

# Integrated energy-efficient and location-aware routing in wireless sensor networks

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## ABSTRACT

Sensor nodes in wireless sensor networks are commonly distributed randomly across a given landscape, and their placement may be randomized for specific applications, even extending to national deployments. The energy consumption associated with data transmission and reception by the cluster's leader is notably higher compared to other nodes. To address this issue, it is recommended that wireless sensor networks adopt a more energy-efficient routing technique. This proposed technique assumes a spatial separation between different node types. Elevating the threshold enhances the likelihood that nodes with ample remaining power will endure as cluster leaders. Ultimately, a hybrid data transfer strategy is formulated, wherein data is directly exchanged between the base station and cluster heads among the super nodes containing advanced nodes. Most nodes employ a combination of single-hop and multi-hop approaches for data transport, aiming to minimize the power required for transmission between the cluster's control node and the base station. According to simulation results, this proposed method surpasses the stable election protocol (SEP), demonstrating superiority over the improved threshold-sensitive stable election protocol in terms of the operational duration of a wireless sensor network.

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## 1. INTRODUCTION

Two distinct types of wireless sensor networks exist, each presenting its own set of advantages and disadvantages. The first type is the homogeneous wireless sensor network, characterized by sensor hubs featuring identical programming and hardware configurations. On the other hand, the heterogeneous wireless sensor network (HWSN) comprises sensor nodes, each equipped with at least two types of distinctive features. These features encompass computing power, communication protocols, range, transmission speed, function, energy, and various other factors, resulting in a network with diverse characteristics. In wireless sensor networks, the electrical energy for sensors can originate from various sources such as batteries, renewable energy, or perpetual power sources. This introduces the concept of energy heterogeneity within the wireless sensor network. The focus of this research is on investigating the variations in energy resources among sensor nodes in HWSNs [1]–[5].

Since sensors rely on battery power, their capabilities are constrained. Despite the reality that numerous routing methods for HWSNs have previously been recommended for establishing a system through a longer lifetime and low-energy consumption information collecting, numerous investigators remain interested in discovering strategies to improve the lifetime with wireless sensor networks. To choose a cluster

leader, the stable election protocol (SEP) [6] distinguishes between specialized and standard nodes. That is calculated using the percentage of every node’s remaining energy that is used to calculate its weighted election probability for inclusion within a cluster head. The SEP algorithm may function without having complete information about the energy levels in each election cycle. Many different kinds of SEP-based heterogeneous protocols will be developed in the future. Overall zonal-stable election procedure [7]–[9] was a zone-based clustering technique whereby the most advanced nodes were more likely towards elected as the cluster leader. It is not possible to randomly deploy nodes; instead, a cluster of just the most capable nodes is hand-picked. The best cluster head was selected with the usage of a Ridge approach in that ridge technique-based cluster head selection process [10], and the algorithm favors picking leaders from nodes through greater remaining energy. Overall heterogeneous protocol modified stable election protocol (M-SEP) [11] constitutes a clustering-based protocol that takes into account the presence of several transmission types.

By exclusively clustering nodes along the event-to-sink data flow corridor, our event-to-sink guided clustering technique [12] achieves energy effectiveness throughout a sensor organization. That is done to prevent clusters from forming where they aren’t needed and to lessen the number of bounces expected to lessen the number of bounces expected to transfer data in the desired direction. Adding a special energy advanced node protocol into the SEP framework results in the lowest energy adaptive clustering hierarchy [13]–[15]. To balance the energy utilization across the nodes, it employs a hybrid procedure for data transmission. The total number of nearby nodes, alongside the base station’s location and any remaining energy, are taken into account by the process for choosing cluster leaders in the enhanced energy-aware dispersed unequal clustering protocol [16]–[18].

The strategy used here is useful for minimizing clustering overhead since it allows the same clusters to be retained for several iterations. As a means of extending the steady duration of mist-upheld sensor networks while holding energy utilization under wraps, that delay stable election routing algorithm [19]–[21] is carried out. Along these lines, the threshold-sensitive stable election protocol (TSEP) algorithm [22] serves as an enhancement of that SEP procedure. The network’s functionality is enhanced with super nodes via the TSEP method. However, with TSEP, data still uses single-hop transmission to get through the base station (BS). A great deal of electricity would be used up by this path. Section 2 explains the TSEP protocol procedure in depth [23]–[25].

In this research, we develop a new routing protocol over heterogeneous WSN that saves energy and keeps the network’s load evenly distributed by enhancing the TSEP algorithm. By factoring into each node’s remaining energy and it is distance from the base station, the suggested approach raises the bar for selecting the cluster head. The collective leaders further use multi-hop data transfer to prevent eavesdropping and lessen their overall power needs. This enhanced protocol reduces network downtime and improves energy efficiency.

## 2. METHOD

For wireless sensor networks, TSEP is used as a routing method. This algorithm is a two-tiered HWSN method, with standard nodes plus advanced nodes making up the network. There are three types of nodes in the TSEP algorithm used in HWSNs: regular nodes, new nodes, and super nodes. That power supply in the super node is far more powerful than those in the more advanced node plus the regular node. Our TSEP algorithm’s network model is used in the suggested algorithm. The TSEP algorithm contains 2 parts: the initial stage and the information broadcast stage. During initialization, the wireless sensor network’s nodes are spaced out throughout the area in a manner that ensures no two nodes are located near one another or to the base station. Here, the node’s initial energy determines the round selection likelihood of a cluster head. Every node’s potential promotion to cluster leader is calculated utilizing the threshold’s probability formula. In [14], Kashaf offer the following formula as given in (1).

$$T(s) = \begin{cases} \frac{p}{1-p \times r \times \text{mod}(1/p)} & , \text{if } s \in G \\ 0 & , \text{if } s \notin G \end{cases} \tag{1}$$

Wherever r represents the round number, s represents the node. G represents the set of nodes where nobody has been chosen as the head of the cluster yet, and p represents the probability that will ultimately be chosen. The probabilities of every node’s energy level vary. The TSEP method classifies nodes as either “normal,” “advanced,” or “super,” with probabilities that are, in order.

$$P_{nrm} = \frac{P_{opt}}{1 + \alpha \times m + \beta \times br} \times (1 + \beta) \tag{2}$$

$$P_{adv} = \frac{P_{opt}}{1+\alpha \times m + \beta \times b} \times (1 + \beta) \tag{3}$$

$$P_{sup} = \frac{P_{opt}}{1+\alpha \times m + \beta \times b} \times (1 + \beta) \tag{4}$$

Where  $P_{opt}$  represents the optimal probability for every node to develop the cluster’s leader,  $a$  represents the super node’s energy relative to the one of a normal node,  $b$  represents the sophisticated node’s energy relative to the fact that of a normal node,  $m$  represents the fraction of super nodes relative to the all-out number nodes  $n$  via energy higher than the remaining portion of the remaining nodes, and  $b$  represents progressed the fraction of nodes. Through probability  $P_{opt}$ , every node can become the group's leader. A node may only serve as the cluster leader once per  $1/P_{opt}$  iteration. Unselected nodes are shifted to the G, while the process of picking the cluster leader continues in the following iteration.  $P_{opt}$  gives more or less importance to nodes with higher or lower starting energy.  $P_{sup}$ ,  $P_{adv}$ , and  $P_{nrm}$  represent the respective weighted probability of super nodes, progressed nodes, and normal nodes, correspondingly. By substituting (2), (3), and (4) for the likelihood  $p$  in (1), normal nodes progressed nodes, or super nodes receive the corresponding thresholds required to choose the cluster head. An arbitrary number is somewhere in the range of nothing and one is going to be generated by the nodes. To begin, as indicated in Figure 1, the sensing nodes are dispersed throughout three distinct zones. The state of the water inside the fish pond may be monitored with it is help. The standard sensor nodes are set up in a ring around the middle of the pond. At the water’s edge, you’ll find both the advanced and super nodes. Batteries swapping for sensor nodes placed around the pond’s perimeter is a breeze. In addition, if the batteries in each of the sensor nodes start at an identical level, the network may be converted into a heterogeneous wireless sensor network simply by swapping out the nodes located around the pond’s perimeter.

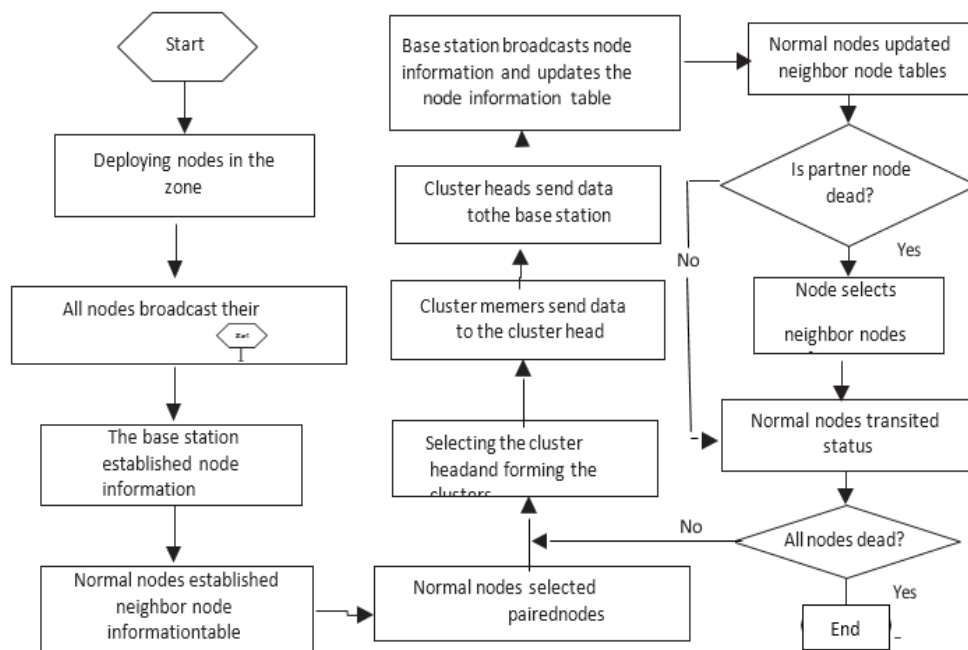


Figure 1. Flow chart of our proposed algorithm

The node in question is selected for the current bunch head if it is irregular number is more modest than the associated threshold; the associated  $T(s)$  is subsequently set to 0 to prevent the node from being elected for a cluster head again. Once a cluster leader has been chosen, the nodes in that cluster will use a nonpersistent carrier-sense multiple access algorithm to send out an advertisement message. Once other nodes have received these notifications, they will evaluate the signal quality of each message and choose the node via the strongest signal as their cluster head. The head of the cluster subsequently creates a time division multiple access (TDMA) time slot schedule table after receiving the demand message from a node that is not the cluster head. The timetable is then sent to the node within the group that isn’t the bunch head to

make that node aware of its existence. Data transmission from the cluster head can happen within a limited window of time and while the cluster has fully formed. The head of the cluster then sends the combined data directly towards the base station throughout the data transmission phase.

**2.1. Proposed methodology**

In this subsection, a more effective method for dealing with the TSEP issue is presented. During setup, we distribute three distinct sources of initial energy over the board. The node having the highest residual energy stands a better chance of being chosen as the cluster head (CH) if the threshold formula is optimized. In Area 2, we employ a node state transition method to regulate the concentration of CHs in densely populated node regions. We use both single hop and multiple hop data transfer to cut down on power consumption during communications between CHs and BS. The particulars of the enhanced procedure are discussed below. Figure 2 energy distribution of 3 distinct nodes.

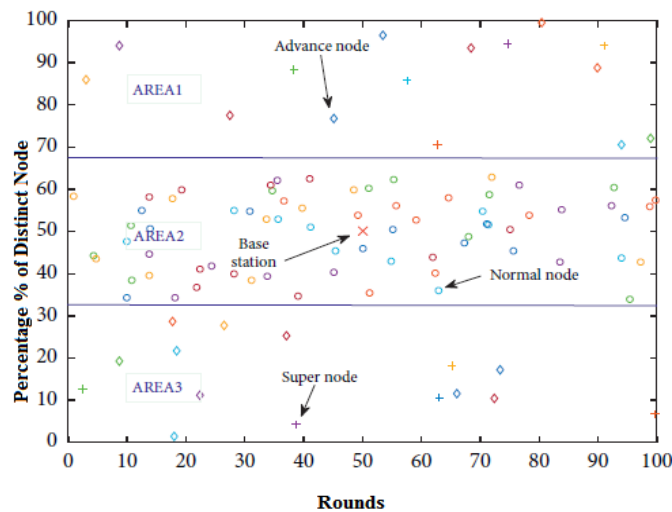


Figure 2. Energy distribution of 3 distinct nodes

**2.2. Setup phase**

The TSEP technique for HWSN uses a completely randomized deployment of nodes. Any node can get chosen as a CH. A CH candidate could be the node with the least amount of remaining energy. As a result, fewer nodes will be able to make it. To send data, a CH that is situated far away from the BS would rapidly drain more energy, as predicted by the radio energy consumption model given in the literature [7]. As a result, the algorithm positions the super nodes and the advanced nodes in a region far away from the BS, while the other nodes are situated in a region near the BS. Following that, Area 1, Area 2, and Area 3 are created by partitioning the square MM into equal-sized sections. The BS may be found in Region 2. When transmitting data via BS, nodes within Area 2 use less power than those in Areas 1 and 3. As a result, Area 2 is randomly distributed with 70 regular nodes, whereas Area 1 and Area 3 each include 5 super nodes and 10 advanced nodes. Figure 1 depicts the widespread nature of these sensor nodes.

After the nodes are assigned, each one in the network sends out a broadcast with data about itself, such as the node’s label, it is remaining energy, and its status. The BS is responsible for receiving messages and maintaining the node information table, which contains data like the node label, and the node’s remaining energy, including the node’s condition. The typical node gets messages from its neighbors and maintains a neighbor node information table such as the labels and states of its neighbors. After the network node has been deployed, this procedure is carried out once and for all. Then, we’ll look at two different approaches to choosing the CH. One approach is used in Areas 1 and 3, whereas a different one is used in Area 2. CH selection is carried out in Areas 1, 2, and 3 using the corresponding equations.

**2.3. Data transmission phase**

Data is going to be sent directly through the cluster’s central node to the network hub using the TSEP algorithm. Longer travel times from the cluster’s head and the base station need more power from the cluster head. The cluster head’s durability is so diminished. We are going to use two different methods of data transfer in our new and enhanced protocol. Data from Area 1 and Area 3 CHs is sent straight through the

BS. However, Area 2 has lower node energy compared to both Area 1 and Area 3. So, to get data into the BS, the CH in Area 2 is going to employ a hybrid of multi-hop and single-hop techniques [21]. Below, we'll break down Area 2's specific way of transmission. The BS determines the ECi-BS for CH i communication throughout the transmission over 1-bit messages straight to the BS based on the node's information table. This equation gives us the value for ECi-BS as given in (5).

$$E_{Ci-BS}(l, d_{Ci-BS}) = \begin{cases} lE_{elec} + l\varepsilon_{mp}d_{Ci-BS}^4 & d_{Ci-BS} \geq d_0 \\ lE_{elec} + l\varepsilon_{fs}d_{Ci-BS}^2 & d_{Ci-BS} < d_0 \end{cases} \quad (5)$$

Where  $E_{elec}$  is the amount of energy needed for a single sensor node to receive or send a single bit of data. In the free-space propagation model and the multipath fading model, accordingly, the energy utilized by a signal amplifier processing 1 bit of data is expressed by the parameters  $\varepsilon_{fs}$  and  $\varepsilon_{mp}$ . The metric for describing how far away the sensor node is from both the starting station was  $d_{CiBS}$ . This for this is mentioned in (6).

$$d_{Ci-BS} = \sqrt{(x_{Ci} - x_{BS})^2 + (Y_{Ci} - Y_{BS})^2} \quad (6)$$

Sensor node  $i$ 's coordinates are given by  $(x_{Ci}, y_{Ci})$ , while the main stations are given by  $(x_{BS}, y_{BS})$ . The value of  $d_0$  is only a cutoff. The equation for this is as follows as given in (7). The ECi-BS may be calculated using (8)-(10) as input. If the requirements in formula (11) may be satisfied, then the head node of cluster  $j$  will function like a sensor node connecting its cluster head node  $i$  and the base station. If the subsequent condition fails to be satisfied, the node  $i$  closest to the cluster's center will bypass the remaining nodes to transmit information to the base station. Distance from cluster  $i$  and cluster  $j$  are denoted as  $d_{Ci-Cj}$ , where  $d_{Cj-BS}$  represents the distance from the starting station and cluster head node  $j$ . The next equation provides an expression for both  $d_{Ci-Cj}$  and  $d_{Cj-BS}$  as shown by (9).

$$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \quad (7)$$

$$E_{Ci-BS}(l, d_{Ci-BS}) \geq E(l, d_{Ci-Cj}) + E(l, d_{Cj-BS}) \quad (8)$$

$$\begin{aligned} d_{Ci-Cj} &= \sqrt{(x_{Ci} - x_{Cj})^2 + (Y_{Ci} - Y_{Cj})^2}, \\ d_{Cj-BS} &= \sqrt{(x_{Cj} - x_{BS})^2 + (Y_{Cj} - Y_{BS})^2} \end{aligned} \quad (9)$$

Using this technique, the cluster head can save power while sending data to the main station. Consequently, the cluster head remains in contact with the base station via the intermediary cluster head, no matter how far away the second one may be. When this occurs, the secondary cluster leader forwards the information to the main cluster leader. The state of the cluster's master node will change after the data transmission is complete. If both the sensor node and its neighbor remain alive, the status quo should be maintained. If one of two sensor nodes within a pair goes offline, the remaining node will remain active and look for a replacement. The BS then broadcasts the updated node information table to every one of the nodes, and each node does the same with its neighbor node information table based on the information it has received. A refers to the end of a round means that it is over.

### 3. RESULTS AND DISCUSSION

#### 3.1. Experiments

The study assumes the existence of 100 nodes in total, with 10% being super nodes, 20% being advanced nodes, with the other 90% being standard nodes. When first created, the advanced nodes have 50% more electrical power than the standard nodes, while the super nodes have 100% more energy. Each super node is assumed to have 1 Joule in energy, while each advanced node and regular node have 0.75 Joules and 0.5 Joules of energy, accordingly, in the experiment. These nodes are dispersed around a 100 m<sup>2</sup> square, with the BS near the middle, as a component of the experiment. Every node's greatest chance of becoming a CH is 0.1. Our suggested approach is similar to the strength of the source TSEP algorithm in that it is dependent upon the SEP algorithm. For this work, we use MATLAB along with a simulation tool to examine how well our proposed approach stacks up against two other popular algorithms, TSEP and SEP. Table 1 lists the necessary experiment parameters.

Table 1. Simulation parameters of the experiment

Parameters	$d_0$	$\epsilon_{fs}$	$\epsilon_{mp}$	$E_{elec}$	$E_{DA}$	$l$
Values	87	10	0.013	50	5	4,000

The proportion of nodes dying in each round is shown in Figure 3. Each node’s residual energies for SEP, TSEP, as well as the proposed algorithm are displayed in Figure 4. The ratio of packets exchanged by the BS and the CHs that occur throughout a certain number of rounds can be observed in Figure 5. The sensing nodes are also all clustered together in one general area. Figure 6 depicts the relative number of terminal nodes in a given region. Figure 7 displays the remaining energies of every node according to SEP, TSEP, and suggested methods. Figure 8 displays the throughputs for the three different approaches.

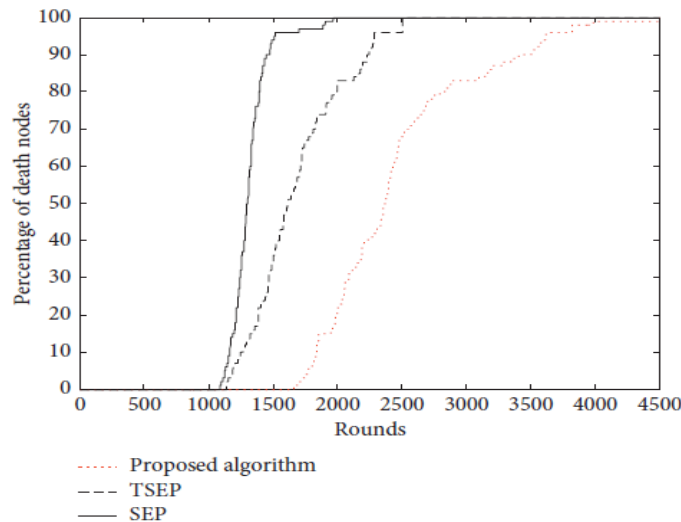


Figure 3. Percentage of death nodes with tree zones

### 3.2. Results analysis

As shown in Figure 3, nodes utilizing SEP and TSEP begin to die after approximately 1,200 rounds. Whereas using the suggested technique, nodes begin to die at around 1,700 rounds. At 2,000, 2,500, and 4,500 rounds, respectively, when utilizing SEP, TSEP, and our solution, all of the nodes died.

The new approach, if you will. At 2,500 rounds, the strategy suggested still has around 30 functioning nodes. Figure 4 shows that, although the leftover energy falls as the number of rounds increases for all techniques, it is higher for the suggested method. This progress was made possible by revamping the CH selection and routing system. Nodes with high residual energy benefit more from a raised threshold.

Chance of evolving into CHs to save low-energy nodes from dying via overheating. While the CH sends data through the BS directly in SEP and TSEP, the suggested approach uses both a single hop as well as multiple hops to reduce energy consumption. This demonstrates that the suggested approach helps the network function for a longer period. Since the proposed method increases the network’s lifetime if more nodes survive, it follows that more CHs will ultimately be chosen. The second area’s state transition mechanism may be effective.

Redundancy issues, and data inconsistencies between TSEP and SEP. Since just the cluster head communicates with the base station, SEP and TSEP have a lower throughput compared to our suggested approach, as shown in Figure 5. Data from regular sensor nodes goes directly to the central station according to our suggested technique, whereas data from super and advanced sensor nodes, which have greater available power, is relayed to its base station through the cluster head. The suggested approach also outlasts competing approaches in terms of network uptime. It takes more time to send data. Figure 6 shows that nodes begin to die at about 1,300 rounds when employing SEP, 14,000 rounds while using TSEP, and 1,800 rounds when utilizing our suggested technique. Furthermore, the nodes entirely died at around 3,000 rounds when employing SEP, 4,000 rounds while using TSEP, and 5,000 rounds while employing our proposed method. Figure 7 displays the remaining energies of every node according to SEP, TSEP, and suggested methods. Figure 8 displays the throughputs for the three different approaches.

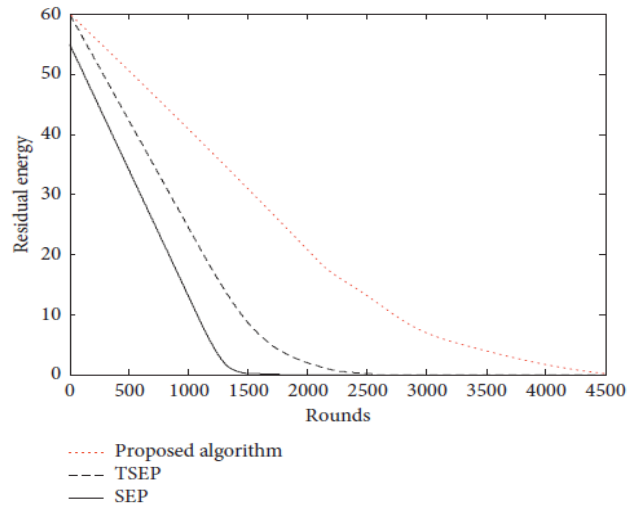


Figure 4. Residual energy with tree zones

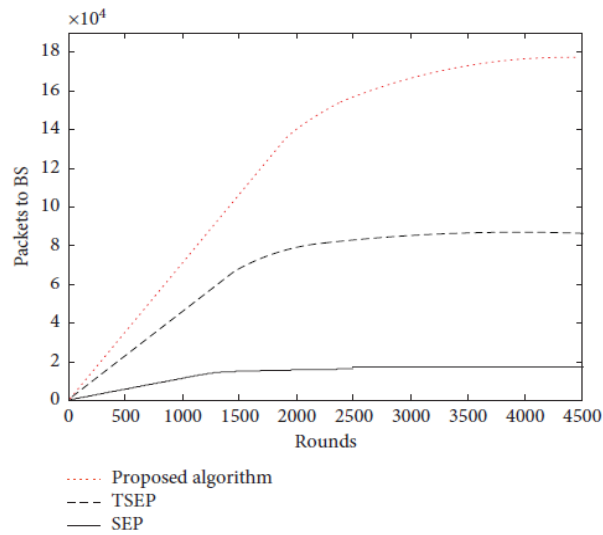


Figure 5. Throughput with tree zones

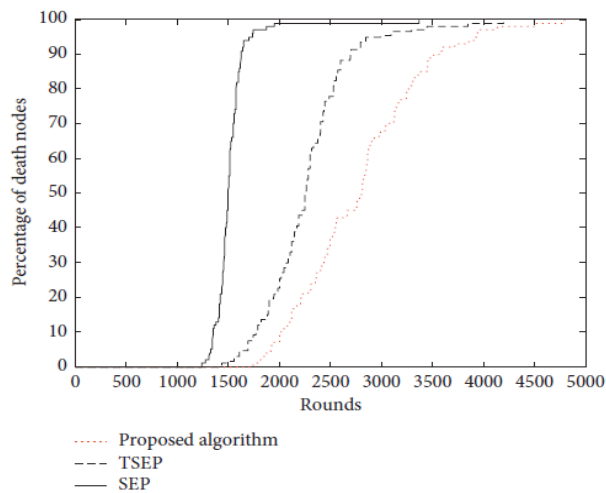


Figure 6. The percentage of death nodes with a single zone

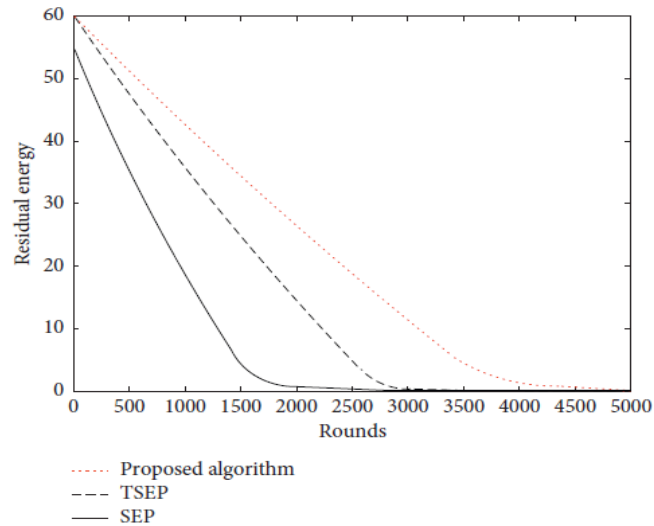


Figure 7. Residual energy with a single zone

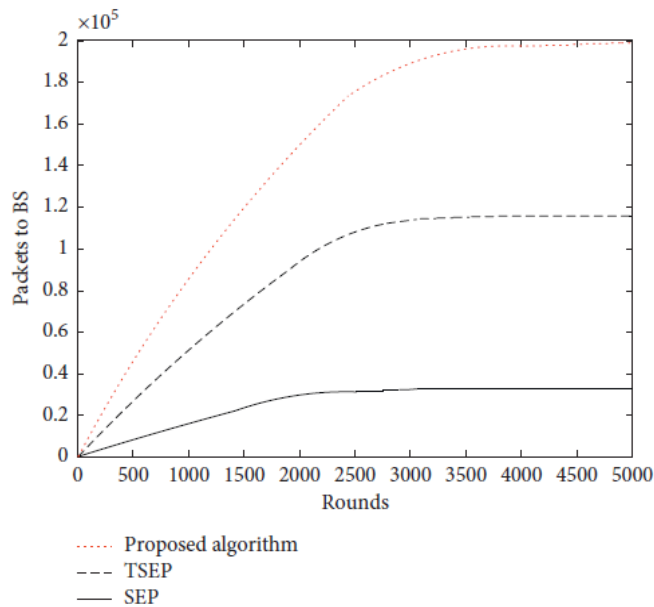


Figure 8. Throughput with a single zone

Here, we see the regarding 2,000 rounds are required for SEP, 3,000 for TSEP, and 4,500 over our proposed method to achieve zero residual energies. Figure 8 shows that not only does the suggested approach have a higher lifespan than all of the other ways, but it also has a higher packet count. These outcomes indicate that the proposed technique outperforms the baseline for both tree- and single-zone distributions of sensor nodes, thereby extending the lifetime of the network.

#### 4. CONCLUSIONS

An enhanced technique for lowering energy usage and increasing network lifespan across 3 energy levels in HWSN was recently developed. To facilitate the deployment of super nodes, enhanced nodes, and regular nodes, we partitioned the sensing area across three distinct zones. Setup-time threshold tuning selects nodes with elevated leftover energy, addressing the issue of poor CH selection. Area 2, employs a node state transition method to regulate the concentration of CHs. To save as much power as possible during the data communication phase, it chooses the way that uses the least amount of power as the best routing path. The suggested strategy increases network durability compared to other approaches. We assumed in the suggested



strategy that a typical sensor node would transmit data directly to the starting station. Network lifespan is affected by factors such as the number of typical nodes and the magnitude of the surrounding zone. Moreover, the proposed approach added time complexity, which will impact the network's real-time performance. Using multi-hop transmission and data packets creates a hotspot issue, which is disregarded by the -e method. The feature needs further investigation into the data loss issue and time complexity. While it is assumed in this paper that electronic sensor nodes are unable to be relocated, investigating methods for increasing the longevity of sensor nodes that may be relocated is an important topic in its own right.

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