power consumption criterion, which is the primary key, need to be fulfilled during the construction of the WSN. Several programming methods, which concentrate on low-level machine problems, have been proposed in existing real-world WSN implementations [51]. High-level processes have been recognized, and many solutions have been suggested to simplify the architecture of the WSN and abstract from low-level technical data. The model-driven engineering (MDE) methodology, in particular, is becoming a promising alternative [52]. Figure 2 shows the recently utilized communication technologies in IoT.

2.2. Communication Protocols. A set of data communication rules is known as a protocol. Two devices must be used as a protocol to perform communication to send or receive bit-streams to each system. And all the entities should be agreed on a "Protocol" to do contact. We handle the following queries [53, 54].

(i) What is communicated?

(ii) How is it communicated?

(iii) When is it communicated?

Protocols act like an agreement among communicating devices. Following are the elements used in the protocol.

(1) Syntax: data structure or format means the order in which data is presented. Like the simple protocol, the design uses the first 8 bits as the sender address, the second (after the first 8 bits) 8 bits used as the receiver address, and the rest

(2) Semantics: each section's bit meaning is known as semantic

(3) Timing: is a combination of two things

(i) When sent the data

(ii) How fast we sent it

If both sides do not use the compatible mechanism, some data may be lost on the receiver side. Two systems may be interconnected but can neither send the data nor communicate without a protocol. Communication protocols act as the rule descriptions through which devices are allowed for communication. They deal as one component of the DC system.

2.2.1. Transmission Control Protocol (TCP). TCP is the significant communication protocol in two or more electronic systems on a network setup. TCP allows the devices to transmit data among them. TCP breaks the data before sending them into IP packets and reassembles them at the receiver. A system sends a request to another device through TCP for communication, sending the request to the receiver's accurate address. After getting an agreement between two parties/systems, TCP allows communication after setting up a "Full-Duplex." Full-Duplex maintains a communication line between designs and work until one of the systems disconnects or closes the path. TCP/IP have several further protocols inside them, like TCP between applications, User Datagram Protocol (UDP) for the most straightforward communication among applications, Internet Protocol (IP) communication between computers, Internet Control Message Protocol (ICMP) to handle errors and check statistics, and Dynamic Host Configuration Protocol (DHCP) used for "Dynamic Addressing."

2.2.2. Internet Protocol (IP). Communication-less means no physical line (cable) for communication is required between two systems. The communication-less protocol is known as the Internet Protocol. This protocol uses a subnet mask

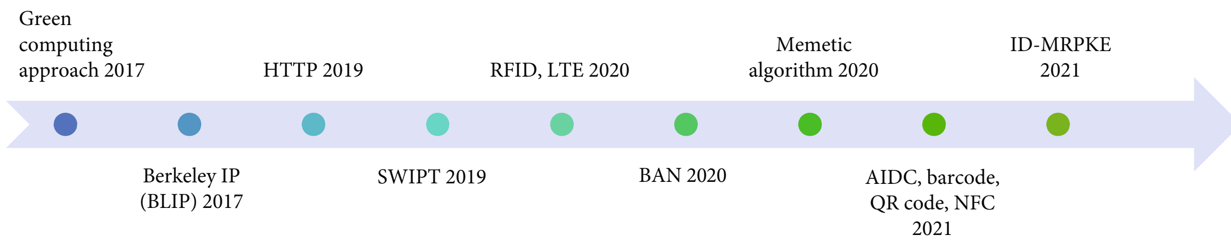

Figure 2: IoT communication techniques.

and IP address to determine whether the data is remote or on a local network. A default gateway is used to forward data known as a "router" if a remote network links to another network. IP used a hop to keep track of the transverse number towards the destination.

Internet Protocols support all the local area network (LAN) types and have a point-to-point link with nodes. IP can solve the Ethernet problem of scaling. Through IP, we can achieve universal "connectivity." IP supports global routing and addressing mechanisms to send packets of information from one host to another. The most common version is IPv4, also known as version 4; it has 4 bytes, which means 32 bits. The specific point of IPv4 from IP is that it has two parts of address: the "network part" and the second "host part." The router is vital in sending packets toward the accurate destination system. Same as TCP, IP splits the data into small-sized boxes (independent) and is sent via the Internet to the system. The benefit is that each communication line can be used simultaneously among different methods.

2.2.3. Wireless Routing Protocol (WRP). This protocol comprises a routing protocol, also known as vector routing. Routing tables are used to store each node's information. The store's data is node distance value, link cost, routing information, and information about the "Message Retransmission List (MRL)." Each node in this interconnectivity has its own path known as the "Shortest-path Spanning Tree (SST)" within their adjacent nodes. These adjacent nodes get updated information. If no change occurs in the direction, then information is directly transmitted among nodes; otherwise, a new path is built after the new shortest path for routing information. All the data is updated in the table. WRP has faster transmission of information because this protocol does not use the loop phenomenon in algorithms.

2.2.4. Address Resolution Protocol (ARP). In the TCP/IP protocol, another protocol is named "Address Resolution Protocol (ARP) in the network layer protocol bottom." The HOST part is identified by 32 bits (Portion in IP address). TCP/IP has a different addressing scheme name, "Medium Access Control" or MAC, and uses 48 bits for address. The network layer receives a packet and checks the destination IP address. The packet is directly sent from the sender machine to the destination machine if the destination is at some network (local network). If the destination is different, then a router path would be found. The sender machine needs the MAC to address the destination machine for sending direct packets. ARP can accomplish this. It also has an ARP cache to make the temporary memory map 32 bits address to 48 bits address scheme. ARP sends the request message (ARP request) and receives a reply (ARP reply). ARP request is a form of the message, and in this message, it depends on the MAC address. Then all the hosts broadcast this request. ARP reply is a form of the message containing the MAC address requested.

2.3. Protocol for Specific Purpose. Specific protocols are designed to perform a specific task (single task) for communication through network systems. Some of these protocols are listed below, and their functionalities are for analysis purposes.

(1) Hyper-Text Transfer Protocol (HTTP) maintains the communication between the browser and server [41]. For this communication, it uses a request which sends from the browser (client) to the server (web), and in return for this request, web contents are sent from server to browser (client), as shown in Figure 3

(2) Hyper-Text Transfer Protocol Secure (HTTPS): when the "S" letter is attached to the HTTP, it indicates the communication (above mention) is secure [22, 55]. It means S has a specific meaning. Usually, bank transactions have sensitive data, so they use this protocol

(3) Secure Socket Layer (SSL): this protocol is worn for data encryption to perform secure transmission of data [56, 57].

(4) Multipurpose Internet Mail Extensions (MIME): this protocol transmits binary data and voice and audio (multimedia files) across the TCP/IP network

(5) Internet Message Access Protocol (IMAP): this protocol's specific use is retrieving and arranging (sorting) email data

(6) File Transfer Protocol (FTP) handles the file transmission between the systems [58] (Mazin, 2013)

(7) Network Time Protocol (NTP): its particular purpose is to perform time synchronization between systems [56, 59]

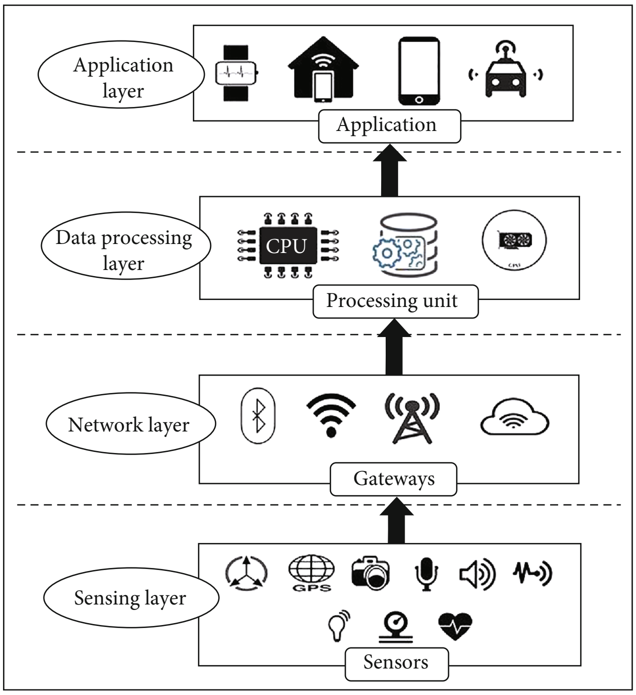

Figure 3: IoT architecture.

(8) Dynamic Host Configuration Protocol (DHCP): this protocol is used for IP address dynamic allocation of systems into a network [60].

(9) Simple Network Management Protocol (SNMP) is used explicitly for computer network administration [61]

(10) Lightweight Directory Access Protocol (LDAP) gathers the Internet user's email address and information

(11) Internet Control Message Protocol (ICMP): if any error handling occurs in the network, this protocol takes care of it

(12) Address Resolution Protocol (ARP): it must find the computer network address based on a card-based IP address [23, 62]. Figure 4 shows the purpose of each protocol in visual form

2.4. Agriculture. Agriculture is the most recent trend that has gained popularity due to its collaboration with systems and the Internet. Using network capabilities and computing power can enhance the agriculture growth rate. Instead of traditional tools, computers and the Internet can also facilitate agriculture without physical objects. For example, applying different sensors to get field updated status could not be done with old traditional tools. In 2025, according to the report of the United Nations organization named the "Food and Agriculture Organization (FAO)," the total population will increase by up to 8 billion people. This means we must build a mechanism to increase the food growth rate (practical food production will be increased by up to 70%). To achieve the target of FAD mention number and provide food to each person globally, we need to introduce the modernization of agriculture technology and generate high-quality products. Resources and a high-water supply are mandatory to get all the beneficial agriculture points.

Collecting valuable measurements from raw information is the goal of any research. Get the crop data that needs to be processed in a well-defined manner. A year ago, the term "precision agriculture" came into the research field to perform crop management, generating digital data (digital information). To get the appropriate or correct decision related to the crop conditions and crop diseases, an entire development process is needed to get the crop diagnoses. Diagnoses of any crop or field can only be made with field experience, and data can be perceived over a farmer's eye. Our primary purpose of this research is to manage the crops and farms with the help of information related to the field and make intelligent decisions after diagnosing. A proper system must connect smart devices or sensors to achieve the abovementioned objectives. The interconnectivity of these devices can generate desired information about crops. This information acts as the data that is retrieved directly from the soil and crops. There are two ways to retrieve the data from the soil. First is using the sensors and getting information through these sensors in the form of fields. Second, use an application or software. This application is usually synchronized with the Internet. In our research, we use these two steps in the same order. We interconnect devices through the computer network protocol and will build an application. After receiving data from the sensors, our control unit will perform a decision that means physical action execution. This action can be in any form, which means we can achieve any specific action from our machinery after any command.

2.4.1. Computer Network in Agriculture. A lot of work has been done in the last decade to enhance the growth rate of agriculture. People have used Internet functionalities and physical things such as sensors in the previous decade to get the highest growth rate target. When the Internet functionalities and material objects known as "things" are combined, it made a new concept of research named the "Internet of Things" (IoT). The structure of IoT is built upon the three layers. The three layers are (1) perception layer, (2) network layer, and (3) application layer. The perception layer has sensing ability; the network layer is used to send data or as a data transfer, and the application layer stores the data and performs data manipulation.

Our primary research topic is a computer network in agriculture and IoT. The first word, "Internet," is used to get all the Internet features and functionalities.

2.4.2. Computer Network Functionalities in Agriculture:

(1) Perception Layer. As we mentioned earlier, this layer has sensing ability, which means a wireless sensor node is used, and its processing module is known as microcontroller unit (MCU). One or maybe more external or embedded digital or

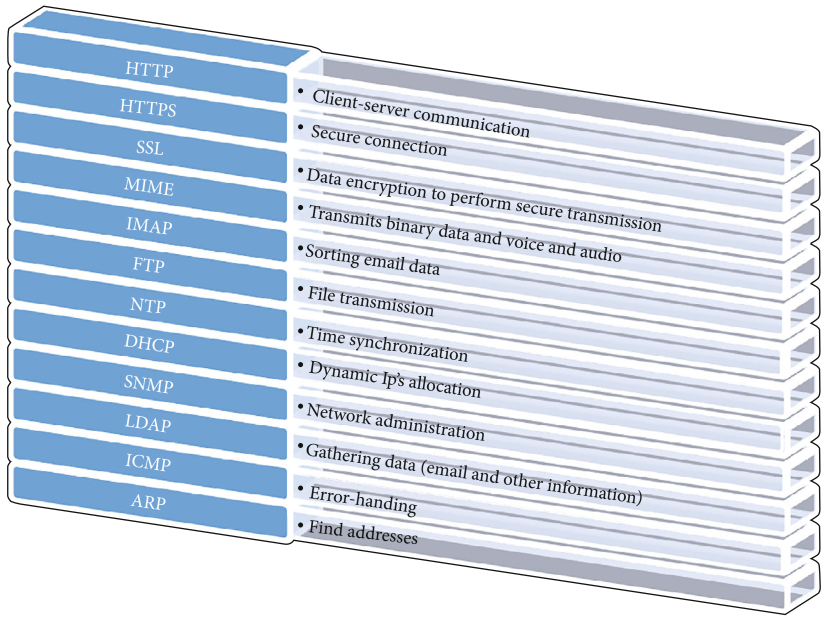

Figure 4: Discussion of IoT protocols.

analog device for sensing is used along with this node. The next step is to get control of identifying monitoring and agriculture tracking during production. To get the control mechanism during the show, WSN is used for logistics and storage control facilities and performed monitoring.

(2) Network Layer. As the name shows, the network layer can connect neighboring nodes for communication, interact with the environment or physical objects through WSN, and build a network for data forwarding to get valuable information for further analysis. Communication protocols facilitate network functionalities and act as the bridge between end nodes and Internet gateways. Standard protocols used in this step are ISA100.11a, Zigbee, Sigfox, one-NET, and wireless HART [63].

(3) Application Layer. As we know globally, billions of systems are available and provide Internet access and functionality control; identification is necessary. To access Internet mobility, we use IPv6 to handle identification problems. This layer has a challenging responsibility because devices' uniqueness is identified at this layer. Another challenge is heterogeneity, which means it should achieve diversity in different machines, either they are compatible with another device or control power related to computing and adjust to the environment. To handle the identification challenges, IPv6 supplementary uses context-aware addresses and meta-data. One software layer is used between the application layer and the primary device. This software layer is middleware and has a particular scope in the new service development. Using this middleware mechanism, we get the combined functionalities of the sensor network and service-oriented architecture (SOA) infrastructure.

2.5. Computer Network Protocol Analysis in Agriculture. Interconnected services in wireless technology are mainly split into six categories. These categories are Global System for Mobile Communication (GSM), Wireless Personal Area Network (WPAN), Wireless Regional Area Network (WRAN), Mesh, Point-2-Point (P2P), and Low Power Wide Area Network (LPWAN). The purpose of highlighting the wireless technology categories in the analysis section is to compare them and measure their functionality levels. Readers can select the appropriate protocol for agriculture research and projects by comparing and analyzing this review paper. They can increase the growth rate, as we mentioned earlier. This wireless interconnectivity provides a wide bandwidth range for an extensive communication range. It can perform security measures and less power consumption. Our research focus is network protocols in agriculture, so we provide a summarized protocol comparison in Table 3 as our research finding. These protocols are used in the agriculture field with specific requirements. Through our research findings, readers can easily select proper computer network protocols with high efficiency and compatibility with the device. However, the comparison of IoT protocols is also shown in Table 4.

In agriculture, two phenomena work as vital entity in any project or research named (1) humidity and (2) temperature. Like temperature, humidity can irrigate the system and wireless nodes (radio wave propagation). At temperatures like 270C to 600C, received signals have some unwanted data. This is a severe issue in the development of agriculture while using the wireless transceiver, their number of nodes, and the distance among the used nodes.

2.6. Research Approach. Climate changes are usually considered an initial parameter to measure the changes and check the soil condition. We apply different sensors (more than one) to get these measurements in the soil. These sensors generate the data that guides us in many directions, which leads us towards the higher growth of crops. For example,

Table 3: Comparison of computer network protocols and features.

Routing protocol name	RPL	P2P-RPL	CORPL	CARP	LOADng	Citations
Strategy	Proactive	Reactive	Proactive	Reactive	Reactive	[63]
Traffic type	MP2P, P2P, & P2MP	P2P	MP2P, P2P, & P2MP	MP2P, P2P, & P2MP	P2P	[63]
Mechanism	Energy-aware metrics & multipath routing	Energy-aware metrics	Energy-aware metrics & multipath routing	Energy-aware metrics & multipath routing	Energy-aware metrics	[63]
Algorithm	(i) Distance vector (ii) Source routing	(i) Distance vector (ii) Source routing	Distance vector	Link state	Distance vector	[63]
IPv6 support	Yes	Yes	Yes	Yes	Yes	[63]
loT routing challenges met	Local and worldwide repairs Reduced energy use Improved mobility The power to grow to any size The use of RAM is not taxing	Fixes for local and global issues, energy conservation, mobility, and scalability	The data management and server technology are two challenges	The administration of data and storage is another concern	This is a winning combination in energy use, mobility, high scalability, and low memory utilization	[63]
Main characteristics	Identification and avoidance of loops. In addition to self-configuration, timer management is also available in this system	Discovers the most efficient path for every given source-to-target pair	RPL-based opportunistic forwarding strategy	Links of high quality for packet forwarding and a high delivery rate increase traffic	AODV in a more compact and efficient form More broad traffic patterns may be accommodated	[63]
Restraints	No security	(1) Insufficient security (2) excessive use of system memory	Security and storage management is absent.	No security no security No server technologies No re-use of previously obtained data	There is no security. There is no local repair Long route-finding lag time	[63]

Table 4: Comparison of CN protocols [64].

Features	MQTT	AMQP	HTTP	HTTP+Nabto	CoAP	CoAP+Nabto	Citations
Transport	TCP	TCP	TCP	TCP + UDP	UDP	UDP	[64, 65]
Low latency	✓	✗	✓	✓	✓	✓	[64–66]
Messaging type	Async	Sync	Sync	Sync	Sync	Sync	[65]
Lightweight	✓	✗	✗	—	✗	—	[64, 65]
Build-in security	✗	✗	✗	✓	—	✓	
Easy to build on	✗	✗	✓	✓	✓	✓	[65]
Encrypted	✗	—	✗	✓	✗	✓	[65]

how much water is needed for a specific plant? How do we preserve crops from water (a high water level is dangerous for some crops; it varies from crop to crop)? What is the impact of extra irrigation on the earth's level? What is the atmosphere condition? Some researchers use additional optical sensors to map the ground's situation and sense the remote temperature. Our integration of interconnectivity of network protocol can cover the larger area of the field, and through sensing devices, we can get more accurate conditions related to soil and weather. With the help of this precise information usage, we can increase the growth rate of crops. Another reason to use wireless network protocol sensors is that they are available at reasonable prices, which means we have less impact on cost. It allows researchers to connect end devices more sophisticatedly and have higher computational capabilities with sensor incorporation. The connectivity of nodes will increase the processing. Some researchers use camera devices to get images of the crop. Using these images, they implement different image processing algorithms and predict the attack of insects.

2.7. Technologies Used in Agriculture

2.7.1. Sensors. Sensors are intelligent devices designed to get specific information from humans or the environment. These sensors are attached or deployed on the ground or in the inner soil in agriculture. After deploying the sensor, the next challenge is to get a wide range of sensors to cover the maximum area of sensors. A wide range can reduce the overall deployment cost because we can cover a larger area of any field. But the issue is that most organizations focus on the data only and ignore the range parameters. IoT sensor nodes capture data from the farming environment, such as soil moisture, air humidity, temperature, soil nutrient components, pest images, and water quality, and then send it to IoT backhaul devices. IoT sensor nodes can be deployed as RFDs (reduced-function devices), which only connect with FFDs (full-function devices), depending on the operational purpose and installation location. Farmers can use smart mobile devices, such as smartphones and tablets, to access real-time agricultural data (soil and plant condition, irrigation, fertilization [65].

2.7.2. Satellites. Satellites are another artificial medium through which we can get remote data to achieve smart farming. Foreign countries are making a lot of investments in getting satellite data, for example, “GeoEye-1 system”, “European Sentinel 2 Satellites”, “American Landsat Satellite,” and “WorldView3.” Asian countries do not have any success stories about satellites to get information about field or weather data. The only solution is to use ground-level sensors and their interconnectivity. It is reasonable to claim that precision agriculture, which involves gathering and utilizing data about crops, soil, and weather conditions via remote sensing, significantly reduces human effort in farm and field management in North America. With a market value of $6,215.9 million in 2021 (compared to $2,792.3 million in Europe), the area had the most significant tech market value globally.

2.7.3. Aircraft Systems. The distance is too long to get accurate information and point at the target through satellite. The minimum length is 700 kilometers, measured between the satellite and the soil. To overcome the distance issue, aircraft systems are used. The minimum distance between the aircraft and the soil is 100 meters. In Spain, 120 meters is considered the legal distance of an aircraft system. Commonly two aircraft systems are used. The first is the “unmanned aerial vehicles (UAVs),” and the second is the “remotely piloted aircraft (RPA).” Aircraft systems have importance because they can work where conventional ground vehicles cannot perform their duties. UAV has more benefits in precision agriculture.

2.7.4. Proximal Sensing. Sensors are known as proximal sensing when information is gathered from the platform based on the ground. In other words, ground-based plate forms are proximal sensing. “Ground vehicles” also work as proximal sensing because these vehicles are the nearest to the crop. They can get more accurate crop data and more feasible per meter crop samples. They can also solve the limitation problems of sensor implementation. But they can detect the weather conditions, for example, high temperature and appropriate sunlight needed for the specific crop. Aircraft systems cannot perform soil scouting and crop analysis. Most of the research progress in achieving the robots' tilling, seeding, pest control, field scout, transplanting, soil analysis, and crop harvesting.

2.7.5. Data Gathering. The traditional farming mechanisms differ from the latest farming techniques because they cannot gather crop data. All crop decisions are taken by the visual assessment done by the farmer's eye. Modern technology assesses and generates production decisions by using quantitative data. If we can compromise on the cost, we can hybridize two or more technologies and techniques for more accurate data and gain a broader range of data. For example, sensors can perform crop data acquisition, and aircraft systems can be used for other crop-related functions.

2.7.6. Data Representation. Crop data is usually represented in a coherent, understandable composition for the end-users. The simplest way to show the “homogeneous zone” and mapping is maps format in agriculture. In agriculture, maps represent larger areas and are used in the design, making questions to answer them. We can add or be interested in several parameters to the plan. Many software is used to generate a map of a specific area. We can also add coordinates to the map. The “Local Tangent Plane” system can do this and provide Euclidean geometry features. Another feature, the name grid, is used in the map representation to show the systematic. By using it, more accurate information can be produced.

2.7.7. Software. “Geographic Information Systems (GIS)” is used to get the practical answers and display this information into map representation (as we mention in the data representation section). This information manages all the fields. GIS acts as a “computer-based” tool. Using this tool, we can get, manipulate, analyze, and store field information. As we mentioned earlier, “precision agriculture” has a broader scope; a unique software is designed to get the information about precision agriculture known as “Filed Level Geographic Information System (FIS).” The drawback of this software is that it can operate only on previous operating systems like Windows NT, 98, and 95. Some updating is done in FIS to provide the information for management purposes. The updated version is the “Farm Management Information System (FMIS).” A tool to help farmers manage their farms more successfully and efficiently is the FMIS. To cultivate the farm, a system called FMIS deals with the accuracy of data, optimization of the use of resources, and procedures. FMIS aims to minimize the production cost, maintain agriculture standards, maximize production quality, and provide accurate decisions. Another advantage of this software is that we automate the whole data acquisition process. We can monitor the entire process, plan better, and make accurate decisions according to the situation. Some software is so intelligently designed that they produce proper map representation and a decision-based model, which means beginners can also make the appropriate decision. Furthermore, this software also provides information about the weather through which risk levels will be minimized.

2.7.8. Actuation. Actuation is the situation in which an executable decision is made after obtaining the crop's appropriate information. The executable decisions mean farmers can use the advanced tools and equipment; more spray medicine can be used to prevent insects' crops from being attacked after gathering computerized information from the control unit. Actuation can increase the production profit and reduce the impact on the environment. The actuation can increase the production rate by 35% in one field or farm. So now, we can roughly measure or assume that the whole process positively impacts crop growth rate when we gather it from area to field.

2.7.9. The Technology of Swath Control. Swath control can handle the overlapping issues in the area mapping. With the swath control, all the guidelines will lead to how to invest in farming. A farmer can increase his farming capabilities with swath size controlling through this approach. The field's size and shape can change the need for fertilization and seeding process and may cause irregulating applications. Radio frequency energy harvesting technique is also used in the agriculture domain [66].

2.7.10. Controlling and Monitoring via Smart Devices or Smartphones. Smartphones have become a necessary part of our lives and played an essential role in controlling and monitoring our daily life tasks. Researchers try to use smart devices in agriculture, especially smartphones, to manage and monitor purposes. An application is installed on the smartphone to control his irrigation system. Smartphones already have weather condition checking applications to reduce the cost of weather detection sensors. But still, some sensors are required because they are not embedded in smartphones. For example, a moisture checking sensor is still needed to get the soil moisture level data. We can control the amount of water with moisture information and decide accordingly.

2.8. Network Challenges in Agriculture. In agriculture, mainly farming, various challenges arise. We discuss these challenges step by step and according to their categories.

2.8.1. Hardware. Hardware can be directly exposed to the perception layer due to a challenging environment. A challenging environment can cover many factors like high temperature, extreme humidity, high radiations of solar, increased rain, earth vibration in an earthquake, and strong air (winds) that can destroy the capability, functionality, and hardware structure.

Another hardware factor is batteries used as power resources; their functionalities will not be the same for long periods. As a result, substantial and long-term batteries and appropriate tools for programming act as mandatory. Any resulting program or structure and replacement of batteries will also increase the cost and the time factor. As well, the disconnectivity of interconnected devices will lead to data loss. Devices sometimes lack tamper-resistant enclosures since doing so would increase their cost. The absence of tamper-resistant boxes leaves the system vulnerable to interactions with outside forces, including humans, animals, and farm machinery. The system integrity may be compromised if a farm worker or wild animal accidentally bumps against a sensor, displacing or removing the object from its original position. A tractor or other farm equipment might strike the device, resulting in either temporary or permanent physical damage, data corruption, data loss, or device damage.

2.8.2. Interoperability. In agriculture or food industries, infrastructure aims to exchange goods, supply globally, and optimize production. The interconnectivity of devices will gradually transform business and make product or food flow continuous with real-time visibility. With the interconnectivity of computer protocols, we can get high-quality product data, handle computational process and storage issues, and get high quality. It is a deliberate alteration of the resources of an autonomous system. Robotics, autonomous tractors, and unmanned aerial vehicles (UAVs) are precision agricultural technologies that are becoming more common, especially on big farms. Sensors, cameras, GPS, maps, and remote-control systems are just a few of the aspects that make this equipment function. The autonomous system may operate incorrectly or experience/cause mishaps if an adversary alters one or more components. Failures might cause significant losses due to poor soil or crop management, destruction of crops, structures, machinery, and equipment, or even the autonomous tractor itself.

2.8.3. Networking. The network layer has an impact on the environmental characteristics. In agriculture, wireless communication is preferable because it can reduce the wire cost. Using multipath propagation's effect, we can increase the link quality level. Like hardware, the network is also affected by humidity, high temperature, and different obstacles existing in the space. So, it is a big challenge to transfer the data into its original shape in this environment's rural behavior.

2.8.4. Security. Your data sent through the computer network protocol should be secure from external threats or attacks. When paired with Internet connectivity, storage, administration, and data processing create a slew of difficulties and security risks. When data transfer occurs through the interconnectivity of devices, confidentiality, security, stakeholder privacy, and authentication are the primary concerns. The perception layer sends the protected data to the network layer (secure data aggregation), and then this data accessible can be modified in the application layer. Hardware physical security and acquisition of information are involved in the perception layer. We can summarize the security into three further requirements: (1) access control, (2) confidentiality, and (3) authentication. As we know, devices are deployed in open areas of agriculture, which means machines are doing their functionalities for a long time without any surveillance. Other concerns are attached to the security, such as modification of tag frequency, tag blocker usage, encryption, tag destruction policies, and jamming. When we talk about intelligent device restrictions, many things are involved with hardware restrictions, such as key distribution and routing, security, intrusion detection mechanisms, and encryption algorithms. Other security threats are tempering, replay attacks, cheating, and wiretapping. For example, routing attacks change network paths to gain traffic control. Malicious nodes on IoT networks may attempt to change routing pathways while data is being sent. Attacks like wormholes and sinkholes might compromise the communication network and gain unwanted access.

2.8.5. Stack. Middleware is used between the two layers (network and application). The responsibility of middleware is to act as an interface and is responsible for communication and data processing. Threats can be handled at the network layer by detecting intrusion, authentication, negotiation mechanisms, authentication, negotiation mechanisms, and key management. The application layer exists when data stream flow ends. In other words, the nearest to the cloud is the application layer. Here, control structures are also required to access the management rights and data administration ownership.

2.8.6. Agriculture Potential Points. Many services and applications emerge with computer network protocols and agriculture, gaining popularity in recent research. Many researchers are studying a system or device heterogeneity and implementing device integrations. In a different business process, optimization analytics deals with big data. Our government is trying to increase food production with food quality and enhance meat production (which can be done only with the care of animals with each animal's up-to-date and accurate data). The meat and food production increment can increase the consumer's request/demand. The interconnectivity of devices in the agriculture field can improve and have the ability to increase the production cycle. It means that the agriculture field has a secure future in the income sector, and this field has a higher impact on any country's economic rate. Figure 5 shows the network challenges in agriculture.

2.9. Discussion and Future Direction. We focused on three questions in this study, addressed at the outset. As a result, various protocols, such as SSL, HTTP, and ARP, have been discussed in the literature. On the other hand, SSL establishes a secure connection and transmits data. This may be accomplished by using an encryption mechanism that ensures the security of user authentication, data, and information security. The server/client connection is established through HTTP as well. The ARP protocol is used to keep the routing table updated so that linked devices can be

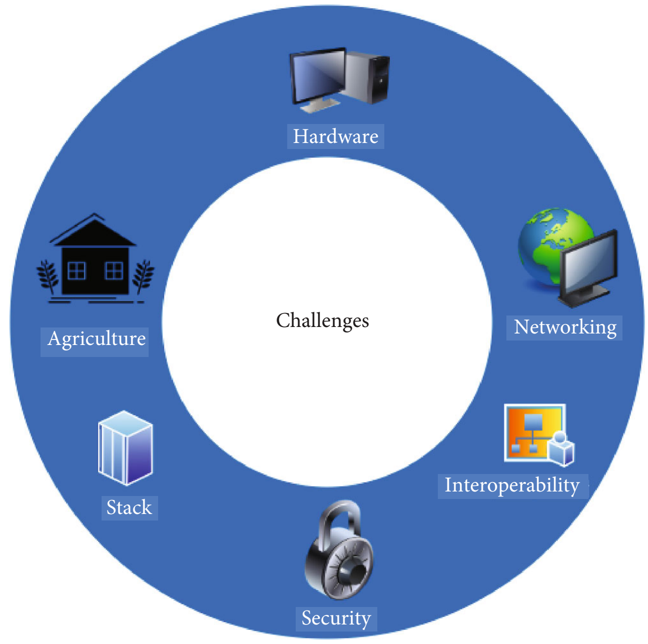

FIGURE 5: Network challenges in agriculture.

reconfigured. In addition, choosing the right IoT protocol for your next IoT project is crucial. As a result, this article analyzes IoT protocols and provides a concise overview of the advantages and disadvantages of each primary standard. Developers may use Nabto Edge to build Constrained Application Protocol (CoAP) request/response clients. It does, however, circumvent either peer's firewall setups. This dramatically boosts the message's credibility. Anonymity is also assured out of the box since Nabto Edge bundles CoAP with authentication, encryption, and other features. Nabto+CoAP is superior in terms of latency, messaging type, built-in security, ease of development, and encryption. At the same time, it is limited in terms of lightweight. MQTT, on the other hand, is lightweight and ideal for low-power and compact devices. Finally, the obstacles in agricultural networks were highlighted, which helped the reader and developer grasp the issues of farm networks when designing IoT applications for agriculture. In the future, we will discuss how to make Nabto+CoAP lightweight and ideal for low-power device compared to MQTT. What kind of parameter may be improved upon or changed to make Nabto+CoAP optimal and lightweight?

3. Conclusion

In this research, all the essential concepts of computer network (CN) protocols are discussed in precise form. Although many research works are done in agriculture, no one provides the best protocol mechanism for specific scenarios and requirements. Initially, the paper details the utilization of CN protocols in agricultures in literature. After describing other CN protocols (TCP, UDP, ICMP, etc.), the suggested article pointed out that TCP is superior since it is more effective in terms of a three-way handshake, which is a crucial requirement for networks. We have also performed CN protocol analysis related to agriculture. Based on characteristics such as latency, messaging type, built-in security, ease to build on, and encryption, we determined that Nabto+CoAP is far superior, although it is not lightweight. MQTT, on the other hand, is lightweight and suitable for small and low-powered devices. Similarly, several network difficulties are also covered in this study to provide readers a thorough understanding of them while considering network agriculture. Agriculture is an open field environment, and temperature and humidity can change our signal values so that sensors can generate false output due to high temperature and humidity levels. As we know, many foods are destroyed due to excess rain. Our research findings explain the Internet's existence in the agriculture field and the whole mechanism and enhancement of growth rate with collaboration.

Data Availability

No data were used.

Conflicts of Interest

All authors have no conflict of interest.

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