Energy Efficient Clustering for Precision Agriculture using LEACH Protocol

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Abstract

The development of recent technologies in Wireless Sensor Network (WSN) enhance the Internet of Things (IoT) domains. These emerging technologies satisfy the needs of end-user and minimize resource utilization. However, some setbacks detain the performance of these domains, reasonable distance, neighbour node attraction, packet delivery, etc. This paper proposed an Energy Efficient Low Energy Adaptive Clustering Hierarchy (EE-LEACH) for precision-based agriculture development to reduce energy consumption and effective data transmission using Signal-to-Noise Ratio (SNR). Election of Super Cluster Head (SCH) is proposed for rapid and secure data transmission and ensures the one-hop data communication to the BS for efficient data transmission. Additionally, this proposed work identifies the malicious node with higher data aggregation to outperform the existing schemes regarding minimum energy consumption, Packet Delivery Ratio (PDR), Packet Loss Ratio and Network Latency using Network Simulator 3 (NS3).

Keywords: WSN, IoT, Precision Agriculture, SCH, EE-LEACH

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1. Introduction

Emerging IoT automates distinct domains such as WSN, smart city, smart applications, healthcare, security, and energy consumption. A cloud-based Internet of Agriculture Things (IoAT) is recommended for the smart irrigation system. It collects data from the deployed area and sends it to the Base Station (BS) to complete the required task. These innovations show the need for digital inventions to improve the quality of delivery services from various domains and create a supportive environment to enhance the yield from the agricultural field [1-3]. This improvement uplifts urban area people's lifestyles higher than those of the metro cities [2].

Precision agriculture is primarily a term used to study the features of agriculture fields to better crop yield and secure the crops from harmful insects, environmental disasters, and other improvements. IoT is the primary core for precision agriculture to guarantee and ensure proper growth in the agriculture field. Using the latest mathematical logic to improve crop yield predictions of water level in the area, the need for pesticides enhances the need for precision agriculture. These improvements develop a new domain through IoT called the Internet of Agriculture Things to concentrate on agricultural needs and developments. According to the Business Insider report, one hundred million IoT devices will be shipped in 2022 [4]. Through drones, sensor deployment, and Global Positioning System (GPS), the IoAT has enhanced its wings in agriculture development around the globe. The countries where agriculture played a vital role are the places for developing IoAT applications and devices. According to Romit Atta [5], between 2017 to 2022 IoT market will be improved to 16% to 17% of the Compound Annual Growth Rate (CAGR) and witness more than 620 million sensors used in the agriculture fields. Figure 1 shows the smart agriculture field with different sensors and other nodes [6,7].

In Figure 1, sensors forward the collected information from the field to the CHs (represented using black-dotted lines). After receiving the report, CHs forward the data to BS (defined using brown lines). Likewise, BS forwards the data to the cloud server for other processes (represented using green lines) and finally, from the cloud server user receives the information (expressed using black-dotted lines) [8].

The significance of CH's involvement can be seen in Figure 1. CHs must collect information from member nodes, organize it, and relay it to the BS. As a result, the CHs must be designed to communicate successfully with the BS, either single-hop or multi-hop communication. Furthermore, CHs have a memory to store the collected data from the members for a specific time and forward it to BS. Security to be improved on these sensors, as these can be attacked effortlessly compared to the other sensors such as industrial IoT devices and underwater sensors [7]. Sometimes sensors are deployed as offline data collectors to secure the field. Yet, the drastic changes in the environment cannot be intimated immediately and thus shows the need to maintain internet connection round the clock [9,10].

Figure 1. Smart Agriculture Field with Sensor Connectivity [8]

This work focused on utilizing the state-of-the-art IoT network for secured data collection and forwarding from the deployed environment to the BS. This work's design focuses on extracting information such as the humidity of the environment, temperature, water level monitoring, and moisture in the air [11-13].

The sensors that monitor humidity, temperature, water, moisture, and heat are scattered in the environment to identify the necessary information. The information collected from these sensors is communicated securely to the elected CH, which works as a memory buffer to store it and forward it to the BS. BS delivers the information to the cloud, and the cloud communicates the same to the user with a minimal delay for further efficient decisions [14,15]. The proposed framework enables the farmers to utilize a minimum effort and time to identify the environment, the need for the environment, and the crop yield. Through forwarding the collected information efficiently and securely, the productivity from the field improves to a maximum. As a result, the proposed work allows us to manage sensors in the required agricultural field to enhance the routing strategy to increase the network's energy efficiency and focus on security to minimize security assaults in the farm field to the greatest extent possible. When comparing the proposed and present schemes, it becomes clear that the suggested approach outperforms the others in terms of network throughput, Packet Delivery Ratio (PDR), and other factors.

The following are the specifics of this work: Section 2 contains a list of related works. The proposed work EE-LEACH protocol is presented in Section 3. Section 4 discusses the performance comparison of the proposed and existing schemes, and Section 5 concludes the paper.

2. RELATED WORK

In recent years, WSN focused on applications with low cost and easily accessible deployment. Generally, many sensors are placed in the environment to access the environment with less effort. Furthermore, the collected details are forwarded to BS, typically using single-hop or multi-hop communication through the available sensor nodes [20-21]. The economic growth of a country is primarily relying on agricultural development. In such a way, governments are focusing on developing better utility and applications for monitoring and developing IoT-based smart agriculture systems. Likewise, data protection is a significant challenge in WSN because of its easily accessible and free-space communication nature. The WSN is prolonged to the maximum through the latest research advancements and thus improves the network's lifetime and maintains energy-efficient data transmission. Many types of research have been carried out to enhance different clustering models to improvise the lifetime and data transmission. Researchers have proposed one CH to gather and forward the data to the BS in the deployed environment. Additionally, the sensor nodes are moved to sleep nodes to prolong the network's lifetime [22-24].

LEACH proposed with Analytic Hierarchy Process (AHP)[25] to improve the energy efficiency of the network through a better cluster selection approach with an efficient CH election process. In [26-28], the proposed Energy-efficient K-Means technique (EKMT) scheme identifies the CH node based on the distance parameter. The elected CH should be closer to the BS, and member nodes of the previous cluster are the only eligible condition to become CH. This type of CH election is energy efficient due to no other formation of new clusters. However, the security attacks may happen because of minimal security checks, and the same cluster formation for a maximum period creates complications in identifying the security breaches.

Previous work [29-31] elects the CH using Multiple Attribute Decision Making (MADM) and fuzzy logic for other energy-efficient CH selection. The drawbacks of these works include a lack of focus on better routing and security features. In [32], describe the Improved Chain-based Clustering Hierarchical Routing (ICCHR) algorithm for forming a cluster with CH selection. These works perform better residual energy than the other compared schemes. Like other works, it fails to concentrate on better load balancing and securing the network from malicious node attacks. In [33] optimized zone-based energy-efficient routing (OZEEP) scheme is proposed to improve better election of CH after considering parameters such as distance, density, and mobility. However, this work attains a better network lifetime, and yet this work does not concentrate on securing the deployed environment.

3. PROPOSED WORK

The proposed work focused on optimal decision function to select appropriate CHs from the deployed sensors in precision-based agriculture. It follows the basic architecture of the LEACH protocol to incorporate the formation of clusters and other basic procedures. Additionally, SCH is elected among the CH for effective and secured data communication. This framework focuses on balancing the load among the sensors and chooses the CHs using a multi-criteria decision function. This work employs single-hop communication rather than multi-hop communication for effective network latency maintenance. Figure 2 depicts the proposed IoAT framework's research flow.

LEACH PROTOCOL

LEACH is one of the premier protocols in cluster-based routing. The primary role of this protocol is to focus on improving the network lifetime by electing an efficient CH node among the sensor nodes for smooth and secured data transmission.

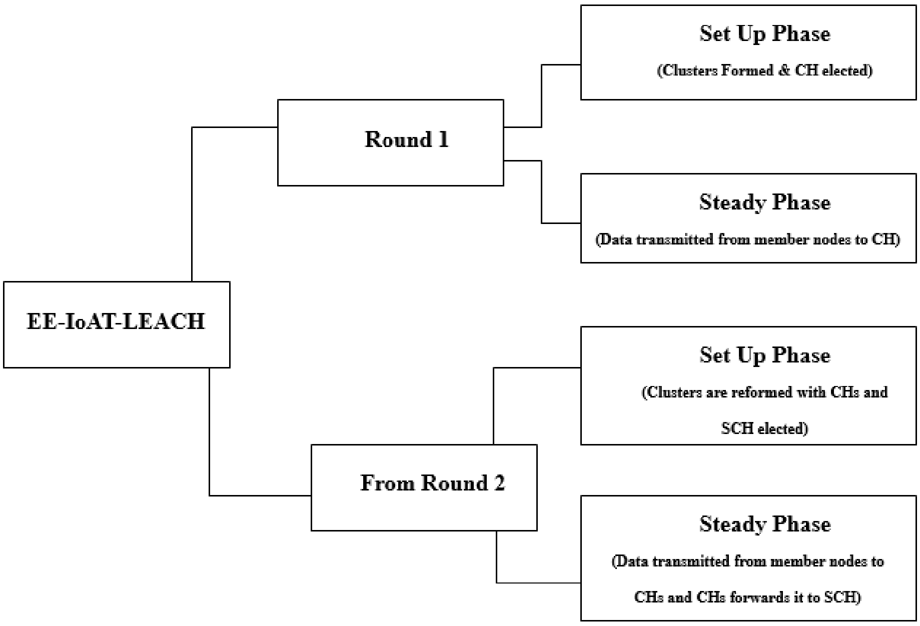

Figure 2 Research flow of the proposed IoAT Framework.

The protocol performs its CH election in two states. They are, set up state and steady-state. This traditional protocol follows a unique way of CH election. It is,

- Allocates a random number between zero and one to all nodes.
- Time Division Multiple Access (TDMA) schedule is processed with the help of the threshold function as explained in Eq. 1.
- The sensor node that holds a higher Eq. 1value than the other friendly nodes is elected as CH for this round.
- The node that acts as CH for the previous round will be given the least priority in the current CH election.

$$T(n) = \begin{cases} \dfrac{p}{\left(1-p \times \left(r \bmod \left(\frac{1}{p}\right)\right)\right)} & , if\ n \in G \\ 0, & otherwise \end{cases} \quad (1)$$

Where p denotes the possibility of a node acting as CH., r represents the number of completed rounds, and G indicates a set of nodes that would not work as CH in the 1/p rounds. Figure 3 depicts general clustering with the LEACH protocol.

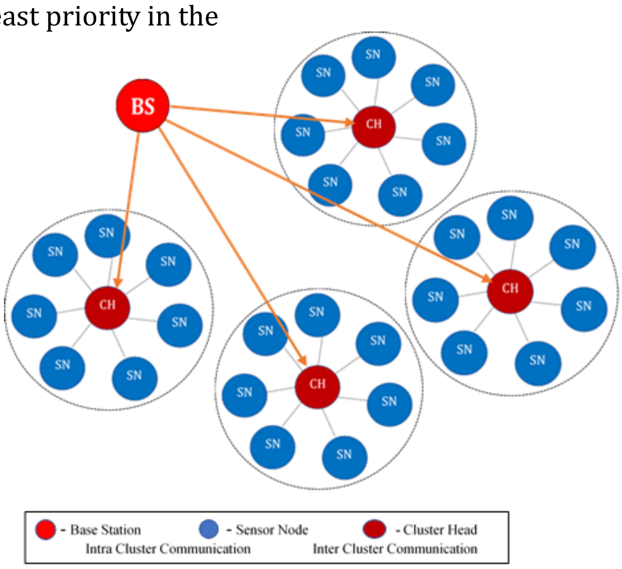

Figure 3 General Cluster Formation using LEACH Protocol

EE-LEACH:

This section presents a design of the proposed EE-LEACH to maintain better energy and link towards achieving the best routing methodology. Firstly, the CHs are elected through the proposed protocol in Eq. 2.

$$T(n) = \begin{cases} \left(e_i + \left(\frac{1}{dist_{BS}}\right) + \left(\frac{1}{SNR_i}\right)\right) \times \frac{p}{\left(1 - p \times \left(r \bmod \left(\frac{1}{p}\right)\right)\right)}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad (2)$$

Where $dist_{BS}$ denoted as distance to BS, SNR_i represents Signal to Noise Ratio (SNR) of the particular node i. Finally, the value of Eq. 2 ranges from 0 to 1, where the default setup phase of LEACH can perform its regular functionalities.

This Eq. 2 presents a better CH election mechanism than the current works through multi-level decision functions. The Energy model for this work is considered the default energy model as represented in the LEACH protocol. Figure 3 presents the energy model of the LEACH protocol. The proposed EE-LEACH Protocol is given below.

EE-LEACH Protocol

For Each (N)

i) N selects a random number T(n) between 0 and 1

ii) N selects distance parameter to check the distance between node and BS

$$T(n) = \begin{cases} \left(e_i + \left(\frac{1}{dist_{BS}}\right) + \left(\frac{1}{SNR_i}\right)\right) \times \frac{p}{\left(1 - p \times \left(r \bmod \left(\frac{1}{p}\right)\right)\right)}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

iii) Then, the signal to noise ratio is calculated through

$$T(n) = \begin{cases} \left(\left(\frac{1}{SNR_i}\right)\right) \times, & if\ n \in G \\ 0, & otherwise \end{cases}$$

If (T(n) < threshold value)

N receives the announcing message of CHs

N becomes a CH

N transmits a msg announcing CH's status

If (N == CH)

CHs ready to choose Super CH (SCH)

N becomes a typical SCH when the node satisfies the below condition

$$SCH = \left[\left[1 - \frac{dist_{BS}}{distance_{far}}\right] + \left[E_{init} \times \frac{\sum_{i=1}^{No} E_{cur}}{No_{Tot}}\right]\right] \times \begin{cases} \frac{p}{1 - p \times (r \bmod (\frac{1}{p}))}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

Then N receives all CHs data and forwards it to BS

Else

No transmission occurs

End if

End if

End for

Sensor nodes of the proposed protocol are one hop distance to reach the elected CHs. Then, the CHs aggregate the collected data and select SCH among the current round's CH to forward the collected information. The parameters considered to elect SCH are minimum distance to the BS and high residual energy. Eq. 3 presents the election of SCH.

$$SCH = \left[\left[1 - \frac{dist_{BS}}{distance_{far}}\right] + \left[E_{init} \times \frac{\sum_{i=1}^{No} E_{cur}}{No_{Tot}}\right]\right] \times \begin{cases} \frac{p}{1 - p \times (r \bmod (\frac{1}{p}))}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad (3)$$

Where E_{init} denotes the initial energy of a node, E_{cur} denotes the node's current energy, and No_{Tot} represents the total number of nodes.

4. RESULTS AND DISCUSSIONS

Network Simulator (NS3) version 3.25 [33] is used to simulate the proposed Scheme, and NS3.25 outperforms in comparison with the other simulation tools. The implementation of NS3 becomes flexible with the help of Otcl and C++ programming techniques. The tool helps analytically prove the theory.

Three hundred nodes were placed in a 500 X

500 Meter square region for 400 seconds of simulation time in the simulation. Table 1 presents the simulation parameters used in the proposed Scheme.

Table 1 Simulation Parameters for the proposed Scheme

Parameters	Value
Network Space	500 X 500
Nodes count	300 (0-299)
No. of CH	5 (5%)
Base Station	300th Node
Position of BS	50,100
Initial Energy	1 Joule (J)
Packet Length	200 bits
Simulation Time	400 Seconds
Time for each Round	10 Seconds
Protocol	LEACH

ENERGY CONSUMPTION

The sensors are typically attached with a non-chargeable battery, and the areas where they are deployed will have fewer human interventions. In such cases, energy consumption is a significant constraint to improving the network's lifetime. As shown in Figure. 5, the proposed EE-LEACH maintains efficient energy consumption. As a result, the proposed EE-LEACH outperforms the other existing schemes by 22%.

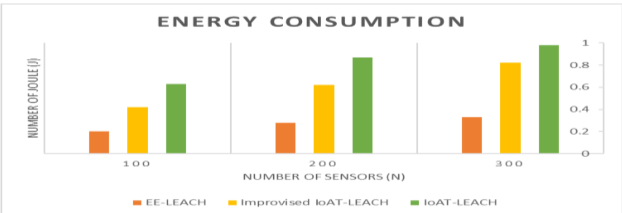

Figure.5 Energy Consumption

PACKET DELIVERY RATIO

The Packet Delivery Ratio is the parameter to compare the performance of PDR among proposed protocols and other existing schemes. Figure 6 shows that the proposed protocol improves PDR more than the other schemes by 20%. The improvement is achieved due to an intelligent selection system to elect CH and SCH.

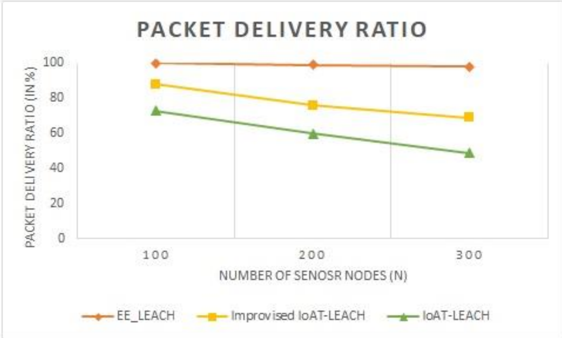

Figure. 6 Packet Delivery Ratio

NETWORK LATENCY

Figure. 7 presents the network latency between the proposed EE-LEACH and other existing schemes such as Improvised IoAT-LEACH and IoAT-LEACH. The proposed work follows the SNR factor while choosing the route to reach the CH, where the cause of selecting a weak node or malicious node is avoided chiefly. Therefore, the proposed framework improves the performance by 25% more than the existing approaches.

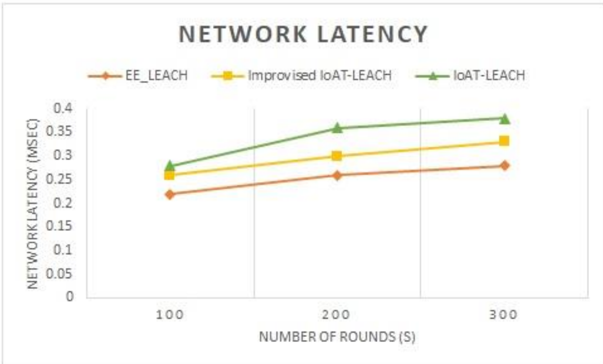

Figure. 7. Network Latency

PACKET LOSS RATIO

Figure 8 shows the packet loss ratio between the proposed and existing models. The proposed EE-LEACH maintains a better delivery ratio, so the Scheme achieves an efficient loss percentage. This loss ratio shows the model's efficiency in CH election and cluster formation. EE-LEACH maintains a 10% or less loss than the other models.

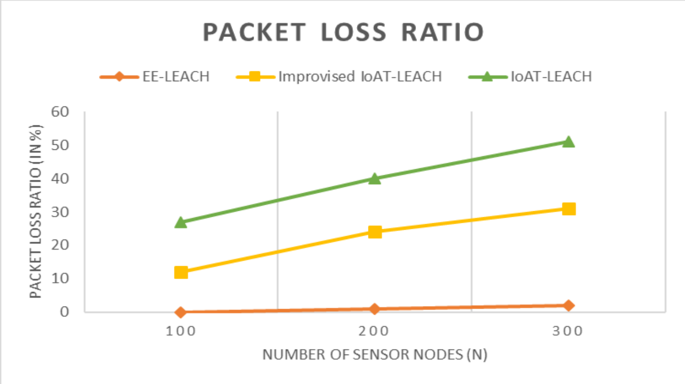

Fig. 8. Packet Loss Ratio

Table 2 shows the simulation results between the proposed and existing schemes.

Name of the work	Energy Consumption (For 1 Joule)			Packet Delivery Ratio (For %)			Network Latency (For MSec)			Packet Loss Ratio (For %)		
	Simulation Time			Simulation Time			Simulation Time			Simulation Time		
	100	200	300	100	200	300	100	200	300	100	200	300
EE-LEACH	0.2	0.28	0.33	100	99	98	0.22	0.26	0.28	0	1	2
Improvised IoAT-LEACH	0.42	0.62	0.82	88	76	69	0.26	0.3	0.33	12	24	31
IoAT-LEACH	0.63	0.87	0.98	73	60	49	0.28	0.36	0.38	27	40	51

Table 2 shows the results of the proposed and existing schemes. EE-LEACH maintains better results in all parameters than the other schemes.

5. CONCLUSION

Through the emergence of IoT technology, WSN has been implemented in significant domains to equip the user's needs. Precision agriculture is among the environment where the IoT is utilized to maintain and predict the available resource condition and reduce the wastage of such resources in incompetent situations. The proposed work EE-LEACH focused on determining the formation of the cluster with efficient CH selection to maintain less consumption of energy, better PDR, and network Latency. It outperforms the above parameters over the existing schemes due to better cluster formation and a novel SCH election method for one-hop communication to the BS. The next task is to select the malicious node in the network and monitor the security breach to improve the network's lifetime and performance.

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