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RESEARCH ARTICLE

Optimized Data Fusion With Scheduled Rest Periods for Enhanced Smart Agriculture via Blockchain Integration

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ABSTRACT The study introduces an efficient data aggregation technique for smart agriculture by leveraging Blockchain technology and a novel method referred to as the "cluster head sleep schedule." The primary objective is to enhance the data collection process within a large-scale agricultural setting where multiple sensors continually generate vast amounts of data while monitoring and safeguarding crops from pest attacks. The proposed method involves the segmentation of sensors into clusters, each led by a designated cluster head responsible for collecting data from its constituent members deployed in the field to monitor pest attacks and promptly report any issues to the management. To curtail data redundancy, the study employs a fuzzy matrix to group nodes based on high-similarity data. This approach enables the selective suspension of certain nodes while others remain active. The data received from these nodes undergoes analysis using a fuzzy similarity matrix for clustering, ensuring that only unique data is transmitted to the base station. Redundant nodes from all clusters are identified and placed in a sleep mode, thus conserving energy and prolonging the network's lifespan. This sleep scheduling mechanism is implemented subsequent to data redundancy reduction, facilitating immediate pest attack control in agriculture. By implementing these techniques, smart agriculture stands to benefit from optimized energy utilization and reduced costs associated with monitoring and pest control, thereby fostering sustainable and efficient operations. The cluster head is responsible for storing the data on a base station positioned at the network's edge, allowing for local processing and prompt communication of pest attack information to the farmer for immediate action. Moreover, this edge system stores the data on a Blockchain network for future analysis and serves as a guideline for pest attack control in the pesticide industry, thereby enhancing data security and immutability. In addition to these advantages, the research also emphasizes the importance of controlling pest attacks to enhance crop production in the field, ultimately contributing to the country's economic growth. Simulation results affirm that the proposed approach leads to notable cost reductions, decreased energy consumption, improved crop production, precise crop monitoring to prevent pest attacks, and a prolonged network lifespan. These outcomes underscore the effectiveness of this approach within the context of smart agriculture and its role in enhancing the monitoring system for smart agriculture and bolstering security through Blockchain technology.

INDEX TERMS Smart agriculture, blockchain technology, sleep field monitoring, Internet of Things, wireless network.

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I. INTRODUCTION

The growing popularity of the Internet of Things (IoT) is evident due to the rise of smart devices and networks. This phenomenon is marked not only by the increasing number and diversity of available applications but also by the expanding user base for these applications. IoT, as an emerging concept, enables developers to connect multiple intelligent devices through various systems and technologies. This amalgamation of devices serves specific purposes, such as facilitating online learning and enabling multi-objective positioning.

The IoT has had a significant impact on various aspects of human life, both in personal and professional domains [1]. It empowers machines to handle laborious tasks, automate mundane activities, and ultimately enhances human well-being by promoting a healthier, more productive, and more comfortable lifestyle. One industry significantly influenced by the IoT is agriculture, which has seen advancements in the precise and efficient management of farms and crops through the use of sensors, data analytics, and automation [2].

Smart agriculture systems, driven by the IoT, provide real-time insights into crop health, soil moisture levels, and weather conditions, enabling farmers to make informed decisions and optimize their operations. This data can be analyzed to make well-informed choices about irrigation, fertilization, and other aspects of crop management, resulting in more efficient and sustainable farming practices. Smart agriculture systems play a crucial role in helping farmers optimize crop yield, reduce waste, and enhance sustainability.

However, the massive volumes of data generated by smart agriculture systems can pose challenges in terms of data storage, processing, and transmission. In response to these challenges, this research paper proposes an efficient data aggregation method for smart agriculture systems that utilizes blockchain technology [3].

A. DATA AGGREGATION IN SMART AGRICULTURE

Data aggregation in the realm of smart agriculture involves the collection of data from diverse sources associated with farming, such as sensors, drones, weather stations, and farm management systems. Subsequently, this data is merged and analyzed to facilitate informed decision-making. It plays a pivotal role in optimizing various facets of farming, including crop management, water usage, and resource allocation. Smart agriculture technology has brought about a revolution in the way farmers approach their operations.

By deploying an array of sensors and monitoring equipment, farmers gain instant access to critical information concerning their crops, soil quality, and atmospheric conditions. This data guides decisions about when to plant, irrigate, and harvest crops, as well as determining the optimal fertilizer application and seed selection. Enhanced efficiency is one of the key advantages of data aggregation in agriculture [4]. The data gathered through these monitoring devices empowers farmers to make more informed choices about the efficient use of resources, leading to reduced waste, increased crop yields, and higher profits. Additionally, data aggregation aids in reducing the carbon footprint by minimizing resource use and waste generation on the farm.

Improved crop management is another significant benefit of data aggregation. Through sensors and monitoring equipment, farmers can monitor crop growth and health in real-time. This real-time data informs decisions about irrigation, fertilization, and harvest timing, resulting in enhanced crop yields and decreased waste. Data aggregation also offers valuable insights into weather conditions and climate patterns. This data assists in determining the optimal timing for planting crops, as well as the appropriate water and fertilizer application. Moreover, it aids in anticipating weather-related challenges and planning accordingly.

Smart agriculture encompasses the collection of data from a range of sources, including drones, sensors, farm management systems, and weather stations. This data is then transmitted to a central hub for aggregation and analysis. Utilizing data analytics, farmers harness this collected data to make well-informed decisions aimed at optimizing their operations. Ensuring the accuracy and reliability of data remains a primary challenge in data aggregation within agriculture [5]. This necessitates the proper installation and maintenance of sensors and monitoring devices, along with careful consideration of the data types being collected and analyzed. Additionally, the secure storage and protection of data are crucial to enable its effective use in the future.

In addition to real-time data aggregation, smart agriculture incorporates advanced technologies such as precision farming, IoT (Internet of Things) sensors, drones, and machine learning algorithms. These technologies empower farmers to monitor and manage their crops and resources with greater precision, efficiency, and sustainability.

As the global population continues to grow, the demand for food production is rapidly increasing. In response, the adoption of smart agriculture practices offers a promising solution to address this challenge while simultaneously mitigating the environmental impact of farming. This translates into heightened efficiency, improved crop management, and reduced waste, making it a critical tool for farmers aiming to excel in an increasingly competitive market.

B. BLOCKCHAIN

Blockchain technology was first introduced in 2008 through Blockchain technology made its debut in 2008 with the release of a white paper authored by an enigmatic figure who operated under the pseudonym "Satoshi Nakamoto." This groundbreaking document proposed the concept of a decentralized system for recording and verifying transactions through the use of cryptography and a distributed network of nodes [6].

The year 2009 marked the unveiling of the inaugural version of blockchain technology in the form of the Bitcoin network, a digital cryptocurrency that harnessed blockchain technology to establish a decentralized, peer-to-peer system for the exchange of value without reliance on a central authority. Since that time, blockchain technology has undergone significant evolution and found applications in a multitude of industries, with experts forecasting its continued capacity to reshape industries and generate fresh prospects for innovation and advancement [7].

The potential applications of blockchain technology span across a wide spectrum of industries due to its ability to facilitate secure and transparent data sharing, unalterable record-keeping, and decentralized transactions. It offers a more efficient and secure approach to data and transaction management, eliminating the need for intermediaries or central authorities. Each block within the blockchain includes an exclusive digital signature, a timestamp, and a reference to the previous block, resulting in a virtually immutable record that is highly resistant to alteration or tampering. Blockchain technology possesses the potential to revolutionize a range of industries and applications beyond the realm of financial transactions.

In the domain of supply chain management, for example, blockchain can significantly enhance transparency, traceability, and the efficiency of goods and services transportation. Likewise, in healthcare, blockchain technology can be harnessed to safeguard medical records and bolster patient privacy [8]. IoT based crowd management model is presented [9].

In voting systems, blockchain can play a pivotal role in fortifying security and transparency in the electoral process. Its potential to enhance transparency, security, and efficiency in data transfer and storage has the capacity to transform numerous industries.

C. BLOCKCHAIN IN SMART AGRICULTURE

The integration of blockchain technology into the realm of smart agriculture offers numerous benefits to the sector. Blockchain provides a secure and decentralized ledger system capable of tracking food supply chains, fostering transparency, and building trust among stakeholders. With blockchain, crucial data such as soil health, weather patterns, and crop yields can be recorded in an immutable fashion, serving as a reliable source of information for farmers and other industry participants. Furthermore, the adoption of blockchain-based smart contracts streamlines payment and settlement processes, reducing the risk of fraud and enhancing overall efficiency. The infusion of blockchain technology into smart agriculture plays a vital role in ensuring equitable pricing for farmers' products and bolstering consumer confidence in the origin and quality of their food [10].

In comparison to other sectors, the agricultural industry has been relatively sluggish in embracing the latest technologies. Although modern machinery is utilized for production, pre-harvest and post-harvest processing still predominantly rely on traditional methods. This outdated approach results in farmers receiving inadequate payments, consumers lacking vital information prior to purchase, and intermediaries inflating retail prices. The incorporation of blockchain, smart contracts, and IoT devices can automate the entire process while establishing trust among all involved parties. This study delves into various facets of amalgamating blockchain and smart contracts with IoT devices for the pre- and post-harvest stages in agriculture. Our proposed system rests upon blockchain technology as its foundation, with IoT devices collecting field-level data and smart contracts governing interactions among all stakeholders. We provide illustrations and explanations of the system's implementation, along with associated gas costs to enhance cost comprehension. Additionally, we conduct an analysis of the system's challenges and advantages. Our study underscores the secure, transparent, and immutable attributes of blockchain technology within the agriculture industry, underscoring the substantial potential unlocked through the integration of blockchain, smart contracts, and IoT devices [11].

1) USE OF BLOCKCHAIN IN CLOUD ARCHITECTURE

The use of blockchain technology in cloud architecture is gaining attention from researchers due to its potential to enhance security. This innovative idea is appealing because it offers a new approach to securing cloud infrastructure. There are several reasons why blockchain is considered necessary for distributed cloud storage, as outlined below.

By employing blockchain technology, a decentralized cloud data storage system can be established, where data is stored across multiple nodes that are distributed globally. This approach offers redundancy and decentralization, which helps to ensure data security and. The use of blockchain technology can enable the efficient utilization of on-demand resource services requested by intelligent IoT devices through the use of intelligent contract algorithms. Once the requested services are completed, payment is automatically processed utilizing this technology [12]. Blockchain technology empowers every user to manage their private key while guaranteeing that each block in the blockchain contains encrypted data. As a result, it delivers comprehensive security without necessitating a third-party intermediary. With blockchain technology, it is possible to track the use of resources and verify service level agreements between clients and service providers. This capability enhances the quality of services provided by ensuring that all parties adhere to the agreed-upon terms [13], [14]. To create a secure and scalable infrastructure in an IoT network using edge computing, certain requirements must be met. The system design should adhere to the following principles:

High-performance edge computing: The infrastructure should utilize edge computing technology to ensure that data processing and analysis would be ended quickly and efficiently.

Scalability: The infrastructure should be designed to handle an increasing number of connected IoT devices without compromising security or performance.

Security: The infrastructure should be built with security as a top priority, implementing measures such as encryption, authentication, and access control.

Service-oriented architecture: The system should be designed with a service-oriented architecture, allowing for the creation and management of scalable, flexible, and secure services [15].

Interoperability: The system should support interoperability between devices and services, ensuring that data can be shared securely and efficiently. By adhering to these design principles, a secure and scalable infrastructure for IoT networks using edge computing can be developed to meet the challenges and future requirements of the IoT ecosystem. Remote sensing is used for the data monitoring

2) RESEARCH CONTRIBUTIONS

Utilizing edge computing to process IoT data streams can help reduce the load on centralized systems and improve data processing efficiency. Additionally, edge computing can enhance the security of data by performing analysis closer to the source, reducing the risk of data breaches during transmission. By developing an energy-efficient and secure framework for smart agriculture, the proposal can potentially improve the overall productivity and sustainability of the agricultural industry. On the IoT layer, in addition, a fuzzy-based algorithm is employed for the purpose of data aggregation to decrease redundancy and network traffic, which improves system efficiency. The edge server's cache contains the most frequently used services, which the requested IoT devices will get. Blockchain technology is used in the procedure of registering newly requested IoT devices like sensors edge servers. Upon completing the registration process, the IoT system receives the preferred service code via the cloud server.

3) ORGANIZATION

The rest of the paper is structured as follows: Section II. discusses the related work. Section III presents an Efficient data aggregation with smart agriculture using the emerging technology of blockchain for validation of the edge server and services provided to the IoT devices from the proposed energy-efficient data aggregation algorithm; Section IV demonstrates the simulation results and performance from different points of view. Finally, section V suggests future work and the conclusion.

II. RELATED WORK

The growing popularity of the Internet of Things (IoT) is evident due to the rise of smart devices and networks. This phenomenon is marked not only by the increasing number and diversity of available applications but also by the expanding user base for these applications. IoT, as an emerging concept, enables developers to connect multiple intelligent devices through various systems and technologies. This amalgamation of devices serves specific purposes, such as facilitating online learning and enabling multi-objective positioning. The IoT has had a significant impact on various aspects of human life, both in personal and professional domains [16]. It empowers machines to handle laborious tasks, automate mundane activities, and ultimately enhances human well-being by promoting a healthier, more productive, and more comfortable lifestyle. One industry significantly influenced by the IoT is agriculture, which has seen advancements in the precise and efficient management of farms and crops through the use of sensors, data analytics, and automation [17].

Smart agriculture systems, driven by the IoT, provide real-time insights into crop health, soil moisture levels, and weather conditions, enabling farmers to make informed decisions and optimize their operations. This data can be analyzed to make well-informed choices about irrigation, fertilization, and other aspects of crop management, resulting in more efficient and sustainable farming practices. Smart agriculture systems play a crucial role in helping farmers optimize crop yield, reduce waste, and enhance sustainability. However, the massive volumes of data generated by smart agriculture systems can pose challenges in terms of data storage, processing, and transmission. In response to these challenges, this research paper proposes an efficient data aggregation method for smart agriculture systems that utilizes blockchain technology [18].

Data aggregation in the realm of smart agriculture involves the collection of data from diverse sources associated with farming, such as sensors, drones, weather stations, and farm management systems. Subsequently, this data is merged and analyzed to facilitate informed decision-making. It plays a pivotal role in optimizing various facets of farming, including crop management, water usage, and resource allocation. Smart agriculture technology has brought about a revolution in the way farmers approach their operations. By deploying an array of sensors and monitoring equipment, farmers gain instant access to critical information concerning their crops, soil quality, and atmospheric conditions. This data guides decisions about when to plant, irrigate, and harvest crops, as well as determining the optimal fertilizer application and seed selection. Enhanced efficiency is one of the key advantages of data aggregation in agriculture [19].

The data gathered through these monitoring devices empowers farmers to make more informed choices about the efficient use of resources, leading to reduced waste, increased crop yields, and higher profits. Additionally, data aggregation aids in reducing the carbon footprint by minimizing resource use and waste generation on the farm. Improved crop management is another significant benefit of data aggregation. Through sensors and monitoring equipment, farmers can monitor crop growth and health in real-time. This real-time data informs decisions about irrigation, fertilization, and harvest timing, resulting in enhanced crop yields and decreased waste. Data aggregation also offers valuable insights into weather conditions and climate patterns. This data assists in determining the optimal timing for planting crops, as well as the appropriate water and fertilizer application. Moreover, it aids in anticipating weather-related challenges and planning accordingly. Smart agriculture encompasses the collection of data from a range of sources, including drones, sensors, farm management systems, and weather stations. This data is then transmitted to a central hub for aggregation and analysis.

Utilizing data analytics, farmers harness this collected data to make well-informed decisions aimed at optimizing their operations. Ensuring the accuracy and reliability of data remains a primary challenge in data aggregation within agriculture [20].

This necessitates the proper installation and maintenance of sensors and monitoring devices, along with careful consideration of the data types being collected and analyzed. Additionally, the secure storage and protection of data are crucial to enable its effective use in the future. In addition to real-time data aggregation, smart agriculture incorporates advanced technologies such as precision farming, IoT (Internet of Things) sensors, drones, and machine learning algorithms. These technologies empower farmers to monitor and manage their crops and resources with greater precision, efficiency, and sustainability. As the global population continues to grow, the demand for food production is rapidly increasing. In response, the adoption of smart agriculture practices offers a promising solution to address this challenge while simultaneously mitigating the environmental impact of farming. This translates into heightened efficiency, improved crop management, and reduced waste, making it a critical tool for farmers aiming to excel in an increasingly competitive market. Cloud and IoT technology are commonly employed for real-time monitoring and evaluation of water reservoir quality and ranking. At present, this technology is being utilized for overseeing and collecting data on dam health to prevent the need for immediate action. In the proposed research, IoT sensors situated on cloud nodes will gather and transmit data to the dam management system. This system is constructed employing a blockchain architecture that offers security, verification, storage, data integrity, traceability of delivery tasks within the monitoring cloud system, and reimbursement of all responsible stakeholders for the delivery and sensing tasks [21]. The primary goal of utilizing blockchain technology is to operate in a decentralized model while maintaining a high level of security. According to recent research, blockchain and Bitcoin are considered the future of the finance industry [22]. The widespread use of IoT technology has raised various security risks, particularly when data is taken from a network cluster. Blockchain technology has the potential to improve the inherent privacy and security of IoT, as well as the dependability of data aggregation and data management. This paper describes a data-driven method for on-chain data allocation in an IoT blockchain system. A system is also built to arrange data using fuzzy logic to determine the Rating of Allocation value while taking into account many scenario elements such as data, network, and excellence [23].

In 2050 food, fiber, feed, and fuel were predicted, and according to this prediction, to meet global demand, important challenges must be overcome in order to obtain the agricultural production level required. Farming has faced important problems in the past that will have an impact on productivity increases by 2050 [24]. These difficulties include finite resources, a lack of highly skilled labor, a lack of fertile land, and changing weather. This paper expresses that farming must become more intelligent by using new technologies and creativity that are built; this is focused on the integration of the Internet of Things (IoT) technology and information and communication technologies (ICT) in smart agriculture. Using fertilizer, water, and agrochemicals in a smart way in order to increase production. In this concept, the land becomes a subspace, where different sorts of sensors may collect diverse data. All sensors are internet-connected, and the information they gather is kept in a database that has all the necessary details on the land's attributes [25]. Furthermore, implementing a dynamic sleep scheduling mode can enhance the longevity of a network compared to a fixed sleep scheduling method. A proven method for enhancing the lifespan of the network is to adopt this approach [26].

Agriculture, a critical industry serving as the primary source of food for human consumption and driving economic growth, is undergoing significant transformation with the advent of smart agriculture. This approach, leveraging technologies such as artificial intelligence, cloud computing, big data, and edge computing, aims to enhance agricultural operations. However, the security aspects of smart agriculture need attention despite its essential role. This study evaluates recent advancements in smart agriculture security, particularly focusing on open-field agriculture, addressing security concerns, design issues, and future prospects. The proposed smart system incorporates four layers—perception, network, edge, and application—to efficiently collect, process, and utilize agricultural data [27]. The Internet of Things (IoT) has emerged as a result of widespread smart technology use, impacting various industries, including agriculture. In smart agriculture, sensor nodes collect field or greenhouse data, sent to a control center for operational decisions. This research proposes an efficient data collection method prioritizing privacy and security. Utilizing a genetic algorithm and unmanned aerial vehicles, the study enhances system performance, emphasizing six critical components: system user, control center, UAV, greenhouse, smart sensor node, and automatic control equipment [28]. Addressing the challenges faced by smallholder farmers, who contribute significantly to global food production, this study introduces blockchain technology. It facilitates trust, reduces transaction-related risks, and provides confidence to farmers in their exchanges. Moreover, IoT merged with unmanned aerial vehicles presents a low-cost platform for agricultural modernization. This approach, employing IoT-based aboveground and below-ground sensors, facilitates data collection, enhancing environmental forecasting and agricultural productivity [29], [30]. Smart agriculture, utilizing technologies like IoT, addresses challenges in food production. This study aims to identify essential IoT-enabled smart agricultural infrastructure, including platforms, networks, data processing technologies, techniques, and applications. Unlike traditional passive data approaches, modern techniques enable proactive agricultural disease prevention and crop diagnostics [31]. In the domain of agricultural production, wireless sensor networks powered by IoT have been employed to determine production or yield status. However, these networks face limitations in processing power, energy consumption, transmission range, and memory capacity. To address these challenges, the researchers suggest an IoT-based wireless sensor network framework. This framework, incorporating security measures, enables effective data collection, transmission, and processing across various fields, including agriculture, industry, and environmental monitoring [32], [33]. The 21st century has witnessed a transformative impact of IoT and smart computing technologies on various aspects of life, including smart agriculture. Farmers use smart devices for real-time monitoring of crop conditions and soil moisture, employing technologies like drones for tasks such as pesticide spraying and field monitoring. This comprehensive study delves into security and privacy concerns in the context of a smart farming ecosystem, addressing prospective cyber-attack scenarios, open research issues, and future directions [34]. Blockchain technology, when combined with IoT, proves transformational. This study introduces an effective routing method incorporating blockchain for distributed nodes. IoT devices, though intelligent, face challenges due to limited power and storage. The study showcases how these devices solve global community problems efficiently [35]. The proposed protocol operates on a heterogeneous Internet of Things (IoT) network to determine a route to the base station, aiming to block and delete redundant data, mitigate IoT architecture attacks, and reduce energy usage while extending network life [3]. In wireless sensor networks (WSNs), including applications in communication, industry, and agriculture, the integration of IoT and WSNs automates farm systems, enhancing crop productivity through various sensors. Researchers propose an energy-efficient data aggregation protocol in an IoT-based WSN architecture for smart agriculture, employing sensors to gather field data and determine cluster heads. The clustering concept, widely used in wireless sensor networks, extends device life and conserves energy, with the integration of a sleep node scheduling approach to reduce data redundancy, network traffic hopping, and transmission costs. The article also introduces blockchain into a cloud server for security purposes [36]. The Internet of Things (IoT) is progressively transforming the traditional Internet into a network of wireless objects, linking sensing devices. However, energy consumption by IoT routing protocols can impact network lifespan, leading to transmission collisions and data security concerns. To conserve energy, nodes are placed in sleep mode, utilizing a fuzzy matrix to split nodes based on similarity [4]. The advent of IoT devices has given rise to the concept of "smart farming," allowing real-time data collection in agriculture. The agriculture sector, crucial for meeting global food demands, has undergone a redesign with IoT technologies, enhancing resource efficiency. This comprehensive investigation explores the use of IoT devices and wireless sensors in agriculture, detailing various sensors for soil grounding, harvest monitoring, irrigation regulation, and pest detection. The proposed IoT-based WSN architecture for smart agriculture involves stages of sensor deployment, cluster head determination, signal intensity maintenance, and security measures for data transmission [37]. Smart technologies, including IoT, cloud computing, machine learning, and artificial intelligence, play a pivotal role in agriculture. The integration of IoT devices and wireless sensors has revolutionized the sector, enabling informed decision-making for farmers. Various technologies and sensors in smart farming address tasks such as weather data collection, crop monitoring, disease detection, and livestock tracking. Challenges and gaps in current research related to IoT in smart agriculture are identified, urging further study for global food production improvement [38]. The application of cutting-edge technology like IoT and artificial intelligence provides practical solutions to global challenges, particularly in addressing food scarcity and population expansion. This article explores novel techniques in intelligent farming, involving data gathering, transmission, preservation, and examination. The use of unmanned aerial vehicles (UAVs) and robots is highlighted for tasks such as harvesting, planting, and insect control. Leveraging 5G mobile networks is emphasized for building smart systems, crucial for rapid data transfer and efficient device management [39]. The Internet of Everything (IoE) serves as a contemporary platform connecting people, data, and objects over a shared network. This study presents an efficient IoE smart agricultural model and introduces soil smart agriculture, a method for monitoring soil quality based on sensors. The comprehensive IoE framework is interconnected, incorporating a case study called SSA for soil data gathering and transmission [40]. Research on energy-efficient wireless sensor networks in IoT-based smart agriculture emphasizes the challenge of finding data efficiency at the base station. Energy harvesting is employed to maintain energy balance, investigating topics like estimating solar energy for energy neutrality and calculating energy requirements at random times. Precision agriculture utilizes various sensors for continuous field monitoring, and an Improved Duty Cycling algorithm is proposed to enhance energy efficiency, outperforming other algorithms in metrics such as average energy consumption, residual energy performance, and throughput [1]. Recent years have seen increasing interest in using IoT in agriculture, with wireless sensor network (WSN) based IoT installations recommended for various industries. The Routing Protocol for Low Power and Lossy Networks (RPL) has been introduced for IoT, but modifications are needed for precision agriculture. This study presents an adapted version of RPL specifically designed for IoT-based precision agriculture, proposing an energy-efficient hierarchical routing structure. The improved RPL is scalable and low-energy, with performance analysis based on an analytical model and future scope considerations [41].

Smart agriculture, a rapidly expanding study area, addresses the increasing demand for food production driven by a growing human population. It transforms farming methods by enabling real-time data collection for informed decision-making. The focus is on improving food quality through regulated production, emphasizing nutritional elements and reduced pesticide usage. Electronics and sensor technologies play a pivotal role in achieving these goals, with sensors evaluating plant health and fruit conditions, including chlorophyll meters, moisture sensors, and color sensors. Additionally, sensors monitor ambient conditions like temperature, humidity, and light. This comprehensive overview empowers farmers to make informed decisions on crop management [42]. Automation in agriculture becomes crucial to meet rising food demand due to population growth. Traditional farming methods prove inefficient, leading to disrupted agricultural development. This study explores the adoption of the Internet of Things (IoT), aerial photography, and various cameras coupled with machine learning and artificial intelligence to address agricultural challenges. These technologies effectively tackle issues such as plant diseases, pesticide control, weed management, irrigation, and water management, ultimately enhancing crop output and soil fertility [43]. The shift toward a "smart" approach in agriculture, driven by emerging technologies, introduces Radio Frequency Identification (RFID) sensing technology. This technology finds applications in four key aspects of agriculture: plant environment, harvest quality, soil characteristics, and plant growth. The study outlines the benefits and drawbacks of adopting RFID sensing technology to address agricultural challenges [44]. The integration of IoT in health monitoring systems for COVID-19 patient detection aligns with the global goal of achieving "Zero Hunger." Current technologies optimize agricultural activities sustainably, supporting farmers and increasing productivity. The drive for technical progress revitalizes old agricultural processes, leading to recyclable, supportable, and efficient farming practices. The survey explores technological approaches, application sectors, available datasets, research issues, and proposes solutions and potential research directions [46]. Precision farming, enabled by cutting-edge technologies like unmanned aerial vehicles (UAVs) and IoT, has ushered in a new era. This study provides an overview of IoT technology, encompassing intelligent sensors, diverse IoT sensors, networks, and protocols specifically employed in agriculture. It emphasizes IoT and UAV as critical technologies revolutionizing traditional agricultural methods into precision agriculture intelligence [2]. The agricultural industry's adoption of new technology lags behind other sectors, with traditional methods still prevalent in tracing, storing, and disseminating agricultural data. This study proposes a system for automating pre- and post-harvest phases using blockchain, smart contracts, and IoT devices. Leveraging these technologies enhances confidence and transparency among stakeholders, utilizing IoT devices for data collection and blockchain for data storage, immutability, transparency, and security [48]. Smart farming, extensively employing the Internet of Things, aims to collect and utilize data efficiently for increased agricultural productivity. Addressing security and privacy concerns associated with data collection, this article suggests a blockchain-based solution for smart agricultural data aggregation with privacy protection and fault tolerance, demonstrating effectiveness in safeguarding both privacy and data [49]. The essay explores research issues around safe and private green IoT-based agriculture, presenting a four-tier architecture and evaluating threat models. It provides a taxonomy and comparative analysis of privacy protection methods, including consensus algorithms and blockchain-based solutions. The study identifies future research areas, emphasizing security and privacy for green IoT-based agriculture [50].

Agriculture, a vital component of human life, sustains the world's population and provides employment opportunities. Despite its significance, many farmers still rely on conventional techniques, resulting in low yields. Challenges such as crop selection and support system implementation impact agricultural production. This study introduces a framework for smart crop tracking and monitoring, utilizing Internet of Things (IoT) camera mobile applications and big data analytics. Employing hardware like Arduino Uno, sensors, and a Wi-Fi module, the goal is to reduce waste and enhance energy efficiency [51]. The domain of smart farming, influenced by IoT, involves data collection for analysis and decision-making. This survey explores big data classification in smart farming, detailing common uses and machine learning approaches for data analysis. It addresses challenges in big data analysis for smart farming and suggests approaches for more successful farming through informed decision-making using relevant data [52]. Information and communication technology advancements in agricultural machinery, sensors, and IoT have led to modern techniques disrupting traditional practices. This research explores wireless sensor applications, potential challenges, and the integration of robots and artificial intelligence. The study envisions technological benefits across the crop cycle, from planting to harvest, with applications in packaging and transportation [53]. Smart farming, a modern approach to agriculture, leverages IoT technologies for efficient farm management. This study discusses the emerging concept of "smart farming" and its reliance on IoT-enabled sensors and drones to monitor environmental factors. Smart farming enhances operational efficiency and enables rapid responses to weather conditions. The study emphasizes the problems and uses of smart farming for agricultural growth [55]. Conventional agricultural practices, still prevalent globally, hinder crop output. The IoT emerges as a crucial technology to revolutionize agriculture, addressing issues of productivity, quality, and costs. Sensors and devices connected through the IoT allow remote monitoring of crops and soil conditions, making the process more efficient and data-driven. Smart farming, facilitated by the IoT, holds the potential to address critical food-related challenges [57]. The integration of blockchain with IoT aims to establish secure communication infrastructure.

This study explores the viability of cloud and fog computing as hosting platforms for blockchain. It introduces a novel blockchain-based mechanism called Dual Fog-IoT, dividing fog levels into distinct parts to manage real-time data transmission and network traffic. The study also proposes a data-centric solution for on-chain data allocation in an IoT blockchain system, enhancing privacy, security, accuracy, and efficiency [59], [60], [11]. Various security issues in IoT data collection are addressed through blockchain technology. This study proposes a data-centric solution using fuzzy logic for on-chain data allocation, considering situational factors like data, network, and quality. Additionally, an energy-efficient data communication system using blockchain in smart cities is presented [61], [62].

III. PROPOSED FRAMEWORK

Figure 1 illustrates the proposed architecture of the smart agriculture system, consisting of five primary components: sensors, a base station, a mobile app, an edge server, and a cloud layer with integrated blockchain technology. The sleep schedules method is applied to group and schedule sensors for data collection at specific times, reducing energy consumption and extending battery life. Each group or cluster is directly connected to the base station, utilizing the LEACH wireless network protocol for clustering and data transmission. IoT devices collect data from monitored agricultural infrastructure, filter it using a fuzzy matrix, and transmit it to the local base, which forwards it to the edge server located outside the fields. The edge server plays a crucial role in real-time processing and analysis, receiving requests from IoT devices, examining service requests, and checking the cache for recent service usage. When a service request is received, the edge server verifies the cache, providing an immediate response if available; otherwise, it connects with the cloud server to obtain the necessary service securely using blockchain technology. To optimize communication and reduce power consumption, IoT devices employ various techniques such as signal strength detection, distance calculation, and power consumption adjustment using sensors. All IoT devices have data fusion capabilities, transmitting equal-sized data packets over the network. Energy consumption during data transmission cycles is calculated based on communication and data reception efficiency, enabling a more precise estimation of the energy required for data transmission. Each IoT device has a unique ID for identification purposes, and message scheduling in the IoT-based network is presented to save network energy [63].

Furthermore, the cluster formation involves placing wireless sensor nodes in the field, organizing them into clusters based on geographical closeness and other characteristics. Each cluster is managed by a cluster head (CH), serving as a liaison between the nodes and the base station. The sleep schedule, controlled by the CH, ensures nodes conserve energy by staying in sleep mode when not scheduled to communicate. The sleep schedule is designed to stagger wake-up times, reducing the likelihood of collisions and interference

FIGURE 1. Proposed system architecture.

within the same cluster. Data collection involves each node within the cluster gathering data on environmental factors relevant to crop growth, such as temperature, humidity, and soil moisture. Data aggregation occurs when a node wakes up according to its schedule, transmitting collected data to the CH, which aggregates it for further analysis at the base station.

A. PROPOSED AN EFFICIENT DATA AGGREGATION FOR SMART AGRICULTURE

To monitor the condition of the fields, sensors are strategically positioned in the area. Spatial correlation is present in the data collected from these fields. To enhance energy efficiency and streamline data collection, a combination of sleep and wake modes is implemented, emphasizing the importance of sleep patterns in managing data redundancy and communication variations. Utilizing sleep and scheduling strategies enables nodes to conserve significant amounts of energy by entering a dormant state. The key objective is to employ a fuzzy matrix to categorize nodes with a high degree of data similarity. The Cluster Head (CH) analyzes the data received from member nodes to further process the information.

To ensure effective clustering, an initial step involves creating a fuzzy similarity matrix. Following the clustering process, specific wireless sensor nodes are selected from each group to serve as redundant nodes. Subsequently, a sleep scheduling technique is applied to reduce data redundancy, alleviate network congestion, and minimize transmission costs. The collaboration effectiveness between two wireless sensor nodes, Xa and Xb, is evaluated based on their spatial distance using a calculated function denoted as (a, b). When the distance between two nodes is significant, data is collected under the assumption of no spatial correlation

TABLE 1. Existing work comparison regarding their features, drawback, and advantages.

Features	Existing Work	Advantages	Drawbacks
- Blockchain with IoT for smart agriculture	Awan et al. (2020)	- Emergent routing scheme	- Specific routing scheme not detailed
- IoT and Agricultural UAVs in smart farming	Boursianis et al. (2022)	- Comprehensive review	- Limited technical details
- Introduction to Agricultural IoT	Colizzi et al. (2020)	- Comprehensive introduction	- No specific framework discussed
- IoT-based sustainable agriculture	Dhanaraju et al. (2022)	- Focus on sustainability	- Limited technical details
- IoT and wireless communication for smart farming	Dhruva et al. (2023)	- Focus on wireless communication	- Limited scalability analysis
- Security and privacy in green IoT-based agriculture	Ferrag et al. (2020)	- In-depth security review	- No specific IoT framework discussed
- Plants and environmental sensors for smart agriculture	Garlando et al. (2020)	- Overview of sensor applications	- Focus on sensor technology
- Security and privacy in smart farming	Gupta et al. (2020)	- Discussion on security and privacy	- Limited technical details
- Monitoring and control strategies in smart agriculture	Hassan et al. (2021)	- Systematic review	- No specific framework discussed
- Survey on smart farming technologies	Idoje et al. (2021)	- Addresses challenges	- Limited technical details
- IoT applications in smart agriculture	Kassim (2020)	- Highlights IoT applications in farming	- Limited technical details
- IoT for sensor-based smart farming	Kaur et al. (2023)	- Focus on sensor applications	- Limited scalability analysis
- Blockchain for trust between smallholder farmers	Kumarathunga et al. (2022)	- Trust in agricultural futures market	- Limited technical details
- UAVs in smart agriculture	Maddikunta et al. (2021)	- UAV applications in farming	- Limited discussion on other IoT aspects
- DualFog-IoT: Fog layer for blockchain integration	Memon et al. (2019)	- Addresses blockchain integration in IoT	- Limited scope on smart agriculture
- Securing cloud native applications using blockchain	Mendki (2021)	- Focus on security	- Limited agricultural context

between them. This approach aims to optimize the utilization of resources in wireless sensor networks and enhance their overall efficiency.

The clustering of observed items is executed using the fuzzy matrix, resulting in diverse categorization outcomes at distinct confidence levels, ultimately generating a dynamic clustering network.

$$X = \{X_1, X_2, X_3 \ldots X_\mathrm{n}\}, \tag{1}$$

Let us assume that the sensor network represents the total number of deployed nodes within the cluster, where 'x' denotes the count of all the sensor nodes present. The matrix 'M' is defined as a two-dimensional array of size 'n * t', where 'n' represents the number of member nodes and 't' represents the number of intervals. Each element of the matrix 'Mab' represents the data collected by the member node 'Sa' at the time 'u'.

$$M = (M)n^*t$$

In the beginning, standard and shift deviation transformations were used to normalize the elements of the matrix 'M'.

$m'_{ab=}\frac{m_{ab-\bar{m}_b}}{n_b}$, (a=1,2,3..., n, b=1,2,3..., n)

$$\bar{m}_{b=}\frac{1}{n}\sum\nolimits_{b=1}^{n} x_{ab}, n_{b=}\sqrt{\frac{1}{n}\sum\nolimits_{a=1}^{n}(m-m_b)^2}, \tag{2}$$

In the equation, 'm_{ab}' represents the element in the matrix 'M' at the row 'a' and column 'b'. 'm_b' represents the mean value of the data in column 'b', and 'n_b' represents the number of elements in column 'b'. The standard and shift deviation transformation is used to make the data in the matrix 'M' comparable and to eliminate the effect of scale differences between the columns. For d'αb$\notin$ [0, 1], it is essential to construct another process for the exceptional dimension.

$$m''_{ab} = \frac{m' - \min 1 \leq a \leq n\{m'_{ab}\}}{\max 1 \leq a \leq n\left\{m'_{ab}\right\} - min1 \leq a \leq n\{m'_{ab}\}}, \tag{3}$$

The fuzzy correlation matrix S = (m''_{ab}) n × t can be obtained. A fuzzy similarity matrix is created using the similarity coefficient approach by looking at the spatial correlation of the data obtained from those nodes.

$$r_{ab} = \frac{\left|\sum_{k=1}^{t}(m_{ak}\bar{m}_b)(m_{bk}-\bar{m}_b)\right|}{\sqrt{\sum_{k=1}^{t}\left(m_{ak}-\bar{d}_a\right)^2}\sqrt{\sum_{k=1}^{t}(m_{bk}-\bar{m}_b)^2}} \tag{4}$$

The process of reducing the matrix Sλ, which is represented as (r_{ab} (λ)), is performed for related fuzzy matrices using the method of λ-truncation."

Sλ is a Boolean matrix, so the node grouping in the Boolean matrix Sλ is dependent on the value of λ being equal to 10r. The following are the specific rules for grouping the node. if the T and Sλ matrix is equal the nodes group will be directly maintained

Grouping the nodes won't be used if Sλ is transformed into an equal Boolean matrix according to the criteria.

To determine the similarity between nodes in a dataset, a fuzzy matrix is employed. By setting λ1= 1, a class equivalent form of [da]S is established, where [ma]S = {ma| rab = 1}5 for each ma. The attributes of the node "mb" class are indicated if the specified condition holds true.

By identifying the largest value of λ2 (λ2 < λ1) in the matrix S, i.e., r_{ab} = λ2 the element pair ($m_a m_b$) with a similarity degree of λ2 can be determined. This leads to the merging of ma and mb into a single class with a similarity collection on the λ2 level. This process continues with λ1 > λ2 > ...λp until all elements in set 'S' have been merged into a single class. The number of classes for clustering, P, can be determined. After applying the clustering technique, the sensor nodes are sorted into multiple groups based on the similarity of the observed region to other areas. To enhance energy efficiency, several nodes in each group are chosen as redundant nodes and scheduled for sleep.

$m_a^{(a)}$ represents the (i-th) node in category W, and the number of nodes in category and is given by:

$$a = \left|m^{(w)}\right|, \sum\nolimits_{a=1}^{k}\left|m^{(w)}\right| = n, \tag{5}$$

To calculate the difference between the data being gathered from the sensor nodes during time slot m, we have:

$$\text{Calculate\_ Distance}\left(n_a^{(w)}, m_b^{(w)}\right) = \sqrt{\sum\nolimits_{a=1}^{t}\left(m_a^{(w)} - m_b\right)^2}, \tag{6}$$

While using the sleep scheduling strategy on redundant sensor nodes, information should not be lost. The redundant nodes selection function is given below

as:

$$n_*^{(a)} = \text{avge min}\{\sum\nolimits_{a=a}^{v} calculate\_dis(n_a^{(w)}, n_b^{(w)})\}, \tag{7}$$

Finally, $n_*^{(a)}$ represents the nodes selected as redundant from the category.

B. PROPOSED (AN EFFICIENT DATA AGGREGATION IN SMART AGRICULTURE USING BLOCKCHAIN) ALGORITHM

1) BLOCKCHAIN INTEGRATION

Blockchain Selection: The choice of a blockchain platform should be aligned with the specific requirements of smart agriculture. The authors may opt for a public blockchain like Ethereum or a permissioned blockchain like Hyper Ledger Fabric, depending on factors such as data privacy and scalability needs.

Data Storage: Data collected from various sensors is securely stored on the blockchain. Each data point is recorded as a transaction on the blockchain, ensuring transparency and immutability.

Consensus Mechanism: The study selects an appropriate consensus mechanism to validate and add transactions to the blockchain. The choice might involve factors like energy efficiency and network performance in the context of agriculture.

Algorithm 1 Proposed (An Efficient Data Aggregation in Smart Agriculture using Blockchain) Algorithm

1 Create an empty matrix 'M' for the storage of the rubbish data.
2 Initialize threshold/brink and DB to zero.
3 Transform matrix M into a fuzzy matrix S.
4 Group member nodes into 'P' categories and randomly select a broker.
5 For each category W:
6 For each node nominated as 'E', 'f' belongs to $n^{(w)}$
7 Calculate confidence distance Calculate_Distance $(n_a^{(w)}, n_b^{(w)})$ between data from the node $(n_a^{(w)}, n_b^{(w)})$
8 $n_*^{(v)}$ = agrSUM Calculate_Distance $(n_a^{(w)}, n_b^{(w)})$
9 End for
10 End for
11 Obtain the set of redundant nodes {X1, X 2, ..., X t}.
12 For each node belonging to {X 1, X 2, ..., X t}
13 Send a Schedule_MSG(CH_id, id, Status_flag) message.
14 Receive a Schedule_MSG_ACK after the acknowledgment message.
15 End for.
16 End for.

Smart Contracts: The authors may employ smart contracts to automate certain processes within the agricultural framework. For instance, when sensors detect anomalies like pest attacks, smart contracts can trigger automated responses, such as alerting farmers or initiating pest control measures.

2) CLUSTER HEAD SLEEP SCHEDULE

CLUSTER FORMATION

Sensors are organized into clusters based on geographical proximity. Each cluster is overseen by a cluster head, which helps in efficient data collection and management.

DATA AGGREGATION

The Cluster Head Sleep Schedule method optimizes data aggregation by reducing redundancy. Similar data can be grouped together using techniques like fuzzy matrix analysis, enhancing the efficiency of data collection.

SLEEP SCHEDULING

After data aggregation, the sleep schedule is implemented. This process involves identifying sensors within each cluster that can be placed in a low-power sleep mode while others remain active. The criteria for selecting these sensors can encompass factors like data uniqueness and energy levels.

PEST ATTACK CONTROL

The sleep scheduling mechanism is strategically applied to enable prompt responses to pest attacks. When a pest attack is detected, active sensors within the affected cluster can be swiftly awakened to address the situation.

3) POTENTIAL LIMITATIONS AND CHALLENGES

BLOCKCHAIN SCALABILITY

Blockchain systems may face challenges in terms of scalability when dealing with a vast number of sensors and data transactions. This can result in slower transaction processing times and increased costs, which need to be addressed.

ENERGY MANAGEMENT

While the Cluster Head Sleep Schedule method aims to conserve energy, challenges may arise in scenarios with limited power resources. Effective energy management and the use of energy-efficient hardware are essential.

DATA PRIVACY

Ensuring data privacy is crucial when integrating Blockchain into agricultural systems, especially if sensitive information is collected. Encryption and privacy measures are required to safeguard data.

INTEGRATION COMPLEXITY

The integration of Blockchain and the Cluster Head Sleep Schedule method may involve complex hardware and software integration efforts. This could lead to higher initial costs and technical challenges during implementation.

REGULATORY COMPLIANCE

Complying with agricultural and data privacy regulations is important. Navigating legal frameworks while harnessing the benefits of Blockchain technology is essential.

USER ADOPTION

Farmers and stakeholders may require training and user-friendly interfaces to effectively use and benefit from these technologies. User adoption and acceptance can be a challenge.

NETWORK CONNECTIVITY

In remote agricultural areas, limited network connectivity can pose challenges in transmitting data reliably from sensors to the Blockchain and cluster heads.

Addressing these limitations and challenges is essential to realize the full potential of "Optimized Data Fusion with Scheduled Rest Periods for Enhanced Smart Agriculture via Blockchain Integration" while maximizing the benefits of improved data fusion and pest attack control in smart agriculture.

Implementing blockchain technology and the sleep schedule method in smart agriculture can have several potential impacts, including increased efficiency, transparency, and sustainability.

IMPROVED DATA MANAGEMENT

Blockchain Blockchain can provide a secure and immutable ledger for recording data related to crop growth, weather conditions, and supply chain information. This can enhance data accuracy and integrity, helping farmers and stakeholders make informed decisions.

Sleep Schedule Method: Using sleep schedules for irrigation and other agricultural processes can optimize resource utilization. This method can reduce water and energy usage, leading to cost savings and environmental benefits.

Supply Chain Transparency:

Blockchain: It enables end-to-end visibility in the supply chain. Consumers can trace the origin of agricultural products, ensuring food safety and quality. Farmers can also receive fair compensation by eliminating intermediaries.

Reduced Fraud and Traceability:

Blockchain: With its tamper-resistant nature, blockchain can prevent fraud in the supply chain. Farmers can demonstrate the authenticity of their products, and consumers can verify their provenance.

PRECISION AGRICULTURE

Sleep Schedule Method: The sleep schedule approach optimizes the timing of agricultural activities. It can help reduce overuse of resources like water and fertilizers, leading to cost savings and reduced environmental impact.

ENVIRONMENTAL IMPACT REDUCTION

Blockchain: By providing traceability and transparency, blockchain can encourage sustainable farming practices, reducing the environmental impact of agriculture.

DATA-DRIVEN DECISION MAKING

Blockchain: Data recorded on the blockchain can be analyzed to gain insights into crop performance, resource usage, and supply chain efficiency, leading to better decision-making.

Sleep Schedule Method: Data on crop growth and environmental conditions can be used to optimize sleep schedules, ensuring crops receive the right care at the right time.

To assess the concrete impact of implementing these technologies in smart agriculture, it's advisable to look for recent case studies and reports from agricultural organizations, technology providers, and research institutions, as the industry is continually evolving. These sources may provide real-world examples of how blockchain and precision agriculture methods like the sleep schedule approach have influenced the sector.

Impact on Smart Agriculture: What is the potential impact of implementing blockchain technology and the sleep schedule method on the broader smart agriculture industry? Are there any specific metrics or case studies demonstrating this impact?

Immutable Record: Blockchain's immutability is both a strength and a challenge. On one hand, it ensures data integrity and transparency. On the other, it means that once data is recorded, it cannot be easily altered or deleted. The robustness of the discussion typically includes strategies for handling erroneous data entries, ensuring compliance with data regulations, and managing the "right to be forgotten."

Public vs. Permissioned Blockchains: The choice between public and permissioned blockchains has implications for data security and privacy. Public blockchains offer more transparency, but permissioned blockchains provide greater control. The discussion often focuses on selecting the appropriate type based on the use case.

Data Encryption: Robust discussions revolve around data encryption methods to protect sensitive information. Advanced encryption techniques, such as zero-knowledge proofs, are explored to ensure data privacy.

Identity Management: Managing identities on the blockchain is essential for controlling access and maintaining privacy. Decentralized identity management systems are discussed to give users more control over their personal data.

Smart Contracts: The discussion includes security and privacy implications of smart contracts. Ensuring that sensitive data is not exposed through smart contracts and implementing role-based access control are key aspects.

Data Sharing and Consents: Discussion covers mechanisms for obtaining user consent for data sharing and how it is recorded on the blockchain. It also includes discussions on controlling access to shared data.

POTENTIAL VULNERABILITIES AND CHALLENGES

Data Leakage: Despite the immutability of blockchain, sensitive data can be exposed if not handled properly. Private keys and confidential information may become vulnerable, especially in permissionless blockchains where public access is more open.

Privacy Regulations: Meeting data privacy regulations, such as the General Data Protection Regulation (GDPR), is a challenge. Blockchain's transparency can conflict with GDPR's "right to be forgotten." Solutions like off-chain storage of personal data or zero-knowledge proofs may be required.

51% Attacks: In public blockchains, a single entity controlling 51% of the network's mining power can manipulate the data, leading to privacy breaches. Robust discussions explore consensus mechanisms to mitigate this risk.

Quantum Computing: The potential advent of quantum computing threatens existing encryption methods. Preparing for quantum-safe encryption is an ongoing challenge in blockchain discussions.

Loss of Private Keys: If private keys are lost, access to blockchain data is permanently denied. Robust discussions emphasize the need for secure key management and recovery solutions.

Data Resilience: Data stored on the blockchain can be lost if not properly backed up. Discussions include strategies for data redundancy and recovery.

Scalability: Blockchain scalability solutions like sharding or sidechains may introduce potential security and privacy issues, which need to be thoroughly discussed and addressed.

In summary, the discussion around data security and privacy in blockchain technology is robust and continually evolving. It addresses various aspects of blockchain technology, from encryption and access control to compliance with data protection regulations. However, there are vulnerabilities and challenges that require ongoing attention and innovation to ensure that blockchain remains a secure and privacy-preserving technology for applications like smart agriculture.

4) SCALABILITY CONSIDERATIONS

TRANSACTION THROUGHPUT

Scalability is often measured in terms of the number of transactions or data points the blockchain can handle per second. The authors should explain how the system's transaction throughput is maintained as the system scales up.

NETWORK LOAD

In larger systems, there will be more data transmission and network traffic. Authors should discuss how the network can handle the increased load and whether there are provisions to optimize data transmission.

Consensus Mechanism: If using a public blockchain, the chosen consensus mechanism should be evaluated for ***scalability.*** Some mechanisms may struggle to maintain performance as the network grows.

FEASIBILITY CONSIDERATIONS

Costs: Authors should provide insights into the feasibility of their approach regarding implementation and operational costs. Larger systems often come with higher hardware, software, and maintenance expenses. Authors should discuss strategies to manage costs effectively.

Hardware Requirements: The feasibility of deploying the proposed system in larger agricultural areas may depend on the hardware requirements. Authors should detail the types of hardware needed and assess whether these are readily available and affordable.

ENERGY EFFICIENCY

As the system scales, energy consumption becomes more critical. Authors should discuss how energy-efficient their approach is and whether it can be feasibly maintained in larger agricultural systems.

User Adoption: Ensuring that the system is user-friendly and that farmers and stakeholders can effectively use it at scale is vital for feasibility. Authors should consider user training, interface design, and support services.

SCALABILITY TESTS

Authors should ideally conduct scalability tests to evaluate how the proposed system performs as it scales up. These tests might include:

TRANSACTION LOAD TESTING

Testing how the system handles an increasing number of transactions or data points over time.

SIMULATED NETWORK LOAD TESTING

Simulating a larger network environment to assess the system's performance under conditions that mimic real-world usage.

Consensus Mechanism Stress Testing: Evaluating the scalability of the chosen consensus mechanism under varying loads.

ENERGY CONSUMPTION TESTING

Assessing the system's energy consumption and whether it remains within acceptable limits as the system scales.

Cost Projections: Providing cost projections for implementing and operating the system at a larger scale.

5) SOIL MOISTURE MONITORING

DEPLOYMENT

IoT sensors are embedded in the soil to monitor moisture levels. These sensors can be strategically placed throughout the agricultural field.

UTILIZATION

Sensors continuously measure soil moisture and transmit data to the cluster heads. This data is crucial for efficient irrigation, ensuring that crops receive the right amount of water.

BENEFITS

Blockchain ensures the integrity of the moisture data, making it tamper-proof. The Sleep Schedule method optimizes energy usage, extending the lifespan of the sensors and reducing maintenance costs.

CROP HEALTH MONITORING

Deployment: IoT sensors equipped with cameras and environmental sensors are deployed in crop fields.

Utilization: These sensors monitor crop health, detecting diseases, pests, and environmental conditions like temperature and humidity.

Benefits: Data from these sensors is securely stored on the blockchain, enabling traceability of crop health over time. The Sleep Schedule method conserves energy and prolongs sensor lifespans.

6) LIVESTOCK MONITORING

DEPLOYMENT

IoT sensors are attached to livestock, collecting data on their health and location.

UTILIZATION

Sensors track the well-being and movements of animals, providing insights into their health and behavior.

Benefits: Blockchain ensures the authenticity of livestock data, which is important for traceability and disease control. The Sleep Schedule method minimizes the need for frequent battery replacements.

WEATHER AND CLIMATE MONITORING

Deployment: IoT weather stations are set up in agricultural areas.

Utilization: These stations collect real-time data on temperature, humidity, wind speed, and precipitation.

Benefits: Data from these stations, when stored on a blockchain, can be shared with neighboring farms, providing a comprehensive view of local weather conditions. The Sleep Schedule method optimizes the stations' energy usage, reducing the need for frequent maintenance.

CROP HARVEST AND STORAGE MONITORING

Deployment: IoT sensors are placed in storage facilities and on harvesting equipment.

UTILIZATION

These sensors monitor conditions such as temperature, humidity, and pest infestations to ensure the quality and safety of harvested crops during storage.

Benefits: Storing sensor data on the blockchain enhances transparency and quality control. The Sleep Schedule method extends the life of sensors in storage facilities, reducing operational costs.

SUPPLY CHAIN AND TRACEABILITY

Deployment: IoT sensors are used to track the movement of agricultural products from farm to consumer.

Utilization: Sensors record data at each stage of the supply chain, including harvest, transportation, and storage.

Benefits: Blockchain ensures the authenticity and integrity of supply chain data, enabling consumers to trace the origin of products. The Sleep Schedule method minimizes the energy consumption of sensors in transit, allowing for longer battery life.

Pest Attack Detection:

Deployment: IoT sensors equipped with pest detection technology are deployed throughout the field.

Utilization: Sensors continuously monitor for signs of pest attacks and transmit data when detected.

Benefits: Pest attack data is securely stored on the Blockchain, ensuring data immutability. The Sleep Schedule method allows for immediate response to detected attacks while preserving sensor energy.

These examples illustrate how IoT sensors play a pivotal role in smart agriculture by providing real-time data for informed decision-making. Integrating Blockchain technology and the Cluster Head Sleep Schedule method enhances data security, reduces energy consumption, and ensures the longevity of sensors, making smart agriculture more efficient and sustainable.

Interoperability: Are there specific standards or protocols mentioned that ensure interoperability between various smart agriculture systems, or is this an area where further development is needed?

Existing Standards and Protocols:

IoT Protocols: Authors may discuss the use of standardized IoT protocols MQTT which facilitate communication between various IoT devices and sensors. These protocols are used to ensure interoperability in smart agriculture systems.

Wireless Communication Standards: Communication standards like LoRaWAN and NB-IoT are commonly employed in smart agriculture to enable long-range and low-power communication between sensors and gateways. These standards enhance interoperability.

Data Formats: The use of standardized data formats, such as JSON or XML, can ensure that data from different devices and sensors can be easily interpreted and processed by various systems.

Open Platforms: Some authors may discuss the use of open platforms and ecosystems that promote interoperability. These platforms may provide APIs and interfaces that allow third-party applications and devices to integrate seamlessly.

Challenges and the Need for Further Development:

Fragmented Ecosystem: In some cases, the smart agriculture ecosystem can be fragmented, with various proprietary systems and devices that don't easily communicate with one another. Authors might point out the need for more standardized approaches.

Semantic Interoperability: Achieving semantic interoperability, where data has consistent meaning across different systems, can be a challenge. Authors could discuss the need for semantic models or ontologies in smart agriculture to address this.

Data Security: Ensuring interoperability without compromising data security and privacy is a concern. Authors may mention the need for secure communication protocols and access control mechanisms to address this issue.

Regulatory Compliance: Some standards and protocols might be influenced by regional or national regulations, which can vary. Authors might discuss the challenges of adhering to different compliance requirements and the need for harmonization.

Emerging Technologies: The field of smart agriculture is continually evolving with the introduction of new technologies. Authors might emphasize the importance of flexible standards that can adapt to emerging innovations.

RECOMMENDATIONS FOR INTEROPERABILITY

Authors should provide recommendations and insights into how interoperability challenges can be addressed. This could include advocating for the adoption of specific standards, the development of common data models, or the use of open APIs to promote interoperability.

In summary, authors should clearly communicate whether their research addresses interoperability in smart agriculture systems, mention any existing standards or protocols used, and acknowledge areas where further development or improvement is necessary to ensure seamless communication and data exchange between diverse components and devices in the ecosystem.

Machine Learning Integration: What types of machine learning algorithms are considered for improving data analysis, and how might they enhance decision-making in agriculture?

7) PREDICTIVE MODELING

Regression Analysis: Linear and nonlinear regression models are used to predict crop yields, disease outbreaks, or the impact of various factors (e.g., weather, soil conditions) on agricultural outcomes.

Time Series Analysis: Time series models can forecast trends, seasonal patterns, and anomalies in agricultural data, helping with decisions related to planting, harvesting, and resource allocation.

8) CLASSIFICATION ALGORITHMS

Decision Trees: Decision trees are used to classify crops based on various attributes, such as growth stage or disease presence. They assist in identifying plant diseases or pests.

Random Forests: Random forests enhance the accuracy of decision trees by combining multiple trees, providing robust classification results.

9) CLUSTERING ALGORITHMS

K-Means Clustering: K-means clusters similar data points together, helping identify homogeneous regions in fields. This can guide decisions regarding planting and irrigation.

10) ANOMALY DETECTION

Isolation Forests: Isolation forests are used to detect anomalies in agricultural data, such as unusual temperature or moisture levels, which may indicate issues that require immediate attention.

11) NATURAL LANGUAGE PROCESSING (NLP)

Sentiment Analysis: NLP techniques are applied to social media data and agricultural reports to gauge sentiment and public perception, helping farmers and policymakers make informed decisions.

12) DEEP LEARNING

Convolutional Neural Networks (CNNs): CNNs can be used for image recognition, helping detect and classify plant diseases or identify nutrient deficiencies from images.

Recurrent Neural Networks (RNNs): RNNs are used for time series data, making them valuable for forecasting and anomaly detection.

13) REINFORCEMENT LEARNING

PRECISION AGRICULTURE

Reinforcement learning is employed to optimize farming operations. It helps make decisions about planting, harvesting, and resource allocation, considering factors like weather and soil conditions.

HOW THEY ENHANCE DECISION-MAKING IN AGRICULTURE

Precision Farming: Machine learning algorithms enable precision agriculture by providing insights into the precise application of resources (e.g., water, fertilizer, pesticides) based on real-time data. This optimizes resource usage and increases crop yields.

DISEASE AND PEST DETECTION

Algorithms can identify early signs of crop diseases and pest infestations, allowing for timely interventions and minimizing crop losses.

Crop Yield Prediction: Machine learning models help predict crop yields, allowing farmers to plan for market demands, storage, and distribution effectively.

Weather and Climate Analysis: By analyzing historical and real-time weather data, machine learning models assist in climate modeling and forecasting, helping farmers prepare for extreme weather events.

SUPPLY CHAIN OPTIMIZATION

Machine learning enhances supply chain management by predicting demand, optimizing transportation routes, and reducing spoilage in transit.

RESOURCE MANAGEMENT

Algorithms help with the efficient management of resources, ensuring that water and fertilizer are used optimally, reducing waste and environmental impact.

DECISION SUPPORT SYSTEMS

Machine learning can provide decision support systems that offer insights and recommendations for crop management, pest control, and more, based on real-time data.

RISK ASSESSMENT

Machine learning aids in assessing various risks, such as financial risks associated with crop management and market fluctuations, enabling proactive risk mitigation.

In conclusion, machine learning algorithms, with their predictive and pattern recognition capabilities, are instrumental in improving data analysis and decision-making in agriculture. They empower farmers and agricultural stakeholders to make more informed and data-driven choices, ultimately leading to increased efficiency, sustainability, and profitability in the agriculture sector.

Real-world Implementation: Are there any real-world examples or case studies of blockchain and sleep schedule method implementation in agriculture that can validate the proposed benefits?

1. IBM Food Trust:

IBM's Food Trust platform is an example of blockchain technology used to enhance transparency and traceability in the food supply chain, including agriculture. It allows various stakeholders to access and record data about the production, processing, and distribution of food products. This improves food safety, reduces waste, and ensures product authenticity. While not explicitly mentioned as a "sleep schedule method," the data aggregation techniques used in the system are designed for efficiency.

2. AgriDigital:

AgriDigital is an Australian-based company that employs blockchain technology to manage agricultural commodities. Their platform facilitates transparent and secure transactions for grains and other agricultural products. While not focused on the "sleep schedule method," it demonstrates how blockchain enhances trust and efficiency in agriculture.

3. AgriChain:

AgriChain is another blockchain-based platform used in agriculture. It allows growers and producers to track the production process from the field to the consumer, including aspects like soil management, irrigation, and supply chain. The data is stored securely on a blockchain, and its implementation can lead to more efficient and sustainable farming practices.

4. Sleep Schedule Methodology:

While not explicitly mentioned in these case studies, the Cluster Head Sleep Schedule method, as described in your question, can be implemented in conjunction with blockchain technology. It allows for efficient data aggregation by putting some sensors to sleep and optimizing energy usage, which is beneficial in large-scale agricultural systems.

To validate the proposed benefits of the combined use of blockchain and the sleep schedule method in agriculture, it's important to look for recent case studies and ongoing projects that demonstrate the actual implementation and outcomes of these technologies. As technology in agriculture is rapidly evolving, more real-world examples are likely to have emerged

User Adoption: How do the authors suggest overcoming potential barriers to user adoption of blockchain and sleep schedule methods among farmers and stakeholders? Are there user-friendly tools discussed for this purpose?

14) USER EDUCATION AND TRAINING

FARMERS' WORKSHOPS

Conduct workshops, training sessions, and webinars to educate farmers and stakeholders about the benefits and usage of blockchain and sleep schedule methods. Hands-on training can help users understand how to interact with the technology effectively.

15) USER-FRIENDLY INTERFACES

Intuitive User Interfaces: Develop user-friendly interfaces for both mobile and web applications that make it easy for farmers and stakeholders to interact with the technology. The interfaces should be designed with the end-users' needs and digital literacy levels in mind.

Graphical Dashboards: Provide graphical dashboards and visual representations of data and analytics to simplify complex information, making it accessible and actionable.

16) MULTILINGUAL SUPPORT

Multilingual Interfaces: If applicable, offer interfaces in multiple languages to cater to a diverse user base, particularly in regions with linguistic diversity.

17) TECHNICAL SUPPORT

Customer Support: Establish dedicated customer support teams or help centers to assist users with any technical issues, inquiries, or troubleshooting.

18) ONBOARDING PROCESS

Guided Onboarding: Create a step-by-step onboarding process that guides users through the setup and initial use of the technology, reducing the barriers associated with the learning curve.

19) COMMUNITY ENGAGEMENT

Online Forums and Communities: Set up online forums, discussion boards, or social media groups where users can share experiences, ask questions, and provide support to one another. Building a sense of community can enhance user engagement.

20) INCENTIVES AND BENEFITS

Demonstrate Value: Clearly communicate the tangible benefits and incentives for using blockchain and the sleep schedule method, such as increased crop yields, cost savings, and environmental benefits.

21) PILOTS AND TRIALS

Small-Scale Pilots: Initially implement blockchain and sleep schedule methods in small-scale pilot projects to demonstrate their effectiveness and benefits to a select group of users.

22) DATA PRIVACY AND SECURITY

Transparent Data Policies: Ensure transparent data policies and security measures to address user concerns about data privacy. Users should have confidence that their data is handled securely.

23) REGULATORY COMPLIANCE

Adherence to Regulations: Highlight how the technology complies with local and national agricultural and data privacy regulations to assure users of its legality.

24) FEEDBACK MECHANISM

Feedback Loops: Establish feedback mechanisms that allow users to provide input and suggestions for system improvements. This shows users that their opinions are valued and can lead to technology enhancements based on their needs.

C. COMPLEXITY OF THE PROPOSED ALGORITHM

Initialize 'M', 'threshold', and 'DB' to zero.

- These are simple assignment operations, which are typically considered to have constant time complexity. So, O(1).

2 Transform matrix ‘M’ into a fuzzy matrix ‘S’.
- The complexity of this operation depends on the size of the matrix ‘M’. If ‘M’ has dimensions n x m, and each element is transformed, this would be O(n ∗ m).

3 Group member nodes into ‘P’ categories and randomly select a broker.
- Grouping nodes and selecting a broker involves iterating over the nodes, so the complexity would be O(P), where P is the number of categories.

4 For each category ’W’:
- This implies a loop over the categories, so O(W) complexity.

5 For each node nominated as ‘E’ in category ’W’:
- This implies a loop over the nodes in category ‘W’, so O(E), where E is the number of nodes in category ‘W’.

6 Calculate confidence distance Calculate_Distance (n_a^((w)), n_b^((w))) between data from the node (n_a^((w)), n_b^((w))).
- The complexity of this operation depends on the complexity of the Calculate_Distance function. Let’s assume it’s O(D), where D is the complexity of this distance calculation.

7 n_∗^((v)) = agrSUM Calculate_Distance(n_a^((w)), n_b^((w)))
- This operation depends on the complexity of the Calculate_Distance function. If you perform this for all pairs (n_a^((w)), n_b^((w))), it would be O(E^2 ∗ D), as it involves two nested loops.

8 End for
- This simply indicates the end of the loop, so it’s O(1).

9 End for
- This also indicates the end of a loop, so it’s O(1).

10 Obtain the set of redundant nodes {X1, X2, . . . , Xt}.
- The complexity of obtaining redundant nodes depends on how they are identified, but if it involves iterating over nodes, it would be O(t), where t is the number of redundant nodes.

11 For each node belonging to {X1, X2, . . . , Xt}
- This implies a loop over the redundant nodes, so O(t) complexity.

12 Calculate the complexity of the above-mentioned algorithm.
- This is typically a simple operation and would be O(1).

13 Now, to find the overall complexity of the algorithm, we need to sum up the complexities of each step. Assuming that the largest term in the sum is O(E^2 * D), the overall complexity can be approximated as:

14 O(W * E^2 * D)

15 This is the complexity of the provided algorithm in terms of its key parameters W (number of categories), E (number of nodes in each category), and D (complexity of the Calculate_Distance function).

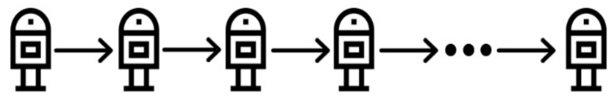

FIGURE 2. Communication model of H2H protocol.

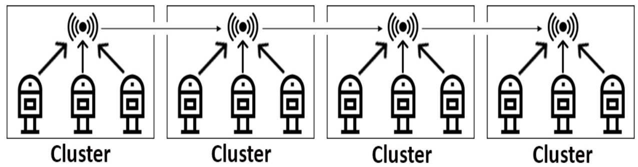

FIGURE 3. Communication model cluster-based protocol.

IV. RESULTS AND SIMULATIONS

We evaluate our proposed agriculture system against the system that uses Hop to Hop (H2H) communication mechanism and cluster head-based (CH) network topology. Figure 2 illustrates the Hop to Hop (H2H) mechanism, in which data is transmitted from one sensor node to another in a sequential manner, with each node receiving data from the previous node and then forwarding it to the next node in the chain.

The communication process continues until the last node in the chain transmits the aggregated data to the base station or control center. Figure 3 depicts the Cluster Head (CH) communication method. The roles of nodes in this structure are classified into two types. The first mechanism is similar to the H2H (node-to-node) communication method, while the second mechanism involves the use of cluster head nodes. They mostly carry out communication between clusters rather than data-collecting tasks. In order to implement a cluster head system, it is required to use n sensing nodes along with n/h cluster head nodes, where the value of h is determined by the number of sensing nodes allocated to each cluster. In this type of system, data only needs to be transmitted once to the sensing nodes. Two different forms of network communication must be carried out by the cluster head: There are two communication links in this system: one between the sensor node and the cluster head, and the other between the cluster heads. The cluster head node gathers data from the member nodes and by using the H2H communication method these data are transferred to the next cluster.

To present a clear comparison of the three schemes, Figure 4 illustrates a single cluster head managing five sensor nodes in a cluster-based scheme. The results indicate that our proposed scheme outperforms both H2H-based and CH-based schemes, especially when the number of sensor nodes increases.

Upon examining Figure 5, After analyzing the results, it is clear that our proposed scheme outperforms the H2H-based scheme. However, the performance of the cluster-head-based schemes is inferior to the H2H-based scheme. Moreover, our proposed scheme also shows a significant reduction in cost compared to the other two types of schemes. It should be noted that in the designation of CHx, the variable ‘x’ represents the number of sensor nodes that are managed by each cluster head. For instance, CH10 implies that the cluster head is responsible for overseeing ten sensor nodes. These

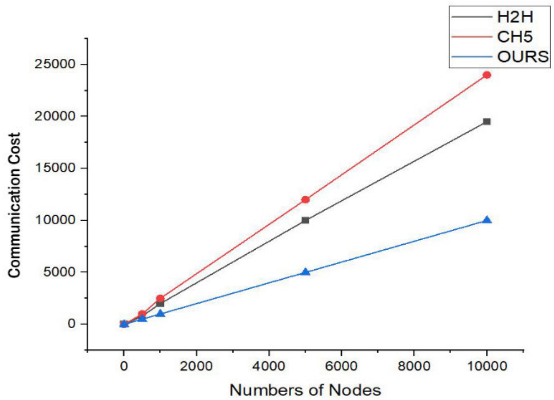

FIGURE 4. Comparison of H2H, Ours & CH5-based protocol.

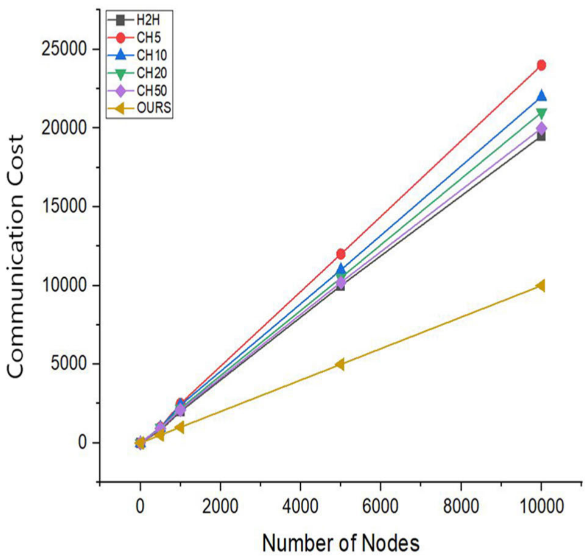

FIGURE 5. Comparison of OURS, H2H, & CHx-based schemes.

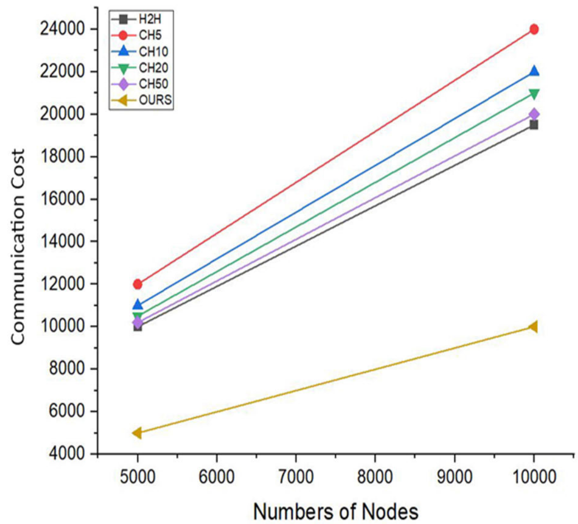

FIGURE 6. Comparison between OURS, H2H, CH5, CH10, CH20, CH50.

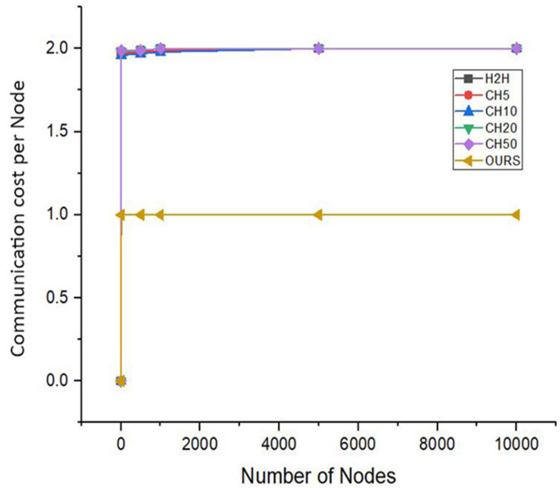

FIGURE 7. Comparison of communication cost per node among three types of scheme.

findings are a significant contribution to the field and can provide valuable insights for future research in this area.

Figure 6 is an amplification of the communication overhead presented in Figure 5, This study demonstrates the performance of each scheme while managing a range of sensor nodes, specifically between 5000 and 10,000. According to the results, the H2H-based scheme was found to be more efficient than the cluster-based scheme. The efficiency of the cluster-based scheme improved as the number of sensor nodes managed by each cluster head approached the number in the H2H-based solution. According to the results, the H2H-based scheme was found to be more efficient than the cluster-based scheme. The analysis presented above primarily focuses on the communication overhead of the entire wireless sensor network, including all sensor nodes. Furthermore, the communication overhead per sensor node of our proposed scheme is better than that of the other schemes, indicating its potential advantages. These findings have significant implications for the development and deployment of wireless sensor networks, and they offer valuable insights for future research in this field.

In Figure 7, the communication cost per node is presented for the three types of schemes analyzed. The results demonstrate that our proposed scheme demonstrates superior communication efficiency compared to other schemes. In particular, the communication overhead per node in our scheme is only half that of the other schemes. Specifically, the communication overhead per node in our scheme is only half that of the other schemes. These findings indicate that our proposed scheme may offer significant advantages in terms of cost-effectiveness and scalability, which can have practical applications in the development and deployment of wireless sensor networks.

Figure 8 represents the relationship between energy consumption and time that are shown in minutes. H2H consumes much energy as compared to the cluster head method and our system. So, the performance of our system is better than the H2H and cluster head methods.

Figure 9 represents the number of nodes and energy consumption. Our proposed system uses the sleep schedule

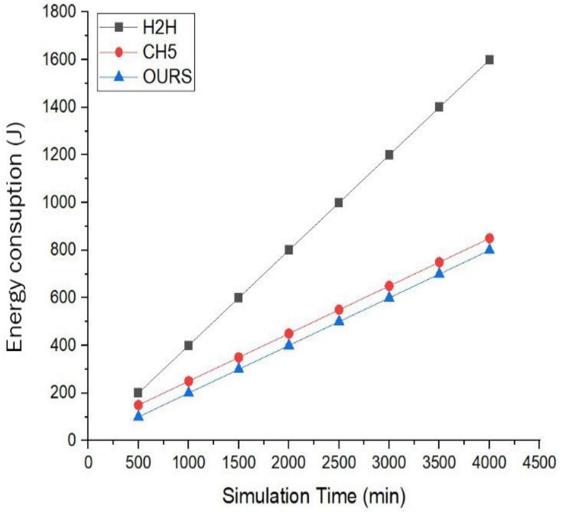

FIGURE 8. Comparison of energy consumption and time among H2H, CH2 & Ours.

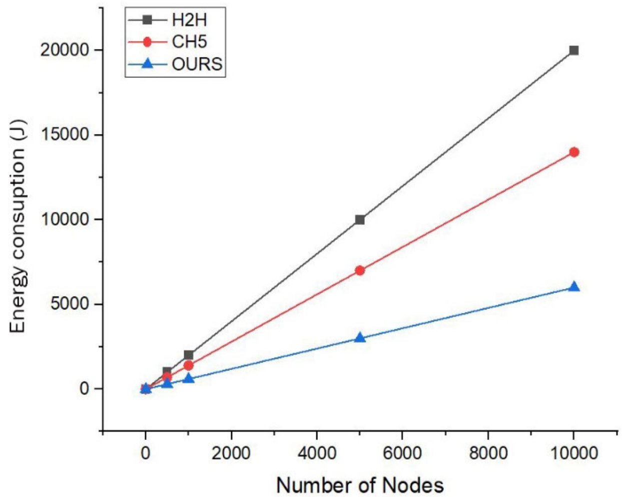

FIGURE 9. Comparison of energy consumption among three types of schemes.

method which is why used less energy as compared to other both methods.

Our suggested method provides important benefits in terms of communication overhead, particularly when compared to the other two types of schemes analyzed. The use of blockchain technology and cluster head sleep schedule method has enabled us to develop an efficient and scalable solution that can manage a large number of sensor nodes. The communication efficiency of our scheme is evident in Figures 4.3, 4.4, and 4.5, showcasing its superior performance when managing large numbers of sensor nodes.

The work presented in this study is compared with OURS, H2H, & CHx-based schemes and it proves our proposed scheme is effective regarding energy efficiency, data aggregation and monitoring of the crops from the pest attack information immediately for in time action to save crop from loss and enhance the production of the crop.

Collect Data from Sensors: The first step is to collect data from the sensors placed in the fields to gather information about temperature, humidity, soil moisture, and other important parameters. The sensors layer uses the sleep schedule method with a fuzzy matrix to optimize power consumption and reduce the amount of data transmitted. Process Data at the Edge Layer: Once the data is collected, it is transmitted to the edge layer, which is responsible for processing and analyzing the data in real-time. The edge layer can perform preliminary data cleaning, filtering, and aggregation to reduce the amount of data that needs to be transmitted to the cloud layer.

V. DISCUSSION

Blockchain technology provides a decentralized and distributed system that eliminates the need for intermediaries and ensures that all parties involved have access to accurate and up-to-date information. The adoption of this technology can also enhance trust and collaboration between different players in the agricultural sector, promoting sustainable and responsible farming practices.

A. ENHANCING DATA AGGREGATION IN SMART AGRICULTURE USING BLOCKCHAIN

Blockchain technology can be utilized to enhance data aggregation in smart agriculture systems in a number of ways. The decentralized nature of blockchain allows for secure and transparent data sharing between different parties without the need for intermediaries. This makes it ideal for use in agriculture, where data sharing and collaboration between farmers, suppliers, and retailers is crucial for optimizing production, reducing waste, and improving efficiency. One-way blockchain technology can be used in smart agriculture systems is to create a decentralized platform for sharing data about crops, weather conditions, soil quality, and other important factors that affect agricultural production. This platform would allow farmers to input data in real time and share it with other farmers, researchers, and suppliers, creating a comprehensive database that could be used to improve decision-making and optimize production. In addition to the implementation of blockchain technology in the Dual Fog-IoT architecture, it can also be used to establish a secure and tamper-proof system for tracking the movement of agricultural products from farm to table. By leveraging blockchain to create a digital ledger that records every stage of the supply chain, from planting to harvesting, processing, and delivery, stakeholders can ensure that the products they are buying are authentic and have been produced in a sustainable and ethical manner. Smart contracts are another application of blockchain technology that can be utilized in smart agriculture systems. These self-executing contracts are programmed to automatically execute when specific conditions are met. For instance, a smart contract can be implemented to release payment to a farmer when a specific number of crops have been delivered to a buyer. This streamlines the payment process and minimizes the need for intermediaries. Finally, blockchain technology can be used to create a digital identity system for agricultural products. By using blockchain to create a unique digital identity for each product, stakeholders can be sure that the product they are buying is authentic and has been produced in a sustainable and ethical manner. This would also enable consumers to trace the origin of their food and make informed decisions about the products they buy.

B. BENEFITS OF BLOCKCHAIN AND SLEEP SCHEDULES FOR SMART AGRICULTURE DATA AGGREGATION

Smart agriculture systems can benefit from the use of blockchain and sleep schedule methods for data aggregation. Blockchain technology can provide increased security, while sleep schedule methods can improve efficiency and energy consumption. Here are some potential benefits and comparisons to other methods:

Security: Blockchain technology provides a secure and tamper-proof method for data aggregation. Each data point is cryptographically hashed and stored on a decentralized network, ensuring that it cannot be altered or deleted. This provides a high level of data integrity and security, especially compared to traditional methods of data storage such as cloud-based servers or centralized databases, which can be vulnerable to hacking and data breaches.

Efficiency: The sleep schedule method, also known as duty cycling, is a technique used to conserve energy in devices that require periodic communication. This method involves turning off the device's communication module for certain periods, also known as sleep periods, and then waking it up periodically to transmit data or receive commands. By scheduling sleep periods for sensors, devices, or gateways, the system can reduce the amount of energy consumed during idle periods. This can significantly extend the battery life of the devices and reduce maintenance costs.

Reliability: Using blockchain technology and sleep schedule methods can increase the reliability of data aggregation in smart agriculture systems. Blockchain's decentralized nature ensures that data is not lost or corrupted, and the sleep schedule method ensures that data is transmitted efficiently and accurately. In comparison, traditional methods of data aggregation may be prone to errors or data loss due to technical failures or human error.

Scalability: Blockchain technology and sleep schedule methods can also offer scalability for smart agriculture systems. As the system grows and more devices are added, blockchain's decentralized network can accommodate the increased demand for data storage and transmission. The sleep schedule method can also be adjusted to accommodate the increased number of devices, ensuring that data is transmitted efficiently and accurately.

C. SCALABLE AND ADAPTABLE DATA AGGREGATION FOR SMART AGRICULTURE DEPLOYMENT

Data aggregation systems are crucial for collecting and processing large amounts of data in smart agriculture. However, to make these systems scalable and adaptable for large-scale deployment, several factors need to be taken into account. One of the key ways to achieve scalability is through cloud computing. By leveraging cloud-based platforms, such as Amazon Web Services (AWS), Microsoft Azure, or Google Cloud, data aggregation systems can dynamically scale up or down depending on the volume of data being processed. This can help reduce costs, improve efficiency, and provide the flexibility needed to handle large-scale deployments. Interoperability is another important consideration in making data aggregation systems scalable and adaptable. Open standards and APIs can help ensure that different systems can work together seamlessly. This can help enable data to be easily shared and analyzed, regardless of the source or platform. Data security and privacy are also critical factors to consider when designing data aggregation systems for smart agriculture. Robust encryption, access control, and data governance policies can help ensure that sensitive information is protected. Finally, data analytics can help make sense of the large volumes of data collected in smart agriculture. Machine learning algorithms can be used to identify patterns and trends, enabling farmers to make more informed decisions about crop management, irrigation, and fertilization. Resultantly, making data aggregation systems scalable and adaptable for large-scale deployment in smart agriculture requires a combination of cloud computing, edge computing, interoperability, data security, and data analytics. By addressing these key factors, data aggregation systems can help enable more efficient and sustainable agricultural practices.

TABLE 2. Simulation parameters for experiment.

Parameters	Value
Network interface	Wireless
Number of Nodes	100
Initial Energy in each node	0.5 j
Duration of Round	10 s
Base Location	(200,100) m
Size of Network	100x100m
Size of Packet	512 bytes
Threshold of Residual Energy %	0.30
Data rate	1 abs
Threshold of distance	75m
Idol power	13.5m^{w}
Sleep Power	1.5 JW
Eelec	50 J/bit/signal
EDA	0.0013pJ/bit/m4
Efs	10 PJ/bit/m2

D. SCHEDULE METHOD FOR EFFICIENT DATA AGGREGATION IN SMART AGRICULTURE

The sleep schedule method, also known as duty cycling, is a technique used to conserve energy in devices that require periodic communication, such as smart agriculture systems. This method involves turning off the device's communication module for certain periods, also known as sleep periods, and then waking it up periodically to transmit data or receive commands. In smart agriculture systems, the sleep schedule method can be applied to improve the efficiency of data aggregation. By scheduling sleep periods for sensors, devices, or gateways, the system can reduce the amount of energy consumed during idle periods. This can significantly extend the battery life of the devices and reduce maintenance costs.

To apply the sleep schedule method, the system needs to be designed to support duty cycling. This means that the devices must be able to switch between active and sleep modes automatically and reliably. In addition, the system must also have a reliable way to synchronize the sleep schedules of the devices to avoid data loss and ensure that the devices are awake when they need to be. One way to implement the sleep schedule method in smart agriculture systems is by using a hierarchical architecture. In this architecture, sensors and devices are organized into clusters, and each cluster has a gateway that acts as a coordinator. The gateway is responsible for synchronizing the sleep schedules of the devices in its cluster, as well as aggregating the data collected by the devices and forwarding it to the next level of the hierarchy.

Another way to implement the sleep schedule method is by using a distributed scheduling algorithm. This algorithm allows devices to negotiate their sleep schedules dynamically based on the network conditions and the amount of data that needs to be transmitted. This approach can be more flexible and efficient than a hierarchical architecture, but it also requires more complex algorithms and protocols. In conclusion, the sleep schedule method is a powerful technique that can be used to improve the efficiency of data aggregation in smart agriculture systems. By reducing energy consumption and extending battery life, this method can help reduce maintenance costs and increase the reliability of the system. However, it requires careful planning and design to ensure that the sleep schedules of the devices are synchronized and optimized for the specific application.

VI. CONCLUSION AND FUTURE WORK

The rapid advancement of smart devices and networking technologies has given rise to numerous popular Internet of Things (IoT) applications. This paper primarily delves into the significance and potential of smart agriculture, considered one of the most promising applications of IoT. The incorporation of blockchain technology for data aggregation in smart agriculture, particularly through the implementation of the Cluster Head Sleep Schedule method, represents a promising development that can significantly contribute to the industry's progress.

Employing a decentralized system that ensures data integrity, security, and immutability, farmers can have heightened confidence in the accuracy and transparency of data collected from IoT sensors. This, in turn, fosters more informed decision-making concerning resource allocation, crop management, and other farming operations, ultimately leading to increased crop yields and more sustainable agricultural practices.

The Cluster Head Sleep Schedule method, which optimizes the energy consumption of IoT sensors by scheduling their sleep patterns, further enhances the efficiency and effectiveness of data collection in smart agriculture. This method not only reduces the power consumption of IoT devices but also extends their lifespan, eliminates data redundancy, and lowers the overall operational costs.

In summary, the integration of blockchain technology and the Cluster Head Sleep Schedule method in smart agriculture promises numerous benefits for the industry, including heightened efficiency, improved sustainability, and enhanced decision-making capabilities for farmers. As technology continues to evolve, we can expect to witness even more innovative solutions for data aggregation and management in smart agriculture, ushering in a more productive and sustainable future for the sector.

While the utilization of blockchain and the sleep schedule method has demonstrated promising results in efficient data aggregation for smart agriculture, there is still ample room for improvement and further exploration. One potential avenue for future research could involve investigating the potential advantages of integrating machine learning algorithms into the system. This could potentially enable more accurate and efficient data analysis, as well as the development of predictive models to assist farmers in making informed decisions.

Additionally, there is a need to explore the scalability and feasibility of this approach in large-scale agricultural systems. This may entail testing the system in various environments and assessing its performance under diverse conditions. Furthermore, there is a requirement for the development of user-friendly interfaces and tools to facilitate the easy adoption of this technology by farmers and other stakeholders. This could involve the design of intuitive dashboards and visualizations that provide relevant information and insights to users.

While the use of blockchain and the sleep schedule method holds the potential to revolutionize data aggregation in smart agriculture, there is still considerable work to be done to fully unlock its potential and make it accessible to farmers and other stakeholders.

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