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Energy-Efficient Rotating Clustering with Load Balancing for Heterogeneous Wireless Sensor networks

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Abstract

Clustering is a common method for prolonging a wireless sensor network lifetime. We can achieve higher energy efficiency by implementing multi-hop communication. Because of the induced load on the middle clusters, they die faster in comparison to the clusters on the borders. There is an efficient protocol for Rotating Energy-Efficient Clustering (REECHD). In this article, we introduced a load-balancing technique for the REECHD protocol to solve the energy hole issue. Initially, the base station calculates a maximum and minimum cluster range based on node density. We calculate the cluster range for each layer. The final values for these cluster ranges are then used as inputs in the REECHD protocol. The energy efficiency of this technique is compared with the REECHD protocol. The results show that our proposed technique enhances the REECHD in the matter of the first node dies (FND) and half node dies (HND) measure criteria (respectively 15% and 11.5% for 250 nodes) and also it prolongs the network lifespan by balancing the load on inter-cluster communications.

Keywords: clustering, load balancing, energy efficiency, network lifetime, wireless sensor network

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1- Introduction

To gather data from a physical environment we can use a network of sensors that are connected wirelessly. These networks can gather a great amount of data, and they can have heterogeneous properties including processing power, ram, and transmission power. Dividing a network into clusters is a technique that extends a sensor network lifespan and optimizes its' productivity. Clustering splits up a network into sensor groups called clusters. A leader is assigned to each sensor group which is called a cluster head (CH). A sensor group leader collects packets of information from its member nodes, this is called intra-cluster transmission. Clustering proved that it can enhance the sensor network lifespan by gathering data, decreasing communication burden, and arranging routing paths in an efficient way [1, 2].

The energy of these sensors is provided by batteries, aggregating data from them is an important and challenging research field [1]. Typically, due to their deployment in remote or inaccessible regions, it is frequently impractical to exchange or recharge the batteries of these networks. In a conclusion, transmitting information packets from the sensing groups to the base station using a technique that saves their battery power is essential.

A great number of research articles are about reducing the usage of battery power in wireless sensor networks [1-6]. CHs may have the capacity to transmit the collected information packets straight to the sink, as a second option, they can cooperate to send out their data packets to the BS which is called a multi-hop transmission. Transmitting data by utilizing single-hop mode is not energy efficient as further nodes from BS need to use more energy to send their data [1]. On the other hand, multi-hop limits transmission radius to neighboring clusters. However multi-hop communication can cause an induced load on middle clusters that are near the BS as they are imposed to relay other clusters' packets to the BS, as a result, these clusters consume their battery power faster in comparison to other clusters. So, to balance the consumption of energy across the network we need to come up with a load-balancing solution.

In this paper, we introduce a load-balancing technique. The proposed method estimated the cluster ranges formulated on their distance to the sink. Rest of the paper is organized as follows. Section 2 describes the related works and Section 3 describes proposed method. In Section 4 we provide simulation result. Finally, In Section 5 conclusion of the paper is presented.

2- Related work

Many research articles have been published about clustering techniques. In this segment, we review several clustering techniques that are designed to enhance homogeneous and heterogeneous network productivity. While examining every one of these protocols, we consider if they have properties like equal-size or unequal-size clusters, also study their rotating or non-rotating CH role techniques, and we examine their usage of single-hop or multi-hop transmission mechanisms.

2-1- Clustering techniques for homogeneous devices

In the article [3], researchers presented LEACH. This protocol is one of the first articles that proposed the clustering technique for WSNs. To execute the clustering procedure, it considers the node remaining energy. LEACH uses probability for the election of CHs and their member nodes. All clusters use single-hop mode to send out their data to BS and multi-hop data transmission never happens. When this algorithm selects a sensor node as a CH, it may nominate the same node in the next CH election phase. LEACH also introduces a CH rotation technique.

In article [4] authors create equal-sized clusters using HEED. The HEED algorithm has two stages: the clustering and the network stage. The clustering selects CHs according to their remaining energy and other nodes connect to the nearest CH. Through the network stage, BS receives the gathered data from CHs using the multi-hop communication mode. The clustering and network stages repeat each round. This protocol prevents the selection of two CHs if they are along the same communication range. In this method nodes that are closer to BS consume their battery power much quicker in comparison to other nodes. This problem happens because of a higher burden on nodes that are near BS which are forced to relay other clusters' data.

In the article [5], the authors presented DWEHC which is a clustering algorithm that creates equal-sized clusters. This protocol uses multi-hop communication for its' inter-cluster communications. Every sensor node performs DWEHC by itself to determine if they are going to act as a CH or a member node. In this protocol, the clustering phase is based on HEED. As the result showed the placement of clusters is balanced and it improved the network lifespan.

There are a lot of articles in the unequal clustering field that proposed an unequal-sized clustering solution to enhance the wireless sensor networks' energy consumption rate.

In an article [6], researchers introduced EEUC which is one of the pioneer algorithms in this field. In EEUC cluster size increases by going further from BS while the area close to BS has to be populated with smaller size clusters. This method decreased the induced work on CHs that are near the BS and it reduced the hotspot problem.

In reference [7], the UHEED protocol introduced an unequal clustering approach. UHEED uses the EEUC idea to reform HEED such that it creates unequal-sized clusters. In UHEED the size of clusters depends on their distance from BS; the further away clusters are from the BS the bigger their conflict range gets. UHEED decreases the hotspot issue and enhances the network lifespan.

In an article [8], researchers introduced a rotating unequal form of HEED (RUHEED). This method reduced the hotspot issue and enhanced the lifespan of the HEED. This procedure has these stages: CH election, cluster arrangement, and cluster rotation. HEED perform CH election according to nodes remaining energy and their communication cost. During the rotation step, the CHs nominate the next CHs according to their remaining battery power. This technique prevents the execution of the CH election. As the result this technique prolongs the network lifetime. CH election only happens if a node consumes its battery power completely. RUHEED reduces battery power usage and lessens the CH election operations.

In an article [9], researchers proposed an ERHEED that enhanced the efficiency of HEED using a technique that rotates leader duty within a sensor group. This protocol has three phases that include: CH selection, cluster arrangement using HEED, and CH rotation. During the clustering phase, similar to RUHEED, the CHs nominate the next CHs according to their remaining battery power. This schema reduced the quantity of cluster election phases. The Cluster election phase which is based on the HEED algorithm only happens if any node depletes its' energy completely. The performance of the ERHEED protocol is much higher than UHEED, HEED, and RUHEED algorithms concerning the first node die measure criteria.

2-2- Clustering techniques for heterogeneous devices

WSNs can have nodes with different properties including energy volume, data rate, communication radius, data collection efficiency, and computational capacities. This diversity influences network lifespan and also reduces network latency [10]. In this segment, we focus on different protocols that are proposed for heterogeneous WSNs. Clustering protocols may have various concepts about the diversity of the network properties.

In an article [1], researchers proposed a load-balanced distributed clustering protocol (DBLC). In this protocol, the range of clusters is important to achieve efficiency in the usage of battery power, also balancing the load on multi-hop data transmissions is important. This algorithm can produce a load-balanced set of clusters. This is achieved by using a different-sized cluster at each level.

In an article [11], researchers proposed DEEC. This technique creates equal-sized clusters. This protocol calculates the percentage of the node's unconsumed battery power to the median of the sensors' overall battery power and uses it as a probability function for CH selection. In this protocol, the CH role rotates within the cluster based on nodes' remaining energy this technique makes sure that the energy consumption is balanced across the sensors. Nodes that contain the most battery power are more likely to get selected as a CH. BS sends out the median of sensors' overall power to the entire network.

In an article [12], researchers proposed a load-balanced distributed clustering protocol (DEBC). Nodes with diverse energy volumes are one of DEBC assumptions. Nodes' unconsumed battery power is used for CH selection. Nodes that contain the most battery power have the highest probability to get selected as a CH. DEBC verifies its supremacy in comparison to SEP and LEACH by examining them in a simulation environment.

In an article [13], researchers proposed a distributed clustering protocol with a CH selection method for heterogeneous devices. A weighted probability is being used for CH election. This protocol assumes three different nodes and they have different thresholds. The weight that has been assumed for each node decides the CH selection.

In an article [14], researchers proposed an energy-efficient clustering algorithm (EEHC) that has been designed for heterogeneous devices. In EEHC some nodes have a different level of the battery volume. EEHC focus on network reliability and performance. EEHC uses nodes' remaining energy for CH selection like DEBC and DEEC.

In an article [15], researchers presented SEP. This algorithm extends the network lifespan concerning the first node dies measure criteria. SEP suggests two independent nodes which are called normal and advanced nodes. SEP uses nodes' remaining energy and starting energy for CH selection. Simulation results prove that SEP increases network lifespan and the average output of the network.

In an article [16], researchers proposed an unequal clustering protocol with a feedback mechanism (FMUC) for heterogeneous devices. The purpose of the FMUC is to avoid the hotspot issue. In the beginning, FMUC divides the sensors into several groups. This protocol balances the usage of battery power and the overall starting energy of the network by using a mathematical model. It sets every cluster to a layer and it uses the layer consumption rate to determine the size of each layer. The sink receives cluster range values from CHs and broadcasts these values back to the network. Every node gets this data however only CHs determine their bounds based on them.

In an article [17], researchers presented REECHD which has been designed for heterogeneous devices. REECHD proposed a schema to limit the intra-traffic communication rate and also introduced a CH selection probability function. In this research, REECHD has been compared with multiple clustering algorithms. This contrast has been made by simulating different algorithms using common assumptions and case studies. Simulation results show that REECHD is more successful in the reduction of battery power usage in comparison to homogeneous clustering protocols including UHEED, HEED, and ERHEED, and heterogeneous clustering protocols including DEBUC, EEUC, and FMUC.

In an article [18], researchers introduced an unequal-sized energy-aware clustering algorithm (EAUCA) that investigates the hotspot issue and focuses on enhancing network lifespan using unequal clustering. In this research unequal clustering has been done by calculating candidate CH's competition range according to their unconsumed battery power and distance to the sink. EAUCA also uses node degree to select its CHs. Every sensor node joins CHs which needs minimum required energy to transmit data to it. EAUCA also proposes a routing technique linking CHs and BS that enhances the sensor's battery power usage. Relay nodes are elected according to their remaining energy, their distance to BS, and their degree.

In an article [19], researchers introduced an energy-efficient CH election. Cluster election executes with attention to parameters like (distance to BS, distance between nodes, energy, and CH probability). CH election determines network performance as CH has an important role in clustering protocols.

In an article [20], researchers proposed a heterogeneous clustering protocol to improve the network lifespan. In this protocol, a heterogeneous model has been used which nodes have different initial energy at the beginning. These energy levels are set to nodes based on their application. This protocol categorizes nodes into normal and power nodes. Power nodes have extra energy. The proposed scheme selects a node as the CH that enhances network lifetime. This protocol uses a probability function to select CHs in different operative rounds. CH election is performed by using overall energy, starting energy, and remaining energy.

In an article [21], researchers proposed a three-level heterogeneous clustering algorithm for WSNs. This protocol categorizes the nodes into (normal, middle, and super) according to their energy. It uses nodes' energy for the CH election. This algorithm performs the CH election by randomly selecting a digit inside the 0 and 1 range and comparing it with a threshold number. If a node fulfills the threshold norms, it will be selected as a CH. All nodes have the chance to get selected as the CH. All nodes cooperate to improve the network lifespan.

In an article [22], researchers proposed an entropy-based clustering algorithm (EBCS). To execute clustering, it uses entropy to examine the local node data. This protocol uses nodes with three-level energy for the clustering process. Also, it uses specifications including, distance to the base of the sink, remaining energy, and node closeness for CH election. Also, an entropy weight and weight model are being used for the Ch election. Nodes that contain more battery power and have less distance to the sink, and more neighbors are more probable to get elected as a CH. CH sends a statement packet to other nodes and they bind to the CH with the least data transmission cost according to the obtained message signal power.

In an article [23], researchers proposed an adaptive clustering technique (ACDH). This technique is introduced for WSNs that have dynamic diverse properties. It examines variable energy diversity and the variable quantity of clusters and uses them to reconfigure the sensor network and it adapts to the topology changes as the result. Also, this algorithm uses the median of the sensors' overall battery power, the unconsumed battery power of the nodes, and their starting energy of them to select the CHs. In this method, each node selects itself as the CH individually. Results prove that ACDH extends the network lifespan. This algorithm can be used for networks including constant monitoring and network monitoring applications that need high accuracy.

In [24], researchers introduced an energy-efficient and dependable clustering protocol (ERCP) for WSNs. Initially, they put forward an effective clustering method aimed at conserving sensor nodes' energy, which takes into account various clustering parameters such as link quality metric, energy levels, distance to neighboring nodes, distance to the sink node, and cluster load metric.

In reference [25], an Energy-Efficient Hybrid Clustering Technique (EEHCT) has been presented. This technique aims to minimize energy consumption during cluster formation and ensure even distribution of network load, regardless of heterogeneity level, thus extending the network's lifetime. Through the effective use of both dynamic and static clustering strategies, EEHCT endeavors to create load-balanced clusters within the network. Its superior performance compared to existing methods has been substantiated through a comprehensive set of simulations and experimental evaluations across various network performance metrics such as stability, throughput, and network lifetime.

In this article, we introduced a load-balancing technique for the REECHD [17] protocol. So the focus of our research revolves around energy-efficient clustering for heterogeneous devices with a rotating approach.

3- Proposed method

3-1- Network model and assumptions

Consider a WSN composed of distributed sensors across the network. These are the properties of this sensor network model:

- Nodes are static in the sensor network. This is a common assumption for WSNs [26].
- Nodes are distributed uniformly across the wireless sensor network.
- Nodes estimate their distance to BS using ultrasound [27].
- Network area is a rectangular NxM shape.

3-2- Load balancing

This article intends to enhance the battery power usage of the nodes by balancing the load on inter-cluster communications in the REECHD algorithm. The main idea is to decrease the size of clusters while getting near the sink. First, BS decides the highest (R_{max}) and lowest (R_{min}) radius of clusters according to the node closeness, node radius limitation, and the environmental limits of the network. R_{max} and R_{min} are the key values that are affecting the energy consumption and performance of the clustering mechanism [1]. Clusters with R_{max} are the furthest cluster layer of the network. This range can be changed based on the width of the network.

$$\frac{M}{R_{max}} = k \tag{1}$$

The sensor network width is presented by 'M' and the quantity of first-layer clusters is presented by 'k'. R_{max} can be changed to a degree to transform k into an integer number. The radius of the next clusters can be calculated by the following method:

$$R_{max} - R_{min} = R_{max-1} \tag{2}$$

First BS calculates the energy consumption of CH with the R_{max} range to transmit its data to CH with R_{max-1}, this action balances the load on inter-cluster communications and also estimates the range of the next layer clusters.

$$E(R_{max} + R_{max-1}) = l_{R_{max}}(E_{elec} + E_{amp}(R_{max} + R_{max-1})^2) \quad (3)$$

Where $E_{elec}l$ = 50 nJ/bit, $E_{amp}l$ = 100pJ/bit/m^2,l is packet size and R_{max}+R_{max-1} is the distance between CHs. It considers that the CHs are in the middle of the clusters and CHs transmit their data directly to the next CH. By using the next equation, we can calculate the volume of packet l_{rmax}:

$$L_{R_{max}} = \frac{(\lambda \times a \times (R_{max})^2 \times \pi \times n)}{(N \times M)^2} \quad (4)$$

The data of a sensor node is shown by 'a' and it is common in every node and aggregation coefficient is shown by 'λ', $((R_{max})^2 \times \pi \times n) / (N \times M)^2$ is the number of nodes in R_{max} CH, and 'n' is presenting the quantity of the nodes in the network.

The amount of energy that is being consumed by CH_{Rmax} for transmitting data to CH_{max-1} is utilized to discover R_{max-2} such that the load on CH_{Rmax-1} is balanced:

$$\begin{aligned} &\left(l_{R_{max}} + l_{R_{max-1}}\right) \times \left(E_{elec} + E_{amp} \times (R_{max} + R_{max-1})^2\right) \\ &\qquad + E_{rec} \times l_{R_{max}} \leq E(R_{max} + R_{max-1}) \\ &R_{min} \leq R_{max-2} \end{aligned} \quad (5)$$

This inequality in (5) explains the energy consumption of CH_{Rmax-1} to receive data from CH_{Rmax} and send all the data to R_{max-2} distance that is next layer clusters. By solving the inequality in (5) we can determine each layer cluster range until $R_{min} \leq R_{max-n}$. Then we can use R_{min} for the closest nodes to BS if it's needed.

Before initiating the clustering procedure, BS sends the "hello" packet to every node [28] and the nodes use the received signal power to calculate their distance to the BS. The second step is to send Forn_Mes which includes the Ex_Dist and the estimated distance App_Dist which is the distance of BS to candidate CHs.

3-3- REECHD

The REECHD algorithm forms clusters of equal size and employs a rotating method to reduce the number of CH election phases. Rotation is a method that improves the battery power usage of the nodes and increases the network lifespan [17].

REECHD consists of these phases:

- CH election: By using a probability provided in [17] a node is selected as a CH.
- Cluster formation: Nodes try to connect to a CH with minimum cost. If CH reaches its' intra-traffic rate limit, it can deny the join requests.
- Cluster iteration: When a node gets an unjoin signal from all accessible CHs, it repeats the CH election and cluster formation stage. The node selects itself as CH after these phases repeat a constant number of times. This method makes sure that the number of CH selections is O (1).
- Rotation phase: CHs select the following CHs by using a probability equivalence. To be more precise, current CHs compute the CH_{prob} of all their member nodes, and nodes with the largest CH_{prob} get selected as the next CH. As a result, the next CHs get selected aside from performing the CH election phase.
- Operation phase: In this step, CHs gather information packets from their member nodes and send them to the sink.

CH election, formation, and cluster iteration perform initially and also when a node consumes its battery power completely. Rotation and operation phases perform as an alternative when no node dies.

3-4- REECHD with load balancing

Figure 1 depicts the proposed method. The suggested procedure has two phases: “Load balancing” and “REECHD”.

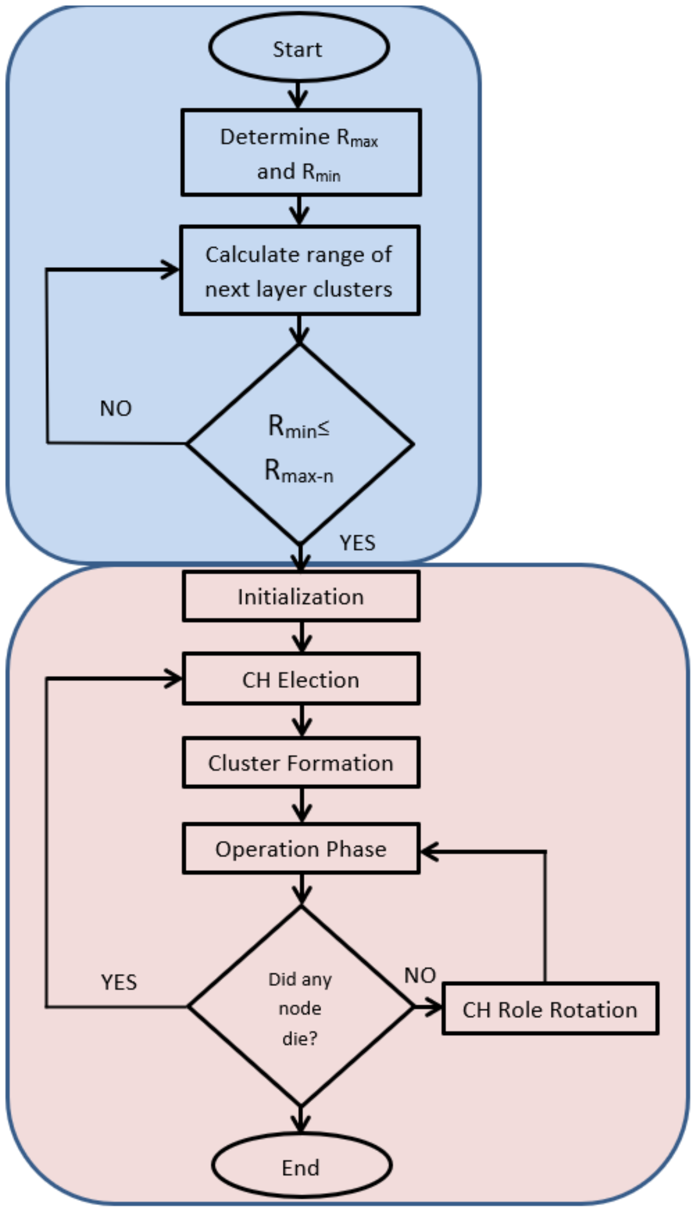

Figure 1: Flowchart of the proposed method

4- Simulation result

This segment describes the simulation results of the proposed method and compares them with the REECHD [17] algorithm. These results are achieved by simulating both the proposed and REECHD algorithm in the MATLAB environment.

4-1- Simulation parameters

Table 1 displays the simulation parameters utilized in this research.

Table 1: Network parameters

Parameter	**Value**
Network area	100 × 100
Base station	50,150
Number of nodes	50,100,200,250
Data packet	4000 bits
E_{elec}	50nJ/bit
Initial energy of a node	2J
E_{amp}	0.1nJ/bit/m^2
E_{DA}	5nJ/bit

4-2- Simulation parameters

Figure 2 presents the total alive nodes according to the operational rounds. Figure 2A depicts the 50-node schema in which the first node dies at round 1340 in the proposed method, whereas the first node dies at round 960 using REECHD. Also, half nodes die after 1875 operational rounds in the proposed method, whereas half nodes die after 1625 operational rounds in terms of REECHD. This result shows that our proposed method increased the network lifespan by 28% concerning the first node dies measure criteria and it increased the network lifetime by 13% concerning half nodes dies measure criteria.

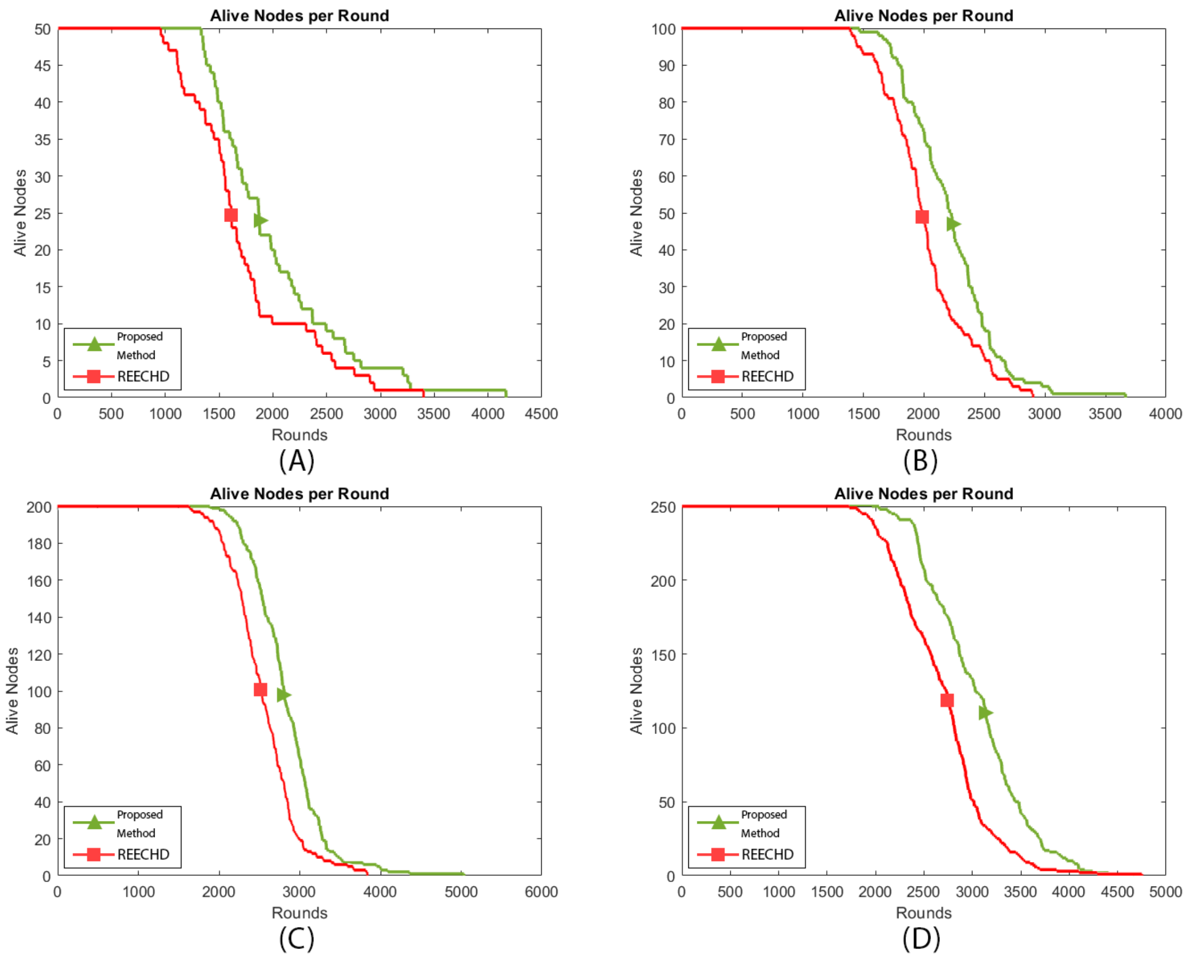

FIGURE 2: Number of alive nodes in the sensor network concerning operational rounds. For A (50 nodes), B (100 nodes), C (200 nodes), and D (250 nodes) schemas

Figure 2B depicts the 100-node schema in which the first node dies at round 1475 using the proposed method, whereas the first node dies at round 1400 using REECHD. Also, half nodes die after 2240 operational rounds in the proposed method, whereas half nodes die after the 2010 operational rounds in terms of REECHD. This result shows that our proposed method increased the network lifespan by 5% concerning the first node dies measure criteria and it increased the network lifetime by 10% concerning half nodes dies measure criteria. Figure 2C depicts the 200-node schema in which the first node dies at round 1900 using the proposed method, whereas the first node dies at round 1645 using REECHD. Also, half nodes die after 2820 operational rounds in the proposed method, whereas half nodes die after 2545 operational rounds in terms of REECHD. This result shows that our proposed method increased the network lifetime by 13.5% concerning the first node dies measure criteria and it increased the network lifetime by 10% concerning half nodes dies measure criteria. Figure 2D depicts the 250-node schema in which the first node dies at round 2045 using the proposed method, whereas the first node dies at round 1740 using REECHD. Also, half nodes die after 3130 operational rounds in the proposed method, whereas half nodes die after 2770 operational rounds in terms of REECHD. This result shows that our proposed method increased the network lifespan by 15% concerning the first node dies measure criteria and it increased the network lifespan by 11.5% concerning half nodes dies measure criteria.

4-3- Number of dead nodes concerning operational rounds

Figure 3 depicts the unreliability of the network as the network operation progress and the number of dead nodes adds up. Our proposed method indicates a notable resistance to the death of nodes. Figure 3A depicts the 50 nodes schema in which 78% of nodes are dead using the REECHD algorithm at around 2000. In the same round, 60% of nodes are dead using the proposed method. Figure 3B depicts the 100 nodes schema in which 50% of nodes are dead the using REECHD algorithm at round 2000. In the same round, 30% of nodes are dead using the proposed method. Figure 3C depicts the 200 nodes schema in which 50% of nodes are dead using the REECHD algorithm at round 2500. In the same round, 20% of nodes are dead using the proposed method. Figure 3D depicts the 250 nodes which 36% are dead using the REECHD algorithm at round 2000. In the same round, 20% of nodes are dead using the proposed method. The results that are achieved by this simulation prove that the proposed method is more resistant to the death of nodes and more reliable compared with the REECHD protocol.

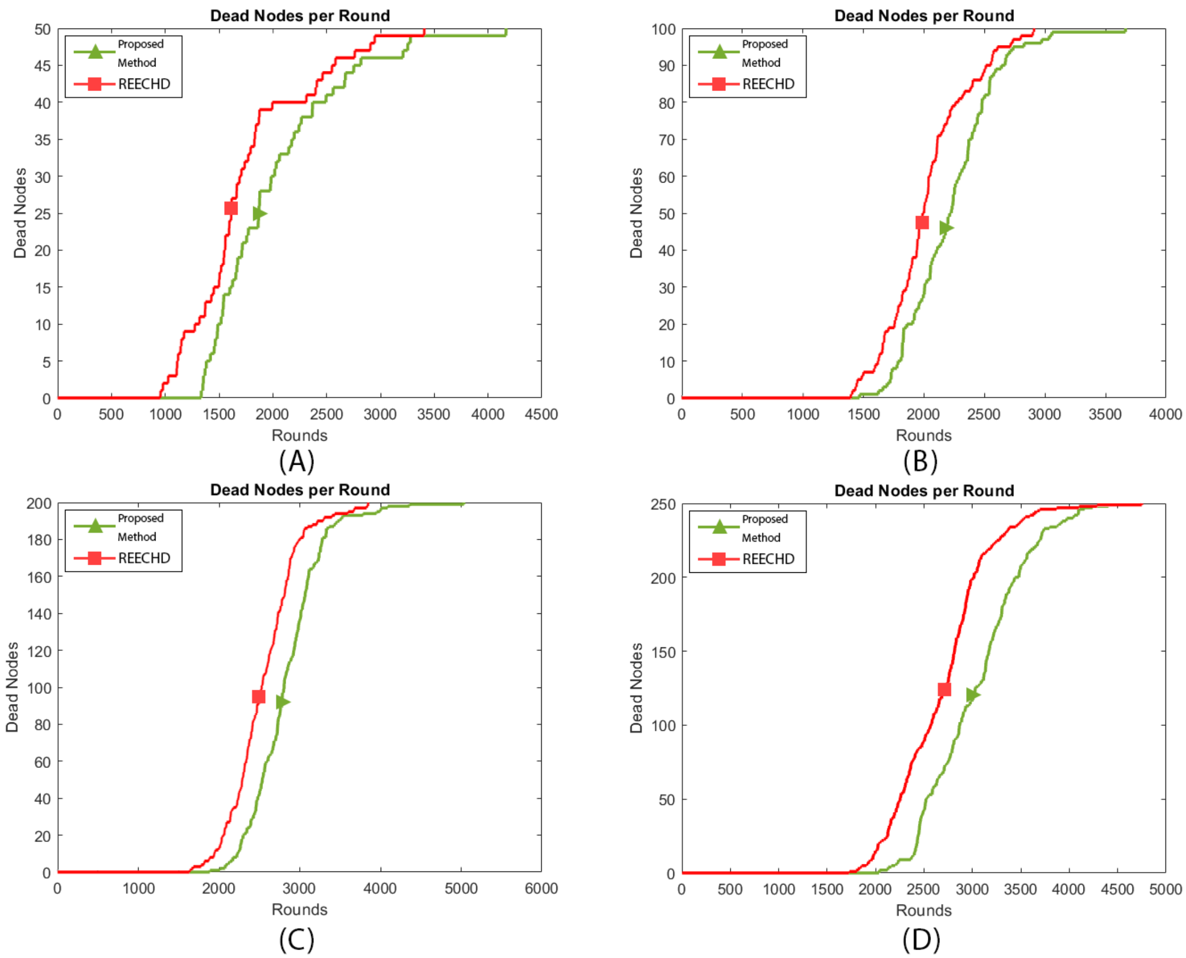

FIGURE 3: Number of dead nodes in the sensor network concerning operational rounds. For A (50 nodes), B (100 nodes), C (200 nodes), and D (250 nodes) schemas

4-4- Residual energy of the network concerning operational rounds

Figure 4 presents the contrast of the overall unconsumed battery power of the network respecting the operational rounds. In figure 4, the vertical axis shows the entire residual battery power of the network in terms of 50-, 100-, 200-, and 250-node schemas. Figure 4A depicts the 50 nodes schema which at round 1500, 8% of the total network battery power remains using REECHD. In the same round, 22% of the total network battery power remains in the proposed method. Figure 4B depicts the 100 nodes schema which at round 1500, 10% of the total network battery power remains using REECHD. In the same round, 30% of the total network battery power remains in the proposed method. Figure 4C depicts the 200 nodes schema which at round 2000, 20% of the total network battery power remains using REECHD. In the same round, 28% of the total network battery power remains in the proposed method. Figure 4D depicts 250 nodes schema which at round 2000, 23% of the total network battery power remains using REECHD. In the same round, 33% of the total network battery power remains in the proposed method. In conclusion, the proposed method reduced the battery power usage of the nodes and increased the network lifespan.

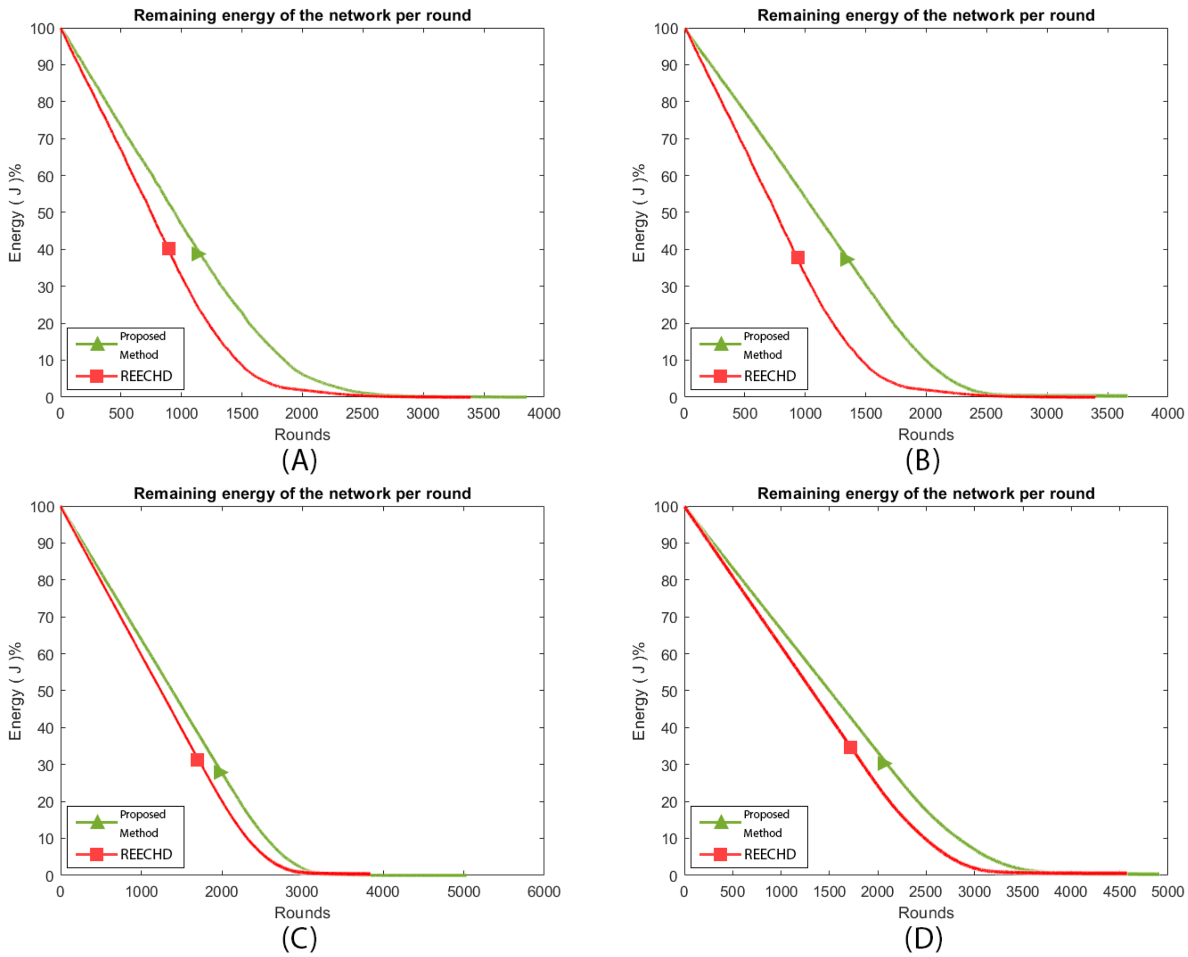

FIGURE 4: Residual energy of the network concerning operational rounds. For A (50 nodes), B (100 nodes), C (200 nodes), and D (250 nodes) schemas

4-5- Energy consumption of the network concerning operational rounds

Figure 5 represents the battery power usage of the network concerning operational rounds. It proves that the proposed method consumes less energy in comparison to REECHD. Figure 5A depicts the 50 nodes schema which at round 1500, 92% of the sensor network battery power is consumed using REECHD. In the same round, only 78% of the starting battery power is drained using the proposed method. Figure 5B depicts the 100 nodes schema which at round 1500, 90% of the sensor network battery power is consumed using REECHD. In the same round, only 70% of the starting battery power is drained using the proposed method. Figure 5C depicts 200 nodes schema in which at round 2000, 80% of the sensor network battery power is consumed using REECHD. In the same round, only 72% of the starting battery power is drained using the proposed method. Figure 5D depicts 250 nodes schema which at round 2000, 77% of the sensor network energy is consumed using REECHD. In the same round, only 67% of the starting energy is drained using the proposed method.

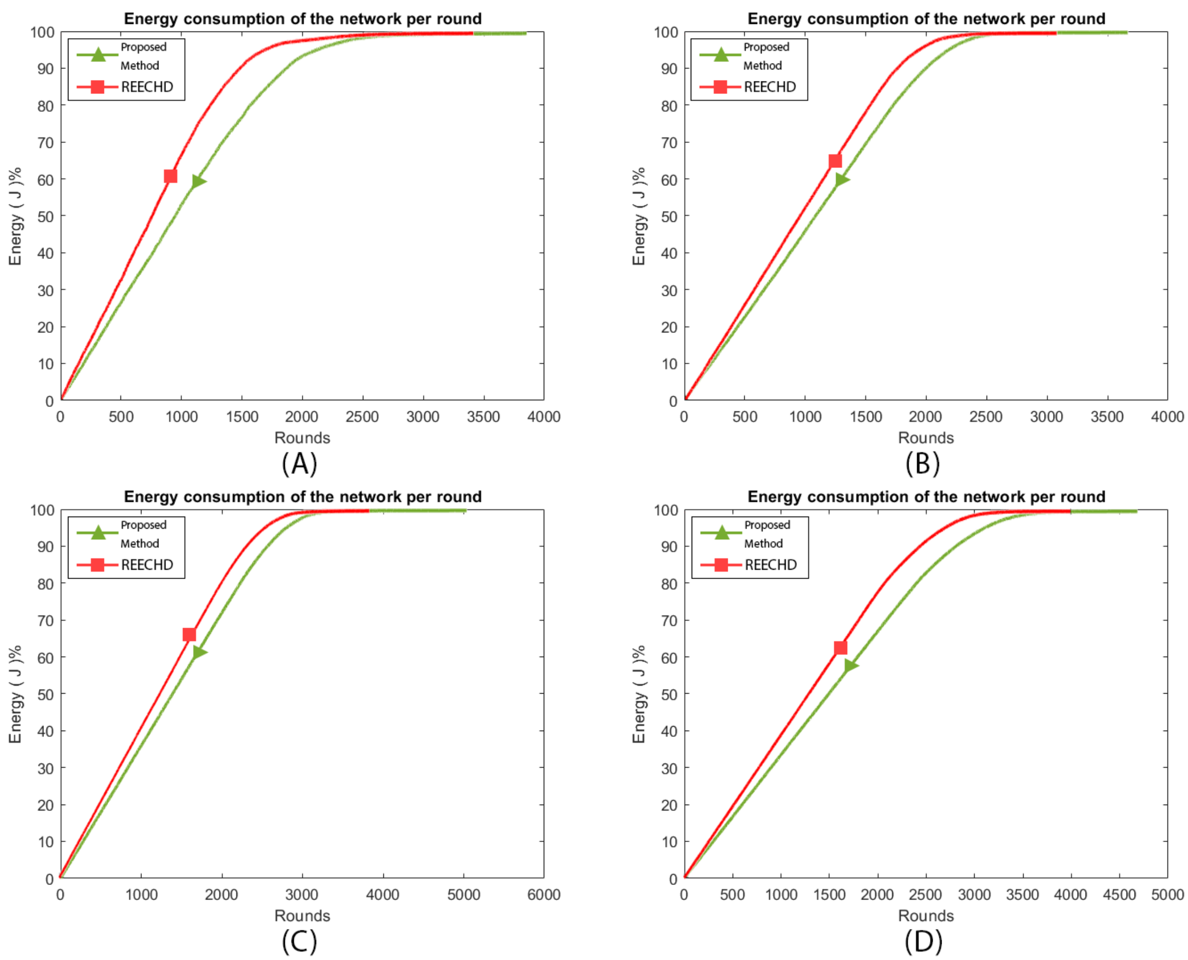

FIGURE 5: Energy consumption of the network concerning operational rounds. For A (50 nodes), B (100 nodes), C (200 nodes), and D (250 nodes) schemas

Our research findings are as follows:

- Enhancing network lifetime by 28%, 5%, 13.5%, and 15% for 50-,100-,200-, and 250-node schemas, respectively, in the matter of the first node dies measure criteria, in comparison to REECHD.

- Enhancing network lifetime by 13%, 10%, 10%, and 11.5% for 50-,100-,200-, and 250-node schemas, respectively, in the matter of half-node dies measure criteria, in comparison to REECHD.

- Reduction in network energy consumption by 14%, 22%, 8%, and 10% for 50-,100-,200-, and 250-node schemas, respectively, in comparison to REECHD.

5- Conclusion

The limitation of the battery capacity and the lifespan of the nodes are two important issues in maintaining WSNs. As the productivity and functionality of WSNs have a direct relation to the network lifespan and range of the nodes, all the layers of these networks have to be designed with attention to energy consumption. One of these energy-aware approaches that enhance the network lifetime is clustering techniques.

The proposed method balanced the load on inter-cluster communications in the REECHD protocol, consequently reducing the induced load on relay nodes. This resulted in a reduction of energy consumption in the REECHD protocol. Our proposed method estimated the range of clusters concerning their distance to the sink. In this research, we introduced R_{max} and R_{min} for the formation of clusters so that we can enhance the network lifetime by configuring these parameters based on the properties of our network. The proposed method increased the REECHD algorithm lifespan and enhanced the battery power usage of the nodes concerning the first node dies and half node dies measure criteria.

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