Iot-Based Secure And Energy Efficient Scheme For Precision Agriculture Using Blockchain And Improved Leach Algorithm

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Abstract: Precision agriculture is a trending technology that helps in improving the agricultural productivity. This technique combines various technologies like Internet of Things (IoT), remote sensing, information technology and wireless sensor networks (WSN). In this research, we propose a new technique for adaptive water scheduling in precision agriculture based on wireless sensors like moisture and temperature sensors. In the proposed framework, the secure data transfer in the cloud is achieved using blockchain technology. Further, energy efficient data transfer is attained by means of Improved LEACH algorithm. The data from the sensors are acquired using PIC micro controller module. The acquired data are then transmitted to the cloud using Raspberry Pi module. This data is then secured and verified using block chain-based IoT technique. In this way, the blockchain technology plays a pivotal role in sharing the agricultural data in the cloud in a reliable and transparent manner. Further, blockchain technology also provides data security in a decentralized manner. The main drawback in wireless sensor-based precision agricultural system is the limitation of battery power. To overcome this drawback, we have implemented Improved LEACH protocol for achieving energy efficiency. In this protocol, a new threshold limit is introduced to increase the level of energy efficiency. The usage of blockchain and ILEACH protocol helps in achieving an intelligent farming system. The proposed technique helped in achieving an increased throughput of 63%. Further, the data from other sensors like pH sensor and humidity sensor were transmitted to the cloud in real-time. The entire sensor data were available to the farmers using IoT-based smart phone module to enable remote monitoring.

Keyworks: Precision agriculture, WSN, IOT, block chain, ILEACH

1. Introduction

Precision agriculture is the main domain that determines the agricultural supply chain of a country. The adoption of blockchain technology helps to ensure the food safety and security. Internet of Things (IoT) and cloud computing technology is used for the enhancement of security. Blockchain systems acts as a front-runner for ensuring the security of the precision agriculture [1]. The main advantage of implementing IoT is its capability to sense the data of the surrounding environment that helps to automate the precision agricultural actions. Further, since IoT involves transfer of data through the cloud it is prone to be attacked by the intruders [2]. Hence, to ensure security of the cloud data, this data is encrypted and is added as a block to the blockchain. The blockchain system is a transparent and decentralized network. Further, the system is highly immutable. The transparency is provided based on a hash function [3]. Sensors involved in IoT application include chemical sensor, moisture sensor, gas sensor, pH sensor, proximity sensor etc. These sensors acquire data at real-time based on the environmental parameters. The wireless sensors are dispersed randomly over the field for the collection of environmental data [4]. Food traceability is one main application of blockchain technology. Management of product life cycle is an important aspect of food traceability. In this scheme, the transparency of food supply chain is provided by means of individual encryption blocks. These blocks add together to form the complete blockchain [5]. Meeting the sustainability of agricultural productivity is a trending research domain. This is because it is essential for the economic development of a nation. Further, the usage of IoT sensors, information technology and cloud computing techniques has enabled the advancement and automation of various agricultural actions [6]. Precision farming tools are also popularly being adopted by the farmers. These tools helps to analyse the statistical data of the agricultural land, practises used, environmental effects, agricultural practises, climatic conditions, tools and techniques employed [7]. Energy forecasting is yet another important aspect of precision agriculture. Since the energy requirement involved in this system is high, there is a need for energy forecasting and energy conservation. This further helps to reduce the energy requirement of the future and the overall cost of the system [8]. The main drawback of using wireless sensors is the low battery capability of these sensors. Hence, it is essential to adopt suitable techniques that minimize the amount of energy required. The main task of the sensors is to collect and transmit the data. Thus, various scheduling tasks are to be framed to optimize the energy spent [9]. Utilization of solar energy is the best alternative as it is available in plenty amount and is also a non-renewable resource. Further, solar energy can be easily harnessed and is available even in remote areas. Since the wireless sensors are deployed mainly for remote sensing, it is highly suitable [10].

2. Literature survey

Torly et al. [11] proposed a scheme for analysing the application of blockchain techniques and IoT technology in precision agriculture. The security issues and privacy challenges of precision agriculture techniques were discussed. Further, the means by which these techniques were solved using blockchain technology were also addressed. Iqbal et al. [12] presented safe farming technique for improving the transparency of precision agriculture. The proposed safe farming technique was proposed by the integration of IoT and blockchain technology. Furthermore, this technique was implemented mainly for the detection of animal attacks that reduces the agricultural productivity. Xiong et al. [13] designed a system in which the applications and drawbacks of the usage of blockchain in the smart farming techniques were discussed. The applications of blockchain in various domains of precision agriculture were also analysed. These applications included transactions related to the agricultural products, insurance, supply chain etc. Bodkhe et al. [14] analysed the supply chain ecosystem based on blockchain for the improvement of security and accuracy of various sensor measurement like water measurement, humidity measurement, temperature measurement, pH level of soil measurement, etc. The transfer of data from the sensor to actuator unit through the cloud systems were used for the study. Hang et al. [15] proposed a scheme for securing fish farming based on blockchain. Blockchain techniques were used for the manipulation and prediction of future data based on the previous acquired data. Such prediction was used for increasing the reliability, profitability, accuracy and efficiency of the fish farming technology. Sanjeevi et al. [16] presented a system for precision agriculture by the combination of IoT devices and wireless sensor networks. Cloud computing techniques were applied on the IoT devices to compute various parameters and for different types of predictions and classifications. The wireless sensor networks were analysed to provide maximum throughput and minimum error. Popescu et al. [17] designed a UAV-WSN scheme for improving the efficiency of precision agriculture. The main aim of this scheme was to improve the performance and productivity of the smart farming system. The unmanned aerial vehicles were adopted mainly for the monitoring of crops to improve the reliability and decrease the manual labour. Singh et al. [18] presented a LoRaWAN technology for the improvement of greenhouse based precision agriculture systems. This scheme utilized low power wide area networks. The main advantage of this system is to transmit the sensor data over long distances through the wide area networks with the minimal consumption of energy. Zervolpoulos et al. [19] proposed a scheme for the synchronization of the data from multiple wireless sensors. The synchronization helped to increase the reliability of precision agriculture especially in case of remote sensing applications. The synchronization was provided based on the usage of time correlation-based measurements in the WSN. Hamouda et al. [20] presented a framework in which the sampling interval of wireless sensors were adjusted and altered with the aim to improve the energy efficiency. Monitoring of water requirement is the main task used in this research. The optimal amount of water required by crops based on environmental parameters were identified and used.

3. Objective

- The main objective of this research is to improve the security of precision agriculture system. This is done using blockchain technology.
- The second objective is the enhancement of energy efficiency. Energy efficiency is improved using a novel algorithm called ILEACH algorithm.

4. Proposed Methodology

4.1. Enhancing security of precision agriculture using blockchain

The blockchain technology comprises of stacks of records that are referred as "blocks". Each block in the blockchain network is connected by means of cryptographic technology. The blockchain technique helps to verify the transactions in a transparent manner. Further, this technique helps to increase the security of transmission of sensor data in precision agriculture systems.

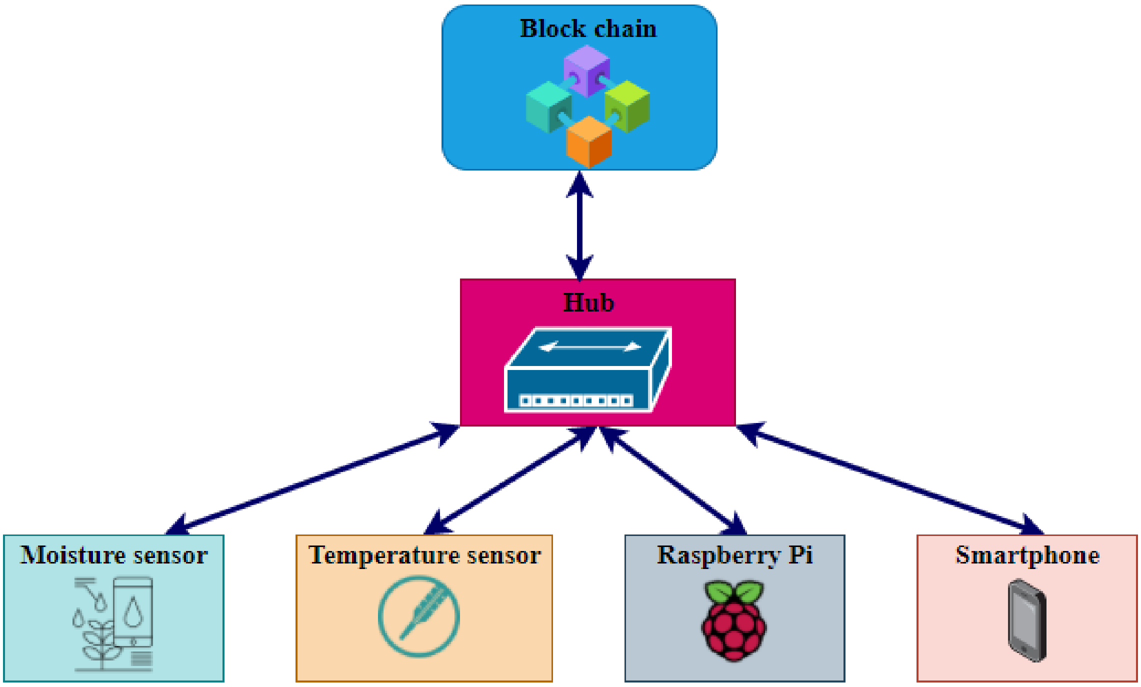


Figure 1. Security enhancement of precision agriculture using blockchain

Figure 1 illustrates the security enhancement of precision agriculture using blockchain. The two main sensor value required for the estimation of plant water requirement are moisture sensor and temperature sensor values. These values are processed using Raspberry Pi module. The amount of water estimated is then given to the smartphone of the farmer. Since this scheme utilized cloud technology it can be easily altered or seen by third party. Thus, the enhance the security level of this system, all these components namely, moisture sensor, temperature sensor, Raspberry Pi module and the smartphone are connected to the management hub. The hub is then connected to the blockchain. When ever the water level estimation is done, a new block is added to the blockchain in a decentralized manner. Thus, the security of the data is ensured.

4.2. Proposed architecture of IoT-based precision agriculture system

The proposed architecture is based on PIC microcontroller module. This module acquires the data from multiple sensors like moisture, temperature, pH and humidity sensor.

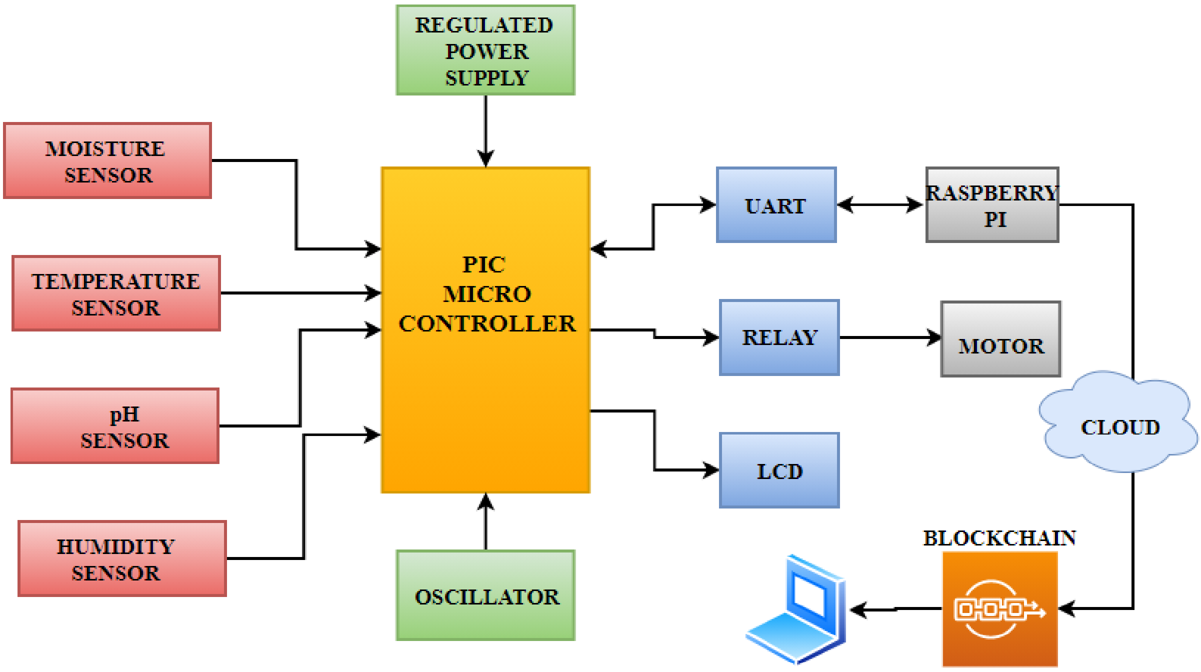


Figure 2. Architecture of IoT-based precision agriculture System

Figure 2 depicts the architecture of IoT-based precision agriculture system. The data acquired by the PIC microcontroller is transmitted to Raspberry Pi module using UART. The data from the moisture and temperature sensor is processed to identify the water requirement for irrigation. The system is designed such that if both the temperature is high and the moisture content of the soil is low, then the irrigation is started else it is stopped. The irrigation process is handled using a motor that is connected to the relay module. The identified result is transmitted to the cloud. The processed data along with the values of the pH sensor and the humidity sensor are added as a new block to the blockchain after verification. This ensures that the block is a valid encrypted block. Thus, data security is enhanced.

Figure 3 shows the main components of data security using block chain for precision agriculture application. The components include wireless sensors, cloud storage, end user and the water management system. In this scheme, whenever a sensor acquires real-time data and transmits it, the data is broadcasted to the complete P2P network system. Every node in the network validates this data based on the block chain protocol. Once the validation is completed, the block is encrypted and is added to the block chain. In this way, the data that finally reaches the end user or the farmer is highly secure and safe.

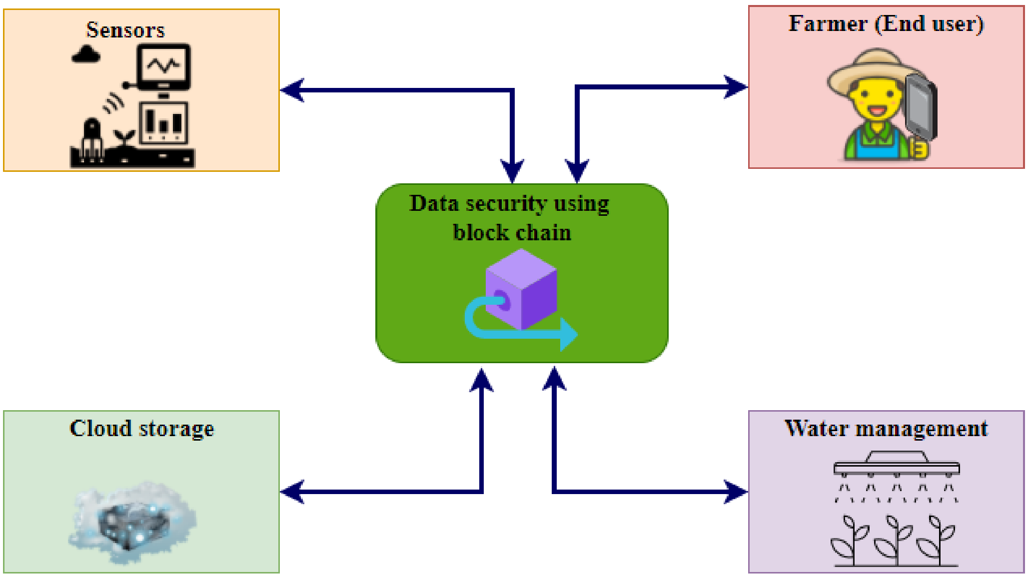


Figure 3. Data security using blockchain

4.3. Proposed ILEACH Protocol

The proposed ILEACH protocol is a modification of the LEACH protocol. This enhancement is done to increase the energy efficiency of the wireless sensor network system in precision agriculture.

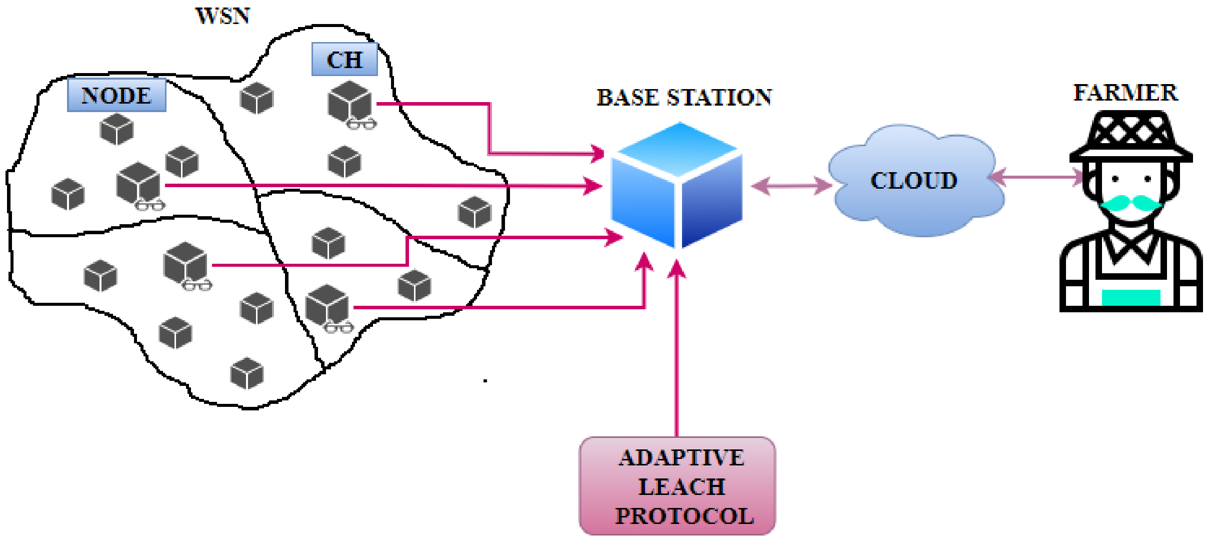


Figure 4. Improved LEACH protocol in wireless sensor network

Figure 4 shows the proposed ILEACH protocol scheme. LEACH protocol works based on time division multiplexing scheme. In this protocol, each sensor node transmits its data to the base station through a cluster head (CH) node. The entire process involves two stages. In the initial set up stage, the selection of CH in LEACH protocol is done based on random number generation between 0 to 1. A node is identified as CH whenever the random value is less than a predefined threshold value. Next, in the steady state stage, every node sends the acquired data to the CH based on its allocated time slot in the TDMA schedule. The main drawback of this scheme is that, there is wastage of energy in the CH. To avoid this, ILEACH protocol is proposed in which a new threshold is selected. Whenever, there is remainder energy in CH at a particular round that is more than the threshold, the CH is allowed to remain as CH in the next round as well. This is described in Algorithm 1.

Algorithm 1: Proposed Improved LEACH Algorithm.
Algorithmic Steps:

1. CH is selected among nodes $N_1, N_2, \ldots, N_n$ based on LEACH protocol.
2. Maximum power $P_{CH} = P_{\max}$ is allocated to the CH node.
3. All nodes transmit data to the CH.
4. The power is lowered after each i^{th} data transmission $P_{CH} = P_{\max} - P_i$.
5. Compute the threshold using

$$Th = \begin{cases} \dfrac{1}{1 - p\exp(r)} \end{cases}$$

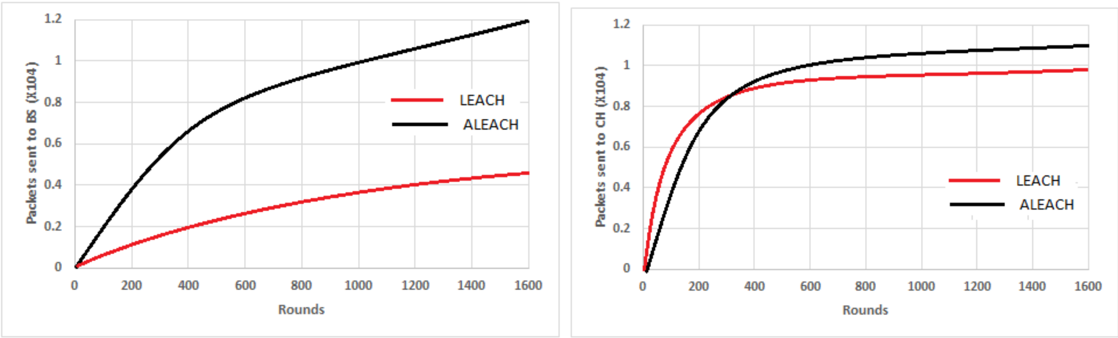
Where *Th* is the threshold, *p* is the sensor node percentage and *r* is the round number.

6. After each round check

if $P_{CH} > Th$
    CH is the cluster head for next round *r*+1.
else
New CH selected.
    end

5. Results and Discussion

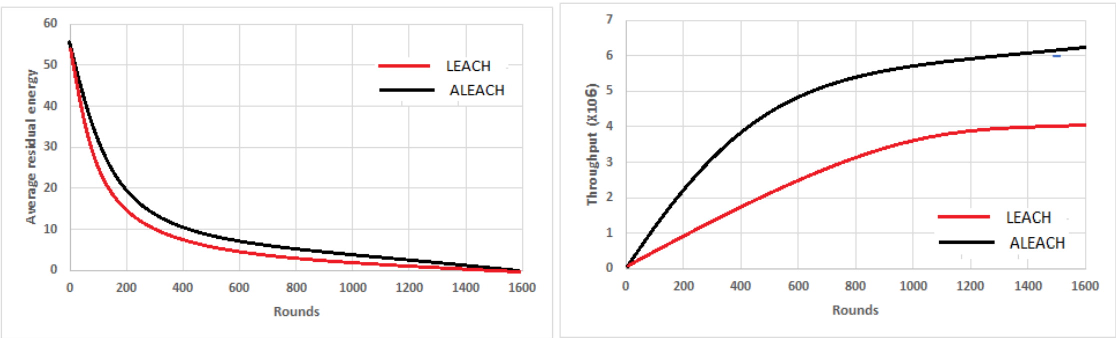
The proposed ILEACH protocol is evaluated using various parameters like number of packets communicated, network performance and lifetime metrics.



(a) (b)

Figure 5. Comparison of number of packets communicated (a) To Base Station (b) To Cluster Head

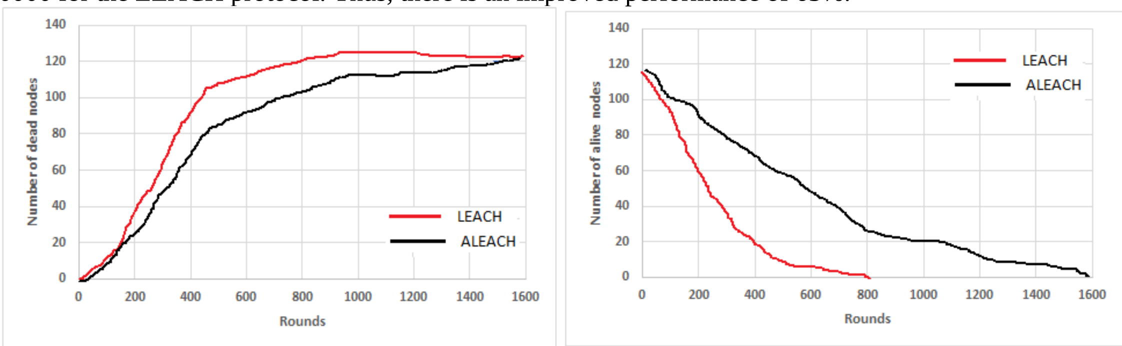
Figure 5 (a) shows the comparison of number of packets communicated to the base station for the LEACH and ILEACH protocol. It is observed that, when the number of rounds increases, the number of packets sent to the base station (BS) increases rapidly for the ILEACH protocol. However, the number of packets sent to the BS increases slowly for the LEACH protocol. For round 1600, the number of packets sent to the BS is around 12000 for ILEACH and only 4000 for LEACH protocol. Figure 5 (b) shows the number of packets sent to the cluster head (CH). Similar to previous case, the number of packets sent to CH for round 1600 is 11000 for ILEACH and only 9500 for the LEACH protocol. Thus, the proposed ILEACH algorithm achieves better performance.



(a) (b)

Figure 6. Comparison of network performance (a) Average residual energy (b) Throughput

Figure 6 (a) shows the comparison of network performance for the LEACH and ILEACH protocol. It is observed that, when the number of rounds increases, the average residual energy decreases rapidly for the LEACH protocol. However, the average residual energy decreases slowly for the ILEACH protocol. For round 400, the average residual energy is around 10J for ILEACH and only 8J for LEACH protocol. Figure 6 (b) shows the throughput for LEACH and ILEACH protocols. For round 1600, the throughput is 6100000 for ILEACH and only 4000000 for the LEACH protocol. Thus, there is an improved performance of 63%.



(a) (b)

Figure 7. Comparison of lifetime metrics (a) Number of dead nodes (b) Number of alive nodes

Figure 7 (a) shows the comparison of lifetime metrics for the LEACH and ILEACH protocol. It is observed that, when the number of rounds increases, the average number of dead nodes increases rapidly for the LEACH protocol. However, the average number of dead nodes increases slowly for the ILEACH protocol. For round 400, the average number of dead nodes is around 90 for LEACH and only 65 for ILEACH protocol. Figure 7 (b) shows the number of alive nodes for LEACH and ILEACH protocols. For round 400, the number of alive nodes for LEACH protocol is 20 for ILEACH protocol is 65.

Table 1. Comparison of lifetime metrics in terms of First Node Dead (FND)

Number of nodes	**Area**	**LEACH**	**ILEACH**
		FND	
100	100	910	1030
	200	740	860
	300	250	270
500	100	1040	1120
	200	850	940
	300	370	450
1000	100	2100	2100
	200	1290	1290
	300	460	460

Table 1 shows the comparison of first node dead (FND) for LEACH and the ILEACH protocol. For 100 nodes, when the area of deployment is 100, the FND is 910 for LEACH and 1030 for ILEACH. For 100 nodes, when the area of deployment is 200, the FND is 740 for LEACH and 860 for ILEACH. For around 100 nodes, when the area of deployment is 300, the FND is 250 for LEACH and 270 for ILEACH. For 500 nodes, when the area of deployment is 100, the FND is 1040 for LEACH and 1120 for ILEACH. For 500 nodes, when the area of deployment is 200, the FND is 850 for LEACH and 940 for ILEACH. For around 500 nodes, when the area of deployment is 300, the FND is 370 for LEACH and 450 for ILEACH. For 1000 nodes, when the area of deployment is 100, the FND is 2100 for LEACH and 2100 for ILEACH. For 1000 nodes, when the area of deployment is 200, the FND is 1290 for LEACH and 1290 for ILEACH. For around 1000 nodes, when the area of deployment is 300, the FND is 460 for LEACH and 460 for ILEACH.

Table 2. Comparison of lifetime metrics in terms of Last Node Dead (FND)

Number of nodes	**Area**	**LEACH**	**ILEACH**
		LND	
100	100	1120	1240
	200	850	930
	300	390	410
500	100	1130	1450
	200	920	1120
	300	450	510
1000	100	2310	2310
	200	1580	1580

	300	520	520

Table 1 shows the comparison of last node dead (LND) for LEACH and the ILEACH protocol. For 100 nodes, when the area of deployment is 100, the LND is 1120 for LEACH and 1240 for ILEACH. For 100 nodes, when the area of deployment is 200, the LND is 850 for LEACH and 930 for ILEACH. For around 100 nodes, when the area of deployment is 300, the LND is 390 for LEACH and 410 for ILEACH. For 500 nodes, when the area of deployment is 100, the LND is 1130 for LEACH and 1450 for ILEACH. For 500 nodes, when the area of deployment is 200, the LND is 920 for LEACH and 1120 for ILEACH. For around 500 nodes, when the area of deployment is 300, the LND is 450 for LEACH and 510 for ILEACH. For 1000 nodes, when the area of deployment is 100, the LND is 2310 for LEACH and 2310 for ILEACH. For 1000 nodes, when the area of deployment is 200, the LND is 1580 for LEACH and 1580 for ILEACH. For around 1000 nodes, when the area of deployment is 300, the LND is 520 for LEACH and 520 for ILEACH.

Table 3. Comparison of energy efficiency

Number of nodes	Area	LEACH	ILEACH
		Energy efficiency (%)	
100	100	71.2	73.5
	200	72.4	75.8
	300	77.1	79.3
500	100	82.9	85.3
	200	84.7	88.1
	300	88.6	89.4
1000	100	89.2	91.5
	200	90.5	93.6
	300	92.4	95.3

Table 3 shows the comparison of energy efficiency for LEACH and the ILEACH protocol. For 100 nodes, when the area of deployment is 100, the energy efficiency is 71.2% for LEACH and 73.5% for ILEACH. For 100 nodes, when the area of deployment is 200, the energy efficiency is 72.4% for LEACH and 75.8% for ILEACH. For around 100 nodes, when the area of deployment is 300, the energy efficiency is 77.1% for LEACH and 79.3% for ILEACH. For 500 nodes, when the area of deployment is 100, the energy efficiency is 82.9% for LEACH and 85.3% for ILEACH. For 500 nodes, when the area of deployment is 200, the energy efficiency is 84.7% for LEACH and 88.1% for ILEACH. For around 500 nodes, when the area of deployment is 300, the energy efficiency is 88.6% for LEACH and 89.4% for ILEACH. For 1000 nodes, when the area of deployment is 100, the energy efficiency is 89.2% for LEACH and 91.5% for ILEACH. For 1000 nodes, when the area of deployment is 200, the energy efficiency is 90.5% for LEACH and 93.6% for ILEACH. For around 1000 nodes, when the area of deployment is 300, the energy efficiency is 92.4% for LEACH and 95.3% for ILEACH.

Table 4. Comparison of error rate

Number of nodes	Area	LEACH	ILEACH
		Error rate (%)	
100	100	25.6	23.8
	200	26.4	24.8
	300	28.4	25.8
500	100	19.5	15.8

	200	20.5	16.3
	300	21.8	17.8
1000	100	13.6	9.5
	200	15.7	10.3
	300	17.4	11.9

Table 4 shows the comparison of error rate for LEACH and the ILEACH protocol. For 100 nodes, when the area of deployment is 100, the error rate is 25.6% for LEACH and 23.8% for ILEACH. For 100 nodes, when the area of deployment is 200, the error rate is 26.4% for LEACH and 24.8% for ILEACH. For around 100 nodes, when the area of deployment is 300, the error rate is 28.4% for LEACH and 25.8% for ILEACH. For 500 nodes, when the area of deployment is 100, the error rate is 19.5% for LEACH and 15.8% for ILEACH. For 500 nodes, when the area of deployment is 200, the error rate is 20.5% for LEACH and 16.3% for ILEACH. For around 500 nodes, when the area of deployment is 300, the error rate is 21.8% for LEACH and 17.8% for ILEACH. For 1000 nodes, when the area of deployment is 100, the error rate is 13.6% for LEACH and 9.5% for ILEACH. For 1000 nodes, when the area of deployment is 200, the error rate is 15.7% for LEACH and 10.3% for ILEACH. For around 1000 nodes, when the area of deployment is 300, the error rate is 17.4% for LEACH and 11.9% for ILEACH.

6. Advantage of the proposed methodology

The first advantage of the proposed system is the increase in the number of packets communicated to the base station and cluster head. The second advantage is the increase in throughput and average residual energy. Further, the security of the proposed system is very high due to the implementation of block chain.

7. Conclusion

In this research, a novel technique is proposed for enhancing the security and energy efficiency of precision agriculture. To enhance the security of this system, a blockchain-based scheme was implemented. In this scheme, the data in the cloud is encrypted and added as a block to the blockchain. Further, the energy efficiency was achieved using a novel Improved LEACH protocol. The wastage of energy in the traditional Leach protocol is avoided in the proposed ILEACH algorithm. The number of packets sent to Cluster Head for round 1600 is 11000 for ILEACH and only 9500 for the LEACH protocol. Similarly, for round 1600, the throughput is 6100000 for ILEACH and only 4000000 for the LEACH protocol. It was also observed that, the number of first node dead is more for ILEACH compared to LEACH protocol. In particular, for 100 nodes, when the area of deployment is 100, the FND is 910 for LEACH and 1030 for ILEACH. Furthermore, the last node dead is also more for the proposed ILEACH protocol. That is, for 100 nodes, when the area of deployment is 100, the LND is 1120 for LEACH and 1240 for ILEACH.

In future, it is possible to implement the proposed ILEACH algorithm using wireless sensor motes. Further, we plan to identify the energy requirement of the system and compare the energy requirement using the sensor motes.

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