In-depth Analysis and Investigation of Internet of Things and WSN for Precision Agriculture

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Abstract

This work analyzes a smart agricultural system with two sophisticated technological implementations—a controller and communication devices—that must be studied and applied in a real-time system to minimize data loss during signal transmission and reception and to enhance the automation process. The model's enhanced features for smart agriculture include monitoring the PH sensor, temperature, humidity, and moisture content in agricultural land; additionally, the automatic control of the water pump is implanted. For communication purposes, Global Positioning System (GPS) and wireless communication devices like Bluetooth, Wi-Fi, and Zibeee are widely used. In today's agricultural industry, power consumption is a big factor. In current processes, solar-based energy is distributed in the agricultural field, and the water pump will give water to the lands based on the sensor values. Because it only supplies power when required, it is also very beneficial for processes involving automation and control that require a lot of electricity. The environmental circumstances determine what movements can be completed in real time on the field, and for analysis in the future, it is crucial that the user saves and sends the data that is obtained. For this reason, the values of the agricultural field sensors are frequently altered. In demand to communicate the detected values controller in the arena and transmit data through a wireless media for the IoT application web page for user identification, the Internet of Things is properly developed. A thorough examination of smart agriculture in wireless networks and the exploration of IoT data have been covered in this survey.

Keywords: Internet of Things, Global Position System, Wireless Sensor Network.

1.Introduction

To enhance agricultural cultivation performance, lower environmental risk, and improve the quality of the farmed area, more sophisticated instruments and procedures are required. Precision farming is defined as using the right tools and methods to produce high-quality agricultural products. Precision farming is the foundation of this agriculture, which is tracked and maintained using a variety of tools like GPS, geographic information, and information systems. The new technology is developing quickly, ushering in a new era of opportunity for research development centered around wireless sensor networks. WSN has a major impact on the agricultural industry and provides a quantity of benefits in relations of size, cost, power consumption, and flexibility of wired technology [1-3]. Wherever a node's resources are constrained, routing takes place in this topology of wireless sensor networks. Since all of the sensor network's nodes now rely on battery power for communication, solar energy shows how beneficial it is for nodes to send and receive data packets to one another. Controllers, transceivers, amplifiers, and power supply are among the nodes that are gathered using the WSN model [4]. The routing packets via the PV-powered system are very dependable and energy-efficient.

Given that various protocols function, as demonstrated by the simulation findings, it may be deemed the primary path for solar-enabled routing protocols through data packets from solar-powered nodes. A protocol is a reduced and conventional form of directional diffusion wherein nodes communicate locally with one another. It usually functions on a small scale, although some protocols have a large range of functionality. Extended iterations of the approved protocols for protocols that come after. According to the findings, directional enhancement is preferable in small sensor networks, whereas larger systems perform better with the alternative protocol [5-8]. Solar observes that the low message transmission overhead indicates that the protocol is an active area that is not very large. The following hardware is part of the modules that generate many sensors simultaneously: A PH sensor measures the pH of water, a temperature sensor measures the ambient temperature, a humidity sensor measures the amount of water vapor in the air, a moisture level sensor measures the quantity of water in the soil, and wireless transceivers allow announcement among sensor nodes that are powered by processing and power supplies. These factors are all effectively processes in the realm of agriculture.

2. Wireless Sensor Network

The following discusses some of the most current WSN studies on the agricultural industry using data advancements based on the Internet of things.

2.1 Wireless Sensor Network Architecture

A collection of compact, high-performance computing devices known as WSNs are useful for tracking various agricultural aspects. These variables are gathered from various sensor nodes. A sink node that gets data from the foundation node is a source node, which is an environmentally sensitive data-gathering node [9-13]. The operating model for the wireless sensor node's agricultural monitoring is displayed in Fig. 1. Controllers, memory, sensors, actuators, electrical devices, and communication devices are examples of sensor nodes. Several programming languages, including C# and microcontroller C, are used by the sensor node. Data collected from sensor nodes and other nodes is stored in memory. A transceiver is a implement by data collection from sensors and communication transmission. The PH sensor, temperature, humidity, and moisture level are the sensors that are furthermost often active in irrigation.

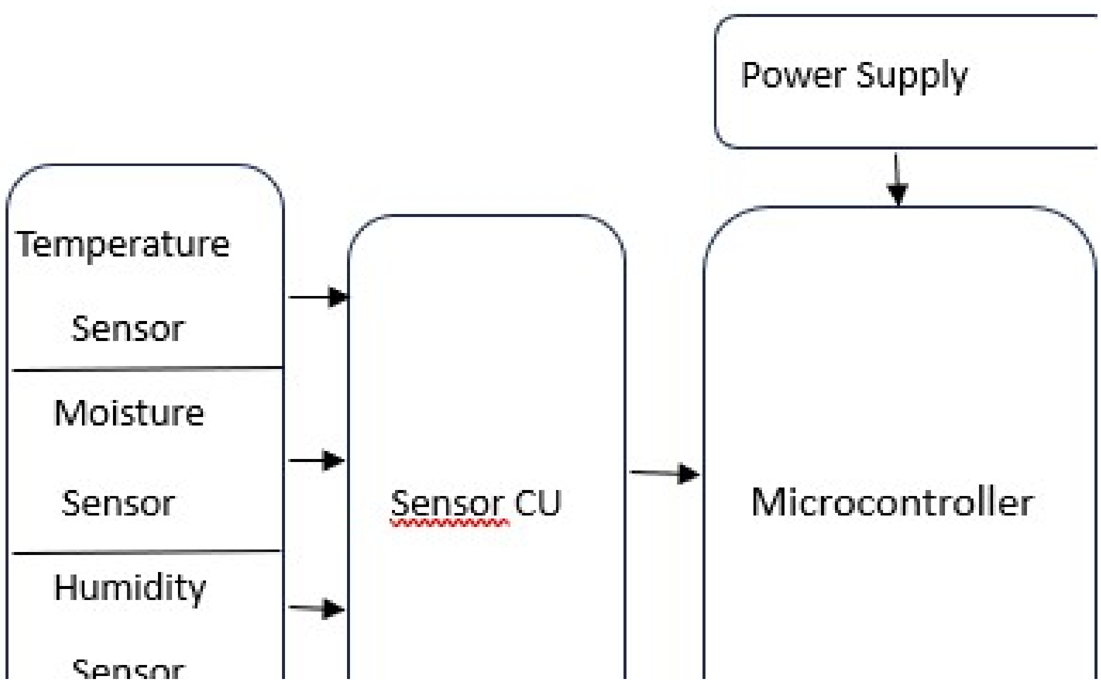

Fig 1 : Architecture of Monitoring System

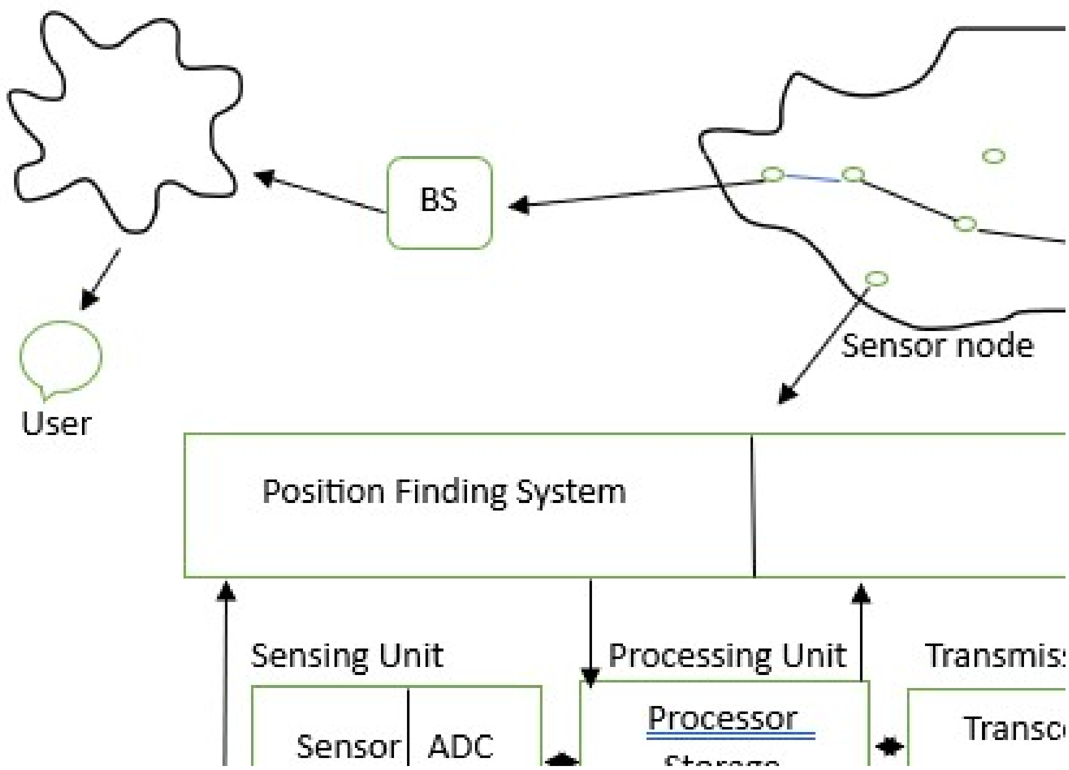

Fig 2 : WSN Architecture

Several sensor nodes are present in a WSN environment to measure data and send it to a base station and other nodes. This step transfers the sensor value to another communication medium, like a remote system, and stores it over the cloud. Fig. 2 illustrates a WSN's structure.

3. Literature Survey

Table 1 : Survey of Related Works

Author	Algorithm	Summary
Suriyachai, P et al.	Interface for Application Programs	In this work, a cloud-based IoT platform and open APIs are used to access many features available through the Internet. In particular, low-cost sensor nodes create a cluster-based WSN to save energy consumption and interact with each other on the platform.
Choudhary, A et al.	ANN-based artificial neural network linearization method	WSN with precision agricultural design modifies channel responsiveness in outside settings. The findings indicate that the internal rate equals the probability of succeeding packets. The rate of packet loss in external environments is extremely high.
Kanupuru, P et al.	Fuzzy logic	The task involves using sensor devices to monitor network traffic. Bandwidth is conserved by having the sensor nodes send data to the base station at

		predefined intervals.

4. A Technology for Wireless Communication

This information technology has wireless systems for many uses, including agricultural ones, and is developed in many communication technologies [14–16]. These skills usually decrease into 3 groups according to the moving distance: long-range wireless technology like, medium-range communication technology like, and small-range wireless communication (SWC) technology like. Small-range wireless communication (SWC) technology like, and distance <+10m. ZigBee, Radio Frequency Identification (RFID), and Ultra-Wideband Bluetooth (UWB) are included in the SWC [17]. With regard to wide-area WSN systems, they are mostly employed in advanced control techniques in telecommunication networks (2G, 3G, and 4G) [18]. The most popular communication methods include Bluetooth, ZigBee, WiFi Wireless, Lora, and NP-IoT, in addition to the ones already mentioned. Table 2 offers a thorough comparison of them with a synopsis of each.

Table 2 : Comparative Analysis of Different Wireless Communication Device Specifications

Parameter/Technology	**Bluetooth**	**ZigBee**	**Wi-Fi**	**LoRa**	**NB-IoT**
Standard	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.11	IEEE 802.15.4g	3GPP release 13
Frequency	2.4 GHz	868/915 MHz, 2.4 GHz	2.4 GHz, 5 GHz	868/915 MHz	LTE Frequency Bands
Modulation	GFSK	BPSK, OQPSK	BPSK, OQPSK	GFSK	SC-FDMA (UL), OFDMA (DL)
Data Rate	1 Mbps	20, 40, and 250 kbps	11-54 Mbps, 150 Mbps	50 kbps	160-200 kbps (UL), 160-250 kbps (DL)
Power Consumption (TX)	10 mW	36.9 mW	835 mW	100 mW	106 mW
Range	Indoor: 20m, Outdoor: 100m	100m	100m	Urban: 2-5 km, Suburban: 15 km	Urban: 1-8 km, Suburban: 25 km

Table 3 : Correlated Works Using Communication Guidelines

Authors	Methods	Summary
Y. Kim et al.	Controllable Logic Device	This project Power management is involved in wireless data transmission. The Bluetooth sensor mode has been changed to transition from standby to sleep mode.
Q. Wang et al.	Relay node modification technique	The sensor node is buried completely and is used to portion the soil.
Cao-hoang et al.	Telemetry transport message queuing (TTMQ) protocol	The work uses Wi-Fi technology to enable IoT-based smart agriculture.

5. Comparing the Power Usage of Communication Devices

Power consumption is the amount of energy a communications equipment uses in a given amount of time. The timing of the communication device used to calculate the energy consumption under the condition of calculating total power [19–22]. Analysis requires minimal power usage and a long standard communication time. The following technologies' energy consumption: Bluetooth, Wi-Fi, and ZigBee. Three communication tests are showed for these technologies' power usage under different conditions, at varying communication distances. The comparison study of the power-consuming devices is displayed in Fig. 3.

Table 4 : Comparing Wireless Standards

Parameter	Wi-Fi	Bluetooth (IEEE 802.15.1)	ZigBee (IEEE 802.15.4)
Standard name	IEEE 802.11	IEEE 802.15.1	IEEE 802.15.4
Applications	Web, Email, Video	Cable Replacement by Wireless	Monitoring and Control Systems
System Resources	1 Mb+	250 kb+	4 kb - 32 kb
Battery Life (Days)	0.5 – 5 days	1 – 7 days	100 - 1000+days
Network Size	32 devices	7 devices	255 devices (per network), 65000+ (total)
Data Rate (kbps)	11,000+ (varies by version)	720kbps	20 – 250kbps
Transmission Range (m)	1 – 100meters	1 - 10+meters	1 - 100+meters
Metrics	Flexibility and speed	Convenience and cost	Reliability, cost, and Power

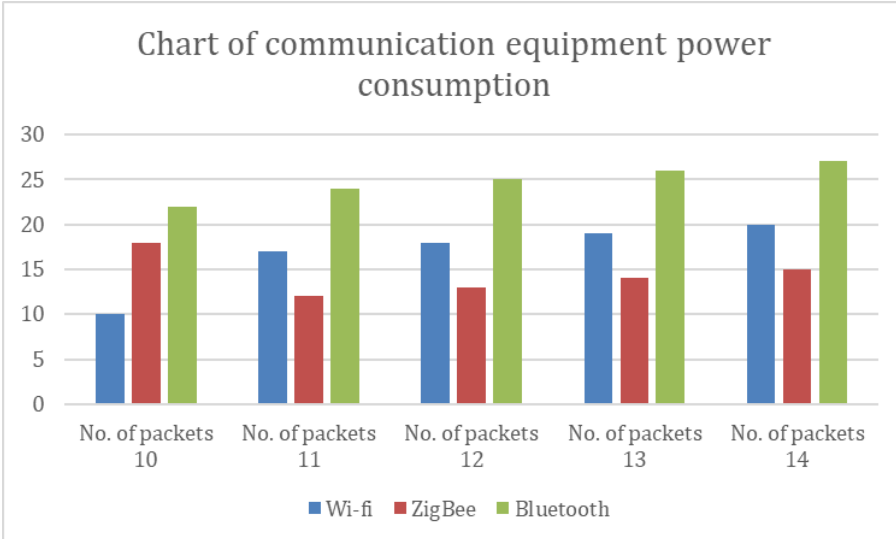

Fig 3 : Chart of Communication equipment power consumption

Table 5 : A Corresponding Work Table for Energy Use

Radi et al.	The mesh topology of nodes	Three slave nodes and the master node, which serves as the coordinator, make up the architecture of the WSN. Following construction, WSN the prototype star topography evaluates its functionality, namely sending data from the slave to the master and vice versa.
Johan J et al.	An Adaptive Power System	An Adaptive Power System feature of the system allows for better data delivery latency in the event of transmitter and receiver failures.
Ashish Gupta et al.	pattern of square deployment	The single moving sink WSN system for real-time agriculture monitoring is described in this article.

6. Methodologies for Communication Protocols in WSN

Liable on the application or network architecture, multiple layers of protocol routing classification are approved out in WSNs. Therefore, the protocol's main goal is to determine the best and most efficient paths between a group of nodes so that a message can be transmitted. These protocols will differ in relations of their features and functionality. Each protocol can employ a diversity of functions, reliant on the configuration network; several protocols and a transmission method are needed to build each protocol [23–27].

I. Routing protocols are the basis of route selection (RPBRS)
II. Link State Routing Protocol Optimization (LSRPO)
III. OLSR Multi-Point Relaying in Operation (OLSRMRO)
IV. Sequence Distance of Destination Routeing using Vectors (SDDRV)
V. Ad-hoc On-Demand Vector of Distance (AOVD)
VI. Routing protocols are the basis of route selection (RPBRS)

This protocol categorization is based on how a method is located at the source node, which discusses to the opening point where communication or data transfer begins. The process involves identifying the method to be used for the communication or operation at this starting point. The target node, or the destination, is then theoretically separated into 2 parts to streamline or optimize the communication process. This categorization helps in determining the most efficient protocol for specific network tasks or data transmissions, enhancing overall network performance.

6.1 Link State Routing Protocol Optimization (LSRPO)

The Link State Routing Protocol Optimization (LSRPO), defined in RFC 3626, is a active routing protocol used in mobile ad-hoc networks (MANETs). It is known as a "table-driven" protocol because it maintains and updates routing tables with the latest network topology information. LSRPO periodically exchanges topology information with other nodes to ensure that all nodes have a consistent view of the network. This method permits for effective routing by pre-emptively maintaining route information, dropping the prerequisite for route discovery. OLSR is particularly suited for dynamic and decentralized networks where node mobility is common.

6.2 OLSR Multi-Point Relaying in Operation (OLSRMRO)

The Link State Routing Protocol Optimization (LSRPO)populates network topology information by spreading OLSR control packets throughout the whole network. These packets, containing network topology details, are broadcasted to all nodes to ensure they have an up-to-date view of the network. To prevent redundant transmissions and loops, packets are marked with sequence numbers, ensuring each is processed only once by the receiver nodes. A key feature of LSRPO is the use of Multipoint Relays (MPRs). MPRs are nominated nodes that reduce the quantity of retransmissions needed for flooding communications through the network. By carefully choosing a subset of neighboring nodes as MPRs, LSRPO minimizes unnecessary packet transmissions, thereby optimizing bandwidth practice and reducing network overhead.

6.3 Sequence Distance of Destination Routeing using Vectors (SDDRV)

Sequence Distance of Destination Routeing using Vectors (SDDRV) is a table-driven routing protocol for mobile ad-hoc networks, created on the Bellman-Ford algorithm. In DSDV, each node maintains a routing table with data about each other node in the network, including the shortest path and the next hop. Nodes occasionally conversation their routing tables with immediate neighbors, safeguarding that all nodes have up-to-date routing information. This frequent table exchange helps maintain consistent network topology knowledge, enabling efficient route determination. By sharing complete routing information, SDDRV helps quickly establish paths to any node, albeit with higher overhead due to constant updates.

6.4 Ad-hoc On-Demand Vector of Distance (AOVD)

The Ad-hoc On-Demand Vector of Distance (AOVD) is a purely reactive routing protocol used in mobile ad hoc networks (MANETs). Unlike proactive protocols, AOVD founds routes only when desirable, which reduces control message overhead. When a node needs to communicate, AOVD initiates a route discovery process to find a path to the destination, supporting both unicast (one-to-one) and multicast (one-to-many) transmissions. Once the route is established, data packets are sent along the discovered path. This on-demand approach makes AOVD efficient for dynamic and rapidly changing network topologies.

6.5 Long-Range (LoRa) Wireless Communication Protocol

Long-Range (LoRa) is a low-power, wide-area network (LPWAN) technology designed for long-distance message with negligible power consumption, making it ideal for Internet of Things (IoT) applications. LoRa uses a blowout spectrum variation technique, which spreads the signal over a wider bandwidth than necessary, similar to the traditional spread spectrum methods. This modulation increases the resilience of data transmission against interference and noise, enabling reliable communication over several kilometers. LoRa's ability to maintain connectivity over large distances with low energy usage makes it particularly suitable for requests in remote or rural areas. It chains a wide variety of IoT devices and is known for its long series life and extensive coverage.

7. Communication Protocols Complying with Standards and Requirements

WSN are composed of numerous sensor nodes that monitor and communicate data about their environment. These nodes have specific characteristics and constraints, which affect their design and operation. Here is a detailed overview of various aspects of WSNs:

7.1. Low Energy Consumption

Energy efficiency is a critical factor in the design of WSNs as sensor nodes are often powered by batteries with limited capacity. A significant portion of the sensor node's energy is consumed during data transmission. To maximize the sensor network's lifetime, it is essential to optimize energy usage.

7.1.1 **Direct Link Challenges**: In scenarios where a direct communication link between a sensor node and a sink (central data collection point) is required, the energy consumption can be quite high, especially if the distance is long. The energy required for transmission increases with the square of the distance, so direct communication over long distances can rapidly deplete a node's battery.

7.1.2 **Multi-Hop Communication**: To conserve energy, sensor nodes typically avoid direct communication with the sink. Instead, they employ multi-hop communication, where data is relayed through intermediate nodes. This approach reduces the energy required for each transmission, as the communication range is divided into smaller hops. Each node in the network collaborates to forward packets, thereby conserving energy and extending the overall network lifespan.

7.2. Compatible with Multi-Hop Communication

Multi-hop communication is a fundamental strategy in WSNs that leverages the collaborative nature of sensor nodes to transmit data over longer distances without expending excessive energy.

7.2.1 **Energy Considerations**: Since energy consumption in wireless communication is proportional to the square or even the fourth power of the distance, multi-hop communication is highly beneficial. By using nearby nodes to relay data, the total energy expenditure is reduced, enhancing the network's efficiency and longevity.

7.2.2 **Network Scalability**: Multi-hop communication also supports scalability, allowing the network to cover larger areas with fewer resources. New nodes can be added without significant alterations to the existing network, enabling dynamic adjustment and expansion as needed.

7.3. Measuring and Maintaining Connectivity

In a WSN, it is vital to ensure reliable communication between sensor nodes to maintain a continuous flow of data.

7.3.1 **Reliable Communication Protocols**: Protocols in WSNs must be robust to ensure that data packets are successfully transmitted and received, flat in the occurrence of interference or node failures. Protocols like Routing Protocol for Low-Power and Lossy Networks (RPL) or Ad hoc On-Demand Distance Vector (AODV) are designed to handle the dynamic nature of WSNs, ensuring data integrity and reducing packet loss.

7.3.2 **Handling Large Networks**: As the scope of the network increases, maintaining effective communication becomes more challenging. A well-established protocol can manage the network's growth, ensuring that all nodes remain connected and that data is efficiently routed to the sink, regardless of network size.

7.4. Reliability in Data Transmission

Reliability in WSNs refers to the consistent and accurate delivery of data packets from sensor nodes to the sink.

7.4.1 **Data Integrity and Monitoring**: Ensuring high performance in data delivery involves mechanisms for monitoring and controlling packet transmission. Techniques like error correction, acknowledgment of received packets, and retransmission of lost packets are essential to maintain reliable communication.

7.4.2 **Minimizing Packet Loss**: Protocols must be designed to minimize packet loss due to factors like node failure, interference, or environmental conditions. Reliable data transfer protocols are crucial for applications where data integrity is vital, such as in health monitoring or industrial automation.

7.5. Limited Processing and Storage Power

Sensor nodes in WSNs typically have limited processing capabilities and storage capacity, impacting their ability to perform complex computations or store large amounts of data.

7.5.1 **Constraints of Sensor Nodes**: Due to the limited computational power and memory, sensor nodes can only handle basic processing tasks. Most nodes can process simple algorithms for data filtering, aggregation, or event detection but are not suited for intensive computations.

7.5.2 **Transient Data Handling**: Given their limited memory, sensor nodes often deal with transient data — processing it on-the-fly and transmitting results immediately to minimize storage needs. This approach is efficient but requires reliable communication links to prevent data loss.

7.6. Dynamic Network

Wireless sensor networks are inherently dynamic, with nodes frequently connection or departure the network due to mobility, power constraints, or environmental factors.

7.6.1 **Node Mobility and Failure**: New nodes can join the network, or existing nodes may fail due to battery depletion or damage. This dynamism requires protocols that can adapt to changes in the network topology without significant overhead or reconfiguration.

7.6.2 Adaptive Protocols: Protocols must be flexible to handle these dynamic changes, ensuring constant process and self-healing capabilities. The capacity to adjust to network modifications is vital for maintaining functionality and reliability in WSNs.

7.7. Massive Data Flow

WSNs often generate large volumes of data, especially when monitoring high-frequency events or in dense networks.

7.7.1 Data Management Challenges: Managing this massive data flow is stimulating due to the limited processing and storage capabilities of sensor nodes. Efficient data aggregation and compression methods are necessary to reduce the volume of data that wants to be transmitted.

7.7.2 Data Analytics: The collected data must be analyzed to extract meaningful insights, considering the constraints of the sensor nodes. Data analytics can help in optimizing query processing, communication efficiency, and storage management, tailoring these aspects to the sensor network's capabilities.

7.8. Challenges and Future Directions

Several challenges remain in the design and operation of WSNs, particularly concerning energy efficiency, scalability, reliability, and adaptability.

7.8.1 Energy-Efficient Communication: Developing communication techniques that balance energy consumption with network performance is crucial. Strategies like duty cycling, energy-aware routing, and low-power communication modes are being explored to extend the network's lifespan.

7.8.2 Scalability and Multihop Capabilities: Ensuring that protocols can scale efficiently and support multihop communication without significant performance degradation is essential for the deployment of large-scale WSNs.

7.8.3 Enhancing Network Lifespan: By focusing on energy-efficient and consistent communication methods, researchers aim to improve the operational lifespan of WSNs, ensuring they can support long-term monitoring applications without frequent maintenance or battery replacements.

Table 6 : Connected Work Table for Interaction Protocols

Authors	Methods	Summary
Radi et al.	MAC	Unmanned aerial vehicles (UAVs) are utilized by Mobile Receivers (MS) in the network layer to gather data transmitted by the application and cognitive layers.
Du et al.	Kalman filtration	The data was continually collected every five minutes and every two hours during the monitoring period. Additionally using Kalman filtering, a GPRS module loads the data into the

		remote monitoring software.
Ge et al.	Examine multiple slot, carrier detection access (CSMA) with frequency hopping and collision prevention (AC).	Although they haven't been thoroughly studied, WBSN systems are significantly impacted by this disruptive fact.

8. Data Gathering, Transfer, and Sampling

Every data set requires energy to process and send the sample. This necessitates not just pertinent and useful data but also optimal and efficient data collection, with the sample rate being occupied without wasting any energy. On the other hand, large-scale packet spread from static data collecting can quickly deplete the battery's capacity. The sample rate of data collecting is typically low in cultivated terrain. But this can be changed based on resources, crop type, and environmental conditions [28-31]. There are various wireless transmission systems available, as seen in Table 7. Strategies for data communication can also be set up to reduce transaction volume and save energy. This covers the local storage of smart data, such as modified or stored values, and sensor data. Furthermore, you can only use features like sleep mode when necessary. To enable dependable multi-hop communication, the sensor nodes should be positioned in close proximity to one another. Reliable communication can also be achieved by turning on the transmitter.

Table 7 : Data Gathering, Transferring, and Counting for Communication Equipment

Parameter	Bluetooth	ZigBee	Wi-Fi
Data Transmission Range	1-10 meters	1-10 meters	Up to 500 meters (depending on the environment)
Communication Channel Model	Through air via mobile devices	Through air via ZigBee nodes	Through air via Wi-Fi routers
Supported Hardware Platform	Virtual Platform	Virtual Platform	Virtual Platform
Energy Profiling	Battery-powered devices	Power-efficient devices	Power-hungry devices
Scalability	More than 100 devices supported	Very low scalability (limited network size)	Medium scalability
Frequency	Very low	Low	High

Table 8 : Correlated Table of Work for Data Acquisition Using Communication Devices

Authors	Methods	Summary
S. Siva Rama Krishnan et al.	Protocols for Sensor Network Security	High data delivery for the sensor nodes in the representation of the real networks.
A. Gangwar et al.	Mesh networks	A microcontroller analyzes the data for this task, and in accordance with the results, an SMS is delivered to the user's mobile device via Bluetooth (for nearest control) and GSM (for distance control).
Diaz. S.E et al.	Manage Automation of the Agricultural Process	The strategy presented in this paper includes a clearly defined phased life cycle of agricultural monitoring with WSN application.

9. Conclusion

Intelligent agricultural environments are used by the wireless sensor monitoring node. Every time there is monitoring, the data is constantly observed. A variety of filtering techniques are applied to enhance real-time data quality and lower data mistakes. The agricultural system's WSN analysis will be inspected from numerous angles, including sensor devices and communication device protocols. The primary purposes of the WSN are the following: network identification, network connectivity, sensor data transmission, power battery information, and data acquisition and processing of various types of sensors in accordance with communication protocols. Task scheduling, data processing, and control over the data of other hardware mechanisms are all part of embedded scheme capability. Certain kinds of Applications-Use Specific Integrated Circuits (ASICs) are used, such as Digital Signal Processors (DSPS), Field Programmable Gate Arrays (FPGAs), and Embedded Process Microcontrollers. Because of its adaptability and status as the most popular embedded processor among its low-cost sensor nodes, the microcontroller is evaluated for connectivity to other devices in each of these options. Based on this system study, significant advancements are required in the areas of power conservation with consistent, continuous data collection as well as latency, throughput, and data prediction on WSN networks for precision agriculture. Communication issues between sensor nodes and new processing devices impair these systems' performance. The lack of sufficient information about user nodes in the system makes it difficult to identify similar processing devices and sensor nodes when they are further to the system. IOT that is built on hybrid systems is frequently utilized to get around this problem. This system uses sensor node power-saving data as well as

Internet of Things monitoring to make predictions and recommendations. Future work will concentrate on increasing the effectiveness of resolving the issues with sensor nodes and new processing devices in the online recommendation system. According to recently completed research, additional features can be introduced to enhance the screening process and address the communication issue.

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