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REERP: A Region-Based Energy-Efficient Routing Protocol for IoT Wireless Sensor Networks

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Abstract: An essential component of the Internet of Things (IoT) is wireless sensor networks (WSNs). Since individual sensor nodes are strongly power-constrained, several techniques are adopted to save power. By grouping nodes into clusters—thus reducing the transmission distance between sensor nodes and the base station (BS)—a clustering protocol can ensure energy preservation and increase the lifetime of the network. However, current clustering techniques have problems with the clustering structure that negatively impact their performance. Whenever routing protocols were implemented for a longer period of time, it was observed that they had a higher rate of energy consumption, a shorter period of stability, and fewer data transfers to the BS. In this paper, an improved region-based routing protocol (REERP) is developed for wireless sensor networks in the IoT is developed. It is based on (i) the addition of new nodes to the already formed clusters, (ii) the selection of the new head node based on the amount of residual energy, (iii) the setup of the multi-hop communication in all the regions of network, and (iv) the utilization of the energy hole reduction method. All of these tactics increase the useful life of the network. Performance has been evaluated against (1) a stable election protocol, (2) a gateway energy-aware routing protocol, and (3) a heterogeneous gateway energy-aware routing protocol, and using the metrics lifetime, energy consumption, number of dead nodes, and number of packets sent to the base station vs. number of packets acquired by the base station. The results of the proposed routing protocol have been found to outperform the state-of-the-art approaches considered.

Keywords: Internet of Things (IoT); wireless sensor networks (WSN); routing protocols; energy utilization

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1. Overview of Wireless Sensor Networks

Wireless Sensor Networks (WSNs) typically consist of large quantities of tiny sensors, their basic component. These sensors enable measurements that are made up of a physical system, such as heat, humidity, vibrations, noise, object presence, etc. [1]. The sensing unit, processing unit, transmission unit, and power supply unit are the four essential parts of a wireless sensor. Data gathering, data processing, and two-way interaction with fewer sensor nodes are its three main functions [2]. A base station (BS) receives from the nodes the data sensed from the environment. The nodes have relatively restricted capabilities, particularly in terms of power supply; to power their numerous operations, they often rely on small batteries. To be able to identify the node's location, a wireless sensor can be fitted with a location system. Some applications that rely on sensors to roam around and complete tasks may sometimes require a mobility system. Most of the time, the energy source is severely restricted and rarely renewable due to the intensive deployment of WSNs [3]. This results in a reduction in energy use and extended network longevity. To ensure that sensor networks last as long as possible, optimal energy utilization must be handled. Several network levels, from the physical layer to the application layer, must take into account energy efficiency. Many definitions and concepts used in previous systems are insufficient for this generation of networks due to the unique properties of WSN, which must use energy efficiently to ensure the delivery of data to the user as long as needed. Energy is a major constraint.

From its very beginnings, the IoT has helped humanity significantly as a WSN, notably in obtaining data from censorious settings. Networks can collect, process, and transfer data from disastrous environmental situations to secure locations. In these networks, when data are collected, the data are often transmitted to the BS, a received node, for additional processing [4]. Small sensor nodes often make up these networks. Sensor nodes use rechargeable and interchangeable batteries as their energy source. Whenever these batteries are used in a hazardous environment, it is difficult to recharge and replace them. As a result, the network's efficiency is always enhanced by the effective utilization of the sensor nodes' scarce resources. The development of techniques (see [4], for example) that can reduce node energy degradation and increase network longevity can boost a WSN's efficiency. After being deployed, sensor nodes are regarded as independent; however, how well they manage their energy utilization will determine how long they last. The secret to reducing node energy utilization and extending network longevity is to develop energy-efficient data-gathering methods. WSNs frequently use clustering with multilevel topologies to reduce energy utilization and ensure a longer-lasting network than those relying solely on direct connection [5].

In this paper, minimized energy utilization for data to be transmitted from the sender to the base station is the major goal. From the sender to the receiver via one or more intermediate nodes; to accomplish the transmission of data, the data are forwarded. In clustering hierarchical structure techniques, the network nodes are organized into multiple regions, which are each headed by a master node called the cluster head (CH), with the remaining nodes being referred to as cluster members. Although each cluster head has a unique set of responsibilities, their primary duty is to acquire the data from the cluster members, which they later transmit to the base station. Providing sensor data in packets rather than each node transmitting direct data to the base station usually requires more energy and causes the node to rapidly lose energy, and this design lowers the energy used for transmitting data. Data processing and consolidation using clustering techniques are quite effective. Each cluster head can run data queries, send messages to other cluster members, and gather important data within its cluster.

The rest of the paper is summarized as follows: Section 2 discusses the existing literature on the energy-efficient routing protocols and research gaps in WSN-IoT; Section 3 proposes the system model for the multihop transmission of the WSN in IoT; Section 4 represents the simulation environment and performance analysis of proposed model; lastly, Section 5 concludes the paper.

2. Related Work

Various work has been completed in recent years. Poonam et al. [5] proposed the SSE path routing protocol as a sustainable, reliable, and flexible routing protocol for WSN-IoT. It uses the least populated route available to send the packets of data from the sender to the receiver. Rana et al. [6] suggested the Advanced Zone-Stable Election Protocol (AZ-SEP), which takes into account the characteristics of various WSNs in IoT scenarios. The authors developed AZ-SEP and made a comparison with the conventional routing protocol known as LEACH. Compared to the existing LEACH convention, the suggested AZ-SEP convention outperforms it with an increase 64% in better results in the form of capacity and an increase in the number of live micro nodes to 2702 rounds, which can be used to extend the IoT lifecycle. Patel et al. [7] suggested a method that is a variation of the AODV protocol and takes into account collisions and energy when establishing a route. The suggested method retrieves collision counts from the MAC layer and connection-relevant data from the PHY layer to create a path and help the network layer make routing decisions. A. Hamodi et al. [8] proposed a reform of the routing protocol, which is dependent on the maximal parent-objective function count (MNP-OF) for the WSN-IoT based on the neighboring metric (N-metric). He tested and compared the proposed MNP based on the remaining energy (MRE) protocol to the standard routing protocol for lossy inexpensive networks (RPL).

Zhong et al. [9] introduced Opportunistic Source Routing (OSR), which provides a flexible and trustworthy downward routing mechanism for WSNs. The authors discussed an analytical model and assesses the performance of OSR using simulations and testbed experiments conducted in the real world. Zhao et al. [10] discussed the CH, which uses the protocol named LTE-M, and the intracluster, which deploys the low power wide area network (LPWAN) self-networking protocol in the WSN. The number of cluster heads and the ideal scale inside each cluster are investigated using the conventional K-mean algorithm. Additionally, based on an enhanced K-means algorithm, a distributed dynamic cluster head selection and clustering strategy are provided. C. Jothikumar et al. [11] suggested a system in which optimized cluster-based routing having efficient energy and network longevity is increased by utilizing a strategy based on hierarchical routing for IoT applications in the context of 5G. Before the chaining phase is activated for the remaining transmitting data, the clustering phase is activated unless three-fourths of the nodes are deceased.

Elappila et al. [12] developed a protocol that is intended to function in networks with a lot of traffic, since it frequently occurs in IoT applications for healthcare monitoring when numerous sources attempt to send messages to a receiver at the same time. Simulation analysis shows that the designed protocol works better in terms of data transmission, delay, packet delivery ratio, and the remaining energy of the node. Le et al. [13] suggested three RPL-based dynamic routing techniques and combined them into a custom IPv6 communication network for IoT. The test results demonstrate that, as compared to the conventional RPL solution, the suggested techniques have improved energy efficiency, network load balancing, etc. These techniques have been deployed in the OMNET++ simulator. Behera et al. [14] concentrated on an effective cluster head election method that alternates the cluster head movements between nodes with higher levels of energy than other nodes. The updated version outperforms the LEACH protocol, according to the simulation study, by increasing throughput by 61%, lifetime by 66%, and residual energy by 65%. Shu et al. [15] concentrated at the same time on wireless power and data transfer technology (SWIPT) and routing mechanisms and applied them to WSN clustering based on multi-hop, in which each cluster can interpret data and acquire energy from a transmitted radio transmitter.

Based on ant colony optimization, Seyyedabbasi et al. [16] proposed a new multi-agent routing protocol that effectively controls network services under realistic conditions. The suggested method locates the most energy-efficient best pathways, extending the useful life of the network in current and sequential scenarios. Compared to previous ACO-based routing protocols, the findings of the proposed technique have shown better output with respect to the network lifetime and energy utilization. Nejakar et al. [17] concentrated on developing a novel node-swapping mode to extend the useful life of mobile nodes. The authors' method takes advantage of the configuration of nodes to reduce asymmetrical energy consumption by placing nodes in places with high power usage while maintaining the current topology. Kiani et al. [18] suggested a new protocol to improve energy conservation. The protocol prioritizes multiple aspects of energy optimization, such as reducing node energy usage, extending the lifetime of the entire network, improving system performance, improving network load balancing, and decreasing packet latency. Bilal et al. [19] covered design issues for schemes based on clusters, crucial parameters, and the categorization of clustering protocols. To assist users in choosing the best technique, existing techniques that are based on cluster and grid are examined while taking specific factors into account. The merits, drawbacks, and usability of various methods in certain situations are also described in a thorough summary.

Rafea et al. [20] considered a refinement of the fundamental routing protocol for low power loss networks (RPL). The Energy Threshold RPL (ETRPL) protocol is recommended to reduce the energy use of the network. Additionally, an optimization model depending on the remaining energy of the desired parent is also proposed. Zrelli et al. [21] discussed routing in WSN, particularly the AODV (Ad hoc on Demand Distance Vector) protocol, which is known to be particularly effective and useful for wireless services. The aim is to strengthen this protocol to consider the impact of communication topologies that can periodically transmit data from several nodes to a single node. Xiumen et al. [22] suggest the environment-fusion multipath routing protocol (EFMRP) as a means of delivering reliable message forwarding in adverse conditions. The fundamental tenet of this strategy is to direct data packets to choose routes that optimize transmission delay, energy consumption, and routing survivability. The results demonstrate that EFMRP can substantially increase packet delivery rate and network longevity under challenging conditions. Thangaramya et al. [23] discussed the routing protocol and cluster formation based on a novel Neuro-Fuzzy rule for effective routing in WSN based on IoT. The presented routing algorithm delivered a maximum performance of the network in terms of the metrics measured, including energy utilization, packet delivery ratio, delay, and life expectancy of the network, according to the experiments conducted in this study utilizing the presented model. Ganesh et al. [24] described the diffusion methods for a protected routing protocol, a data-centric protocol based on the Internet. This unique routing protocol is used to eliminate potential threats and attacks on the routing structure, and therefore, it is examined in terms of security considerations [25].

The authors of [26] stated that the election likelihood of picking cluster heads underwent changes due to the G-SEP approach, which factored in parameters such as distance, average distance, and residual energy of the advanced nodes. Additionally, the algorithm incorporated a central gateway node within the network and positioned the BS (Base Station) beyond the field's boundaries. Through simulations conducted in MATLAB R2017a, it was demonstrated that G-SEP outperformed the Zonal-Stable Election Protocol (ZSEP) in aspects such as coverage, stability period, and network lifetime extension. In [27], the authors drew inspiration from the research presented. In that study, MGEAR was enhanced by utilizing a setup with uniform nodes deployed across all regions. Within this configuration, cluster heads were chosen based on criteria such as distance and residual energy, owing to the nodes' homogeneous nature. This model was enriched by incorporating the concept introduced in [26], where a gateway node was integrated into the Stable Election Protocol (SEP). This gateway node facilitated the repositioning of the BS outside the network. The adjustments made to the SEP protocol also took into account factors such as distance, average distance, and residual energy. Notably, only the homogeneous nodes were responsible for data capture and transmission. These data were then sent to the cluster heads, which were heterogeneous nodes possessing the same energy level as the gateway node that communicated with the base. The network's design excluded any direct transmissions within its various segments. Importantly, this configuration differs from the model employed in GMEAR [28]. The comparison of proposed approach can be found in Table 1.

Table 1. Comparative analysis of the proposed protocol with existing protocols.

Ref. No./Year	Protocol Used	Software/ Simulator	Parameters	Limitation	Future Scope
[29]/2022	Enhanced heterogeneous gateway-based energy-aware multi-hop routing protocol (HMGEAR)	MATLAB R2018a	Number of alive nodes and dead nodes per cluster round, throughput, packets received, residual energy	Reduced the energy depletion of distant nodes as they transmit their reports to the base station	

Table 1. *Cont.*

Ref. No./Year	Protocol Used	Software/ Simulator	Parameters	Limitation	Future Scope
[30]/2022	Efficient multi-hop routing protocol (EMRP)	NS-2.35	Average lifetime, packet delivery ratio, time-slots, communication lost, communication area, first node expiry, number of alive nodes and residual energy	Number of dead nodes are increased	EMRP in grid topology along with available mobility models
[25]/2022	Gateway-based energy-aware multi-hop routing protocol (MGEAR)	MATLAB R2017a	Throughput, network lifetime, alive sensor nodes, energy consumption rate	Fewer data are transmitted when network lifetime is increased	Incorporating the meta-heuristics evolutionary algorithms in the clustering process for more energy efficiency.
[26]/2020	ReapIoT, reliable energy-aware protocol	JiST/SWANS, Java-based discrete event simulator	Energy, reliability	Network lifetime and throughput is lacking	Focus on increased research that tests the impact of throughput and network lifetime
[27]/2021	Cluster-based routing protocol with static hub (CRPSH)	Castalia Simulator	Average energy consumption, end-to-end delay, packet delivery ratio, number of devices alive	Network reliability, mobile hub is the main problem	Machine learning algorithms will be integrated to acquire a more efficient protocol
Proposed Work	Improved region-based routing protocol (REERP)	MATLAB R2019b	Alive nodes, dead nodes, number of packets sent to the base station, number of packets acquired the base station, network lifetime, energy consumption	Consumption of energy is bit to be reduced to increase more network lifetime	WSNs can be deployed as underwater acoustic sensor systems, cognitive sensing and spectrum management, and security and privacy management

Research Gaps

There are various research gaps that researchers have not yet explored:

Stability [6–8]: By expanding the number of IoT nodes in the various advanced zones, the stability period increases to 65%, which can provide higher efficiency and the maximum lifetime of IoT nodes that is considered in the proposed approach, but the number of transmission rounds for data is not taken into account, which leads to achieving lower efficiency and minimum lifetime.

Scalability [9–11]: If the multicast routing and integration of OSR with RPL are not considered when using OSR with WSN for downward multicast routing, which can improve scalability and for massive amounts and limited resources, the coding of the proposed bloom filter path will have a higher false positive rate, which will cause the network to be slower and less scalable.

Reliability [12–15]: This protocol could be expanded with a mac layer created with spread power-management plans and flow-adaptable fluid disagreement doors to have a cross-layer layout, but the absence of survival and connection results in less dependability. By making the network more resilient while preserving connectivity by selecting more resilient paths as routing options.

Network lifetime [16–19]: For WSN/DIoT, this technique can produce superior outcomes in simultaneous and immediate information transfer on a wide scale. Because of this, the effectiveness and longevity of networks are minimized while using the proposed method in a variety of actual-time applications and systems that may be created for the production and analysis of huge data.

Performance [20–24]: The suggested ETRPL protocol can be beneficial for IoT networks with comparatively small regions, increasing the power usage of the entire network. By employing the routing approach, IoT nodes may be deployed in larger areas, minimizing the use of energy.

To revive the network, the sensor nodes are frequently implemented with the same characteristics and initial energy levels (homogeneous networks); a few nodes with additional energy are incorporated into the network, presenting a source of heterogeneity and providing the chance of longer network longevity. Furthermore, the multi-hop region-based routing protocol is developed, in which the CH is chosen depending on the sensor nodes' remaining energy, as different nodes might get deployed in different regions (Figure 1). This will reduce the dissipation of energy amongst nodes, and in this way, nodes with higher initial energies are much more likely than nodes with lower energies to be selected as cluster heads.

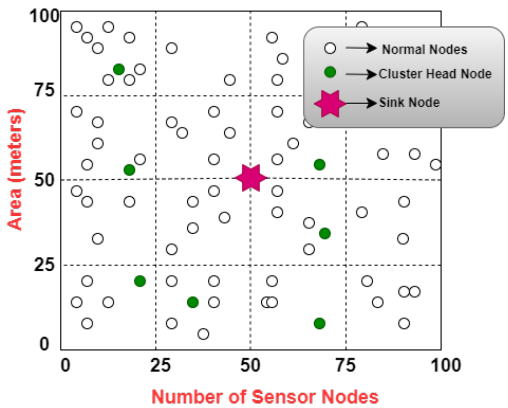

Figure 1. Working of WSN in IoT.

3. Proposed System Model

The SN which comprise of the network topology are designated as $n_1, n_2, \ldots, n_{SN}$. Nodes in a WSN are randomly dispersed within a region of S. In this paper, S and SN are set to 120. Each node seems to have a sensor radius of r_0 meters and a finite radio range. There are three different kinds of nodes included in this framework: normal nodes, CH nodes, and sink nodes.

A clustering strategy is used in communication networks, where a small number of nodes are chosen as CH to collect data from other nodes and transfer it to the sink node. In contrast to the SN, which has minimum energy, the sink node in this paper is believed to be in the region's center and endowed with a limitless energy source. All nodes are believed to have fixed positions and the same initial energy. Furthermore, all nodes have a GPS and their positions have always been known [31–34].

3.1. Energy Utilization Model

When estimating the energy consumption of the IoT device, we must take into account both the transmission and the acquisition of energy. Let $E_{Send}(n, s)$ represent the expense of sending s bits of data over s meters and let $E_{Acq}(n)$ represent the expense of obtaining n bits of data over s meters. As shown in Equations (1) and (2):

For sending n bits:

$$E_{Send}(n,s) = E_{Embb}(n) + EAmp(n)(s^2), s <= s0 \tag{1}$$

$$E_{Embb}(n) + E_{Amp}(n)(s^4), s > s0$$

For acquiring n bits:

$$E_Acq(n) = E_{Embb}(s) \tag{2}$$

In the sleeping state, the energy spent by the devices of IoT is stated in Equation (3):

$$E_{sleeping}(i) = E_{least}(i) \tag{3}$$

where E_{least} defines the energy utilization of any device when in sleep mode for one second. 'i' seconds are spent in sleep mode. The total energy utilized for any device of IoT in the network is shown in Equation (4):

$$E_{total} = E_{Send}(n,s) + E_{Acq}(n) + E_{sleeping}(i) \tag{4}$$

3.2. REERP: Proposed Routing Protocol for Multi-Hop Transmission

The system model was discussed in the previous subsection. There are a total of n sensor nodes that are equally dispersed in $region \times s^2$. The entire network is subdivided into four regions in the proposed network topology. The following are the predictions made:

1. Nodes are designed to remain stable after deployment, but every sensor node is fitted with a GPS to aid in determining the location of the node.
2. Although all sensor nodes have identical processing and communication capacities, their initial energy requirements vary (heterogeneous network).
3. The base station, which is absent from the network as seen in Figure 2, is constantly required to acquire data from the sensors.
4. Sensor nodes are deployed and then left unattended, making battery replacement impossible.
5. There are no energy, computing, or memory limitations in the network, which has only a single base station from outside the network.
6. Data sent from node a to node b use the same amount of energy as data sent from node b to node a, since all wireless connections are symmetric.

In the approach suggested, as presented in Figure 2, multi-hop transmission is deployed to extract the details of the nodes' locations, which is essential to evaluate which transmission method all the nodes should investigate. The network is categorized into four regions based on the locations of every sensor node; all nodes are given a distinct ID (Identification) and fitted with a global positioning system (GPS), which aids in determining which region they should correspond to. As a result of the proximity of the base station to the sensor nodes in the first region, direct communication will be more effective while using less energy versus multi-hop communication. Therefore, to transfer their data, the nodes in this area will rely on a direct connection. Because of their distance from the base station, nodes in the second field rely on multi-hop transmission. These nodes transmit them to the gateway with their data, which then forwards them to the base station. Since there are several sensors in regions 2 and 3 and they are far from the base station, aggregating these nodes and using hierarchical clustering routing is the most effective technique to minimize energy utilization in both regions. For the purpose of aggregating cluster data and transmitting it to the BS, cluster members from all regions designate a CH. In the proposed method, a ratio is used between the remaining energy of the sensor node and the average energy of the network to determine the CH. To overcome this problem and save energy, we rely on the calculation of the baseline energy that each sensor must utilize for each round; this enables us to calculate the energy intensity of every SN during each round. This calculation is based on our estimate of the desired value of the network lifetime.

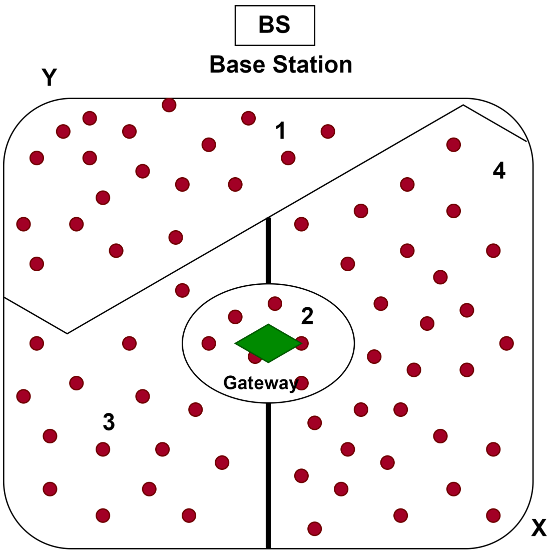

Figure 2. Proposed system model.

The functioning of the suggested system model is shown in the flowchart depicted in Figure 3. In this, first, we will check for all the nodes in the different regions, then calculate the distance for all the regions. If maximum distance > distance, then we add all the nodes to the BS; in case maximum distance $\leq$ distance in region 1, then we add all the nodes in region 2; and if maximum distance == distance, then we add the nodes in region 3, while otherwise, we add all the nodes in region 4. There are three steps in the proposed model:

- **First Stage:** Every node forwards an ID table to the base station when all sensors have been deployed. The address, remaining energy levels, and travel times to the gateway and BS are listed in the ID table.
- **Setup Stage:** This separates the network into four regions on BS, as depicted in Figure 2, by taking into account each node's address. Nonclustered regions are classified as regions 1 and 2. While nodes in Region 2 interact with the Gateway, which combines the data and sends them to the base station, nodes in Region 1 broadcast their data directly to the BS. Nodes in regions 3 and 4 are clustered, and thus, a few cluster leaders should be chosen to gather and broadcast to the BS a packet containing the data gathered by each member of the cluster.
- **Election of CH:** This protocol is considered the most effective energy routing protocol that is used for different sensor networks. For choosing the CH in our proposed model, the execution is performed based on the SN's remaining energy and the average of all the nodes that belong to the same region. Assume that x_i are cluster heads of every node average probability; a node n_i is eligible only once to become a CH in every $R_i = 1/x_i$ iteration. Let us say that in case n_i is chosen as the CH in the first iteration R, it will be again not selected as the cluster head for iteration R iterations. The threshold value will continue to fluctuate depending on the amount of energy remaining and the average energy of the region. When the network is uniform and each of the sensor nodes shares the same starting level of energy, an optimal proportion of nodes must be chosen as cluster heads. However, in a heterogeneous environment, every SN has a distinct R_i, since each node has a different starting amount of energy. Additionally, sensor nodes with greater energy have much more iterations to aggregate at the head to prevent early death of normal nodes; as a result, all nodes die roughly at the same time. Here, $M_{1,2}4$ is the set of sensor nodes in regions 2 and 3, with cluster heads n_{opt} $M_{1,2}$ for each region.

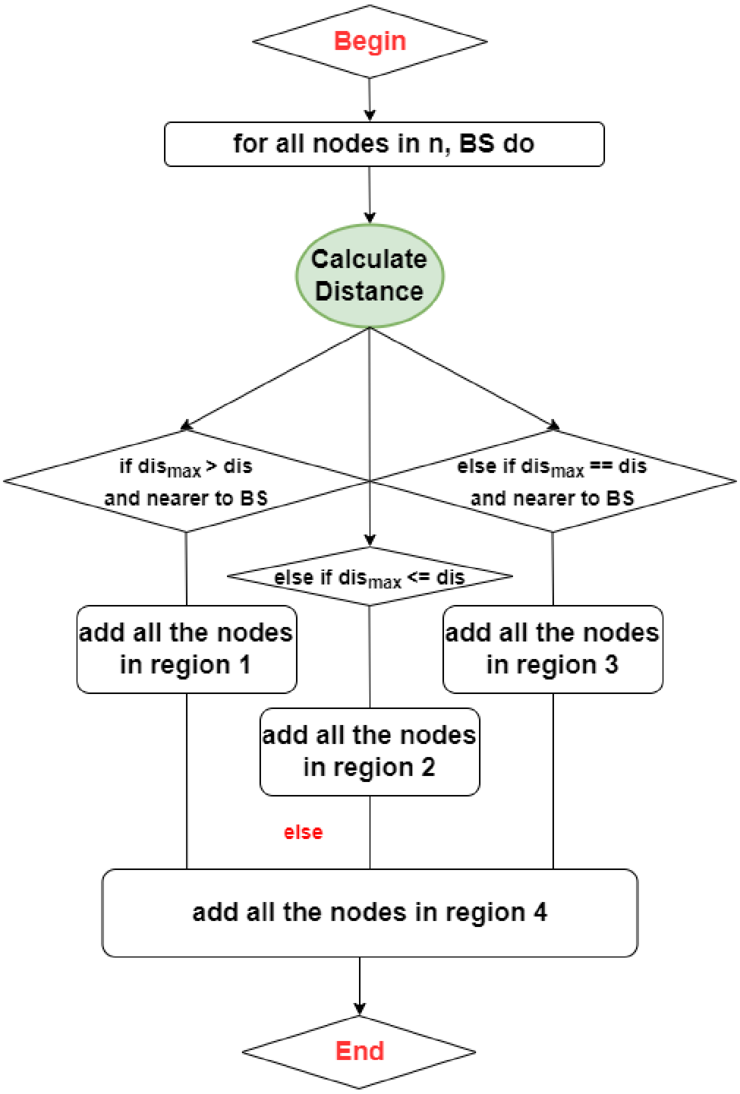

Figure 3. Flowchart of proposed protocol.

The probability of n_i being the cluster head in every iteration is expressed in Equation (5):

$$n_i = n_{opt}[1 - E(R) - \frac{Ei(R)}{E(R)}] = n_{opt}\frac{Ei(R)}{E(R)} \tag{5}$$

where $E(R)$ is the mean energy per iteration of the region and $E_i(R)$ is the remaining energy of node n_i in the nth iteration. The threshold value is evaluated in Equation (6):

$$E(R) = \frac{1}{M_{1,2}} E_{sum}(1 - R/TR) \tag{6}$$

where E_{sum} is considered as the total energy of the region and TR indicates the overall lifetime of the network iterations.

- **Steady Stage:** The energy dispersed by the SNs in each region is decisive and the total energy of the network is evaluated. To impose the dispersed energy, the equation is acquired in the equation. Every least energy acquired of all the sensor nodes in region 1 is denoted as $E_{non\text{-}BS}$ that is transmitted in relaying some bits to sent to the base station is shown in Equation (7):

$$E_{non\text{-}BS} = E_{trans}(numofclusters, dis_{BS}) \tag{7}$$

where dis_{BS} measures the distance between the same nodes present in Region 1 and the base station. The value of TR is computed in Equation (8):

$$TR = \frac{E_{sum}}{E_{iterations}} \tag{8}$$

where $E_{iterations}$ signifies the energy dispersed in the region during each iteration, computed in Equation (9):

$$E_{iterations} = S(2 \times M_{1,2}E_{elect} + M_{1,2}E_{AD} + dis^4_{toBS} + M_{1,2 \in fs}dis^2_{toclusterhead}) \tag{9}$$

where S denotes message size, E_elect denotes energy utilization, E_{AD} denotes the energy used by each cluster head for data collection, dis_{toBS} denotes the average distance between CH and BS, and $dis^2_{toclusterhead}$ denotes the mean distance between CH and SN, as expressed in Equations (10) and (11):

$$dis_{toBS} = 0.974M/2 \tag{10}$$

$$dis^2_{toclusterhead} = \frac{M}{\sqrt{2 \times \pi \times numberofclusters}} \tag{11}$$

In the proposed model, the same technique as in the other protocols is utilized to choose CH. The threshold value and probability of each SN on which it relies is used to determine whether it is a CH. The heterogeneous nodes that did not cluster had previously $\frac{1}{n_{hetero1}}$ iterations R in Region 3. $H1_0$ denotes the collection of heterogeneous nodes that have not yet become the CH in the previous $\frac{1}{n_{hetero2}}$ iterations R in region 4.

4. Results and Discussions

4.1. Simulation Environment

The proposed approach shows the important outcome that has been calculated in MATLAB R2019b [35]. In this paper, the simulation has been performed with existing routing protocols, i.e., stable election routing protocol and gateway-based energy-aware multihop routing protocol, and heterogeneous gateway-based energy-aware multihop routing protocol. In the **stable election protocol**, even though only the heads of the protocol scheme are diverse, the base station was initially positioned in the middle of the network, closer to the nodes. The base station was forced to have the highest rate of electricity consumption because of its outside location and distance from the field, which caused it to run out of energy in the shortest period of time. Utilizing the initial homogenous nodes installed throughout all areas, the **energy-conscious multi-hop routing system for gateways** has been enhanced. The CHs in this approach were chosen on the basis of their distance and remaining energy, since they were primarily homogeneous nodes. In the **energy-aware multi-hop routing protocol for heterogeneous gateways**, the SN are divided into four equal regions based on the threshold value, the base station, and the gateway nodes are positioned outside the field of detection and in the center of the network.

According to the network scenario, the proposed routing protocol was executed on a WSN with nodes randomly distributed on a 2D square area of length with $area \times M2$, with a base station located outside the network. The various predictions of the network are shown as follows:

- After delivery, nodes and the base station are constants.
- The nodes are physically inaccessible and also have equivalent initial energy. Therefore, these nodes were unable to be recharged.
- The base station has unlimited energy, memory, and processing capacity.
- Each node's identity is known to the base station.
- The nodes are aware of where they are and are susceptible to the radio energy utilization model.

The simulation values with regard to the proposed protocol are shown in Table 2.

Table 2. Simulation parameters.

Parameters	Values
Network field	200 m × 200 m
Number of nodes	200
Size of message	5000 bits
The initial energy of normal nodes	1 J
Simulation Time	30 min
Collection of data	Periodically
Maximum number of packets	100
Control size of packets	100 bits
Time taken for communication	200–2000 s

4.2. Performance Analysis and Evaluation

This subsection evaluates according to the parameters evaluated. About 30% more energy is used to generate diverse nodes than homogeneous nodes (n = 0.3 and alpha = 1). After delivery, all nodes are in a steady state. Cluster heads and gateway nodes acquire the reports properly and consolidate them prior to transmission. Thus, even though it would be a useful addition to future studies, fusion verification is not taken into account in this research.

Taking into account performance indicators, the evaluation is utilized to determine the effect that is determined by every parameter:

1. Depending on the number of iterations,the total number of live nodes in each cluster. In the network, the amount of energy still present reflects the number of network nodes that are still functional for each cluster iteration. If a routing method can keep a number of nodes active after numerous routing iterations, it becomes more effective.
2. Nodes that are dead in a cluster iteration. Throughout the overall survival of the network, it levels out within the network as a function of fluctuating energy. This also shows how long the network might still last. If a routing method lowers the proportion of dead nodes in each cluster, it becomes more effective.
3. **Bandwidth:** It refers to how many packets each iteration's nodes send to the BS. The actual energy utilization with respect to the fundamental routing method can be seen in the bandwidth.
4. **Packets acquired:** It displays the precise packets approved by BS. If a routing plan maximizes the number of packets that are delivered to the destination packets, it will be significantly more effective.
5. **Network's remaining energy:** Analyzing the use of energy of nodes during each loop is beneficial. A routing method that guarantees reduced energy use is frequently thought to be more effective.

The routing tree should be updated and the network energy can be balanced by making clusters in each iteration. For each iteration, the worth of each of the mentioned parameters is evaluated and computed.

The lifespan of networks has been thoroughly studied, and the results are depicted. This result presents the total alive SN for every iteration done in clustering of the stable election protocol, a multi-hop efficient routing protocol for gateways, a heterogeneous protocol for multi-hop energy-conscious routing for gateways, and the proposed model. Figure 4 indicates that, in the case of the proposed model, the number of active nodes per iteration slowly decreases compared to other routing protocols. For 3000 iterations, the proposed model acquires 70% of alive nodes as compared to the stable election, gateway energy aware, and heterogeneous gateway energy aware that acquire 10%, 0.5%, and 60%, which clearly shows that the proposed model stays alive longer than the other routing protocols, resulting in a longer network lifetime than the other routing protocols.

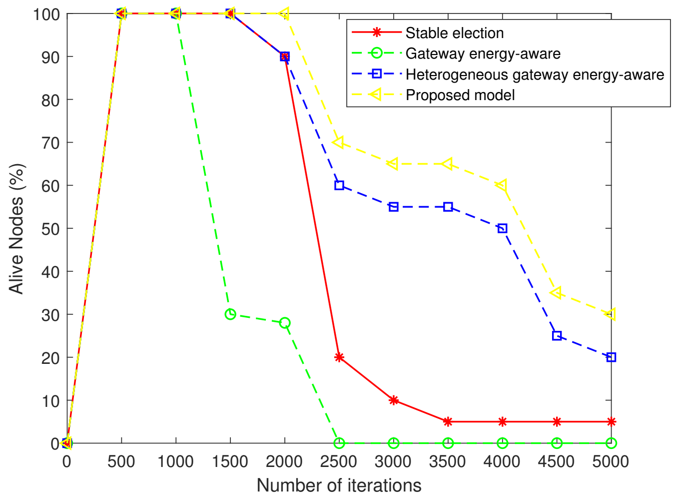

Figure 4. Alive nodes.

It should be noted that the implementation of multihop transmission among CH, the gateway, and the BS is what gives the proposed protocol its efficient implementation. Consequently, the energy usage of the network has decreased due to the reduced rate of data transmission.

Figure 5 depicts the number of nodes that have died overall in a network during each iteration when using any of the multi-hop routing techniques. For 1500 iterations, the proposed model found that 95% dead nodes as compared to the stable election, gateway energy aware and heterogeneous gateway energy aware found 90%, 70%, and 0% dead nodes. It is evident that the novel system has long-term solidity in comparison to the current method. The graph supports the findings shown in Figure 4 and demonstrates that the suggested algorithm records a minimal mortality rate in general rounds of nodes until all nodes have died.

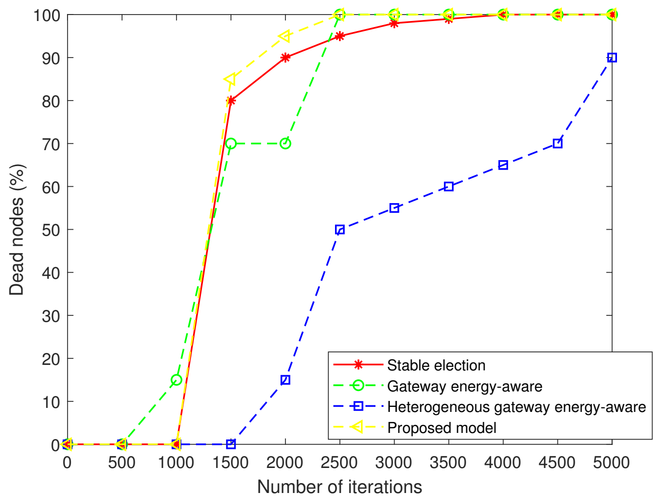

Figure 5. Dead nodes.

The comparison between the packets transmitted to the BS and the packets collected by the BS for each routing algorithm is illustrated in Figures 6 and 7. It was discovered that the proposed method transmitted additional packets to the BS, while the BS also collected more packets from the unique strategy compared to the previous schemes. This is because the new protocol incorporates a multi-hop communication strategy. Up until something reaches the sink, the nodes need much less energy to send their data to the following region. The information is also aggregated by the gateway node rather than the CHs.

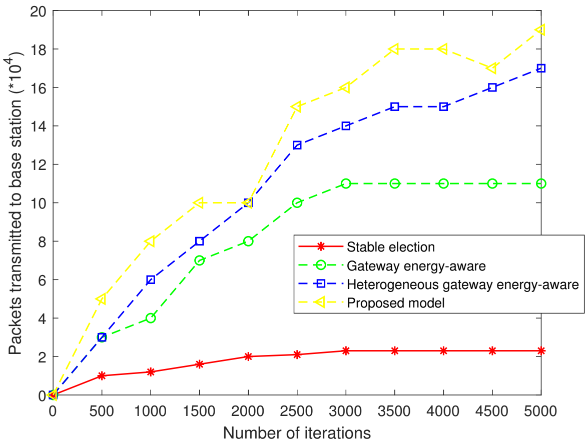

Figure 6. Packets sent to the base station.

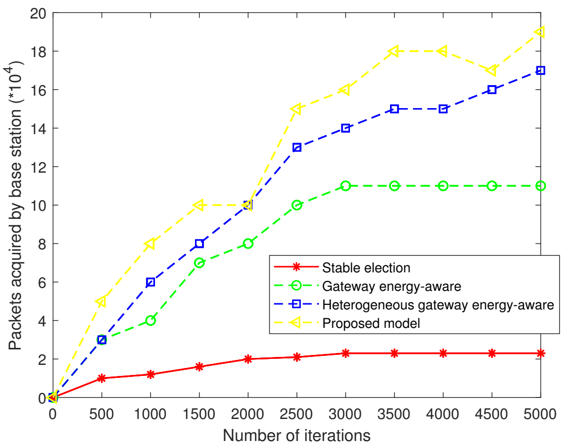

Figure 7. Packets acquired by the base station.

In Figure 8, the network lifespan contrasts with existing protocols in which the proposed protocol acquires the maximum service lifetime of the network. The consumption of energy as shown in Figure 9 achieves a minimum consumption of energy compared to the existing proposed protocols in which the total energy consumed will be analyzed by the network per round. The observation will lead to a maximized network lifetime and a minimized consumption of energy in which the gateway node will be placed in the middle of the network, which will help in lessening the higher cost of energy for communicating the data between SN and BS placed out of the regions.

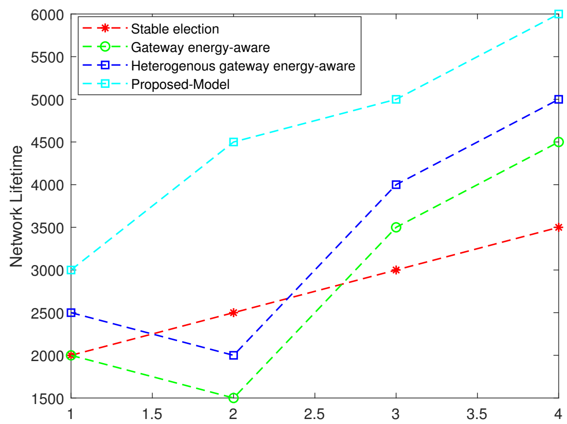

Figure 8. Lifetime of the network.

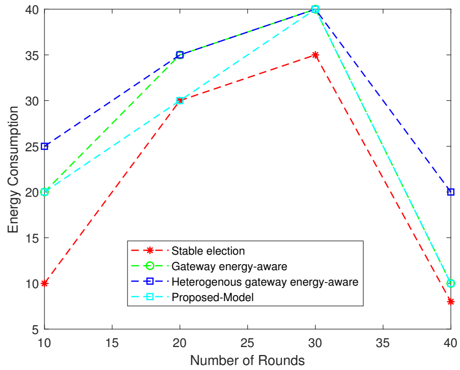

Figure 9. Energy consumption.

5. Conclusions and Future Scope

A routing protocol is developed that addresses the drawbacks of conventional routing protocols. The issue of choosing CH using a probabilistic method was resolved by the proposed approach. The primary purpose of the proposed protocol is to minimize energy utilization by transmitting the data from the source to the BS. To accomplish data transmission, the data must be forwarded from source to destination via one of the intermediate nodes. This work is compared with the state-of-the-art approaches in which bandwidth, acquired packets, remaining energy of the network, and dead nodes are considered while performing the simulations. The proposed routing protocols achieve 10.45% with respect to the stable election protocol, the homogeneity of the gateway, and the heterogeneous routing protocol. The method ensures that residual energy nodes are chosen as heads and are capable of successfully transmitting data to the BS. In addition to using multi-hop communication amongst nodes throughout all regions, the new approach also created diverse nodes in regions far away from the BS. The proposed approach has minimized the depletion of energy of the far-reaching nodes as soon as they send their information to the BS, as shown in Figure 6. Every node-sparing energy approach has been discussed in the proposed approach, which resulted in the least utilization of energy. The simulations are evaluated and show that the proposed protocol was executed with better results than the baseline studies with regard to the stability period, remaining energy, and the useful life of the network.

The following can be concluded:

1. The WSN is one of the most demanding needs in today's time due to its ubiquitous nature. In the near future, WSNs can be deployed as underwater acoustic sensor systems, cognitive sensing and spectrum management, and security and privacy management.
2. The sophisticated algorithms based on machine learning techniques will be integrated to obtain a more energy-efficient and cost-effective protocol.
3. Due to the arithmetic bottleneck and energy consumption limitation of WSNs, machine learning algorithms cannot be deployed at scale in sensors with small computational power and limited energy. However, distributed learning methods require less computational capacity, less energy consumption, and smaller memory footprints than centralized learning algorithms (i.e., they do not need to consider the entire network information). Distributed cooperative learning breaks the arithmetic bottleneck and achieves ML-based green routing with less energy consumption, which is very suitable for WSNs.

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