A Comprehensive Survey on IoT and Wireless Sensor Network-Based Smart Farming Systems for Crop Yield Enhancement

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***Abstract*—Wireless Sensor Network (WSN) comprises the number of sensor nodes deployed across agricultural fields to continuously monitor the environmental and soil parameters. Sensors are limited by node energy, link variability and latency needs. The sensor nodes communicate the data points to the base station for storage and analysis. Internet of Things (IoT) provides seamless connectivity between sensors, communication devices, base station and end users for continuous monitoring and decision-making. IoT-enabled sensor network combines the smart sensors, wireless communication technology and intelligent learning to continuously monitor the agricultural fields and increased the crop productivity. Many researchers carried out their research on IoT-enabled sensor network-based crop yield prediction. But, the energy efficiency and network lifetime during data transmission was not enhanced by existing techniques. In order to address the existing issues, different architecture and network protocols of wireless sensor network is discussed for efficient crop yield prediction performance enhancement.**

***Index Terms*—wireless sensor network, intelligent learning, decision-making, seamless connectivity, base station, continuous monitoring**

I. INTRODUCTION

WSN is a developing technology used in smart agriculture for resource management and precision farming. In agricultural field, WSNs comprises the number of autonomous sensor nodes to monitor and gather real-time data from different points using different sensors like temperature, humidity, soil moisture, light and cameras. The data packets are wirelessly sent to the central base station. WSNs in smart agriculture has number of benefits with huge impact on how farmers handle the livestock and crops. WSNs have capacity to provide data wealth with spatial and temporal granularity for allowing farmers to monitor the farm conditions. Farmers respond to different environmental conditions like pests, diseases, or unfavorable weather patterns. WSNs performed accurate and targeted resource usage with lesser water consumption, fertilizer usage and pesticide usage. WSN encouraged the sustainable agricultural practices through optimizing resource allocation with minimum environmental effects. WSNs are suitable for different farm size and type from small family-owned farms to large commercial agricultural enterprises because of their scalability and flexibility. The survey reviews recent development in WSN based agricultural applications, communication protocols, routing methods, energy-efficient mechanism and challenges associated with deployment in farming environments. The study identifies research gaps and future directions for developing intelligent agricultural systems for attaining better crop yield prediction.

The main contribution of the survey article is given as:

- To explain different methods for IoT based WSN for attaining crop yield prediction in smart agriculture with minimum energy consumption and higher packet delivery ratio
- To discuss the different network protocols and architecture of WSN for crop yield prediction in smart farming application
- To evaluate the different conventional clustering methods in WSN for achieving better smart farming results.

The contents of this paper are arranged as follows: Section 1 presents the introduction to the IoT based smart agriculture and their challenges. Section 2 presents the review of various methods concepts for IoT based smart agriculture data transmission. Section 3 explains the description of different methods for IoT based smart agriculture in WSN. Section 4 explains different performance metrics and results for IoT based smart agriculture data transmission. Section 5 concludes the work with future direction.

II. LITERATURE REVIEW

A heterogeneous sensing system was introduced in [1] with radio frequency-based wireless sensing network for continuous and large-area monitoring. But, adaptive and information-driven strategies were not employed to identify the optimal sampling locations. A low-cost and open-source wireless sensor network was introduced in [2] to automate the irrigation zone control depending on soil water potential (SWP). However, the designed network failed to integrate the pump automation and refine control strategy.

A self-sustaining IoT framework was introduced in [3] with wireless sensor network to track critical indicators in real time applications. But the designed framework failed to optimize the water usage during sustainable sugarcane production. A hybrid information monitoring approach was designed in [4] with personal area network and low-power wide-area network. But the designed sensors failed to monitor additional parameters of interest remotely. In addition, the system functionality was not enhanced by designed approach.

An innovative hexagonal deployment model was introduced in [5] for wireless sensor networks (WSNs) in precision agriculture. However, the designed model failed to address scalability and robustness issues in agricultural fields under different environmental conditions. An ensemble formal approach with IoT was introduced in [6] to enhance and to optimize the network lifetime of wireless networks in smart agriculture. But the designed approach failed to implement in other formal languages like UPPAL, Z, B, Event-B and theorem proving.

A hybrid Express if peer-to-peer protocol (ESP-NOW)/long range (LoRa) IoT monitoring system was introduced in [7] with sensor nodes, aggregator and gateway for data transmission. However, the low-cost imaging modules were not considered to support visual monitoring of crop growth. Open Thread protocol was introduced in [8] for temperature and radiation monitoring. The designed protocol reduced the error for increasing the data quality. However, the designed protocol failed to optimize the node power consumption through sensor sample rate and packet traffic transmission reduction.

A clustered WSN architecture termed SWADS was introduced in [9] with unmanned aerial vehicle (UAV). A long short-term memory (LSTM) forecaster was employed for weather prediction in adverse conditions. But, SWADS failed to enable energy–freshness trade-offs during data transmission. The hierarchical clustering-based dynamic data fusion technique was introduced in [10] for WSNs in smart agriculture with minimum data redundancy. But, stability of dynamic data fusion technique complicated the network performance and reliability in practical scenarios.

Multi-Strategy Pelican Optimization Algorithm (MSPOA) was introduced in [11] for agricultural wireless sensor network to verify their functionalities during environmental crop monitoring. But, MSPOA failed to enhance the adaptability and robustness through dynamic operators. An energy-efficient clustering model termed EECH-HEED was introduced in [12] for efficient soil monitoring in WSNs. The adaptive strategy reduced the energy consumption and increased node lifetime. However, EECH-HEED model failed to reduce the communication latency during data transmission.

An efficient and scalable IoT framework is introduced in [13] for smart farming. The designed framework was employed with wireless sensor actuator network (WSAN) for efficient processing and monitoring. But the time complexity was not minimized by designed framework. An Energy-Efficient Cluster-Based Data Aggregation (E2CDA) Technique was introduced in [14] for agriculture irrigation systems in WSN. The probabilistic clustering method selected optimal number of Cluster Head (CH). However, the computational cost was not reduced by E2CDA technique. Metaheuristic-driven Machine Learning model for Data Clustering (MetaML-DC) was introduced in [15] for wireless rechargeable sensor networks in smart agriculture. But the accuracy level was not improved by Meta ML-DC.

III. RELATED WORKS

A greenhouse gateway with anomaly detection algorithm was introduced in [16] with detection algorithm. The designed algorithm minimized the data traffic and improved F1-score. But the precision level was not enhanced by designed algorithm. A new methodology was designed in [17] for opportunistic wireless charging of sensor nodes through irrigation system. The wireless charging system employed electro-dynamic wireless power transfer (EWPT) to transmit the energy through soil. However, the complexity level was not minimized by designed methodology. A heuristic algorithm was introduced in [18] for addressing the optimization problem. EWNNA reduced the energy consumption during data collection. But the recall level was not improved by designed heuristic algorithm.

An energy-adaptive and self-organizing routing architecture was introduced in [19] for performing congestion-aware and energy-balanced communication. The Designed architecture performed energy clustering with ring adaptation and predictive learning. However, the designed architecture failed to reduce the delay during data transmission. An analytical model was introduced in [20] for minimizing energy loss during data packet transmission. The designed model used node technical characteristics and signal fading depth. But the computational complexity as not minimized by designed model.

The cost-effective IoT solution was attained in [21] for efficient farming practice. An integrated IoT solution in fruit and vegetable farms was employed to attain improved productivity and growth. However, the energy consumption was not reduced during agriculture farming. A soil moisture-based wireless sensor network (SM-WSN) was introduced in [22] for efficient irrigation management. SM-WSN has positive economic returns with minimum environmental impacts. But the reliability level was not enhanced by SM-WSN.

An autoregressive model with Kalman filter approach was introduced in [23] for identifying sensor faults in WSN for smart irrigation. The designed approach minimized computational complexity and increased application reliability. However, the network lifetime was not improved by designed approach. Federated Reinforcement Learning (FRL) framework was introduced in [24] for IoT-enabled WSNs. FRL framework used network operation without sharing raw data packets. But the complexity level was not minimized by FRL framework. The wireless sensor network system was carried out in [25] for energy efficiency enhancement. However, the complexity level was not reduced by designed system. A fresh approach was introduced in [26] with hierarchical clustering for WSNs in smart agriculture. The designed approach increased the energy efficiency and precision in smart agriculture. But the network lifetime was not enhanced by designed approach.

A new Hybrid Adaptive Design Optimization (HAOD) algorithm was designed in [27] with linear discriminant analysis and principal component analysis for energy sensor management. However, the delay was not reduced by HAOD algorithm. A smart crop recommender system was introduced in [28] with decision making and real-time environmental sensing. The designed system used cutting-edge machine-learning modeling for obtaining real-time data. But the energy efficiency was not improved by designed system.

An intelligent indoor environmental control system was designed in [29] depending on multi-sensor fusion and building information modeling. A deep fusion actor-critic reinforcement learning (DACRL) algorithm was used for energy-efficient dynamic environmental control. However, the complexity level was not reduced by designed system. The heuristic-based node localization framework was introduced in [30] to minimize localization error between actual and detected location in WSN. But the time consumption was minimized during node localization.

IV. METHODOLOGY

Wireless Sensor Networks (WSNs) have become essential one in smart agriculture for real-time and autonomous environmental data collection across geographical areas. WSN comprised the energy-constrained sensor nodes to monitor the physical phenomena like soil moisture, pH, temperature and nutrient levels. WSN performed efficient timely decision-making in precision farming. WSN is employed to perform efficient irrigation prediction, fertilization control and improved crop productivity. WSN addressed the elementary challenges through energy limitations. The sensor nodes employed non-

rechargeable batteries in distant regions. In WSN, energy consumption is an essential one for improving the network lifespan.

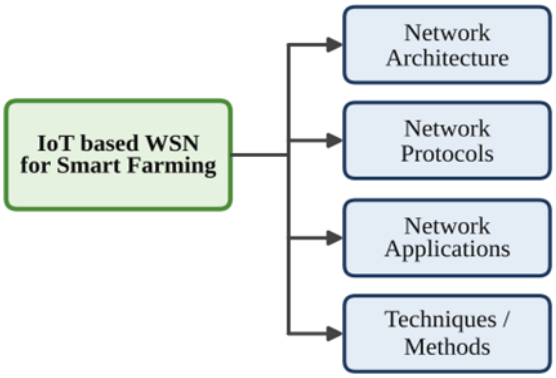


Figure 1 IoT based Sensor Network Architecture for Smart Farming Application

Figure 1 illustrates the IoT based sensor network architecture in smart farming applications. WSNs are used in IoT technology to gather and transmit the data points from diverse physical environments. WSN are employed for gathering and capturing real-time data through different sensors positioned across different locations. WSN used diverse farming techniques in smart agriculture.

4.1 IoT based Network Architecture for Smart Farming Application

WSN comprised the agricultural field sensors to continuously monitor the critical parameters like soil moisture, temperature, and irrigation status. Each sensor nodes is employed for performing the data collection, energy management and guaranteed reliable data delivery. WSN experienced different challenges like high energy consumption, connectivity issues and latency that affect crop yields. WSN integrated with IoT technologies are used across different agricultural domains. IoT system is functioned as physical devices, sensors and objects communicate seamlessly without human intervention. Figure 2 illustrates the IoT architecture in smart agriculture.

Figure 2 illustrates the IoT architecture in smart agriculture. IoT architecture comprised three different layers, namely perception layer, communication layer and application layer for efficient data communication in WSN. The perception layer is an essential component in IoT framework.

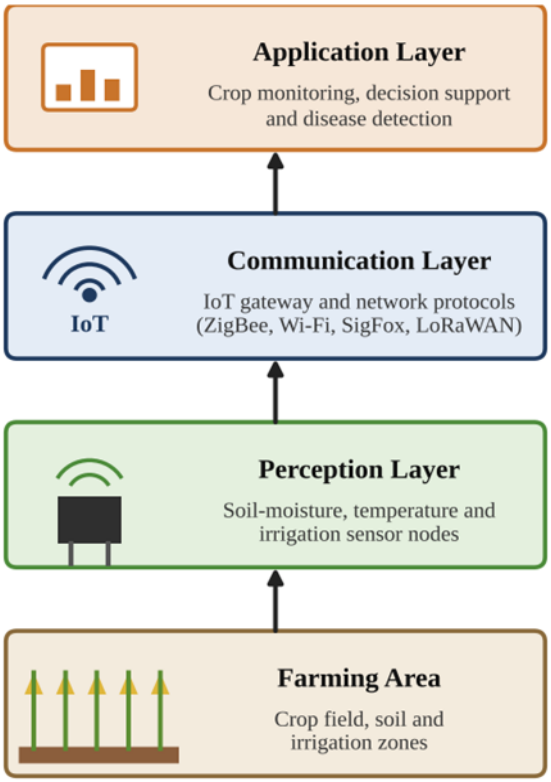


Figure 2 IoT Architecture in Smart Agriculture

The perception layer is used to perform efficient interaction between physical and digital domains. The perception layer is employed for gathering different data from sensors. The communication layer is used to perform uninterrupted communication and data transfer across different devices in IoT architecture. IoT application layer drives the functionality and intelligence in agriculture application.

Multi-Strategy Pelican Optimization Algorithm (MSPOA) was introduced in [11] with 3D spiral Levy flight strategy and adaptive T-distribution variation strategy. The good point set strategy improved the local search capability. 3D spiral Levy flight strategy increased convergence speed and search accuracy. The adaptive T-distribution variation strategy improved the global search ability and pelican movement. The collaboration strategies improved the adaptability and robustness in different agricultural scenarios. MSPOA improved network coverage with adaptability and stability in dynamic agricultural environments.

4.2 IoT based Sensor Network Protocols for Smart Farming Application

WSN comprises several affordable sensing devices with low-power communications network protocols

like ZigBee, Sigfox, Wi-Fi and LoRa WAN. WSNs are distinguished functionally from usual sensing device collection by their network capabilities between sensing assets. The network protocol is classified into long-range and short-range protocols depending on their area coverage and properties. Figure 3 illustrates the network protocols in smart agriculture.

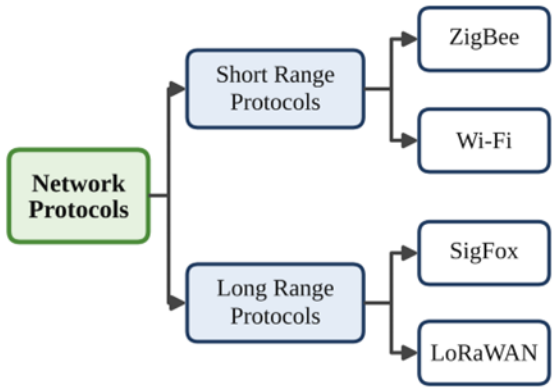


Figure 3 Network Protocols in Smart Agriculture

The brief discussion of different protocols is discussed in the below sub-section with two types of ranges. They are:

4.2.1 Short Range Protocols (ZigBee Technology and WIFI)

Alliance has introduced ZigBee technology based on IEEE 802.15.4 standard with wireless communication approach to conserve the power using energy-efficient standard protocol. ZigBee functioned in multiple radio frequency bands like 2.4 GHz, 915 MHz, and 868 MHz with high transmission speed of 250 kbps. ZigBee operated in low-power sleep mode. ZigBee supported different network techniques like star, tree, and mesh topology. Zigbee wireless networks performed autonomous wireless data transmission in agricultural IoT-WSN. ZigBee guaranteed remote data transmission through successive integration with wired data transmission. Wireless Fidelity (Wi-Fi) has significant development in the wireless technology. Wi-Fi replaced the Ethernet with ability of connecting to internet without wires or cables.

4.2.2 Long Range Protocols (Sigfox and LoRa WAN)

Sigfox is a Low-Power Wide Area Network (LPWAN) technology designed to transmit the data volume ranging from few bytes to hundreds of kilobytes. The modulation technique is introduced with Differential Binary Phase-Shift Keying (D-BPSK) in fixed bandwidth of 100Hz and achieved efficient spectrum utilization. LoRa WAN is a low-power and wide-area networking protocol employed for efficient communication among low-energy devices in different IoT applications. LPWAN technology uses chirp spread spectrum modulation for connecting devices over several kilometers in urban or rural environments. A hybrid Espress if peer to-peer protocol (ESP-NOW) / Long Range (LoRa) IoT monitoring system is introduced in [7] with sensor nodes, master aggregator and gateway for long-range data transmission. ESP8266 nodes gathered environmental data and forwarded the data packets through LoRa for storage, visualization and analysis. Table 1 illustrates the different network protocols in smart agriculture.

Table 1 Tabulation of Different Network Protocols

	ZigBee	Wi-Fi	SigFox	LoRaWAN
Topology	Star and mesh cluster	Star	Star	Star-of-stars
Data Rate	250 kbps	150 kbps	100 bps and 600 bps	0.3–27 kbps
Network	WPAN	WLAN	LPWAN	LPWAN
Frequency	2.4 GHz	2.4/60 GHz	868/902 GHz	-
Standard	IEEE 802.15.4	802.11g	Sigfox	LoRa WAN
Coverage range	10–100m	10-50m	30–50 km/3–10 km	5-15-45 km
Features	PHY and MAC layers of IEEE 802.15.4	Access, availability, flexibility and cost savings	Highly energy efficient and long-range	Low power long range

A hybrid information monitoring approach is introduced in [4] with low-data-rate personal area network depending on IEEE 802.15.4 with low-power wide-area network. The designed method used communication architecture with central node, sub-nodes and end devices to support the large-scale

information monitoring. The main node used LoRaWAN communication technology with photosynthetically active radiation (PAR) with reference radiometers. The sub-nodes employed LoRaWAN, sensor technology and IEEE 802.15.4. A control terminal handled the sensor data and transmitted the collected information to the web application for efficient processing. The designed approach combined IEEE 802.15.4 and LoRaWAN to improve the spatial variability of agricultural fields. The tree and star network topology were combined to gather detailed information about particular crop areas. The designed approach employed low-power and long-distance network services with minimum operating cost of wide-area network information monitoring system. The energy consumption gets minimized during real-time monitoring. The designed approach addressed the needs for data gathering, transmission, storage and processing in large areas. The designed approach used valuable strategies for improving irrigation system and cultivation process of strawberry crops.

4.3 IoT based Sensor Network Applications in Smart Farming

Agriculture is an essential one for any nation. Agriculture is the main backbone for Indian economy. The world inhabitants are increasing and their demand gets increased with increasing in population. The food production and individual fundamental needs are essential one in the agriculture sectors. IoT-WSN is used with wireless network protocols in SA applications. An innovative hexagonal deployment model was introduced in [5] for wireless sensor networks (WSNs) in precision agriculture. The designed model combined adaptive frequency-hopping spread spectrum (AFHSS) mechanism and decentralized real-time adaptation strategy for efficient data transmission in agricultural environments. The hexagonal deployment model positioned sensor nodes in hexagonal grid pattern for efficient coverage of agricultural field. AFHSS mechanism adjusted the frequency channels and robustness against external disruptions.

4.3.1 Irrigation System

The smart irrigation system is used to improve the agricultural productivity and to reduce the environmental impact. The agricultural process created data from different sensors resulted in better operational circumstances and process activities for accurate decision-making. The smart irrigation system enhanced the performance through water usage conservation. The smart irrigation process modifies the irrigation based on actual soil and weather conditions to fulfill their needs. WSN and wireless network protocols are used in irrigation system to attain higher yield.

An automated irrigation system is employed to improve the water-use efficiency in row-crop production. A low-cost and open-source wireless sensor network is used in [2] to automate irrigation zone control depending on real-time soil water potential (SWP). The system combined LoRa-based soil moisture nodes, position-tracking unit and relay-controlled valve array on lateral-move irrigation system. An open-source IoT platform is used to provide the flexible and scalable framework for sensor-guided irrigation automation for attaining precision in variable fields. A self-sustaining IoT framework is introduced in [3] for wireless sensor network to track indicators soil moisture, plant temperature, environmental conditions, groundwater levels and crop height in real time application. An automated irrigation decision introduced crop water stress index and growth tracking. The designed framework achieved higher moisture measurement accuracy with mean absolute error.

4.3.2 Soil Moisture Monitoring System

Soil moisture is an important role in agricultural field for crop growth prediction. Soil moisture is a significant one for plant ecosystems and irrigation system of agriculture field. Soil moisture is variable one and it depends on diverse soil properties. The soil moisture monitoring system is carried out for identifying the soil condition and moisture. The soil monitoring system is carried out to monitor the soil nutrient, PH and moisture monitoring through WSN. Soil moisture is an essential irrigation management, crop yield and sustainable food production for large-scale agriculture. The sensing methods experienced limited spatial coverage, high labor needs and excessive costs. A heterogeneous sensing system [1] employed radio frequency-based wireless sensing network for continuous and large-area monitoring. An autonomous mobile robot is employed for in-situ sampling. A portable handheld probe was employed

for flexible and on-demand data collection. Data from modalities were combined with gaussian process regression to generate high-resolution soil moisture maps with uncertainty quantification.

4.3.3 Crop Disease Detection System

Damaging crop production is mainly due to different factors like pests. The crop diseases are the main issue as the large quantity of crop is wasted in every production cycle by affecting pests and diseases. Therefore, an early-stage decision support system is important one for the farmer to attain profitable harvesting. A smart monitoring system used sensor technology for addressing the plant disease and pest-related concerns. WSN systems gathered the data and stored them in cloud platform with network protocols for early decision making to prevent pest and crop disease.

4.4 Clustering aware IoT based Sensor Network Applications in Smart Farming

WSN is an essential role in precision agriculture for real-time soil health monitoring. The limited energy capacity of sensor nodes has significant challenge to achieve increased network lifetime and reliable data transmission. The conventional clustering protocols struggle with inefficient cluster head (CH) selection, inadequate adaptability to the heterogeneous environments and huge control overhead. A fresh approach is introduced with hierarchical clustering based dynamic data fusion technique in smart agriculture. The dynamic data fusion is carried out in [10] with hierarchical clustering to improve the energy efficiency and event detection precision in smart agriculture. The hierarchical clustering technique is employed to group sensor nodes into clusters. A dynamic data fusion method guaranteed efficient network resource utilization with minimum data redundancy. Extreme Learning Machine (ELM) technology is used to classify and anticipate events.

A hybrid and energy-efficient clustering model termed EECH-HEED was introduced in [12] for soil monitoring in heterogeneous WSNs. The designed protocol implemented the HEED-based CH selection mechanism with residual energy and communication cost for energy-aware clustering. An enhanced EECH-based hierarchical multi-hop clustering strategy employed residual energy and node degree for choosing the CHs. EECH-HEED used dynamic threshold-based sensing mechanism in real-time application depending on environmental change and node energy level.

V. RESULT AND DISCUSSION

The result and discussion section is used to attain the final results of nine existing techniques performance, namely heterogeneous sensing system [1], low-cost and open-source wireless sensor network [2], self-sustaining IoT framework [3], hybrid information monitoring approach [4], innovative hexagonal deployment model [5], hybrid Espressif peer to-peer protocol (ESP-NOW) / Long Range (LoRa) IoT monitoring system [8], dynamic data fusion [10], MSPOA [11] and EECH-HEED [12]. The existing methods used different dataset for conducting the experiments for crop yield prediction in real-time smart framing application. They are: Real-time data [1], Clemson University Edisto Research and Education Center (South Carolina, USA) across three growing seasons (2020–2022) [2], Sensor datasets [3], Strawberry plantation located in Matalas Canas, Huelva, southwestern Spain close to the Donana National Park [4] dataset, Smart Agriculture dashboard [7] and Smart farmland [11]. The performance parameters are energy consumption [4,5,6,8,10], accuracy (A) [2,10], precision (P) [2,10], recall [10], F-measure [10], packet loss rate [4,5,7,9], error rate [1,2,7], computation overhead [10], packet delivery rate [4,5,7,9,12] and latency (L) [4]. The accuracy, precision, recall, and f-measure values are obtained from the True Positive (TP), True Negative (TP), False Positive (FP), and False Negative (FN) values.

Table 2 Performance Metrics

Performance Metrics	Formula
Accuracy (A)	$A = \frac{TP + TN}{TP + TN + FP + FN} \times 100$

Performance Metrics	Formula
Precision (P)	$\mathrm{P} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}} \times 100$
Recall (R)	$\mathrm{R} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} \times 100$
F-measure (F)	$\mathrm{F} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \times 100$
Packet loss rate (PLR)	$\mathrm{PLR} = \frac{\text{Number of packets lost}}{\text{Total number of packets sent}} \times 100$
Packet delivery ratio (PDR)	$\mathrm{PDR} = \frac{\text{Number of packets delivered}}{\text{Total number of packets sent}} \times 100$
Energy consumption (EC)	$\mathrm{EC} =$ Number of sensor nodes × Energy consumed by one sensor node
Error rate (ER)	$\mathrm{ER} = \frac{\mathrm{FP} + \mathrm{FN}}{\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN}} \times 100$
Computation overhead (CO)	$\mathrm{CO} =$ Number of sensor nodes × Time consumed by one sensor node

Table 2 illustrates the performance metrics employed for performing real-time healthcare monitoring. The above-mentioned metrics are measured in terms of percentage. Energy consumption is defined as the total amount of energy consumed to perform efficient crop yield prediction in smart farming. Packet delivery ratio is defined as the ratio of number of data packets correctly delivered to the total number of data packets sent. Packet loss rate is defined as the ratio of number of data packets lost to the total number of data packets sent. Accuracy is defined as the total number of correct classifications to the total number of predictions made. The accuracy is computed based on how effectively the crop yield gets predicted. The error rate is calculated based on how inefficiently the crop yield gets predicted. Precision is defined as the ratio of total number of positive data samples to the total number of positive data samples identified. The recall is defined as number of actual positive data samples to the total number of positive data samples that are correctly identified. Computational overhead is employed for computing the amount of time for real-time farming area monitoring. It is measured in terms of seconds. Latency (L) is an important factor in agriculture application. The latency is measured to evaluate the network system performance. During evaluation, different number of agriculture data is considered as an input. The latency is measured in terms of seconds.

Table 3 Parameters of Existing Methods

Parameter/ Methods	EC	PDR	PLR	ER	CO	A	P	R	F	L	Reliability	De	NL
Heterogeneous sensing system [1]		✓		✓									
Low-cost and open-source wireless sensor network [2]				✓		✓							
Self-sustaining IoT framework [3]											✓		
Hybrid information monitoring approach [4]	✓	✓	✓							✓			

Innovative hexagonal deployment model [5]	✓	✓	✓										
ESP-NOW/ LoRa IoT monitoring system [8]	✓												
Dynamic data fusion [10]	✓				✓	✓	✓	✓	✓				
MSPOA [11]					✓								
EECH-HEED [12]	✓	✓			✓					✓		✓	✓

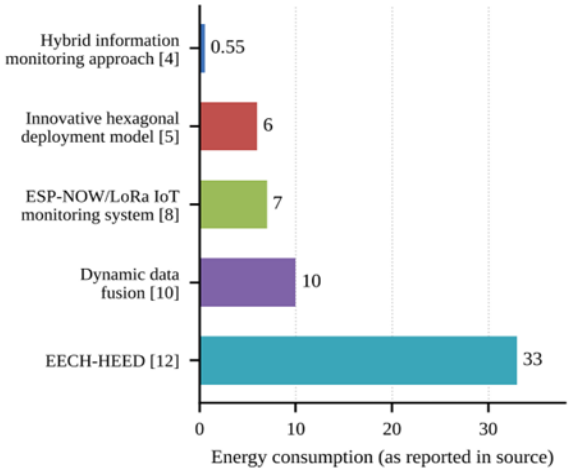


Figure 4 Measurement Analysis of Energy Consumption

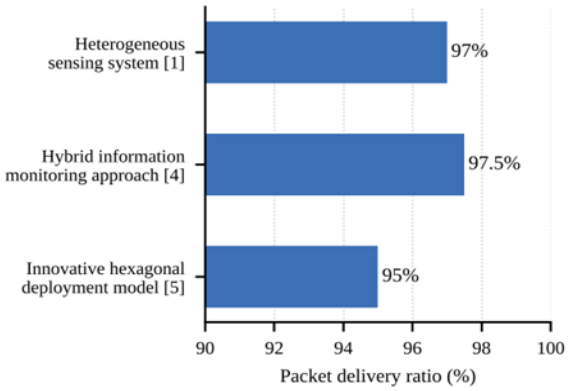


Figure 5 Measurement Analysis of Packet Delivery Ratio

The table 3, figure 4 and figure 5 illustrates the performance metrics table, measurement analysis of energy consumption and packet delivery ratio respectively. In Heterogeneous sensing system [1], the packet delivery ratio attained is 97% and error rate obtained is 1%. Low-cost and open-source wireless sensor network [2] attained the accuracy of 93% and error rate of 7%. Self-sustaining IoT framework [3] attained the 98.7% data transmission reliability with stress detection 24–48 h before visible symptoms with 15% water savings through precision irrigation. In Hybrid information monitoring approach [4], the average energy consumption is only 0.55 mAh, supporting real-time monitoring with latency less than 100 ms and the packet loss rate is 2.5 %. Innovative hexagonal deployment model [5] attains an average latency of 50 milliseconds, a packet loss rate below 2%, a success rate exceeding 95%, and highly efficient obstacle management, with adjusted nodes accounting for less than 5%. ESP-NOW/ LoRa IoT monitoring system [8] consumed energy of 6J. Dynamic data fusion [10] attained 99.54% of accuracy, 99.12 of precision, 98.99% of recall, 99.78% of f-measure. MSPOA [11] improves network coverage by 5.85% and response time by 11.33%. EECH-HEED achieves 33% reduction in Energy Consumption (EC), 15% increase in Packet Delivery Ratio (PDR) and 50% reduction in control overhead.

VI. CONCLUSION

This article reviewed and survey the relevant papers on IoT based WSN for crop yield prediction in smart farming application. IoT is integrated with WSNs in smart farming to maximize yield and optimize the agricultural processes. IoT with WSNs architecture facilitates effective monitoring and control of agricultural fields for enabling data collection to address current challenges. Wireless communication protocols are important for collected data transmission to the system. WSNs with IoT and wireless network protocols are cost-effective and efficient in smart farming applications through reducing the agricultural expenses. The survival study discusses the IoT based WSN architecture with network protocols in smart

farming applications for attaining higher crop yield. The network protocols such as Zig-Bee, Wi-Fi, SigFox, and LoRaWAN have significant utility in IoT-WSNs based smart farming applications like irrigation systems, soil moisture monitoring and crop disease management. In addition, the survival study discusses current challenges and issues in smart farming application to provide strong insights and potential solutions for achieving higher crop yield in IoT-WSNs based smart farming systems.

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