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Research Article

RBM: Region-Based Mobile Routing Protocol for Wireless Sensor Networks

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Wireless sensor networks (WSNs) are employed for different applications for the reason of small-sized and low-cost sensor nodes. However, several challenges that include a low powered battery of the sensor nodes restrict their functionality. Therefore, saving energy in the routing process to extend network life is a serious concern while deploying applications on WSN. To this end, the key technology is clustering, which helps maximize scalability and network lifecycle. Base station (BS) collects data, aggregates it, and extracts the required information. To obtain the maximum outcome, the lifetime of the network is maximized by the use of different techniques and protocols. Data transmissions consume most of the network energy, and the transmissions over normal ranges require less energy as compared to transmissions over long ranges. Moreover, the nodes closer to the BS deplete their energy faster as compared to distant nodes because of traffic overload. The proposed protocol is aimed at reducing energy consumption and increasing the network lifetime. For this purpose, the network is divided into two regions: region 1 closer to the BS communicating directly, whereas region 2 farther away from the BS having routing nodes to communicate with the BS. Routing nodes do not take part in sensing function but will only move in region 2 collecting data and forwarding it to BS. MATLAB is used as the simulation tool for evaluation, and the results are compared with the existing optimized region-based efficient routing (AORED) and low-energy adaptive clustering hierarchical protocol (LEACH) techniques. The comparison showed that energy conservation and lifetime increased by 15%, and throughput is increased by more than 5% approximately.

1. Introduction

During the past few years, wireless sensor networks (WSNs) have earned a great attraction of researchers. WSN comprises of a large number of small-sized and low-cost sensor nodes connected to base station (BS); they are used to gather information from their environment and forward this information to the BS. They have a wide range of applications in different fields like medical, engineering, agriculture, environmental monitoring, surveillance, and battlefields. There are many types of sensor nodes to monitor different physical quantities like thermistors are used for heat sensing, photodiodes for light sensing, GPS sensors to pinpoint the location, etc. The WSNs have a large number of applications but there are some limitations, which restrict their functioning. As the nodes are small in size and low in cost, they are not equipped with a large amount of power supplies. As they are mostly used in open and vast fields, their power supplies cannot be replaced or they cannot be connected with continuous power supplies. This limited power supply also limits the abilities of sensor nodes, like limited life, limited processing power, limited storage capacity, and lower communication ranges. It is required to make the WSN function in such a way that it consumes minimum energy resources. This is done by implementing different routing protocols and routing strategies. The communication in WSNs can either be direct (single-hop communication) or there can be an intermediary node to forward the collected data to BS (multihop communication) [1]. Nodes have a specific communication range within which they can communicate with normal power consumptions, but to communicate over these ranges, extra power is consumed. In the case of large networks clusters are formed and a cluster head (CH) is elected in each cluster, this CH collects and forwards the data of its cluster. Some challenges are faced by WSNs that restrict their working. Some of the main challenges faced by WSNs include limited power supplies, limited processing power, and less memory size. Earlier in the field of WSNs, the nodes were kept static but their topology and protocols kept on changing to gain the maximum output from the network. But during the past few years, mobility of nodes is being introduced in the WSNs to enhance the output of the WSN. Now, many researches are being done on the mobility of nodes in the network.

One solution to enhance the WSN lifetime is to move the sink to the areas in which nodes have more energy. Using a mobile sink is useful for saving energy only when we have an efficient routing strategy towards it. The reason to make the sink mobile was to transfer the load of data processing and power consumption during transmissions, from the sensor nodes to the sink node, so that the network lifetime can be enhanced. As mobile sink moves actively in the network, it moves closer to sensor nodes to reduce the transmission distance, and, hence, there are only a few intermediary nodes left to forward the data. Hence, the consumption of the energy is more equally distributed in the WSN with mobile sink as compared to the conventional WSN with static sink. The main contributions of this paper are

(1) This paper focused on decreasing the communication load on cluster heads that are at a farther distance from the base station by using mobile routing nodes

(2) Enhancing the stability and lifetime of the network by conserving the energy of sensor nodes

The proposed protocol, region-based mobile routing protocol also focuses on the mobility of nodes in the WSN. In the proposed protocol, mobile routing nodes are introduced which will move in the network and will be responsible for communication between CHs and BS but they will not take part in the sensing functions of the network. The protocol operates by dividing the network into two regions, one closer to the sink without mobility and the other farther from the sink with mobile routing nodes. The aim of this study is to enhance the network stability by increasing its lifetime and energy conservation. MATLAB was used as a simulation tool to evaluate the functioning of the proposed protocol. Some other existing techniques were used to compare the results of our proposed technique with existing techniques, i.e., optimized region-based efficient routing (AORED) [2] and low-energy adaptive clustering hierarchical protocol (LEACH) [3]. The comparison showed that the goals set for the proposed technique were achieved as our RBM performed better than LEACH and AORED. The comparison showed that energy conservation and lifetime increased by 15%, and throughput is increased by more than 5% approximately. The results showed that the proposed technique was successful in achieving its goals.

The rest of this article is structured as follows. A brief summary of the literature review is presented in Section 2. Section 3 explains the details of the proposed region cluster-based mobile routing protocol strategy for sensor energy consumption in wireless sensor networks. In Section 4, the performance of evaluation of the proposed region cluster-based mobile routing protocol strategy for sensors energy consumption in wireless sensor networks is given. The paper is concluded in Section 5 with the direction for future work.

2. Literature Review

Wireless sensor networks have an extensive variety of applications and a very complex structure. Thus, many problems are faced by the researchers while dealing with WSNs. Different researches were done to resolve these issues and hence different solutions and routing protocols were introduced. Low-energy adaptive clustering hierarchical protocol (LEACH) is the base of different other protocols. To maintain balance in power consumption of all nodes in LEACH, clusters are formed and a cluster head (CH) is elected for every cluster which is responsible for communication between nodes of its clusters and BS. Afterward, many researchers introduced some changes in LEACH to overcome deficiencies in it [3].

Stable election protocol (SEP) [4] was introduced with some changes in LEACH, in which CHs were chosen on the basis of remaining energy of the nodes. The remaining energy of the node over the average energy of the network was estimated to elect CHs in distributed energy-efficient clustering (DEEC); it was also introduced as the successor of LEACH [5]. In [6], LEACH was improved by introducing the master head and shortest path algorithm, in which data will be forwarded to BS using MIMO. In [7], H-LEACH was introduced in which the nodes that are unable to communicate are made to die; also, a record of alive nodes is maintained.

Multiple mobile data collectors were introduced in [8] to overcome the issue of blockage in the surrounding of the sink because of extraordinary traffic load. Mobile data collectors consisted of mobile sinks (destination for collected data) and mobile relays (agents to carry collected data to destination). In [9], the authors proposed an effective grid deployment method for mobile sensor nodes deployment, in which the plot is separated into many separate grids and environmental factors like predeployed nodes, boundaries, and obstacles are used to estimate the weight of every grid and mobile node focus on the grid having minimum values. In [10], the authors first proposed an approach on election-based mobile collection and framed it into an optimization problem called bounded relay hop mobile data gathering

(BRH-MDG), in which a subgroup of sensor nodes will be designated as polling points and will save locally collected data and upload it to the mobile collector on its arrival.

In [11], a hybrid (mixed) routing protocol was proposed for WSNs containing mobile sinks. The suggested routing protocol is a mixture of proactive and reactive routing protocols for low-power networks with multiple mobile sinks. DAG (directed acyclic graph) is maintained by the nodes within a specific zone nearer to the sink. But the nodes outside this zone do not use DAG, instead they use on-demand sink discovery to discover the sink at the nearest possible distance. But in the situation of high sink mobility path to sink will change repeatedly, so it is better to create small zones. But if the mobility is slow, then, in this case, bigger zones can be created for quick data transfer to the sink node. Maximum Amount Shortest Path (MASP) [12] resolves the issue of a path constrained mobile sink having constant speed because the communication time to gather data from randomly deployed nodes is limited. This issue arises the issues like the amount of collected data and power conservation. The network sensor field is partitioned into two parts, the direct communication area for nearby sensors and the multihop communication area for sensors at a greater distance. In [13], the authors defined distributed heuristics and scalable models for the synchronized movement of multiple sinks in WSN. It was shown in this paper that better performance was observed with controlled and coordinated mobile sinks as compared to static sink or uncontrolled mobility of the sink node. In [14], the authors have proposed a mobility-based clustering (MBC) protocol for WSN containing mobile nodes, a sensor in this protocol elects itself as CH on the basis of its mobility and remaining energy. During the cluster formation process by taking into consideration its connection time with cluster head, its residual energy, and its distance from CH, a noncluster head node will maintain the link stability with CH during the process of cluster formation. By restricting the moving distance of the sink node, the data loss during the movement of the sink node from one location to another can be minimized [15]. In hotspot problem, sensor nodes near the sink have to transmit the data of faraway nodes, and as a consequence, they drain their energy fast, creating a gap in the network reducing the network lifetime. In [16], the authors have addressed this issue and purposed Mobile Sink based Routing Protocol (MSRP), in which a mobile sink will move through the network and collect data from CHs within its locality. Only the CHs in the locality of the mobile sink will transmit their data to the sink, and the remaining will wait for the mobile sink to be in their locality. In [17] is given a cooperative localization algorithm that studies the presence of hurdles in networks with mobile elements. To improve the location performance, the mobile sink will move actively and cooperate with static nodes. In [18], the authors proposed a scheme to increase the lifetime of the delay-tolerant WSN by using a mobile sink. In delay tolerant WSN, a node needs not to transmit the data immediately after it becomes available but it temporarily saves the data and sends it when the mobile sink is at a suitable location. In [19], the authors limit the mobile sink to a specific number of locations and study the joint sink mobility and routing issues. The authors first developed the primal-dual algorithm for a single sink and then generalized it for multiple sinks. Packet delivery ratio along with energy conservation is the issues caused by the mobile nodes in the network. To overcome these issues in [20], the authors have used a cross-layer design between MAC and network layers and proposed a cluster-based routing protocol for mobile sensor nodes (CBR-Mobile).

Purely location information is used in geographic routing protocol instead of global topology information, hence, is considered as simple, efficient, and scalable routing protocol. Frequent location updates are sent to receive data frequently but these frequent updates cause more energy consumption and collisions in wireless transmission. In [21], the authors proposed a new geographic routing protocol named elastic routing to tackle this issue. During the movement of the sink, the location update is sent to the source along a backward geographic routing path. Source will get the location of mobile sink and forwards data, but after the sink has moved to a new location, the last hope forwarding node detects its new location and renews this information in a received packet to a new location. Transmission of this modified packet is overheard by the second last hop forwarding node and alters location information in afterward received packets and forwards them to a new location. As a result, the new location is forwarded to the source. The authors in [2] proposed a new technique using the idea of limiting the topology of communicating nodes using connected dominating set (CDS) of nodes. The authors proposed an optimized region-based efficient routing (AORED) protocol for WSNs to overcome the energy issue. Using CDS, communicating nodes build a virtual backbone in the network by minimizing the number of communicating nodes. In this technique, the authors divided the complete network field into two parts to reduce the transmission energy, direct and indirect communication parts. In [22], the unique characteristics of social relationship with MSN (mobile social network) give rise to different protocol design issues are explained. In [23], a new computing paradigm for the optimization of parameters in adaptive beamforming using fractional processing is given. In [24], modeling and optimization of microwave filter by ADS-based KBNN is presented. The authors in [25] presented the computation and analysis of energy-efficient multirelay and multihop communication scheme in wireless sensor networks.

Vehicular ad hoc networks (VANETs) were studied in [26–28], where two important factors are defined, communication lifetime and distance; these factors were used to find the closest node and time estimation for being in the communication range of forwarder. An efficient method for cluster head selection was adopted, and a reliable and efficient routing protocol was proposed to address the routing issues in [29]. WDARS was proposed in [30], in which a new technique of weighted data aggregation routing was used by studying the prevailing issues, and this technique used a hop-tree to get maximum data aggregation. Enhanced Power-Efficient Gathering in Sensor Information System (EPEGASIS) was introduced in [31] with some changes in PEGASIS to overcome the hot spot issue by following the four steps, calculating optimal communication distance,

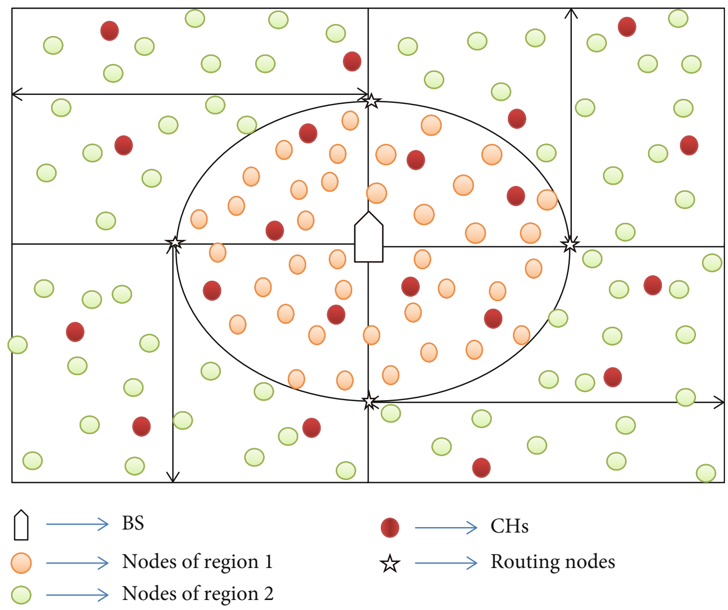

Figure 1: Proposed network architecture and mobility of routing node overview.

using mobile nodes, setting threshold for dying nodes, and communication range can be set by the node itself. Trajectory scheduling algorithm based on coverage rate for mobile sinks (TSCR-M) was introduced in [32], where authors used particle swarm optimization (PSO) along with mutation operator to search for parking positions with best coverage rate and then authors used genetic algorithm (GA) to plan the moving route for mobile sinks. In [33], an affinity propagation-based self-adaptive (APSA) clustering method was introduced, combination of advantage of machine learning algorithm, K-medoids with affinity propagation (AP) was used to get sensible clustering performance, AP calculates the number of cluster heads and enhanced K-medoids form the network topology by iteration.

3. Proposed RBM: Region-Based Mobile Routing Protocol

In this study, sensor nodes were deployed in some prespecified area, i.e., $100 \times 100\,\text{m}^2$, and the base station (BS) was installed at the center of the field. Then, the whole network field was divided into two parts; region 1 and region 2. Region 1 consisted of an area of 30 m of radius from the base station, and the rest of the area was named region 2. The sensor nodes at a distance of 30 m or less from BS were included in the region 1, and the nodes that were farther from this distance were part of the region 2. Clusters were formed, and CHs were elected among nodes based on their residual energy. As the sensor nodes can communicate with normal energy consumptions over a range of approximately 30 meters, that is why such region formation was done. Now as the CHs of the region 1 communicated directly with BS with normal energy consumptions, while for CHs of region 2, four routing nodes were placed at the boundary of regions 1 and 2 along x-axis and y-axis as depicted in Figure 1 to conserve the energy of nodes of region 2 as they were out of normal communication range. The routing nodes installed at the boundary of two regions comprised of same abilities as the other nodes but they did not take part in sensing or other normal functions of the network but they were employed for the specific purpose of gathering data from the CHs of the region 2 and transmit it to the BS. As these routing nodes were not taking part in any other function and only have to transmit data over normal ranges, hence, did not run out of energy fast and also helped the nodes of region 2 to preserve their energy. Also, these nodes had mobility over a specific range of distance where they were free to move while communicating with the BS. The proposed technique consisted of rounds, and every round comprised of two phases named setup and steady phase.

While moving in region 2, the routing nodes will update their position to CHs of region 2; these CHs will then forward the data to routing nodes when they will be in their vicinity at a closer distance. The installation positions of the four routing nodes are prespecified. As depicted in Figure 1, the entire area of the network is $100 \times 100\,\text{m}^2$ with BS at the center position (50, 50). The installation positions of mobile routing nodes are (25, 50), (50, 25), (75, 50), and (50, 75), and their movement directions are also mentioned in Figure 1.

Cluster heads in this phase are randomly selected. These CHs are chosen on basis of remaining energy of the node and threshold $T(n)$. Every node during cluster head selection process determines a random number from 0 to 1. Comparison of this number is then made with threshold $T(n)$, and the node with a number smaller than the threshold will become CH for the current round. The formula to calculate the threshold is

$$T(n) = \frac{1}{1 - (P * r \bmod (1/P))} \quad \text{if } n \in G, \tag{1}$$

$$T(n) = 0 \quad \text{if } n \notin G, \tag{2}$$

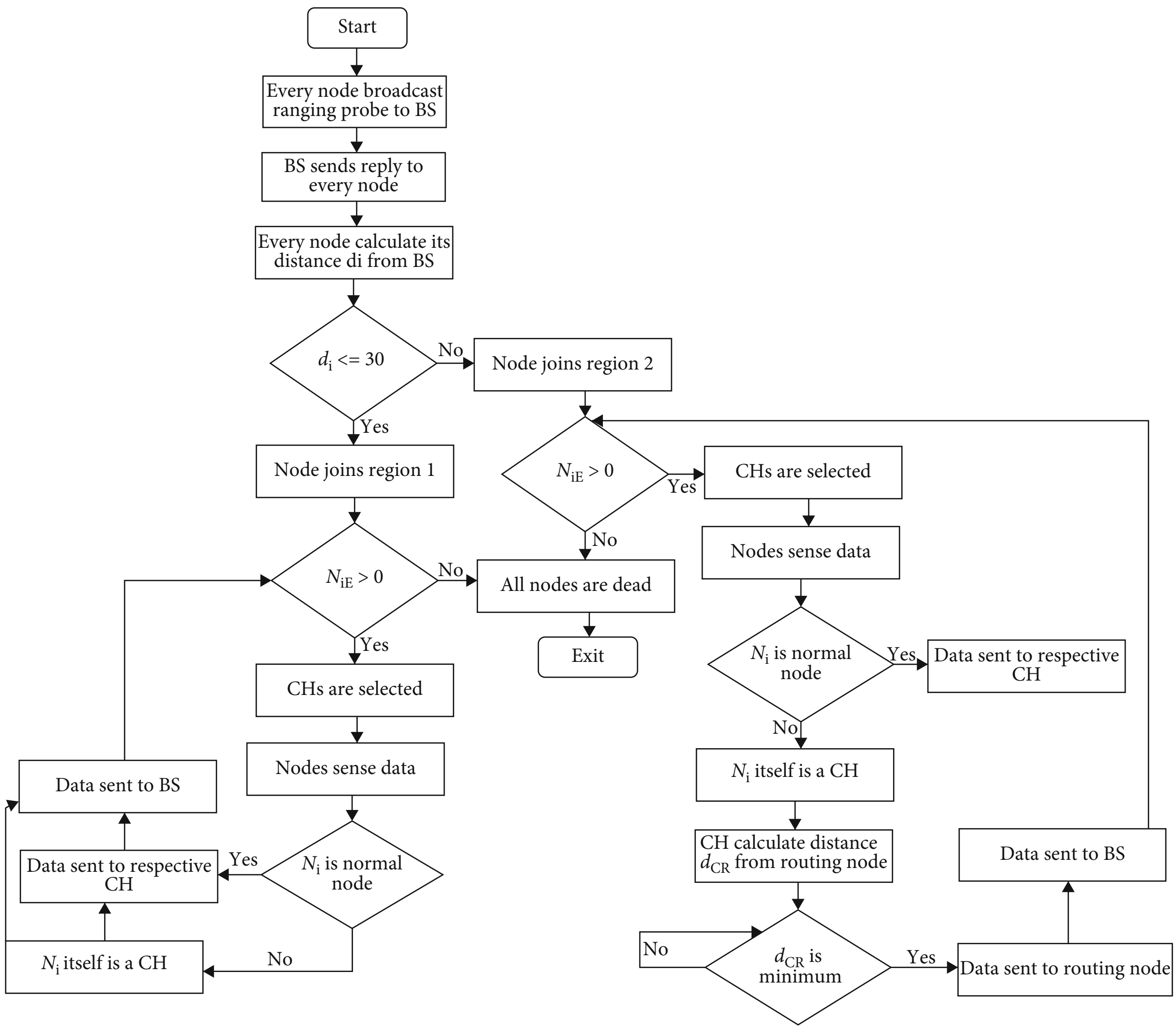

Figure 2: Flowchart of the proposed RBM.

where P is the probability to become a CH, r is the current round number, set of sensor nodes that have not been elected as CH in the last $1/p$ rounds is called G. The purpose of this algorithm is to ensure that in $1/p$ rounds, every node becomes CH only once. These two equations show the criteria for a node to become CH. If a node has not been a CH for the last $1/P$ rounds, then, there is a probability that it can become a CH; otherwise, it will not be considered as candidate for CH.

In the steady phase, the sensor nodes start communicating with their respective cluster heads. Elected CHs will broadcast their status, and on the basis of the strength of these broadcast signals, the sensor nodes will select their CH. After the cluster formation, the CHs will fix a TDMA schedule for members of its cluster and will broadcast this schedule. In region 1, the elected CHs aggregate sensed data and forward the data to BS directly. CHs of region 2 forward the received sensed aggregated data to the mobile routing nodes when they arrive in their locality. Mobile routing nodes send the received data to BS. The complete working of the proposed protocol is depicted in Figure 2.

Consider a two-dimensional area deployed with n number of nodes. According to the present study, these nodes will be categorized into three types, normal nodes, routing nodes, and cluster heads, where each type will perform a specific function. Function like sensing in the network, collection of data after sensing, and transmission of this data to CHs are performed by the normal nodes. Then comes the CHs which will perform the function of transmitting the received data, the CHs of region 1 will forward the data directly to BS while CHs of region 2 will communicate with routing nodes to forward them the received data. Finally, the routing nodes will forward this data of CHs to the BS.

Some mathematical formulas regarding the network's maximum throughput are presented in the literature. According to literature maximum, throughput can be obtained using the equation:

$$d_{\text{Total}} = \sum_{i=1}^{\text{NN}} u_t^i + u_r^i + \int_0^{2\pi}\int_0^r p\left(\pi r^2\right) r dr d\theta, \quad (3)$$

where u_t^i is number of bits transmitted by node i, and u_r^i is the number of bits received by node i. According to equation (3), if the output of the network is to be increased, then the lifetime of the network must be prolonged. To achieve a long network lifetime, the nodes should live for maximum duration. This equation shows that the total number of bits received and transmitted will be greater if the nodes live for a longer period which will only be possible if the energy consumption of the nodes is reduced.

$$\sum_{i=1}^{n} u_t^i + u_r^i \leq E_{\text{Total}} \quad \forall i \in i, \tag{4}$$

where u_t^i the number of bits is transmitted by node i, and u_r^i is the number of bits received by node i. This equation shows that the total energy consumed by the network for receiving and transmission of u bits will always be less than the total energy of the networks. This equation shows that the energy consumed to transmit u bits by the node i has an upper bound by the total energy provided to the network.

$$\sum_{i=1}^{\text{CH}} \sum_{i=1}^{\text{NN}} f_{ci} \leq F \quad \forall c, i \in n, \tag{5}$$

where f_{ci} is data flow between CHs and nodes, and F is the total flow of the network. According to equation (5), the flow of data between CHs and normal nodes has an upper bound by the total flow of the network. This equation shows that the total data flow between nodes to CHs and from CHs to normal nodes will always be less than the total data flow within the network.

$$f_{ci} \leq C_{ci} \quad \forall c, i \in n. \tag{6}$$

The relationship between flow and total capacity of some specific link is explained in equation (6). Where f_{ci} is the data flow between CH and node, and C_{ci} is the capacity of their link. This equation shows that the data flow through a link will always be less than the capacity of that link.

In the network, there are three different types of nodes; each type has different specific functions. Therefore, the energy consumption of each type of node will be different from the others depending upon their roles. The following equation used to calculate the energy consumed by the normal nodes:

$$E_{\text{NN}} = e_s + e_t(d_{\text{NC}}). \tag{7}$$

In equation (7), E_{NN} gives the energy consumed by the normal nodes, while sensing and transmitting their own data, e_s is energy spent during sensing the data, e_t shows the energy consumption in transmitting the data, and d_{NC} represents the distance from normal node to its CH. This equation shows that the total energy spent by some specific node N is the sum of energies spent in sensing the data and transmitting this data to CH over a distance d_{NC}. Equation (7) is a specific equation for some specific single node. We can generalize it for all normal nodes of the network using the following equation:

Table 1: Simulation parameters.

Parameter	Values
Number of nodes	104
Network size	100 × 100 m
Packet size	1 byte
Initial energy	500 mJ
Data aggregation energy cost	50 pj/bit
Transmission energy	50 nJ/bit
Receiving energy	50 nJ/bit
Simulation rounds	6000

$$E_{\text{NN}} = \sum_{\text{NN}}^{n} e_s + e_t(d_{\text{NC}}). \tag{8}$$

Equation (8) is a generalized form of equation (7). It shows that the total energy consumption of all normal nodes while sensing the data and transmitting this data to their respective CHs over some distance d_{NC}.

Assumption is made for CHs that each cluster head shares equal load from normal nodes of its cluster. First, we will take into account the energy consumed by the CHs of region 1, and their energy consumption is depicted in the equation given below:

$$E_{\text{CH},R1} = e_s + e_t(d_{\text{CB}}) + \frac{\text{pn}_{R1}}{m_{R1}}[e_r + e_t(d_{\text{CB}})], \tag{9}$$

where e_s is the energy spent by CH while sensing the data $e_t(d_{\text{CB}})$ is the energy spent while transmitting its own sensed data and also the data from other nodes to the BS, e_r is the energy spent in receiving the data, d_{CB} shows the average path distance from CH to the BS.

For the energy consumption of CHs of region 2, the following equation will be used:

$$E_{\text{CH},R2} = e_s + e_t(d_{\text{CR}}) + \frac{\text{pn}_{R2}}{m_{R2}}[e_r + e_t(d_{\text{CR}})], \tag{10}$$

where e_s is the energy spent by CH while sensing the data $e_t(d_{\text{CR}})$ is the energy spent while transmitting its own sensed data and also the data from other nodes to the routing node, e_r is the energy spent in receiving the data, and d_{CR} shows the average path distance from CH to the nearest routing node.

These equations give the estimation of the energy consumed by the CH. The energy consumption of CH will be greater than the other normal nodes. CHs of region 2 will sense the data and forward their own data along with the data of other connected nodes to the routing nodes. Energy consumption of CHs of region 2 is the sum of energies spent in sensing and forwarding its own data and energy spent in receiving and forwarding the data from other nodes of the same cluster.

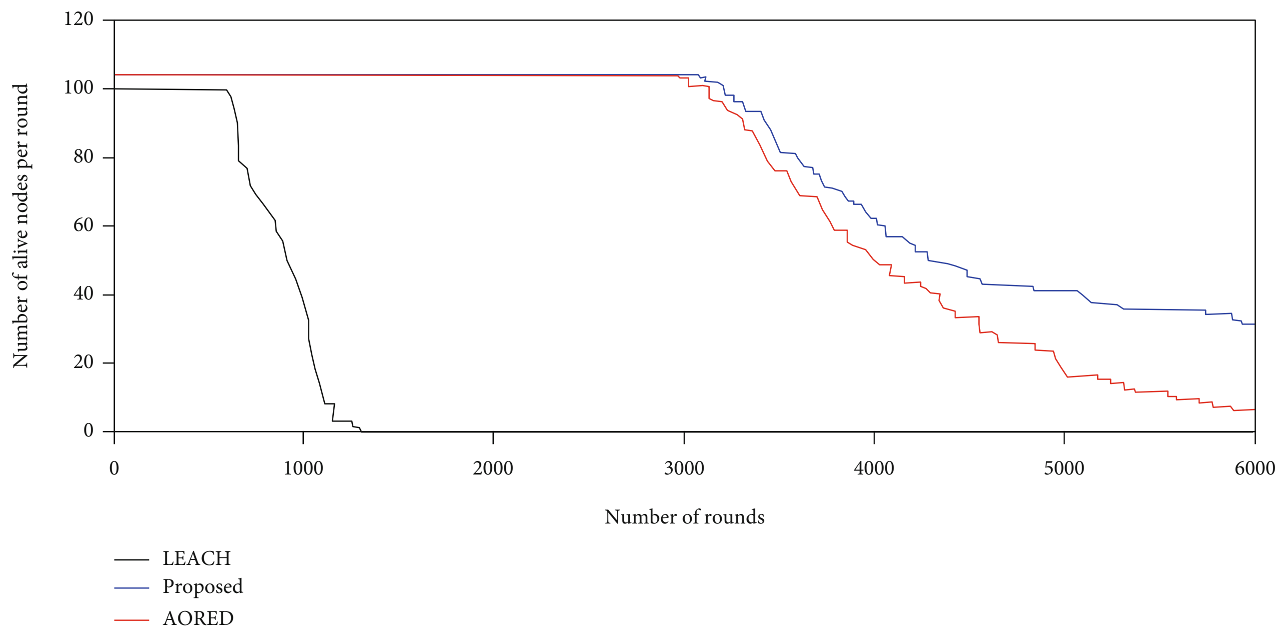

Figure 3: Number of alive nodes per round.

It is assumed about routing nodes that equal load is shared from cluster heads of region 2. The following equation will show the energy consumed by the routing nodes:

$$E_{\mathrm{RN}} = e_t(d_{\mathrm{RB}}) + \frac{\sum_{k=2}^{K} \mathrm{pn}_k}{m_{R1}} \left[e_r + e_t(d_{\mathrm{RB}})\right], \qquad (11)$$

where d_{RB} is the average distance of routing node from BS, e_t is the energy consumed while transmitting the data over distance d_{RB}, and e_r is the energy consumed in receiving the data. This equation gives the total energy consumption of routing nodes which includes all the energies spent in receiving the data from CHs of region 2 and transmitting this data to the BS.

4. Evaluation of the Proposed Region-Based Mobile Routing Protocol

The performance evaluation of the proposed RBM Protocol was done by comparing its results with the results of the AORED and LEACH. Some performance evaluation criteria were considered to determine the performance of the proposed model. These performance evaluation criteria are described briefly. *Stability Period:* this is the period till the first node in the WSN is dead. So we will observe the time period when the first node of the WSN becomes exhausted and remains no more a part of our network. *Lifetime:* it is the time period from the start of network function till the expiry of all nodes in the network is termed as lifetime of the network. We will observe for the network lifetime of our network. *Number of Elected Cluster Heads per Round:* the number of elected cluster heads per round that are capable of gathering and aggregating the data will also be observed to evaluate the performance of the proposed scheme. *Number of Dead Nodes:* to evaluate the network performance, the number of nodes that are dead after some particular round is also observed. *Number of Packets to Base Station:* data sensed by nodes in the network is forwarded to CHs, where this data is aggregated and sent to BS either directly or indirectly. After the network lifetime has expired, the total number of packets received by BS is observed to evaluate the performance of the network. Simulation parameters are given in Table 1.

4.1. Simulation Results and Analysis. To prove the proposed system, MATLAB simulator was used as a simulation tool to study and evaluate its performance. The better working of the proposed protocol was shown by comparing its results with some existing techniques, i.e., AORED and LEACH. The working of both techniques AORED and LEACH has already been explained in the literature review section of this article.

Figure 3 gives a comparison between the number of live nodes (along y-axis) after each round and total number of rounds (along x-axis). This comparison actually gives us the stability period of the network; the time period from the start of network functioning till the expiry of the first node is called the stability period of the network. Figure shows that in the proposed protocol, the first node becomes dead approximately after 3200 rounds approximately, and in AORED, the first node becomes dead at about 2900 rounds, but in the case of LEACH, the first node is dead approximately near about 600 rounds. As the proposed RBM remained stable for more rounds as compared with other techniques, hence, RBM proved to have more stability period than other techniques. The figure depicts that the stability of the proposed protocol has been enhanced by 11% approximately when compared with AORED and more than 400% when compared with LEACH.

In Figure 4, the number of dead nodes (along y-axis) is compared with the number of rounds (along x-axis) to

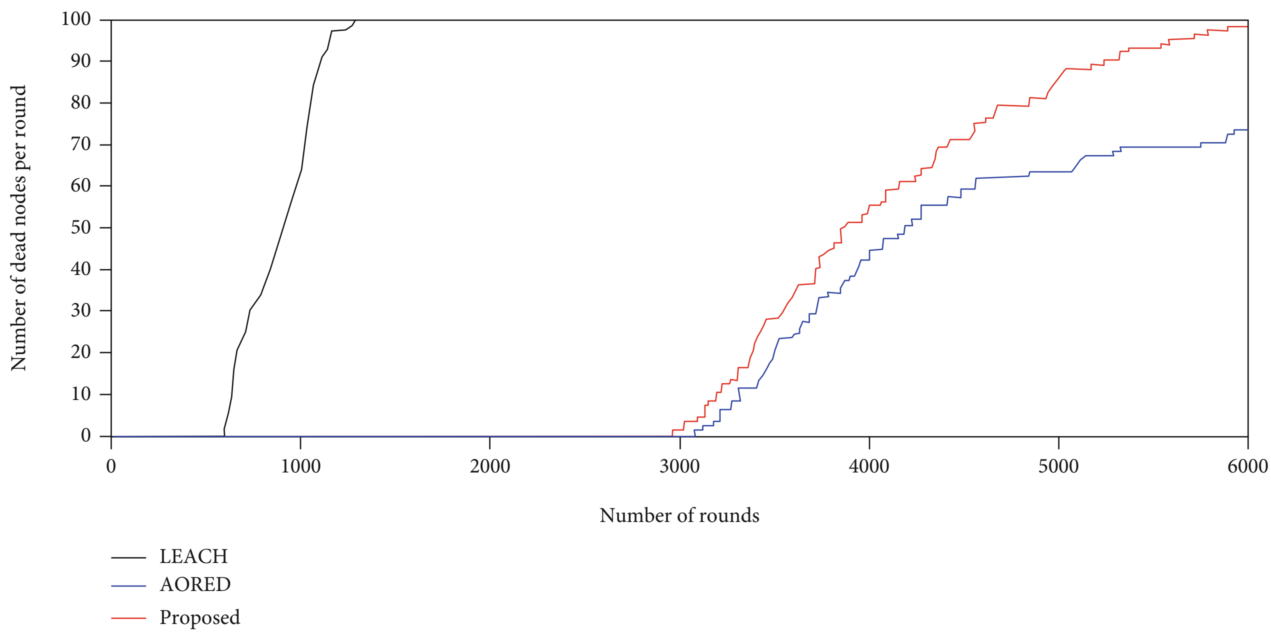

Figure 4: Number of dead nodes per round.

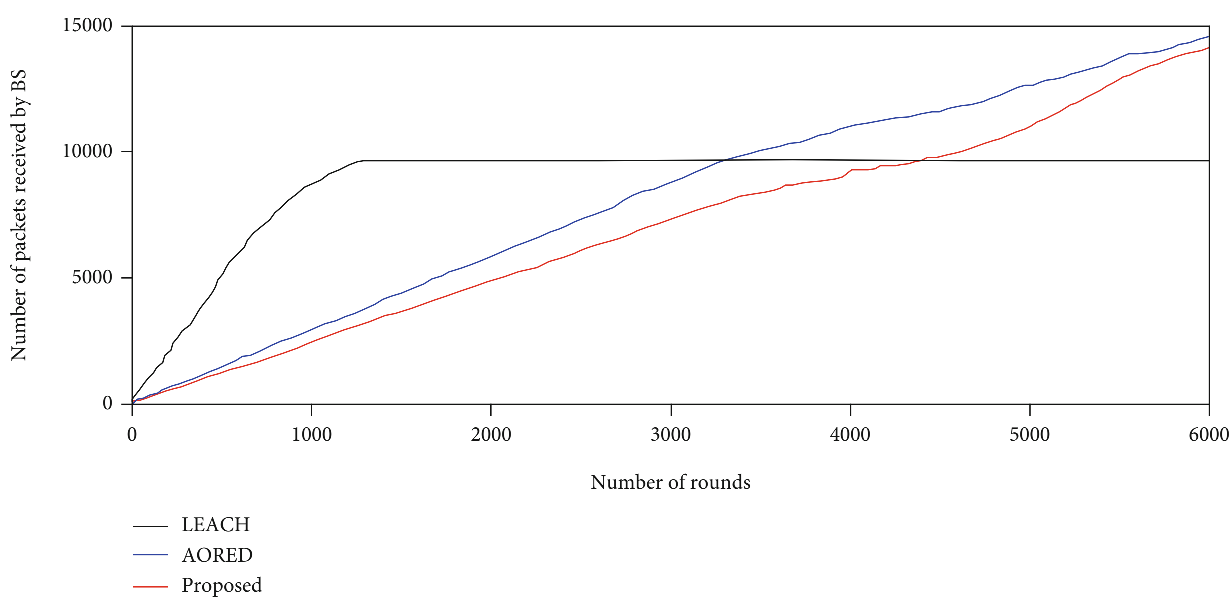

Figure 5: Number of packets sent to base station per round.

calculate the lifetime of the network. The time period from the start of network function till the expiry of all nodes in the network is termed as the lifetime of the network. The first node in case of LEACH becomes dead at near about 600 rounds, and approximately after 1300 rounds, all of the sensor nodes are dead showing that the LEACH has a lifetime of about 1300 rounds only. For AORED, it is observed from the figure that its first sensor is dead nearly at 2900 rounds, and after the completion of 6000 rounds, 99% of its sensor nodes are dead leaving the WSN of no more use. But in the case of the proposed RBM Routing Protocol, it is obvious from the figure that its first node becomes dead after about 3200 rounds, and after the completion of 6000 rounds, it can be seen that about 73% of nodes are dead leaving about 27% of the sensor nodes still in useful state and will continue their function for the WSN leaving the network still in working condition until all of their energy is drained out. These results show that in terms of lifetime, the proposed RBM showed 34% better performance than AORED and more than 4 times better performance than LEACH. Hence, achieving the desired better performance.

In Figure 5, the number of packets sent to BS (along y -axis) and number of rounds (along y-axis) are related to calculate the throughput of the WSN. It has been explained in the working of the proposed protocol that the CHs of region 2 will forward their data packets to mobile routing

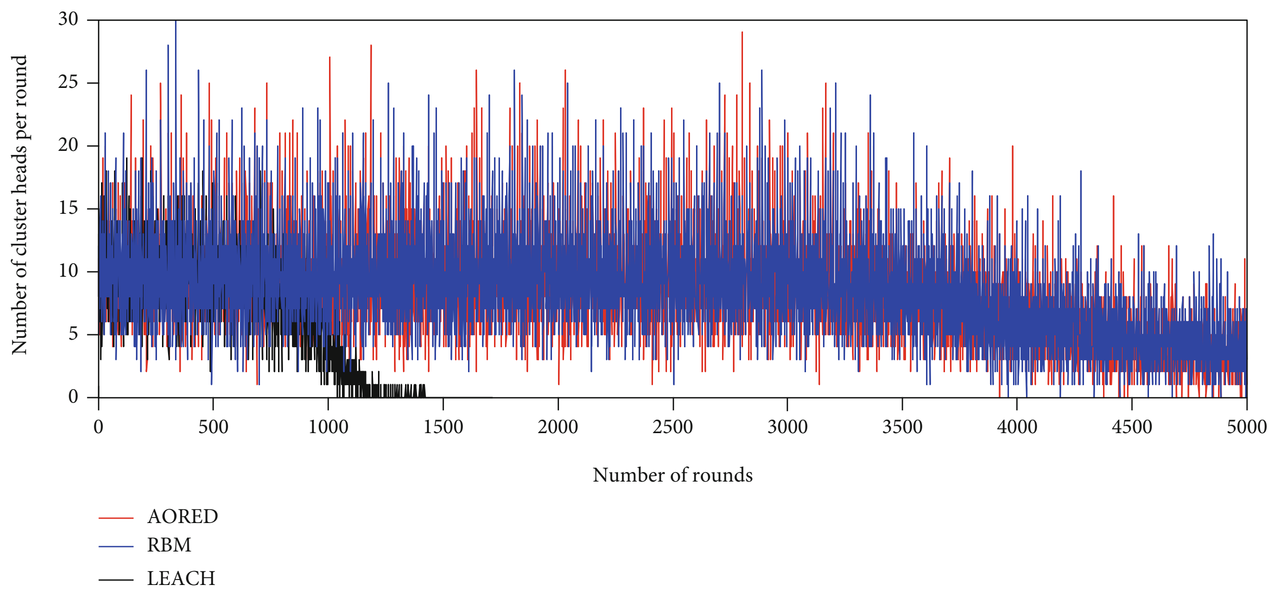

Figure 6: Number of elected cluster heads per round.

nodes. These mobile routing nodes will then send the data to BS after aggregation. In this manner, more than 50% of the data sent to BS is received and controlled through routing nodes. The packets received by BS and it is seen that in the case of AORED and proposed techniques, the packets are sent to BS in a regular manner but the packets sent by proposed are more than AORED is shown in Figure 5 graph. While in LEACH packets sent to BS suddenly reaches its peak and then stops. In 6000 rounds, the proposed RBM sent more than 14500 packets to BS while AORED sends about less than 14000 packets approximately. This shows more than 5% increase in throughput.

Figure 6 shows the number of CHs elected in each round. CHs are responsible to obtain the sensed data from sensor nodes, and after aggregating the data, they forward it to BS. New CHs are chosen after the completion of every round. This election of CHs is in a random manner to keep balance in energy consumption between the sensor nodes. If a small number of CHs are chosen, then, they have to receive, aggregate, and forward the data from more sensor nodes which consume more of their energy. Election of more CHs mean increased capability of receiving, aggregating, and forwarding of more data with less consumption of energy resources.

5. Conclusion and Future Work

In this study, a region-based mobile routing protocol has been proposed for the enhancement of network lifetime in WSN. The network field was first partitioned into two parts on the basis of distance from BS. BS was placed at the center of the network field. CHs of region 1 that were closer to BS communicated with BS directly with normal energy consumptions. Mobile routing nodes were introduced in region 2 that moved on the specified path to gather data from CHs of region 2 and sent it to BS after aggregating it, conserving the energy of nodes and consequently increasing the network lifetime. Simulations were performed using MATLAB simulator, and the results were compared to AORED and LEACH techniques. Evaluation of the proposed RBM technique on the basis of selected parameters, stability period, node lifetime, number of elected cluster heads per round, and number of packets to BS shows that RBM performed better than AORED and LEACH. The simulation results showed that the proposed technique achieved its goals of energy conservation and enhancement of network lifetime.

As future research considerations, the network field can further be divided into more than two regions and introducing some more routing nodes reducing the transmission distance, which will save energy. Also in the same model, the experimentations can be done by changing the movement path or directions of the routing nodes. This study can also be extended by adding more routing nodes in the system.

Data Availability

The data are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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