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RESEARCH ARTICLE

Optimized Cluster Routing Protocol With Energy-Sustainable Mechanisms for Wireless Sensor Networks

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ABSTRACT Clustering algorithms have a key role in decreasing energy consumption and increasing network longevity in wireless sensor networks. This work advances on previous homogeneous and heterogeneous algorithms, including low-energy adaptive clustering hierarchical routing protocol (LEACH), distributed residual energy LEACH (DIS-RES-EL), residual energy LEACH (RES-EL), energy efficient LEACH (EEL), and stable election protocol (SEP), by introducing novel clustering methodologies. It introduces novel improved residual energy LEACH (IMP-RES-EL) and energy efficient stable election protocol (EE-SEP) to improve the efficiency of clustering algorithms in energy savings for homogeneous and heterogeneous wireless sensor networks. The simulation result shows that, in addition to prolonging network lifetime and optimal routing, these methods transported more data packets from the cluster to sensor nodes and then to base stations than other techniques. When compared to the stable election protocol (SEP), the proposed energy-efficient stable election protocol (EE-SEP) influences the number of bunch heads formed over their lifetime, the organization's stability, the number of nodes shipped off the base station from each cluster head, and the organization's overall lifetime. When comparing the two current algorithms, EE-SEP and LEACH, for various topologies, the findings demonstrate that EE-SEP is the most energy efficient directing convention for extending the previously described qualities. This attribute has not been discussed thus far. The results also show that the IMP-RES-EL algorithm successfully increases network lifespan while minimizing energy dissipation and transmissions between sensor nodes and base stations or cluster heads (CHs). For all of the suggested homogeneous and heterogeneous algorithms, network lifetime in rounds rose by 36%, aggregated data packets from CHs to BS increased by 44%, and total data packets to BSs improved by 20%.

INDEX TERMS Base station, clustering algorithms, cluster heads, heterogeneous network, homogeneous network, routing protocol, wireless sensor networks.

I. INTRODUCTION

An administrator can use a sensor network, which is an infrastructure that contains sensing, processing, and communication components, to instrument, monitor, and respond to events and anomalies in a specified climate [1]. Administrators are frequently appointed by public, private, or hybrid organizations. Data collection, monitoring, surveillance, and medical telemetry are just a few of the common applications. A person's interests often extend beyond perception to encompass control and activation [1], [2].

The research community has actively worked to achieve network scalability by clustering sensor nodes. Each cluster has a leader, known as the cluster head (CH). There are several clustering algorithms designed for specific networks; however, most of them focus on creating stable clusters in environments with continually changing nodes. The basic goals of wireless sensor networks (WSNs), such as network lifespan and inclusiveness, are typically overlooked by many strategies, which primarily focus on node reachability and route stability.

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Several WSN-specific clustering algorithms have emerged [3], [4], [5], [6], [7], [8]. Cluster sensors can either select a CH or have one assigned to them in advance by the network architect. Alternatively, a CH can be defined as a node with greater resources or simply one of the sensors. Members of the cluster may be static or susceptible to change. The CH's usage of improved management processes can result in further network optimization and longer battery life for individual sensors and the network.

Gupta et al. presented the energy harvesting -enabled energy-efficient routing (EHEER) method for green communication in WSNs [3]. The primary challenge is the selection of the CH, which aids in the collection, aggregation, and forwarding of data in the cluster-based routing model. To optimize the fitness factors for CH selection, considerations include energy ratio, distance, node density, load balancing, and network average energy. However, their technique is still hampered by the non-uniform distribution of CHs across rounds.

Dogra creates each cluster and then selects two CHs, one of whom is active at any given time while the other remains in sleep mode. First, the gateway node (GN) is chosen for each side of the network (which is divided into two halves), followed by clustering and the selection of two CHs in each cluster [4]. The factors for selecting GNs and CHs include residual energy, node-sink spacing, the number of neighbor nodes, and network residual energy. The network stability of the topology continues to challenge the selection of CHs.

This study investigates the efficiency of clustering algorithms in lowering power consumption in WSNs with a diverse range of sensor types. In this specific sensor network, a cluster head enables each node to connect with the base station by delivering sensor data. The information from all nodes in a group is aggregated and transmitted to the base station by the cluster heads, who are chosen at regular intervals using specific clustering algorithms; the end-users then utilize this gathered data. The assumption that various nodes in the sensor network contain different amounts of energy is one example of heterogeneity [5].

One possible explanation is that the sensor networks were rejuvenated to increase their longevity [6]. The stable election protocol (SEP) approach is presented for heterogeneous remote sensor organizations on two levels. These organizations are divided into two types of hubs based on their initial energy. To begin with, development hubs generate more energy than traditional hubs. According to the study, SEP can withstand more refined hubs' abundant energy use than the low energy adaptive clustering hierarchical (LEACH) approach [7].

Sisodia and Priyadarshini conduct a thorough assessment of clustering approaches in WSNs, concentrating on clustering aims and network features, and examining the most prevalent solutions utilized by clustering techniques to meet the indicated objectives [5], [6], [7]. A significant concern is the lack of focus on network reliability and the number of packets sent to the BS.

For homogeneous networks, two algorithms—energy efficient LEACH (EEL) and improved residual energy LEACH (IMP-RES-EL)—are proposed to improve the residual energy LEACH (RES-EL) and distributed residual energy LEACH (DIS-RES-EL) algorithms. These strategies can extend the network's lifetime by using various clustering algorithms and probabilities. Furthermore, they can transfer more data packets from cluster heads to base stations compared to previous algorithms.

Sahoo's primary focus was on either CH selection or data transfer between nodes. Meta-heuristic approaches are a potential way to achieve optimal network performance [8]. The CH selection and sink mobility-based data transmission are both improved using a hybrid technique that takes into account the genetic algorithm (GA) and particle swarm optimization (PSO) algorithms for each task. The formation of residual CHs is ignored throughout each round of transmission.

Topology management is seen as a feasible method for ensuring stable, dependable, trustworthy, and efficient network infrastructures in ad hoc networks such as WSNs. Clustering is one of the most used approaches for managing WSN topologies [7], [9], [10], [11]. Topology management is a major challenge in computer network architecture, particularly in ad hoc networks where the number of nodes is large and the network infrastructure is unreliable. In ad hoc network topology management strategies, evaluating potential neighbors for connection establishment and identifying the optimal neighbors for hop-by-hop data transmission are critical to improving scalability, resource consumption, and reliability [12], [13], [14], [15], [16].

Grouping is often based on Voronoi diagrams, although it may also be a non-Voronoi chain or spectrum structure. The Voronoi structure divides a 2D or 3D network environment into many (unequal) portions known as clusters [7]. Each cluster has some nodes and communicates with other clusters via CHs or gateways. In chain structures, nodes in a cluster communicate with one another to reach CHs. In other words, each node in the chain has just two connections with its neighbors to reach CHs. In the spectrum structure, node angles to BS are just as essential as distance to BS.

Identifying CHs and encouraging nodes to join a neighboring CH is based on characteristics such as distance to CH and/or distance of the CH to BS. Many management packets must be sent, which can use a significant amount of resources and degrade network efficiency. Distributed approaches, on the other hand, offer lower overhea; however, due to restricted network knowledge, chosen CHs frequently fail to meet all network criteria.

The significance of the topology is that when altering the BS within the network anywhere in the field, the establishment of a uniform distribution of CHs is critical. Because of this gap in the current research, the newly suggested threshold aids in the uniform distribution of CH creation throughout numerous initial cycles until network stability. This relevance is not highlighted in any of the previously published literature.

This paper also examines the heterogeneous efficient stable election protocol (EE-SEP), an energy-efficient routing algorithm for cell sensor networks composed of heterogeneous nodes. In line with typical SEP developments, the proposed technique ensures that all nodes utilize the same amount of energy by evenly distributing cluster heads among them in each cycle. The newly proposed clustering threshold significantly impacts overall WSN performance. When applied to both advanced and regular nodes, the new approach is regarded as the most energy-efficient. As a result, SEP improves network stability, network durability, packet delivery to the BS, and the formation of more energetic CHs in each cycle with varying topologies.

The main contribution of this research is the introduction of novel improved residual energy LEACH (IMP-RES-EL) and EE-SEP to enhance the efficiency of clustering algorithms in energy savings for homogeneous and heterogeneous wireless sensor networks. Simulations with existing algorithms revealed that the suggested algorithms, with the new techniques introduced, improved clustering probability in forming clusters and selecting cluster heads. As a result, they outperformed in terms of network stability, network lifetime, and data packets transmitted to the base station as well as to the CHs.

The organization of the paper includes a system model in Section II and homogeneous and heterogeneous improved clustering strategies for the improvement of network lifetime in Sections III and IV, respectively. Simulation results are presented in Section V, and conclusions are drawn in Section VI.

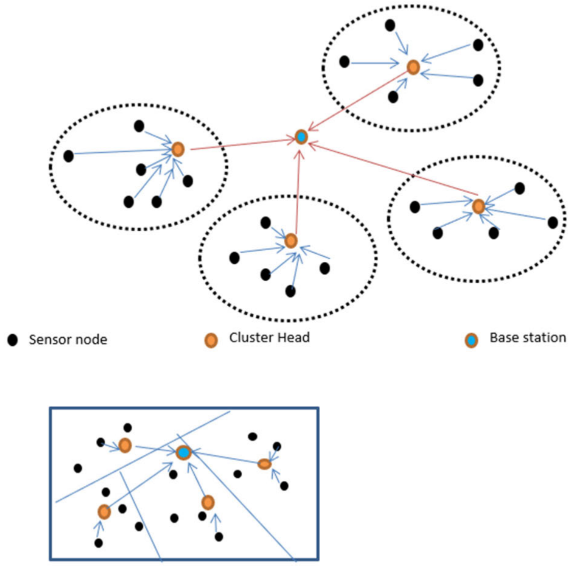

FIGURE 1. Network topology of the model.

II. PARAMETRS AND THE SYSTEM MODEL

Figure 1 depicts the network architecture of a wireless sensor network, highlighting the challenges of maintaining balanced clusters in terms of cluster size, number of nodes, and network load, which can be used as additional criteria to combine nodes and build clusters. Furthermore, high-level factors such as service similarity in applications that use the same network, data collection and data fusion methods, and support for various quality of service (QoS) parameters may also be utilized for grouping. In the proposed topology, sensor nodes are distributed uniformly to each CH throughout each round, and energy distribution is more consistent for all CHs while delivering packets to the BS. As a result, the suggested threshold equations (7) and (8) in this research helps improve the uniform distribution of nodes during each round to every selected CH, which is maintained for several more rounds to enhance network stability and longevity. Assume a wireless sensor network with n sensor nodes, and a single base station. To make things easier, each node is allocated a unique label, as seen below:

i. For a single sensor node: $1 < i \leq n$,
ii. For a single cluster node: j, $n < j \leq m+n$
iii. For the base station, use $n + m + 1$.

Imagine a network with n sensor nodes (1, 2…n) distributed throughout an area and a center station node (t) labeled $n + 1$. The placements of the center station and sensor are predetermined and known. Each sensor generates data as it observes its surroundings. Every time a unit passes, each sensor is programmed to generate one data packet, which is then forwarded to the central station [8], [12]. For ease of reference, each interval of time is referred to as a round. Every data packet should be at least k bits long. At the end of each round, data from all sensor nodes must be collected and transmitted to the center station for processing. There are the following claims:

i. All sensors in the network can send packets to the base station or other sensors. ii. Each sensor has a fixed-life, non-rechargeable Ei battery. iii. Sensors employ battery power to send and receive data packets. iv. The center station has access to unlimited energy.

A. CLUSTER HEAD SELECTION

To call this period of time of rotating epoch, and n_i will be the number of cycles it takes for node s_i to become the cluster leader. To verify that these are averages of p_{opt} N clusters and heads over rounds in homogeneous networks, let each node s_i $i = 1, 2\ldots N)$ become a cluster head once each $n_i = 1/p_{opt}$ round. As the network grows, not every node will have the same amount of leftover energy [17]. As all nodes have the same rotating epoch n_i, the energy will not be dispersed equitably.

The possibility of being a cluster head for n_i cycles is represented by $p_i = 1/n$. Because all nodes have the same amount of energy at every location, choosing the probability of pi being p_{opt} assures that p_{op}tN cluster heads appear in each circle count. If node energy content varies, pi should be larger than p_{opt}. Np_{opt} indicates the optimal quantity of clusters and heads to purchase. To determine whether or not each node will become a cluster leader in a particular round, each node is given a probability threshold [18].

$$T\left(s_i\right)=\begin{cases}\dfrac{p_i}{1-p_i\left(rmod\frac{1}{p_i}\right)} & if\ s_i\in G\\ 0 & otherwise\end{cases}\tag{1}$$

G is the set of possible nodes chosen in round r to act as cluster leaders. If node si didn't function as a cluster leader in the most recent ni rounds, it will choose a random integer between 0 and 1 when it finds that it is eligible to do so in round r. If the number is less than T, node s_i serves as the cluster head for the current round.

III. HOMOGENEOUS IMPROVED CLUSTERING STRATEGIES FOR IMPROVEMENT OF NETWORK LIFETIME

A. RESIDUAL ENERGY LEACH (RES-EL)

No energy will be distributed fairly, and low-energy nodes will die earlier than high-energy nodes if all nodes have the same rotating epoch ni, as proposed in LEACH [19], [20]. In the RES-EL protocol, the node with the highest residual energy (r) at each round r is selected to form the cluster heads.

Ē(r) represents the network's average energy at each circle r, which may be determined by,

$$\bar{E}\left(r\right)=\frac{1}{N}\sum\nolimits_{i=1}^{N}E_i(r)\tag{2}$$

To compute Ē(r) using (2), each node needs to be aware of the overall energy of the network. In the next subsection, an estimate of Ē(r) will be provided. If Ē(r) is used as the reference energy, then

$$p_i=p_{opt}\left[1-\frac{\bar{E}\left(r\right)-E_i\left(r\right)}{\bar{E}\left(r\right)}\right]=p_i\frac{E_i(r)}{\bar{E}(r)}\tag{3}$$

As a result, the total number of cluster heads for each circle count and epoch is guaranteed to be equal to:

$$\sum\nolimits_{i=1}^{N}p_i=\sum\nolimits_{i=1}^{N}p_{opt}\frac{E_i(r)}{\bar{E}(r)}=p_{opt}\sum\nolimits_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)}=Np_{opt}\tag{4}$$

That's the cluster-head number you should strive for. The following modifications are performed to each node's probability threshold when determining whether it will become a cluster leader in a particular round. It is advisable to obtain the specified cluster head number.

$$T\left(s_i\right)=\begin{cases}\dfrac{p_i}{1-p_i\left(rmod\frac{1}{p_i}\right)}\dfrac{E_i(r)}{\bar{E}(r)} & if\ s_i\in G\\ 0 & otherwise\end{cases}\tag{5}$$

Since the aforementioned quantities are derived from (3), the energy of each node is considered. If the number of nodes s_i is smaller than the threshold T (s_i), they become the cluster heads for the same round, much like in LEACH. However, nodes with more remaining energy must turn more frequently than nodes with less residual energy.

B. ENERGY EFFICIENT LEACH (EEL)

EEL is proposed as a remedy for the mentioned problems. In this case, the cluster heads' selection procedure takes into account each node's residual energy level. When a node's residual energy level is larger than the rest of the network, then LEACH clustering probability changes. The purpose is to make it more difficult to pick nodes with low residual energy levels as cluster chiefs, as shown in Fig. 2. When the most recent cluster heads election technique is used, the chances of picking nodes with high lingering energy increase while the chances of selecting nodes with low lingering energy decrease. Node x has a 5% probability of becoming a head node, while node y has a 2.5% chanc. For example, suppose nodes x and y have 50% and 25% of the beginning energy, respectively. This enhances the average life of the entire sensor network.

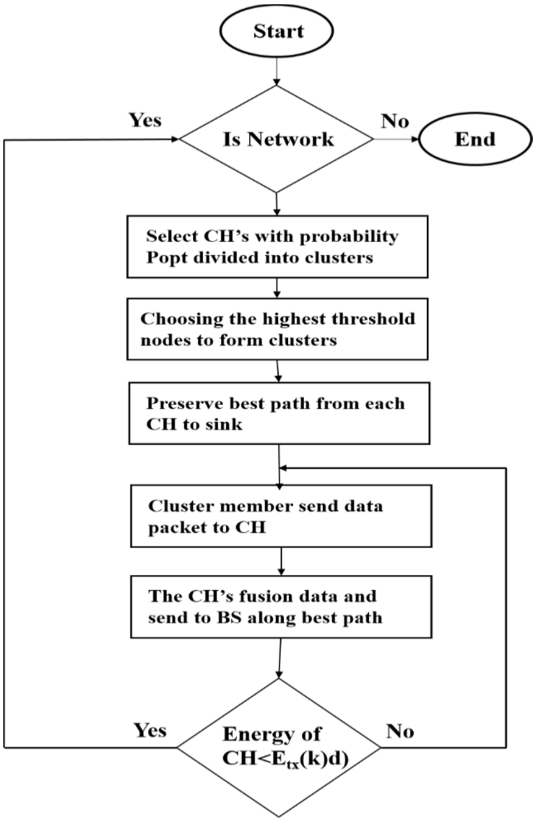

FIGURE 2. Flowchart of EEL.

The rotating epoch is defined as the number of rounds (n_i) necessary for these nodes s_i to become cluster chiefs. Allow each node s_i i = 1, 2,…N) to become a cluster-head once each $n_i = 1/p_{opt}$ round in a homogeneous network to ensure that there are an average of $p_{opt}N$ cluster-heads in each round. Each node s_i utilizes the probability threshold provided by to decide whether or not it will become the cluster's head in each round.

$$T\left(s_i\right)=\frac{2p_i}{1-p_i\left(rmod\frac{1}{p_i}\right)}\frac{E_{res}}{E_{init}},s_i\in G \tag{6}$$

E_{res} and E_{init} indicate each node's residual energy and starting energy, respectively, whereas pi denotes the probability that a node will be chosen as the cluster head.

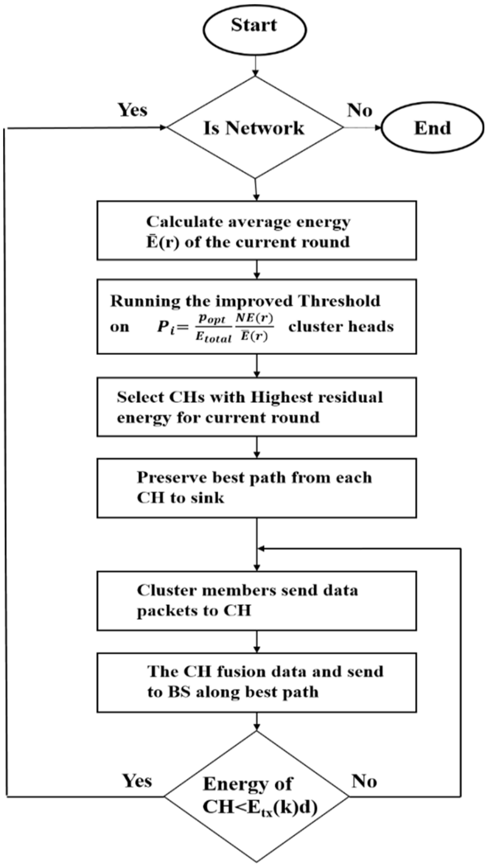

FIGURE 3. **Flowchart of IMP-RES-EL.**

C. IMPROVED RESIDUAL ENERGY LEACH (IMP-RES-EL)

Since EEL outperforms the first three approaches presented, IMP-RES-EL, as shown in Fig. 3, is recommended to extend network lifespan and data aggregation of data packets to be delivered to central stations when compared to the previous four strategies. This strategy has been effective in sending more data packets from cluster heads to the central station than sensor nodes can communicate to cluster heads, as shown in the simulations in section V.

To extend the network's life through optimum routing, additional residual energy cluster nodes are used. The new technique stipulates that each of them can only become a cluster's head once per k/(p+1) rounds, where k = [r/(1/p)]. The epoch for cluster nodes across the network is k/(p+1), with a total of k rounds. For the current round, if the numbers are less than T (si), the node is selected as the cluster leader [21]. This criterion requires each node to lead a cluster at least once over the following 1/p cycles.

The new equation is provided by

$$\boldsymbol{T\left(s_i\right)=\frac{P_i}{(1-P_i)\left[(r-1)\frac{1}{P_i}\right]}} \tag{7}$$

where,

$$\boldsymbol{P_i=\frac{p_{opt}}{E_{total}}\frac{NE(r)}{\bar{E}\left(r\right)}} \tag{8}$$

As a result, the average energy Ē(r) of the r^{th} rounds is the same as in (1), which is provided by

$$\boldsymbol{\bar{E}\left(r\right)=\frac{1}{N}E_{total}(1-\frac{r}{R})} \tag{9}$$

The total energy wasted in the networks during a round is calculated using (9).

$$\boldsymbol{E_{round}=K\left(2NE_{elec}+NE_{DA}+kE_{amp}d_{toBS}^4+NE_{fs}d_{toCH}^2\right)} \tag{10}$$

When the nodes are equally distributed, as in the case of (4),

$$\boldsymbol{d_{toCH}=\frac{M}{\sqrt{2\pi k}},d_{toBS}=0.765\frac{M}{2}} \tag{11}$$

According to (5), the ideal number of clusters is given by

$$\boldsymbol{k_{opt}=\frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{E_{fs}}{E_{ms}}\frac{M}{d_{toBS}^2}}} \tag{12}$$

Equations (8) and (9) are substituted into (10) to yield the energy E_{round} dissipated throughout a round in (10).

As a result, the novel IMP-RES-EL approach beat all four previous methods and enhanced the network's lifetime when compared to all other strategies investigated.

IV. HETEROGENEOUS IMPROVED CLUSTERING STRATEGIES FOR IMPROVEMENT OF NETWORK LIFETIME

A. THE ENERGY EFFICIENT STABLE ELECTION PROTOCOL (EE-SEP)

Selecting the CH that requires the least amount of transmission energy enables EE-SEP to obtain a CH node for every non-CH node with a probability of p [22]. The sensors alternate taking the part of CH based on an arbitrarily picked integer between 0 and 1. Assuming the number is less than the breaking threshold Th ($_{ni}$), which is presented later in this work, a node becomes a CH for the current round:

$$Th\left(n_i\right)=\begin{cases}\dfrac{p}{(1-p)\left\lfloor rem\left\{(r-1)\left(\frac{1}{p}\right)\right\}\right\rfloor} & if\ n_i\in G\\ 0 & otherwise\end{cases} \tag{13}$$

where G is the set of hubs that have been CHs in the last 1/p adjustments, p is the optimal number of CH nodes in the sensor population, and r is the current round number. For each k = [r/(1/p)] adjustment, the new approach ensures that they all become group heads at least once for each k/(p+1) adjustment. The number of rounds is denoted as k/(p+1) in relation to the total number of bunch hubs in the organization.

In the event that α is the expanded energy factor among cutting edge and customary hubs and m is the extent of cutting-edge hubs, then, at that point,

$$p_{inrml} = \frac{p}{(1+\alpha m)}, p_{iadncd} = \frac{p}{(1+\alpha m)} \tag{14}$$

Therefore, the conventional sensor threshold, Th (n_{inrml}), and the advanced node threshold, Th (n_{iadncd}), are used in SEP instead of the one in (1). This is as follows [16]:

$$Th\left(n_{inrml}\right) = \begin{cases} \dfrac{p_{inrml}}{\left(1-p_{inrml}\right)\left\lfloor rem\left\{(r-1)\left(\frac{1}{p_{inrml}}\right)\right\}\right\rfloor} & if\ n_{inrml} \in G' \\ 0 & otherwise \end{cases} \tag{15}$$

$$Th\left(n_{iadncd}\right) = \begin{cases} \dfrac{p_{iadncd}}{\left(1-p_{iadncd}\right)\left\lfloor rem\left\{(r-1)\left(\frac{1}{p_{iadncd}}\right)\right\}\right\rfloor} & if\ n_{iadncd} \in G'' \\ 0 & otherwise \end{cases} \tag{16}$$

During the beyond $1/p_{inrml}$ rounds of the age, G' addresses the arrangement of conventional hubs that impoverished people become CHs, and Th (N_{inrml}) is as widely used to a general population of n (1 → m) regular centers. The current round is r in this example. The foregoing assures that each regular center will turn into a CH decisively once per 1/p*(1 + α m) changes throughout a period, and that n (1 - m) p_{inrml} is the common number of collecting heads that are conventional centers each cycle. New Th (n_{iadncd}) is the restriction imposed to a general population of n*m advanced centers, and G'' is the game plan of cutting-edge centers that needy individuals become CHs during the latest $1/p_{adncd}$ rounds of the age. Each advanced center point will transform into a CH conclusively once every (1/p)∗(1 + α m)/(1 + α) changes, since this is guaranteed.

To achieve an acceptable transmission-to-commotion proportion (SNR) when delivering a B-bit message across a distance d, the radio should waste the energy shown by the radio energy scattering model presented in writing [23], [24].

$$E_{tx} = BE_{elec} + B\varepsilon_{fs}d^2 \ if \ d \leq d_o \tag{17}$$

where d is the distance between the source and the beneficiary, E_{elec} is the energy used per spot to run the transmitter or beneficiary circuit, and ε_{fs} and ε_{amp} depend on the transmitter enhancer type. Setting d equal to d_0 and equating the two equations yields d_0 = sqrt ($\varepsilon_{fs}/\varepsilon_{amp}$). To receive a B-bit message, the radio has to:

$$E_{rx} = BE_{elec} \tag{18}$$

Consider a field with the sink in the center, and the distance between any two centers and the sink or its gathering head isn't exactly or identical to d_0. Following a complete cycle, the amount of energy lost by the cluster's central node may be computed using this formula [25]:

$$E_{CH} = \left(\frac{n}{c} - 1\right) BE_{elec} + \frac{n}{c}BE_{DA} + BE_{elec} + B\varepsilon_{fs}d^2_{toBS} \tag{19}$$

Here, c is the gathering count, EDA is the digit representing the cost per report to the sink, and $_{\text{dtoBS}}$ is the standard distance between the bundle head and the sink. How much energy is used by a hub that is not crucial for a group?

$$E_{nonCH} = BE_{elec} + B\varepsilon_{fs}d^2_{toCH} \tag{20}$$

where d_{toCH} is the mean distance between every hub in the bunch and the hub at the top of the group.

$$d^2_{toCH} = \frac{M^2}{2\pi k} \tag{21}$$

According to [9], the sum of all energy wasted by the network is:

$$E_{total} = B\left\{2n_iE_{elec} + n_iE_{DA} + \varepsilon_{fs}\left(Kd^2_{toBS} + n_id^2_{toCH}\right)\right\} \tag{22}$$

As per [9], the normal distance between a group's hubs and its sink is

$$d_{toBS} = 0.765\frac{M}{2} \tag{23}$$

The most obvious opportunity for a hub to turn into the bunch head, signified as p, is given by [25].

$$p = \frac{K_{opt}}{n_i} \tag{24}$$

where

$$K_{opt} = \sqrt{\frac{n_i}{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\sqrt{\frac{M}{d^2_{toBS}}} \tag{25}$$

Crucial is the ideal cluster construction, which is the same as determining the ideal likelihood for a node to become the cluster head.

V. RESULTS AND DISCUSSIONS

Consider a 100 m by 100 m region covered by a wireless sensor network with 100 randomly distributed nodes [25]. Assume that the central stations are located in the center of the sensing zone. The number of rounds until a node ceases functioning determines the network's lifetime. In this case, minimizing the energy dissipation of the most heavily loaded nodes is far more critical than lowering the overall energy dissipation.

To minimize receiving excessive data, the wireless transmission module may automatically turn off or alter the transmitting intensity based on the distance between the nodes. The methods described in the preceding section were used with identical settings throughout the simulations exhibited, and their features were compared.

TABLE 1. **Radio characteristics.**

Parameter	Value
Size of Networks	100m X 100m
Band-width	1Mb/s
E_{elec} (Radio electronic energy)	50nJ/bit
E_{amp} (Radio amplifiers energy)	100pJ/bit/m^2
E_{init} (Initial energy of nodes)	0.5J
Numbers of node	100
Data Aggregation (EDA)	0.5nJ/bit
ctrPacket Length of EDA	2000 bytes
Packets length	200 bytes
Advanced nodes energy	m=0.1 and α=1 m=0.1 and α=2 m=0.2 and α=1 m=0.2 and α=2 m=0.3 and α=1 m=0.3 and α=2 m=0.3 and α=3
Base station	(50,50), (25,75)
Distance between CH and sensor	d^2(Euclidean distance)

Table 1 shows the parameters of the algorithm [26].

In this case, $p = 0.05$, where p is the chance of becoming clusters heads after each round.

A. COMPARISON BETWEEN HOMOGENEOUS ALGORITHMS LEACH, DIS-RES-EL, RES-EL, EEL AND IMP-RES-EL

More research is being undertaken to solve the flaws of the prior four algorithms, and the performance of the new Improved Residual Energy LEACH technique (IMP-RES-EL) is being presented. Fig. 4 shows that IMP-RES-EL beat all other algorithms. The IMP-RES-EL algorithm successfully increases network lifespan while minimizing energy dissipation and transmissions between sensor nodes and base stations/CHs. According to the simulations, all IMP-RES-EL nodes die after 4895 rounds, which is far better than previous techniques. The results demonstrate that the approach increases network life by more than 92% when compared to LEACH and by a reasonable amount when compared to other algorithms.

Fig. 5 shows that the suggested technique beats LEACH by 82% in terms of data packet delivery to BS while both methods' nodes are offline. Cluster heads' information packet delivery to central stations has substantially improved as compared to previous techniques.

This strategy is the most resourceful algorithm that utilizes the least amount of energy since it sends 28.5×10^5 information packets from cluster heads to base stations rather than 30.5×10^5 information packets received from sensor nodes to cluster heads. IMP-RES-EL is thus recognized as the most conservative algorithm recorded in the literature.

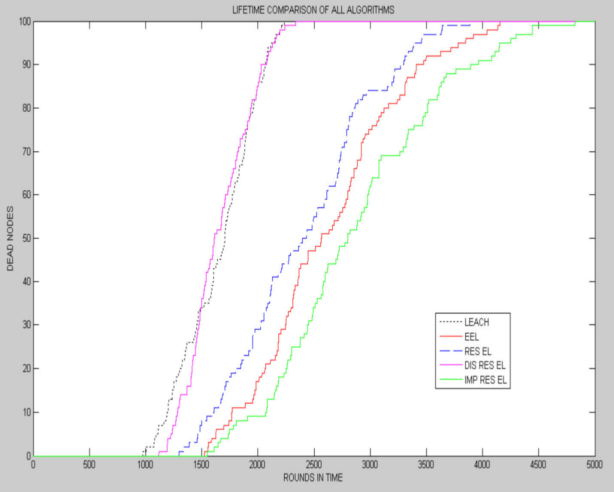

FIGURE 4. **Analyzing the differences between all the algorithms' data packet transfers.**

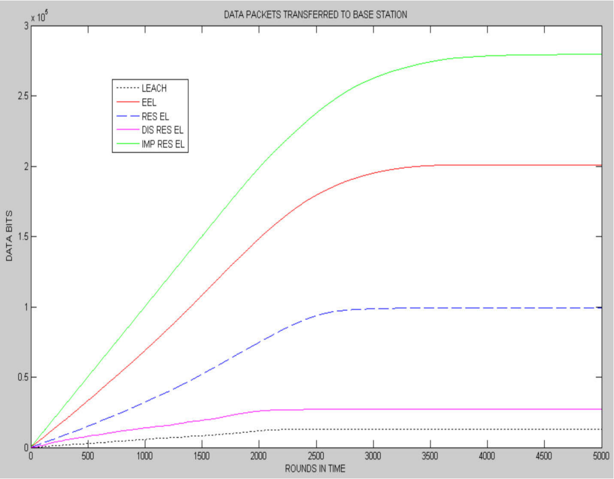

FIGURE 5. **Comparison of data packet transferred between all algorithms.**

TABLE 2. **Comparoison of network lifetime, data packets between all the algorithms.**

Algorithm	First Dead	Total Rounds	Packets to CH	Packets to BS	% data transfer
LEACH	960	2366	155605	13390	10%
DIS - RES-EL	997	2499	165850	30173	20%
RES-EL	1181	3671	173421	77378	44%
EEL	1569	4346	181199	149580	81%
IMP-RES-EL	1611	4895	305544	285826	92%

Table 2 shows a comparison of simulation results for IMP-RES-EL with earlier approaches. Compared to LEACH, the overall longevity, energy dissipation, packets to CH and packets to BS have all been proven. The recommended strategy outperformed in all of these categories, particularly when selecting more energy-efficient cluster heads. The revised methods have forwarded 90% of the information packets to the BS of the corresponding cluster heads and sensing nodes.

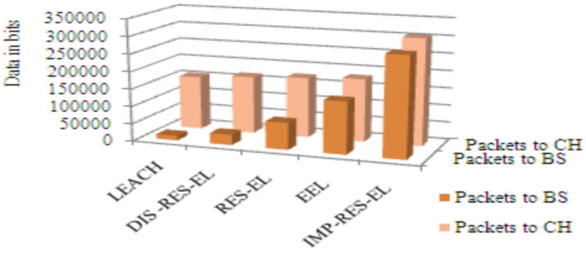

FIGURE 6. Variation of data packets transferring to CHs and base Station from sensor nodes between all the algorithms.

Fig. 6 confirms the data packets that traveled from the observation to the BS and CH. When comparing the four algorithms, the increase in data packet transmission to CH and BS indicates that more energy-efficient cluster heads are chosen in most rounds of IMP-RES-EL. This demonstrates that it is the most energy-efficient algorithm.

B. COMPARISON BETWEEN HETEROGENEOUS ALGORITHMS LEACH, SEP AND EE-SEP

In these simulations, the three techniques are compared using the parameters provided in Table 1, with the assumption that the correspondence energy scattering is dependent on the principal request radio model [10]. In this section, we investigated graphs with various topologies.

To test the algorithms' energy efficiency, we looked at many topologies with heterogeneity, ranging from m = 0.1, 0.2, and 0.3 (more advanced nodes) to $\alpha = 1$, 2, and 3. We conduct a comparison of network lifespan, stability, data packets transported to BS, and CHs created across their whole lifetime; the length of the network's life cycle directly reflects the performance of these topologies.

Fig. 7 indicates that node death occurred at 2150 rounds for LEACH and SEP, and at 4000 rounds for the innovative technique, all utilizing the radio characteristics stated in Table 1. The EE-SEP algorithm outperformed the two routing protocols at m = 0.1 and $\alpha = 1$, respectively. LEACH, because of its homogenous nature, has virtually a consistent lifespan in terms of rounds, regardless of heterogeneity from the SEP and EE-SEP. LEACH assumed m = 0 and $\alpha = 0$ for all simulations, regardless of topology. When we compare the new technique to SEP, we can discover that the network lifespan extension is nearly 35% longer.

Fig. 8 illustrates the network lifespan at m = 0.1 and $\alpha = 2$ using three techniques. Fig. 7 shows that EE-SEP has directly mirrored its lifetime with enhanced energy. It had recorded 6500 rounds, while SEP increased little to 3150 rounds. This implies that the suggested approach outperforms SEP by 55% in this topology.

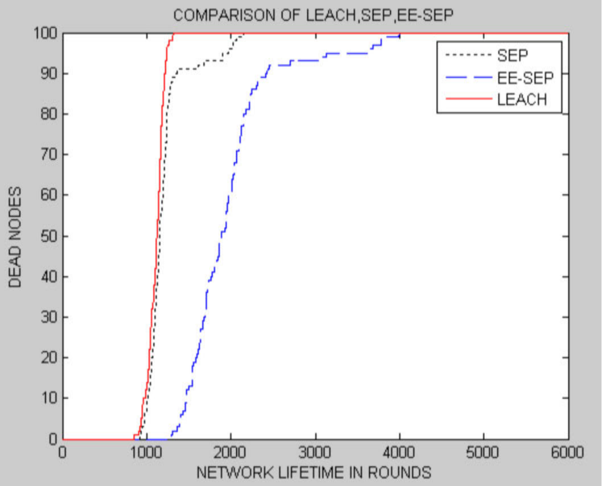

FIGURE 7. Comparison of LEACH network lifespan with SEP, EE-SEP for m = 0.1 and $\alpha = 1$.

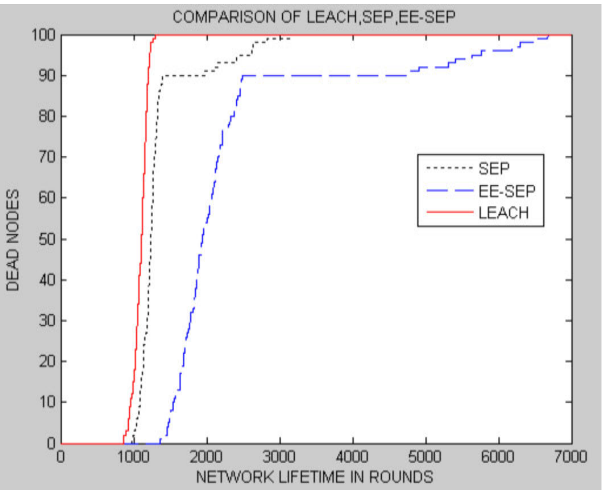

FIGURE 8. Examination of network lifetime between LEACH, SEP, EE-SEP for m = 0.2 and $\alpha = 2$.

Fig. 9 illustrates the suggested approach, which results in node death at 4800 rounds and SEP at 3200 rounds with m = 0.2 and $\alpha = 1$. Also, as the number of advanced nodes increased, EE-SEP demonstrated improved performance. It has 40% longer longevity than the SEP. LEACH remained at 1350 rounds, regardless of advanced nodes.

To display the results for the three methods, m = 0.2 and $\alpha = 2$ were used with a 10% increase in advance energies compared to the graph above. As seen in Fig. 10, the new approach improved to 7200 rounds when compared to the topologies mentioned earlier. It had a 70% higher lifespan than SEP, which occurred in 3100 rounds. So, as the number of advanced nodes and their energies increase, so does the network longevity, according to the suggested algorithm.

Additional attempts were made to increase the number of advanced nodes using m = 0.3 and $\alpha = 1$. There have been

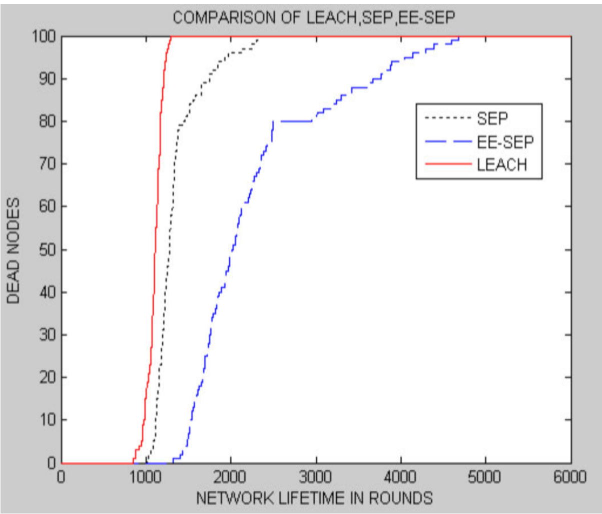

FIGURE 9. Determining of network lifetime between LEACH, SEP, EE-SEP for m = 0.2 and $\alpha = 1$.

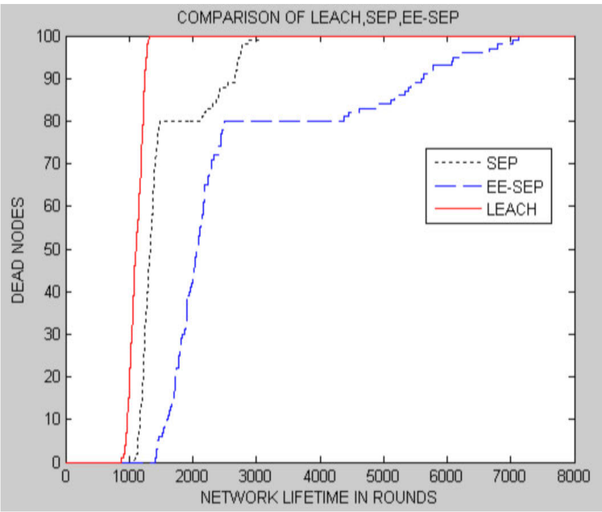

FIGURE 10. Expression of network lifetime between LEACH, SEP, EE-SEP for m = 0.2 and $\alpha = 2$.

comparisons between these algorithms. Fig. 11 depicts EE-SEP at 4950 rounds, with SEP occurring at 2200 rounds. When compared to the present procedure, the proposed method has a 45 percent longer longevity.

Increasing the energies to m = 0.3 and $\alpha = 2$ results in an increase in EE-SEP to 7450 rounds and SEP to 3100 rounds compared to the previous graph. In this observation, the new method has 65% greater longevity than the previous approach, as shown in Fig. 12.

The increase of advanced nodes and their energies in a diverse environment has a direct impact on the network lifetime, as seen in the topologies above. The network lifespan has risen due to issues with both heterogeneous methods.

Concerning the network's longevity, we evaluated and compared three methods while monitoring other factors such as network stability, CH creation, and packets transported to the BS throughout their lifetimes. These are addressed below, along with graphs depicting their respective outcomes.

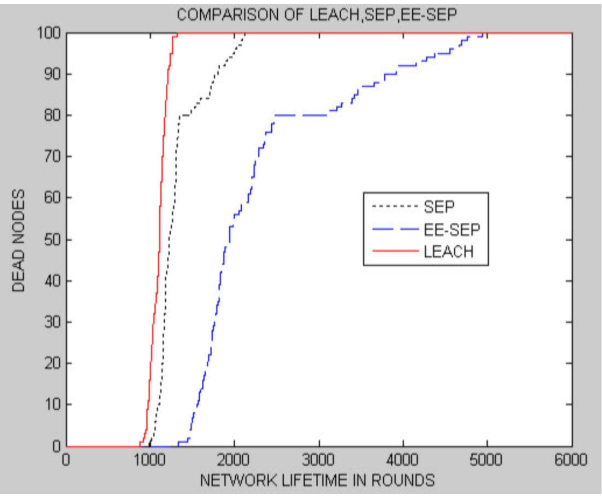

FIGURE 11. Differentiation of network lifetime between LEACH, SEP, EE-SEP for m = 0.3 and $\alpha = 1$.

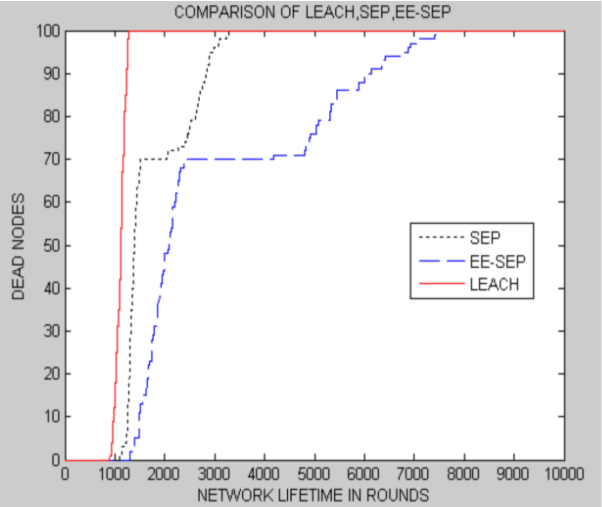

FIGURE 12. Examining the network lifetime between LEACH, SEP, EE-SEP for m = 0.3 and $\alpha = 2$.

Fig. 14 compares the three techniques' displays of aggregate data packets as they transit from CH to sensor nodes and then to the BS. Based on the data shown in this graph, EE-SEP outperformed both algorithms when evaluated against previously specified topologies.

The packet transmission rates to BS were 200% greater than the other two, as seen in the graph.

When comparing CH formation with time, the recommended technique identified more CHs in all topologies than LEACH and SEP. Fig. 15 compares the three mechanisms involved in CH formation across their lives, as well as their different topologies. In this investigation, the suggested approach has at least 30% more CHs across all topologies than SEP.

Fig. 16 depicts another element that affects the three algorithms: network stability. EE-SEP has demonstrated

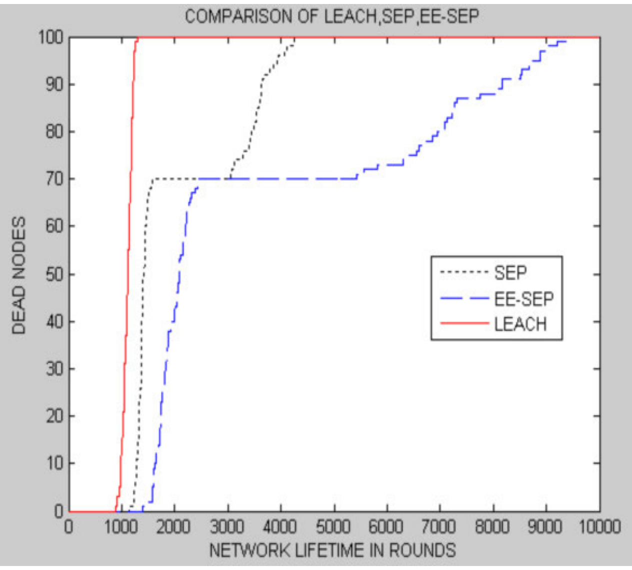

FIGURE 13. Observation of network lifetime between LEACH, SEP, EE-SEP for $m = 0.3$ and $\alpha = 3$.

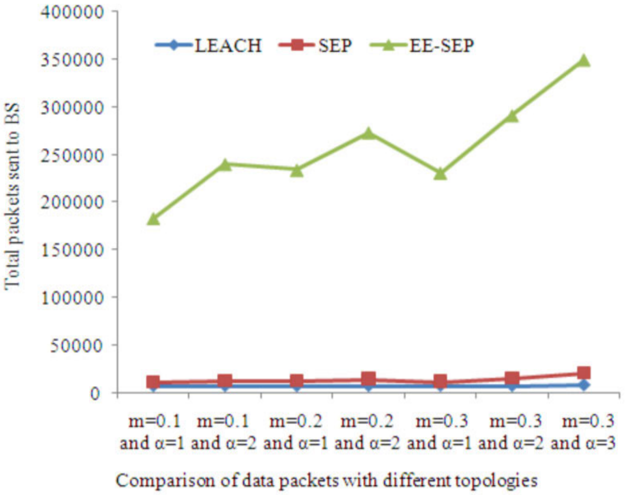

FIGURE 14. Comparison of data packets sent to BS for different topologies with different advanced nodes and energy taken into consideration.

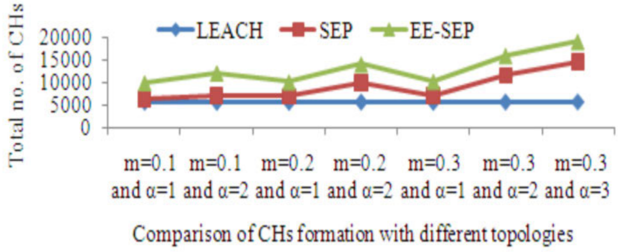

FIGURE 15. Comparison of CHs formed for different topologies with different advanced nodes and energy taken into consideration.

more stability than the other two approaches across all topologies, from the first round until the first node dies (FND). It had around 20% better stability than the SEP in all of the topologies shown here.

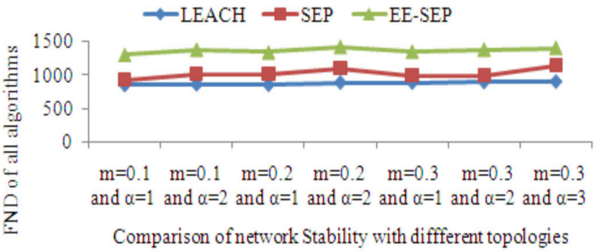

FIGURE 16. Comparison of Network Stability for different topologies with different advanced nodes and energy taken into consideration.

VI. CONCLUSION

The results presented in this paper reveal that the two algorithms, EEL and IMP-RES-EL, outperform existing approaches. IMP-RES-EL, a proposed routing protocol for homogeneous topologies, has become more energy-efficient thanks to the incorporation of new clustering probabilities, residual energy, and cluster head selection. Furthermore, it can now transfer more data packets from the sensor nodes to the central station. Clusters travel to a central station, then to a base station via optimum routing. This ensures that it has retained a more energy-efficient clustering procedure and a well-designed algorithm than the other strategies. EE-SEP, a proposed routing protocol for heterogeneous topologies, is compared to LEACH and SEP. The proposed technique outperforms them in terms of network durability, stability, energy efficiency in CH selection, and data packet transfer from individual CHs to sensor nodes.

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