
Abstract: The inclusion of innovative technology into sensor networks has resulted in notable advancements in several industries, including mining, healthcare, military surveillance, and more. Using a multi-hop approach, nodes are placed strategically across the Region of Interest (RoI) in order to transfer data to the Base Station (BS). In order to address issues with energy consumption, effective cluster head selection, packet loss, routing algorithms, and energy efficiency, the Wireless Sensor Network (WSN) has become a key field of study. The objectives of this research are to increase nodes' Residual Energy, and lengthen the network lifetime. Using an effective clustering mechanism and Cluster Head election procedure is the suggested method. The goal of choosing a CH is to minimize the distance from the base station while optimizing the node's remaining energy. The protocol acts in two stages: firstly, computing a new Threshold value for the cluster head election process, and secondly, applying a data fusion mechanism based energy model is used in the network to reduce redundant energy transfer.

Keywords: Sensor node, Cluster Head, Base Station, Clustering, Energy Efficiency.

I. INTRODUCTION

The current explosion of mobile internet and sensor network technologies has rekindled interest in adopting fresh technical breakthroughs [1]. Sensor Nodes are deployed strategically to cover the monitoring regions and co-operate with the external world via specialized communication protocols[2]. It is important to note, however, that SNs have limited battery power. The tracking of items in the network in real time demands the participation of numerous SNs. Wireless Sensor Networks (WSN) have had a tremendous influence on human life in the twenty-first century, with continual advances in science, engineering, and technology boosting sensor node capabilities and impacting daily activities. The first-generation sensor network, which relied on point-to-point message to transport data to a Base Station (BS), was introduced in the 1970s. As nodes collaborated and gathered data throughout the network, subsequent generations experienced advances, with the second generation demonstrating lower energy usage and autonomous functioning. In the early 1990s, the third generation added additional features such as a device manager and a bus connection scheme for effective information collecting inside the WSN. The most recent fourth generation SNs contain multi-hop techniques and self-organizing features, which improve data transmission efficiency in the WSN [3]. Data collection is the process by which sensor networks collect data from different sources and send it in a single or multiple hop way to the base station[4]. Effective communication linkages within the network are established by collaborative communication between sensor items and observers. Because it is inherently difficult to get data from crucial zones, it becomes essential to deploy several SNs at regular intervals there. There are difficulties in tracking the precise positions of every sensor node (SN) in the network; nevertheless, some sensor nodes have GPS integrated into their design.

Sensor networks are becoming essential in today's environment for protocol designs, deployment techniques, and green communication projects [5]. Sensor networks are widely used in scientific and research pursuits for a variety of reasons, including remote and embedded management. The efficiency of modern sensor network technology surpasses that of its more conventional equivalents, although problems still exist, most notably those related to node energy consumption and environmental disturbances that impact network connectivity.

Optimizing routes effectively and using network resources wisely are essential to overcoming issues with optimizing bandwidth and preserving Quality of Service (QoS) in Wireless Sensor Networks (WSN). Various barriers may affect coverage in dangerous areas when nodes are physically positioned. Energy-efficient coverage techniques are implemented to successfully solve this difficulty and increase network lifetime. In order to provide full coverage and efficient energy use during data transmission inside the network, the Received Signal Strength Indicator (RSSI) is used to compute the current signal power and has been a focus of current research [7][8]. Typically, there are two kinds of transmissions in sensor networks. The first kind deals with real data transfer, where environmental

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conditions and data corruption can cause data loss. The second kind is the data fusion rate, which helps with storage computation, SN computing, and reducing energy usage in the WSN. Because of the unpredictability of node placement throughout the network, long-distance nodes use more energy (RE) than their counterparts with shorter distances. In the current context, wireless sensor network sustainability and efficient operation depend critically on resolving the nuances of various transmission modes and optimizing energy usage.

This organized approach ensures a thorough exploration of the protocol's design considerations, its relationship with existing protocols, and detailed analyses of experimental results for a holistic understanding and potential advancements in the field.

In order to overcome the problem of randomness in Cluster Head (CH) selection, the research presents a novel protocol that suggests a new threshold value that is appropriate for both advanced and normal nodes. Weighted energy and distance ratios are incorporated into this threshold, which is purposefully designed to maximize CH selection and reduce low node failures. To increase data accuracy, a trust-based data fusion mechanism is applied, and an energy model is incorporated to decrease energy usage during transmission in Wireless Sensor Networks (WSN). The study is organized to give a thorough overview; in Section 2, design concerns and associated work are discussed and explores the SEP and LEACH technique. Section 3 provides the specifics of the Proposed procedure, while Section 4 presents the details Experimental results, compared with the SEP and LEACH, Section 5 conclusion.

II. RELATED WORK

Effective energy conservation strategies are essential for increasing Sensor Nodes (SN) energy efficiency (RE) and extending the lifetime of Wireless Sensor Networks (WSN). In order to do this, the WSN area is divided into many zones according to the Base Station's (BS) longitudinal distance. These areas make up the Cluster Heads (CH) in [9], which are in charge of using a multi-hop technique to send data to the BS. In a similar vein, [10] selects CHs based on nodes with greatest RE using static clustering, which reduces system overhead. The CH selection procedure in [11] gives preference to nodes with the highest RE, which increases the number of CHs in an area and, as a result, improves SN RE and system longevity. [12] proposes the LEACH algorithm, leveraging static clustering for choosing the CH and using both the maximum RE of node and the shortest distance from the BS as parameters. Alternatively, using a single-hop system, [13] suggests a minimal spanning tree process for selecting the CH and data transfer to the BS. In [14], the LEACH protocol is further refined by adding a K-means clustering technique for effective cluster node use inside the network, enhancing WSN performance as a whole. [15] divides the WSN into many areas with CHs chosen based on greatest RE and minimal distance from the BS, hence increasing network lifespan. It also presents a clustering approach for SN organization and an effective routing strategy. [16] adopts a multidimensional strategy, employing distance, node density and energy as characteristics to prolong the longevity of the WSN. Taken as a whole, these research present a variety of approaches to maximize energy efficiency and prolong the operating life of WSNs by optimizing CH selection, data transmission, and clustering techniques. In order to overcome the energy problems with the LEACH protocol, [17] suggests modifying the CH formula and accounting for energy and distance as important network factors. The goal of this change is to maximize network energy consumption. Similarly, [18] elects candidate CHs in the network region by combining weight and radius functions. Subsequently, the chosen CHs enable multi-hop data transfer to the Base Station (BS), hence reducing network energy usage. [19] presents the K-Medoids method, which concentrates on network-wide cluster selection and ultimately extends the life of Wireless Sensor Networks (WSNs). In the meanwhile, [20] suggests a fresh approach that makes use of a fusion technique founded on algorithms for ingredient analysis.

This novel strategy seeks to address energy-related problems in the network by exhibiting a wide range of methods for enhancing energy economy and extending the lifespan of WSNs. The authors of [21] draw attention to problems with uneven node energy usage and a network-wide Cluster Head (CH) selection procedure that is carried out at random. In order to mitigate this, an effective CH selection procedure is implemented, which greatly increases node energy (RE) and the Wireless Sensor Network's (WSN) total lifespan. In a similar work, [19] describes a protocol that uses a static clustering approach to routinely divide the WSN into equal-size areas in order to reduce overhead issues. A multi-hop system facilitates data delivery to the Base Station (BS).

Likewise, [22] suggests a protocol in which the RE of Sensor Nodes (SN) is used to pick both CH and non-CH nodes. Effectively designating the CH with the highest RE, energy consumption within the network is efficiently decreased, and overall system performance is enhanced. The study points out flaws in the LEACH protocol's CH
selection procedure, highlighting how crucial it is to improve this area in order to solve a number of network problems. Together, these investigations add to the continuing efforts to maximize energy usage and CH selection for improved WSN lifespan and performance. A trust model is presented in [23] in order to guarantee safe data transfer and alleviate a number of network-related problems. Expanding upon this idea, [24] uses a trust model to protect various network communication levels. In the meanwhile, in order to improve overall system performance, [25] suggests a data fusion procedure that depends on the degree of confidence. Similarly, to identify and steer clear of outliers in the system, [26] presents a data fusion technique based on multivariate data streams. In order to fully address the trust issue, [27] proposes a Trust-Disturb procedure that consists of four stages: grading, network topology management, link quality assessment, and secure data broadcast based on network grade points. This protocol guarantees secure and effective data routing to the Base Station (BS). Integrating trust functions with an energy-efficient clustering technique within the network, [28] accomplishes secure communication. Furthermore, a technique for selecting Cluster Heads (CH) using trust functions is proposed in [29]. The system achieves a higher packet delivery ratio by avoiding needless transmissions through the combined use of trust mechanisms and data fusion. The aforementioned research highlight the importance of trust models in guaranteeing dependable and secure communication in wireless sensor networks.

2.1. LEACH

In WSN, the LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol is considered a pioneering clustering protocol. In order to reduce energy problems and increase the network's life time, the protocol uses a random procedure to choose Cluster Heads (CH) and distribute average energy across all nodes. A CH is chosen from among the several clusters that are established inside the protocol. Non-CH nodes avoid redundancy problems by sending their data to the appropriate CH. Non-CH nodes keep track of cluster header information and a tiny routing table, whereas CHs aggregate the data and send it to the Base Station (BS) [22]. By using a routing table, superfluous network consumption is substantially reduced. The LEACH strategy has advantages and disadvantages. Energy optimization takes place during the cluster creation phase, when a random integer between 0 and 1 is issued to each Sensor Node (SN). The node is selected as the CH for that round if the resultant number is greater than the predetermined threshold $T(n)$. There are two stages to the clustering process: the establishment phase and the stability phase. Using signal strength and non-CH nodes, message-ids are disseminated throughout the network during cluster formation. Every message is requested by CHs, which also keep track of routing tables and adhere to a Time Division Multiple Access (TDMA) schedule for every cluster. The routing table is used to facilitate data aggregation, and the processed data is then sent to the BS [30].

2.2. SEP

In distributed systems, the Stable Election Protocol (SEP) is a consensus protocol that helps a group of nodes pick a leader who will be stable and consistent. Making ensuring that a single node is chosen as the leader in a fashion that is resilient to brief network outages, reconfigurations, or other sporadic problems is the main objective of SEP. By preserving stability in the face of dynamic system changes, the protocol makes it possible to choose a leader in an orderly manner who can successfully organize and oversee dispersed work. For the purpose of reaching consensus across nodes and guaranteeing dependable and fault-tolerant leader election throughout the distributed environment, SEP usually combines voting, timeouts, and communication. The entire performance and dependability of distributed systems depend on this stability, which guards against interruptions brought on by frequent network fluctuations or leader changes [31][32][33].

III. PROPOSED PROTOCOL

The research presents a novel protocol I-LEACH (Improved LEACH) for WSN that divides the network into various zones, each of which contains two kinds of Sensor Nodes (SN): advanced nodes with high energy and regular nodes with low energy. The protocol is carried out in two steps. Initially, the technique comprises distributing SN and establishing a new threshold(TH) value for choosing cluster heads inside the WSN. The correctness of the data is then maintained by using a data fusion approach based on a trust function, which ensures exact data capture. To maximize energy consumption, an energy model is used to diminish wasteful energy transfer in the WSN. The proposed method uses a novel CH selection technique that removes unpredictability in the selection process. Cluster heads are chosen to maximize SN's remaining energy (RE) while decreasing the distance to the base station (BS). The revised Threshold (T(H)) includes a distance ratio and balanced energy, which reduces energy depletion in
cluster heads while also addressing low node energy problems. This strategy increases cluster heads’ remaining energy (RE), while they wait for data transmission activities inside their clusters to be completed. As a result, the protocol significantly decreases energy usage in the WSN, improving overall system performance [34][35][36].

3.1 Assumptions Regarding the Network for Developing the Proposed Protocol

In formulating the proposed protocol, the following considerations have been incorporated:

- Sensor Nodes (SN) are distributed irregularly across the Region of Interest (ROI).
- Sensor Nodes operate deterministically, and the Base Station (BS) maintains a consistent power supply.
- There is no provision for recharging the battery.
- The Received Signal Strength Indicator (RSSI) plays a crucial role in accurately estimating the distance amid two nodes.

3.2. Energy Model

In order to transmit c bits over a distance d, the required broadcast energy (TE) is determined in eq.1 as follows [16]:

\[
T_E = \begin{cases} 
  c \times E_{elec} + c \times E_{fs} \times d^2, & \text{if } d < d_0 \\
  c \times E_{elec} + c \times E_{mp} \times d^4, & \text{else}
\end{cases}
\]  

(1)

In this context, the variables are defined as follows [37][38].

- \( E_{elec} \): Electrical energy essential for the translation of a bit of data to a signal.
- \( E_{fs} \): Power required for free space transmission.
- \( E_{mp} \): Power required for multi-path models.

\[
d_0 = \frac{v}{E_{mp}}
\]  

(2)

The energy needed for receiving c bits can be expressed using eq.3 as follows:

\[
E_{RX} = c \times E_{elec}
\]  

(3)

The energy needed by the Cluster Member (CM) for co-operating c bits is given by:

\[
CM_E = c \times E_{elec} + c \times E_{fs} \times d_{CH}
\]  

(4)

The energy required by the Cluster Head (CH) (CHE) is computed as follows, taking into account the distance to the Cluster Head (dCH):

\[
CH_E = c \times m \left( E_{elec} + E_{fs} \times d_{B} + E_{DA} \right)
\]  

Here, \( m \) is the count of cluster members, \( d_{B} \) is the distance to the BS, and \( E_{DA} \) represents Accumulation Energy.

4.3 Cluster Head Selection Phase

Cluster Heads (CH) are elected based on maximizing the nodes' residual energy (RE) and minimizing the distance from the Base Station (BS). The nodes are classified into two categories: normal nodes and advanced nodes [39][40].

\[
N_p = \frac{p}{1 + N_n a}
\]  

(6)

\[
A_p = \frac{p}{1 + N_n a (1 + N_n)}
\]  

(7)

The threshold calculation, where \( NP \) is the election likelihood of a normal node as a Cluster Head (CH), \( AP \) is the selection possibility of an advanced node as CH, \( N_n \) is the (%) of advanced nodes, and \( N_a \) is the quantity of energy more than the NN, is expressed as follows [41][42].
In the given context, where $T(H)$ represents the Threshold Rate, $r$ is the current count of rounds, and $P$ is the anticipated % of a SN to be a Cluster Head, the updated $T(H)$ is computed by adjusting Eq. 8. The biased energy ($E$), and distance ratio ($D$) are computed as:

$$T(H) = \frac{P}{1 - P \times (r \mod l)} \times \frac{1}{r_{mod} l}, \text{ if } n \in G$$

$$E = (R\text{Ecurrent} - (E_a + E_t + E_r))$$

$$D = \frac{D_{BS}}{D_l}$$

where DL is the longest distance from BS, DBS is the distance to base station, and $E_a, E_t, E_r,$ and $R_{E\text{current}}$ are the current residual energies, aggregation energies, transmission energies, and reception energies. By using the new $T(H)$, the low energy issue is avoided and the CH survival rate is increased. Equation 4.15 may be used to simultaneously increase the distribution of Normal and Advanced nodes in 6, 7, 8, and 9. The following equations, 11 and 12, provide the revised $T(H)$ for Advanced and Normal nodes.

Equations 11 and 12 contribute to the enhancement of energy usage in the Wireless Sensor Network (WSN). Long-distance SNs tend to use more energy than short-distance SNs. By utilizing the updated $T(H)$ for both advanced and normal nodes, the residual energy (RE) of nodes in the WSN is improved, leading to an enhanced distribution of Sensor Nodes (SN).

### 3.3 Proposed Protocol

There are normal nodes and advanced nodes in the network. The Cluster Head (CH) selection procedure becomes less random with the adoption of a new threshold value. For reliable data capture, a data fusion rate with a trust function is used. Energy models are also used to stop pointless energy transfer inside the network [43].

**Algorithm 1: Data Prediction Phase**

1. **Initialization:**
   - HE: Node High Energy
   - H: Transformed High Energy
   - L: Transformed Low Energy
   - CH: Cluster Head
   - BS: Base Station

2. Nodei $\leftarrow$ random(0, 1)
   - if Nodei $\geq$ HE
      - Set H_Nodei $\leftarrow$ High Energy Node
   - else:
      - Set L_Nodei $\leftarrow$ Low Energy Node

3. Calculate energy radio weight

4. Calculate distance parameters

5. Transform H_Nodei $\leftarrow$ H

6. Transform L_Nodei $\leftarrow$ L
   - if $H < T(H)$ and $L < T(H)$
     - Broadcast CH message
     - Nodes receive message
   - else:
     - Non_CH nodes wait for broadcast
     - Nodes receive information intensity
     - Nodes receive message to join CH
     - CH receives request message
     - CH sets TDMA schedule
     - Broadcast TDMA schedule
     - CH receives data
     - CH fuses data
     - CH sends data to BS
IV. SIMULATIONS AND PERFORMANCE EVALUATIONS:

A Region of Interest (RoI) covering an area of (150 × 150) m² was used in the simulation, which was run using Matlab 2017a. There is a predictable pattern to the node distribution in the area. A 10% chance of selecting a Cluster Head (CH) is established. Table 1 details the simulation settings used in [34] to compare the efficiency of the proposed protocol with the SEP (Sensor Energy Protocol).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodes</td>
<td>150</td>
</tr>
<tr>
<td>Network Region</td>
<td>(150, 150)</td>
</tr>
<tr>
<td>Position of BS</td>
<td>(150, 75)</td>
</tr>
<tr>
<td>Efs (Free Space Energy)</td>
<td>10 pJ/bit/m²</td>
</tr>
<tr>
<td>Emp (Multi-Path Energy)</td>
<td>0.0013 pJ/bit/m⁴</td>
</tr>
<tr>
<td>Initial Energy (E0)</td>
<td>0.5 J</td>
</tr>
<tr>
<td>Energy for Reception (E_RX)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Energy for Data Aggregation (E_DA)</td>
<td>5 nJ/bit/signal</td>
</tr>
</tbody>
</table>

The initial deployment of nodes on network is shown in Figure 1.

**Figure 1.** WSN area of 150 x 150, with 100 nodes

**Figure 2.** deployment of Normal Nodes and Advanced Nodes for optimized network performance
In Figure 2, the illustration presents the basic implementation of the network. Advanced nodes are depicted in blue, while typical nodes are represented in red. The Base Station (BS) is marked in black and is positioned at coordinates (150, 75) on X and Y axis. Figure 3 visualizes the dead nodes, Figure 4 illustrates the count of packets transmitted to the Cluster Head (CH), Figure 5 shows energy consumption for each round, Figure 6 exhibits the percentage of remaining energy, and Figure shows the death rate percentage in the network.

The proposed I-LEACH protocol outperforms the SEP and LEACH protocol, as evident in Figure 3, where the first node in the proposed protocol lasts for 998 rounds compared to the SEP protocol, where the first node dies at 411 rounds. Moreover, the proposed protocol maintains a higher number of SNs than the SEP and LEACH in terms of Cluster Head (CH) selection, as illustrated in Figure 4. The figure indicates that in the SEP protocol, the number of CH begins to decline after 410 rounds, whereas in the proposed protocol, the decline begins after 1000 rounds.

Figure 3. Number of Dead Nodes in the network

Figure 4. Number of packets to CH

Figure 5 shows less energy consumption by the proposed I-LEACH protocol compared to SEP and LEACH in 1000 rounds.
It can be seen from Figure 6 that the proposed protocol has more average remaining energy than the SEP and LEACH.

In contrast to the SEP, which shows nearly low energy for each SN, Figure 7 shows that the proposed I-LEACH keeps more energy for each node.
Figure 8. Death rate of the network

As seen in Figure 5.8, the survival rate is more compared to SEP and relatively similar to LEACH.

V. CONCLUSIONS

The proposed approach eradicates randomness from the Cluster Head (CH) selection process. The new threshold, composed of distance ratio, and weighted energy which acts as a safeguard against energy-related issues in the sensor network. Utilizing the energy model, the proposed protocol efficiently restricts energy transmission within the network. Additionally, the data fusion method is employed to ensure accurate data acquisition through the energy model trust. Comparing with the SEP and LEACH protocol, the simulation results reveal that the proposed protocol demonstrates increased longevity, stability period, and survival rate. In future CH selection procedures, a fuzzy logic technique will be incorporated, leveraging network energy usage to further enhance system performance.

REFERENCES


