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Original Article

Improving Network Lifetime for Cluster Based WSN through Energy Aware Routing

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***Abstract** - WSNs, or Wireless Sensor Networks, have become essential and used extensively in healthcare, ecosystem monitoring, catastrophe prevention, farming, tracking regions, fire tracking, and other similar applications. In WSN, the sensor node relies on battery power and has a finite energy supply. The sensor node's energy consumption is vital in WSN routing design to maximize network longevity. In WSN, the cluster-based routing methods have proven energy-efficient solutions. The popular clustering technique known as Low Energy Adaptive Clustering Hierarchy (LEACH) has garnered much interest and explained extending network lifetime. However, LEACH has limitations in random Cluster Head (CH) selection, with low energy nodes being selected as CH and not considering the distance to the Base Station (BS). To overcome LEACH's limitations, an Improved Energy Aware Routing (IEAR-LEACH) for cluster-based WSN is proposed by modifying existing LEACH. In the proposed IEAR-LEACH, there is a possibility of nodes with the highest residual energy having been chosen as the Cluster Head, and also considering the distance to BS, nodes near BS get priority of being selected as CH.*

***Keywords** - Cluster, Energy aware, Network lifetime, LEACH, WSN.*

1. Introduction

Wireless Sensor Networks (WSNs) find applications in domains like health care, military, mission-critical networks and object tracking. WSN promises more significant developments of future generation wireless communication networks, especially the Internet of Things (IoT). WSN comprises low-power, multifunctional and low-expensive wireless sensor nodes that perform sensing, data gathering and processing for specific tasks [1-4]. Sensor nodes are positioned arbitrarily in a sensing area, nodes are self-configured to form the wireless network and fulfil certain assigned tasks.

Sensor nodes have constrained and limited energy, memory space and bandwidth. Due to finite battery power, energy consumption is the most important resource to extend the WSN network lifetime. Clustering methods provide an efficient solution to regulate the energy consumed by reducing sensor transmission range. The network of cluster-based WSNs is organized into clusters; each cluster consists of a sensor node that collects information from the surroundings and forwards it to the respective Cluster Head (CH) [5-8]. CH collects an aggregated data set and then transfers it to BS for further data process through single or multi-hop CH transmissions. LEACH is a well-known clustering protocol that aims to improve energy consumption by implementing a rotation-based CH selection method using a random number.

LEACH protocol functions are made to operate in several rounds. However, conventional LEACH has the disadvantage of randomly selecting nodes as CH and low energy nodes being chosen as CH at different rounds. LEACH does not balance network energy, and low-energy nodes result in early death, hindering the overall network performance [9, 10]. The existing scheme fails to choose the optimal Cluster Head and has a higher overhead during cluster formation.

However, the conventional scheme does not consider distance to BS while selecting CH, which is a prime factor for energy conservation. To overcome the limitations of LEACH, we propose an Improved Energy-Aware Routing (IEAR-LEACH) for cluster based WSN through modifying existing LEACH to extend network lifetime and enhance WSN energy efficiency. The primary objective of IEAR-

LEACH is that the higher residual energy nodes are given precedence for being Cluster Heads. and average distance to BS is also being considered during CH selection. Energy-aware routes are selected during multi-hop transmission from CH to BS.

Following is an overview of the remainder of this literature. A brief introduction is provided in Section 1. An in-depth analysis of the issue statement, as well as motivation, is provided in Section 2, which dives into these crucial areas. Section 3 elaborates on the work done. Section 4 shows the proposed EEO-CR. In Section 5, the examination of the performance, corresponding simulation, and experimental findings are covered. Section 6 is about the proposed scheme's conclusion.

2. Problem Statement and Motivation

Continuous environmental monitoring accelerates nodes' energy depletion, which could cause a node to malfunction or die. Since nodes are deployed in unfriendly locations, replacing batteries and recharging becomes difficult. In a network, the dead nodes impede network performance. However, clustering algorithms are more energy-efficient than flat routing but have some defects. LEACH is considered the most significantly used clustering technique. Even though LEACH increases the network's energy efficiency, it also has some drawbacks.

LEACH reduces network longevity by designating CH nodes with lower energy, which causes early node death from insufficient energy. Random selection of CH leads to uneven distribution of CHs and does not consider distance to BS. Optimal selection of CHs and routed data through energy efficient routes helps to extend network lifespan and balance energy load between nodes. Our proposal for energy-aware routing is motivated by this for cluster based WSN through modifying existing LEACH.

3. Related Works

In [11], the author recommends selecting Cluster Heads by the residual energy; the objective is to choose CH while accounting for essential factors like each node's residual energy, initial energy, and the network's ideal number of CHs. The modified version of the traditional LEACH method is used. After each round, the node's residual energy is computed. In the upcoming round, a non-Cluster Head node has a higher probability of becoming a Cluster Head if it possesses the maximum energy level compared to its counterparts. However, this technique does not consider distance to BS and has a high overhead.

In [12], the author proposed the whale optimization algorithm to select the CH. Using a fitness value that considered energy remaining in nodes and nearby nodes' cumulative energy. The most straightforward approach to find (CHs) increases energy consumption awareness. Network factors such as throughput, energy use, and longevity are measured through the mentioned approach.

In [13], the author proposed an Energy Consumption Optimization-based clustering Routing (ECOR) algorithm to optimize CH selection and decrease energy consumption, leveraging the centroid of hexagon network topology. The CH distribution is more uniform in ECOR. The time slot is dynamically assigned for intra-cluster communication based on the node's circumstance. The Dijkstra approach is used in inter-cluster touch to establish the minimum path among CHs, minimizing the data transmission path.

The simulation's findings show improved performance, particularly regarding lower energy usage and longer network lifespan. However, this scheme is specific to topology design and application. To extend the network's lifetime, a data aggregation strategy based on compressive sensing that is energy aware and energy balanced is suggested in [14].

For the selection of 'CH', the Euclidean distance and remaining network energy are considered in this technique. However, to increase network longevity and balance node energy, these two criteria are unsuccessful. To choose the most suitable Cluster Head, the author in [15] considered multiple attributes and coordinated these qualities. To choose CH from the available options, we have considered Multi-Attribute Decision-Making (MADM) techniques by appropriately coordinating various attributes to investigate the multi-attribute-based Cluster Head selection through cooperation with the disputed characteristics. Parameters like first node death and last node death were used to assess how network lifetime could be improved and how energy usage could be optimized. However, this scheme had higher computation overhead for accessing different attributes.

In [16] the author proposed a threshold-based data collection and clustering method for heterogeneous Wireless Sensor Networks. Heterogeneous and homogeneous nodes are placed inside designated areas in our suggested architecture. The threshold-based requirements are offered for both simulated and real-world applications to avoid sending unnecessary signals when little or no change is seen.

This approach aims to minimize wasteful data transmission. Within predetermined borders, we randomly deploy homogeneous and heterogeneous nodes and use clustering techniques to gather multi-type information. However, this scheme is limited to small areas. The summary of the above literature survey mainly focuses on achieving energy efficiency. However, crucial factors like the optimal selection of CH, distance considerations, and cluster formation for attaining network stability are not considered.

4. Proposed IEAR-LEACH

4.1. Network Model

The network comprises "n" nodes strategically positioned within the sensing area, as illustrated in Figure 1. These nodes can transmit sensed data to BS through multi-hop single-hop or transmissions.

BS is positioned on the top of the network and has an unlimited supply of resources. Cluster groups are created within the network, with a Cluster Head (CH) in charge of each group responsible for acquiring information from the Cluster Members (CM).

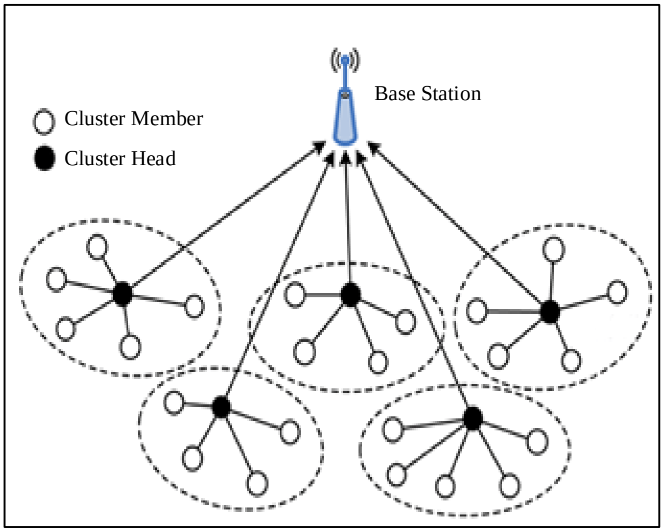

Fig. 1 Network architecture

4.2. Energy Model

IEAR-LEACH employs a free space and multipath channel model during data transmission from CH to BS through computing distance to BS. The energy required for transmission of j bits over a distance D, using free space (D^2) or multipath fading (D^4) is expressed as shown in Equation 1:

$$E(j,D) = \begin{cases} j * e_{elec} + j * \varphi_{fs} * D^2 & D \leq D_0, \\ j * e_{elec} + j * \varphi_{amp} * D^4 & D > D_0, \end{cases} \quad (1)$$

e_{elec} Indicates the energy utilization of the hardware circuit. φ_{fs} Indicates the energy coefficient per bit in multipath fading φ_{amp}. At the receiver, the necessary energy to receive j bits is shown in Equation 2:

$$ER = j * e_{elec} \quad (2)$$

4.3. Cluster Head Selection

The 'CH' selection in traditional LEACH is calculated by taking the energy threshold T_v value and random number generationR_{num}. Each sensor node creates a random number. $R_{num}(0 \leq R_{num} < 1)$. Node is being chosen as CH if the condition $R_{num} \leq T_v$ is satisfied, which is expressed as shown in Equation 3:

$$T_v(n_i) = \begin{cases} \frac{\zeta_{CH}}{1-\zeta_{CH}*(R_{CURR}*mod(1/\zeta_{CH}))}, & n \in V \\ 0, & otherwise \end{cases} \quad (3)$$

ζ_{CH} is the ratio of CH, indicates sensor node selected probability as CH for round 0, R_{CURR} represents the present set of nodes round $V \in [1, n]$ of the given network that isn't possible to select as CH in recent $1/\zeta_{CH}$ round. In IEAR-LEACH, we modified existing LEACH and 'CH' selection as per the residual energy, initial energy, and distance to BS, which is expressed as shown in Equation 4:

$$T_v(n_i) = \frac{\zeta_{CH}}{1 - \zeta_{CH} \times (R_{CURR} * mod(1/\zeta_{CH}))} \times \left(K_{opt} \times \frac{D_{avg}}{D_i}\right) if\ n \in V \quad (4)$$

D_i is the distance that exists between nodes and BS. D_{avg} is the average distance between BS and nodes. And K_{opt} is the optimum constant value.

D_{to-BS} is the distance in between nodes and BS. The distance between nodes (Cluster Members) to CH is denoted as D_{to-CH} and distance is evaluated as shown in Equations 5 and 6:

$$D_{to-BS} = \sqrt{(X_j - X_{BS})^2 + (Y_j - Y_{BS})^2} \quad (5)$$

$$D_{to-CH} = \sqrt{(X_j - X_{CH})^2 + (Y_j - Y_{CH})^2} \quad (6)$$

4.4. Cluster Formation

After CH is chosen, CH broadcasts an Advertisement (CH-ADV) message to sensor nodes using CSMA that contains the CH-ID and coordinates. To build the cluster, sensor nodes that have received a CH-ADV message create a distance table for CH and send JOIN reply messages to CH with the shortest distance. Depending on the size of the CMs, CH distributes the TDMA schedule to the Cluster Members.

4.5. Data Transmission

CH collects data from each Cluster Member (CM) at a distinct timeslot to prevent data collision. Upon data collection, CH performs data aggregation to eliminate redundant data and compress data utilizing data compression techniques for effective bandwidth utilization. Using multi-hop CH broadcasts, aggregated data is transferred to BS via the best path.

Algorithm of IEAR-LEACH
Initialize network procedure CH selection begin CH generate random number $R_{num}(0 \leq R_{num} < 1)$. evaluate the distance to BS, D_{to-BS} if $D_i \leq D_{avg}$ compute threshold $T_v(n_i)$ select the node as CH and send an advertisement message end if end procedure procedure cluster formation and data transmission Cluster Member (CM) sends the reply to the CH message nodes within the CH communication range join to a particular CH and form a cluster CH aggregates data sent by CM transmission of aggregated data from CH towards BS with the optimal route end procedure end

5. Performance Evaluation

The proposed IEAR-LEACH scheme is verified by the simulation using the NS2 tool, and the cluster-based routing scheme has been compared by performance analysis. Table 1 shows the list of parameters used in the simulation.

Table 1. Simulation parameters list

Parameters	Value
Network Nodes	100
Network Area	1000x1000
Simulation Width in sec	200 sec
MAC	802.11
Protocol Routing	ECOR and IEAR-LEACH
Energy	5J
Packet Type	CBR
Propagation Model	Two-Ray-Ground

5.1. Throughput

The suggested IEAR-LEACH's throughput graph compared to ECOR is displayed in Figure 2. It is seen from the chart the throughput of IEAR-LEACH is high compared to ECOR. Additionally, the throughput grows as the simulation time increases.

IEAR-LEACH has a throughput of 117 Kbps compared to ECOR of 73 Kbps. Increased throughput is mainly due to selecting reliable CH through an improved threshold function. However, ECOR chooses the path towards BS based on the back-off timer and assigned weight.

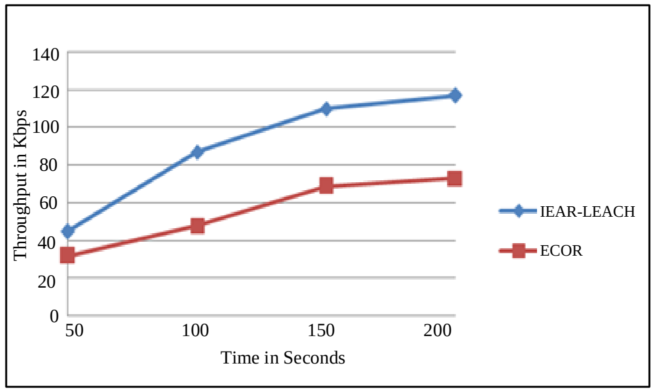

Fig. 2 Throughput vs Varying simulation time

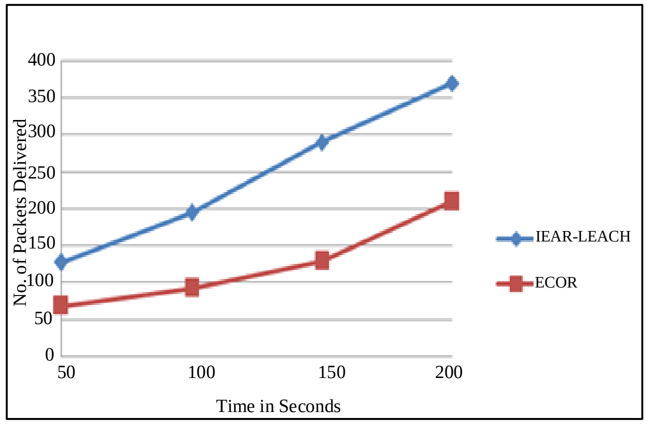

Fig. 3 No. of packets delivered vs Varying simulation time

5.2. No. of Packets Delivered

Figure 3 compares the amount of packets delivered at the IEAR-LEACH BS to the current ECOR. As the period of time increases, the graph indicates that the number of packet delivered at BS is more in IEAR-LEACH than existing ECOR. The path stability of IEAR-LEACH is due to nodes being selected as CH based on the high residual energy using an improved threshold function. At 200 sec, IEAR-LEACH delivers 370 packets compared to the existing LECH, which has 210 packets. Routes towards BS are computed per optimal cost and energy to maximize network longevity while minimizing energy usage.

5.3. Network Lifetime

Figure 4 shows the network lifetime graph of IEAR-LEACH compared with existing ECOR. It is seen from the graph nodes start to die at 100 sec in existing LEACH, plus the quantity of active nodes decreases with increases in time. However, in the proposed IEAR-LEACH, the first node dies at 150 sec, maintaining network stability. The energy among nodes is balanced through the improved threshold, so nodes with only high residual energy and minimum distance to BS are chosen as CH. At 200 sec, it is observed that IEAR-LEACH has more alive nodes compared to existing ECOR.

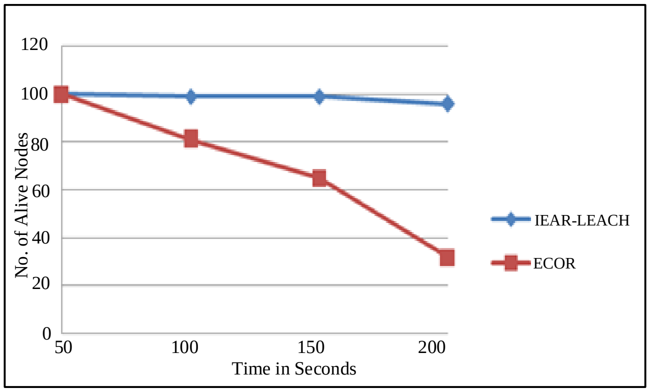

Fig. 4 No. of alive nodes vs Varying simulation time

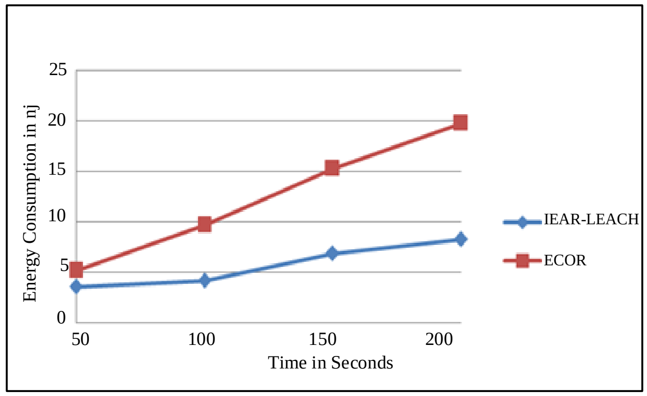

Fig. 5 Energy consumption vs Varying simulation time

5.4. Energy Consumption

Figure 5 shows the energy consumed by the proposed IEAR-LEACH compared with the existing ECOR. The graph displays the amount of energy of ECOR utilized more than IEAR-LEACH. This is because of the path discovery process during data transmission; the shortest paths are computed using the dijkstra algorithm only when CH has data to be sent. Moreover, the allotted time slot is based on the data transmission. IEAR-LEACH, the path construction takes place through energy aware CHs such that data can be transferred reliably.

6. Conclusion

The IEAR-LEACH was proposed for optimizing energy consumption. The average distance to BS and high residual energy are considered when choosing the CH centred on nodes. An improved threshold function and distance to BS are proposed to equalize nodes' energy load evenly.

Based on residual energy, nodes closer to BS are more likely to be selected as CH. In IEAR-LEACH, we modified existing LEACH, and the 'CH' selection is as per the residual energy, initial energy and distance to BS. Data aggregation at CH is done to eliminate redundant data and compress data utilizing data compression techniques for effective bandwidth utilization.

According to simulation studies, the suggested IEAR-LEACH performs better concerning energy efficiency of 27% compared to ECOR and delivers 30% more packets than ECOR. Energy efficient routing scheme for large-scale cluster based WSN can be modelled as an extension work.

References

[1] Sheng-Kai Yang et al., "An Authentication Information Exchange Scheme in WSN for IoT Applications," *IEEE Access*, vol. 8, pp. 9728–9738, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Ashwag Albakri, Lein Harn, and Sejun Song, "Hierarchical Key Management Scheme with Probabilistic Security in a Wireless Sensor Network (WSN)," *Security and Communication Networks*, vol. 2019, pp. 1-12, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[3] Mohammed Belkheir et al., "LE-OLSR Protocol Performance Evaluation in Various Energy Conditions of Mobile Ad-Hoc and Sensor Wireless Networks," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 19, no. 3, pp. 1391–1398, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[4] Xinlu Li et al., "Energy-Efficient Load Balancing Ant-Based Routing Algorithm for Wireless Sensor Networks," *IEEE Access*, vol. 7, pp. 113182–113196, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[5] Abd Elwahab Fawzy et al., "Proposed Intermittent Cluster Head Selection Scheme for Efficient Energy Consumption in WSNs," *34th National Radio Science Conference (NRSC)*, Alexandria, Egypt, pp. 275-283, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[6] Mahdi Zareei et al., "Enhancing the Performance of Energy Harvesting Sensor Networks for Environmental Monitoring Applications," *Energies*, vol. 12, no. 14, pp. 1-14, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[7] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences*, Maui, USA, pp. 1–10, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[8] Jin Wang et al., "An Asynchronous Clustering and Mobile Data Gathering Schema Based on Timer Mechanism in Wireless Sensor Networks," *Computers, Materials and Continua*, vol. 58, no. 3, pp. 711–725, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[9] Jin Wang et al., "An Enhanced PEGASIS Algorithm with Mobile Sink Support for Wireless Sensor Networks," *Wireless Communications and Mobile Computing*, vol. 2018, pp. 1-10, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[10] Walid Osamy, Ahmed A. El-Sawy, and Ahmed Salim, "CSOCA: Chicken Swarm Optimization Based Clustering Algorithm for Wireless Sensor Networks," *IEEE Access*, vol. 8, pp. 60676–60688, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Trupti Mayee Behera et al., “Residual Energy Based Cluster-Head Selection in WSNs for IoT Application,” *IEEE Internet of Things Journal*, vol. 6, no. 3, pp. 5132–5139, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] Ashwin R. Jadhav, and T. Shankar, “Whale Optimization Based Energy-Efficient Cluster Head Selection Algorithm for Wireless Sensor Networks,” *Neural and Evolutionary Computing*, pp. 1-22, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[13] Xu Huibin, and Zeng Mengjia, “An Energy-Efficient Clustering Routing for Wireless Sensor Networks Based on Energy Consumption Optimization,” *International Journal of Digital Multimedia Broadcasting*, vol. 2022, pp. 1-11, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Shima Pakdaman Tirani, and Avid Avokh, “On the Performance of Sink Placement in WSNs Considering Energy-Balanced Compressive Sensing-Based Data Aggregation,” *Journal of Network and Computer Applications*, vol. 107, pp. 38–55, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[15] Ankita Srivastava, and Pramod Kumar Mishra, “Load-Balanced Cluster Head Selection Enhancing Network Lifetime in WSN Using Hybrid Approach for IoT Applications,” *Journal of Sensors*, vol. 2023, pp. 1-29, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[16] Muhammad Bilal, Ehsan Ullah Munir, and Fawaz Khaled Alarfaj, “Hybrid Clustering and Routing Algorithm with Threshold-Based Data Collection for Heterogeneous Wireless Sensor Networks,” *Sensors*, vol. 22, no. 15, pp. 1-24, 2022. [CrossRef] [Google Scholar] [Publisher Link]