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Clustering based Dynamic Routing Algorithm for Efficient Energy Utilization in Wireless Sensor Networks (WSNs)

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ABSTRACT

The significance of proper and efficient energy utilization is quite high in Wireless Sensor Networks (WSNs). As a result, network lifetime can be massively enhanced. Therefore, Graph enabled Energy Optimized Routing (GEOR) algorithm is adopted to extend the lifetime of the sensor network and minimize energy consumption in WSNs. An efficient solution for lifetime enhancement of sensor network and energy minimization are key objectives of the proposed GEOR algorithm. The proposed GEOR algorithm provides improved performance than the traditional Low Energy Adaptive Clustering Hierarchy (LEACH) approach. Here, the proposed GEOR algorithm enhances cluster size and the CH selection process is performed to elect CHs for multiple clusters present in the sensor network. A detailed solution for the optimization problem in WSNs is also presented. The mobility aspect of the sink node has a massive impact on energy consumption in WSNs. Experimental results are evaluated in terms of sensor network lifetime enhancement (number of alive nodes and number of dead nodes). Cluster formation and CH selection are performed based on the mobility cost function. Throughput and network lifetime results are obtained in terms of residual energy using the proposed GEOR algorithm. The result is compared against the traditional LEACH approach and the proposed GEOR algorithm shows superior performance.

Keywords - **Cluster, Cluster Head (CH), Graph enabled Energy Optimized Routing (GEOR) algorithm, Sensor Nodes, Wireless Sensor Networks (WSNs).**

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I. INTRODUCTION

Wireless Sensor Networks (WSNs) has gained immense popularity in recent years due to their various abilities like allows wireless multi-hop communication, performs centralized monitoring, sensors are rapidly deployable and highly scalable. WSNs can be heavily utilized in disaster management, military operations, commercial and industrial applications and to establish communication in places of lower accessibility. WSNs is a network which consists of several nodes which can provide a great communication facility even in hard-to-reach areas [1]. WSNs contains Cluster Head, sink nodes, senor nodes and base station (BS) and nodes has a limited amount of energy stored and WSNs is utilized to track the physical environmental situations [2]. WSNs is a spatially distributed wireless system in which sensor nodes are utilized to exchange information from nodes to the cluster head and group of nodes are selected to form a cluster [3]. Moreover, WSNs permits these nodes to exchange data between them. These nodes are battery enabled sensors and works for a limited amount of time and charging of this sensor nodes is quite difficult process due to they are positioned in hard-to-reach areas. Furthermore, widely evolving technologies like Cognitive Radio Networks, Internet of Things (IoT), and data fusion techniques can be integrated with WSNs to develop smart applications so that current industrial requirements can be fulfilled [4-5]. Here, WSNs is massively utilized to monitor surroundings conditions in physical environment like to sense humidity, temperature, position, vibration, pressure and sound [6]. Thus, establishment of a reliable and energy efficient based routing mechanism in WSNs is a critical task and can heavily affect Quality of Service (QoS). Therefore, several problems are observed in WSNs across the years by varied researchers like congestion in routing process, data transmission delay, energy-consumption and high mobility cost, low data packet delivery ratio, high overhead. Furthermore, mobile sensor nodes can save significant amount of energy. The distance between sensor nodes and CH is determined using a threshold and transmission energy remains directly proportional to the threshold distance. However, routing optimization between sensor nodes and CH is quite challenging. Thus, number of researchers have shown great interest in providing solutions for these mentioned problems. Some of the literatures are as follows:

In [7], a clustering-based node overhaul scheme is adopted to minimize energy consumption so that quality of service (QoS) get improved and data packet efficiency is heavily depends upon prominent standard protocols and senor network parameters. Here, performance of Node Overhaul Scheme is analysed in terms of Node death rate efficiency and network lifetime. This work mainly focuses on energy issues of WSNs using improved LEACH protocol. Here, data packets are transmitted with the help of cluster head. In

[8], data packet loss ratio and energy efficiency enhancement methods are utilized based on software-defined multi-hop WSNs. This methodology is mainly utilized to balance energy levels among multiple routing paths. This methodology enhances lifetime of sensor networks based on data packet aggregation functions. This methodology minimizes network overhead based on the generalized checksum functions. In [9], an energy efficient clustering protocol is presented to enhance transmission efficiency in WSNs. Here, a clustering methodology is utilized to select Cluster Head and to balance energy consumption of nodes in a multi-hop routing mechanism. Here, best route is determined based on the parameters like delay, throughput and connectivity using Soft-k-Means Clustering. An energy efficient clustering mechanism is introduced for data transmission in WSNs based on greedy approach and artificial neural network methods. This methodology enhances network lifetime and maximizes residual energy [10] – [12]. Here, performance is measured based on the parameters like residual energy and the packet delivery ratio. In [13], a Node-Level Error Control mechanism is introduced in WSNs to minimize network overhead and energy consumption. This methodology heavily utilized to reduce computational complexity based on meta-heuristic approaches and mixed-integer programming (MIP) model is utilized to improve transmission efficiency and packet delivery ratio. Here, network capacity is enhanced based on node level error controlling scheme and transmission efficiency is handled using automatic repeat request (ARQ), and hybrid ARQ (HARQ) and forward error correction (FEC) parameters.

The contribution of work can be classified as follows:

However, several problems such as energy-efficient routing, low packet delivery ratio, high overhead which remain unanswered and can heavily impact Quality of Service (QoS) in WSNs. Thus, Graph enabled Energy Optimized Routing (GEOR) algorithm is introduced in this study to enhance energy efficiency in WSNs. This proposed GEOR algorithm improves efficiency of data packet transmission in an intra-cluster configuration. The proposed GEOR algorithm is utilized to define cluster boundaries and multiple clusters are formed and each cluster consists of multiple number of sensor nodes. Nodes present in the neighbouring area of CH, transmit information to the cluster head. Furthermore, the proposed GEOR algorithm reduces network overhead and enhances capacity of WSNs. Hence, Quality of service in WSNs gets heavily improved. Energy consumption is minimized by exploiting mobile sink node mobility. Furthermore, different network parameters and clustering scheme is used to enhance QoS in WSNs. The proposed Graph enabled Energy Optimized Routing (GEOR) algorithm is set up using sensor nodes, base station, sink nodes and clusters. Here, proposed GEOR algorithm enhances cluster size and minimizes energy consumption of nodes. For each cluster, a cluster head is selected and after finalization of cluster head, a low-mobility cost routing path is determined in a multi-hop wireless communication. The performance of proposed GEOR algorithm is evaluated using clustering methods. The simulation results are obtained in terms of alive node, dead nodes, energy efficiency and throughput.

This article is discussed in following style. Section 2, discusses about the mathematical representation of proposed Graph enabled Energy Optimized Routing (GEOR) algorithm for energy efficiency improvement. Section 3, describes about the simulation results and compared with classical WSNs methods and section 4 concludes the article.

II. MODELLING OF PROPOSED GRAPH ENABLED ENERGY OPTIMIZED ROUTING (GEOR) ALGORITHM

In this section, a mathematical modelling of proposed Graph enabled Energy Optimized Routing (GEOR) algorithm is presented to enhance throughput, transmission efficiency and reduce energy consumption in WSNs. Here, adopted GEOR algorithm obtain minimum energy consumption and higher data packet transmission ratio. WSNs is a group of spatially distributed sensor nodes which is utilized to sense data and perform data packet transmission from the monitoring of environmental and physical conditions. This paper provides a detailed solution to form cluster and their boundaries and to select cluster head (CH) using graph theory. The following paragraph shows network modelling in detail. An algorithm 1 is presented using Proposed Graph enabled Energy Optimized Routing (GEOR) algorithm for data packet transmission through cluster formation and CH selection.

Large number of sensor nodes are distributed inside a sensor network. Sensor network is sub-divided into multiple clusters and each cluster contains several sensor nodes. Every cluster contains a Cluster Head (CH). Some conventions are required in modelling of sensor network which are as follows:

1. Each node is able to broadcast and receive information through their neighboring links and contains a unique ID
2. All the nodes are strongly linked to each other in a sensor network.
3. Every node is aware that which node is chosen as CH.
4. Inside the graph, every node has a knowledge of their adjacent node.
5. The unique ID of each node is responsible for data packet transmission.

A hierarchical sensor network is categorized into multiple clusters using proposed GEOR algorithm. An event request is made between mobile sink node and linked sensor nodes and vice versa and Information related to the location of event generation is known using proposed GEOR algorithm based on their strongly linked graph. Mobility cost of transmitted messages is reduced between CH to CH based on the generated optimized route towards mobile sink node in a multi-hop cluster configuration. A random CH is selected based on the mobility cost function for every cluster constructed inside the sensor network so that global energy consumption is minimized in a sensor network.

The ultimate energy efficiency and node connectivity is massively enhanced using proposed GEOR algorithm. However, reduction of energy consumption is a challenging task which can be handled using cluster boundary formation dynamically. Each sensor node receives information related to the event from the mobile sink node to extend coverage potential. Certainly, sink node is massively benefited by having an idea about the network structure through signal transmission to the sensor nodes and graph theory based dynamic routing model is utilized to estimate cluster boundaries. As a result, formation of cluster boundaries is massively depends upon the node density and energy consumed by those nodes in a certain time period. Thus, main role of graph theory based routing model is to minimize energy consumption and improve node connectivity and extent cluster size. Cluster Head (CH) selection is carried out after certain interval of time and once the re-election of CH is performed, then process of cluster boundary formation using Graph theory gets repeated. Furthermore, this process is performed at the mobile sink node till the re-selection of new CH and network boundary formations. After formation of cluster boundaries, mobility cost based energy optimized routing algorithm is performed dynamically to evaluate route with lowest mobility cost in between CH to the sink node. The proposed GEOR algorithm is capable of handling multi-hop communication.

The sensor network is sub-divided into different clusters and sink node is responsible for CH election, boundary formation and signal transmission between different clusters. Some network dynamics are discussed in the following paragraph.

1) Cluster Head (CH) Election:

When cluster head (CH) election process starts, then mobile sink node is utilized to select a sensor node which has maximum energy and CH selection is performed using following equation,

$$S(f) = \frac{t}{1 - t\big(m \bmod (1/t)\big)} \frac{N_d}{N_g} \tag{1}$$

Where, a cluster consists of several nodes and these nodes are indicated by $1/t$ and the number of times CH re-election procedure is conducted is denoted by m and residual energy of sensor nodes are indicated using N_d. Further, the potential preliminary energy is defined by N_g. Moreover, CH election process is repeated for each sensor node present in the cluster and a sensor node with highest energy $S(f)$ is chosen as CH. A message is transmitted by the mobile sink node to all the sensor nodes inside the cluster, once largest energy CH is selected.

2) Cluster Boundary Formation Dynamically:

First of all, node distances are evaluated using proposed GEOR algorithm and then, maximum distance between sensor nodes is indicated by H_r and minimum distance between nodes is denoted by H_y, respectively. A distance between Sink node and all the sensor nodes are evaluated to determine radius of a cluster using following equation,

$$X_b = 1 - \delta\left(\frac{H_r - h(f_v, SN)}{H_r - H_y}\right) \tag{2}$$

Where, for b^{th} cluster, the radius of cluster is indicated by X_b and the number of clusters available inside the sensor network is indicated by B and where b is represented as $1,2,3, \ldots \ldots B$. Then, energy normalization per cluster is given by δ which ranges from 0 to 1. Then, energy normalization δ is given by following equation,

$$\delta = \frac{\sum_{v=1}^{f} N_v}{X_v} \tag{3}$$

3) Proposed Graph enabled Energy Optimized Routing (GEOR) algorithm:

An efficient solution for optimization problem and energy minimization is the main focus area of proposed GEOR algorithm. The, a route with minimum mobility cost is selected using GEOR algorithm and set points are evaluated using Graph theory and then, transmission route from CHs to mobile sink node is determined with minimum distance. Then, probability of selection for cluster v and cluster i to transmit signals from one cluster to another is defined by below equation,

$$T_{vi} = \aleph \eta_{vi}^{\delta} \beta_{vi}^{\varphi} \tag{4}$$

Here, normalization constant parameter $\aleph$ ranges from 0 to 1 and heuristic and probability parameter values are indicated by β and η, repectively. The relative impact of probability parameter values and heuristic values is defined using δ and φ, reprectively. When, value of probability parameter becomes zero then, two closest clusters are chosen. On the other hand, when value of heuristic value becomes zero then, only probability parameters are utilized. Therefore, heuristic parameter values considering two adjacent CHs such as v and i are given by below equation,

$$\beta_{vi} = \Omega\left(1 + \left(\frac{H(i,u)}{H(v,u)}\right)^{\Psi}\right) \tag{5}$$

Where, energy consumed from v to i is defined by Ω and represented by following equation,

$$\Omega = \frac{N}{H(v,i)} \tag{6}$$

Where, a controller parameter Ψ is utilized to handle functions of normalization and back-up CH is chosen to connect v and i are indicated by u. Thus, probability parameter values are updated using following equation,

$$\eta_{vi}(s+1) = (1-t)\eta_{vi}(s) + \xi t \eta_{vi}(s+1, s) \tag{7}$$

Where, rate of probability evaluation is determined by $t = \frac{1}{F_d}$ and this probability evaluation rate is adopted to permit negative reinforcements. Then, a shortest transmission route is defined to send data packets to the Sink node and the number of nodes remain available are represented by F_d. ξ is determined using following equation,

$$\xi = \frac{N_v + N_i}{H^2(v,i)} \tag{8}$$

Algorithm 1 Proposed Graph enabled Energy Optimized Routing (GEOR) algorithm

Step 1: Use all sensor nodes to construct cluster using GEOR algorithm

Step 2: Node distribution in Cluster based on indicator

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values
Step 3 : For Each Cluster Head Selection
Step 4: If SN then
 Repeat CH re-selection process
 End if
Step 5: Use Graph theory to transmit message to all nodes
Step 6: Execute Graph enabled Energy Optimized Routing
Step 7: Hop Exploration
Step 8: Manage acquired paths
Step 9: Evaluate mobility cost and path with lowest mobility cost selected
Step 10: Link CHs to nodes with elected path
Step 11: if well-defined margin then
 Do network observing
 End if
Step 12: Update feature weights and Probability parameters
Step 13: Get Sensor Output

III. Result and Discussion

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

This section discusses about the performance results using proposed Graph enabled Energy Optimized Routing (GEOR) algorithm in WSNs and compared against traditional optimized routing methods. Moreover, Graph theory based routing is utilized to achieve simulation results. Here, training matrices like number of alive nodes, number of dead nodes, energy consumption and mobility cost function are selected using proposed GEOR algorithm and simulation results are compared against Low Energy Adaptive Clustering Hierarchy (LEACH). Further, adoption of mobile sink node, has shown massive improvements in efficiency of data transmission and energy consumption.

A detailed exanimation is performed to analyse performance efficiency of proposed GEOR algorithm and the main objective of this study is cluster creation and formation of cluster boundaries. Here, multiple nodes are placed inside cluster and these nodes are strongly linked with each other. Data transmission take place between mobile Sink node and CHs and a threshold is defined and compared against obtained random number regularly. The resultant output helps to construct cluster borders. Then, CH is elected for each cluster to transmit data packets efficiently. Training performance is analysed based on number of rounds and it is stated that the time period of data transmission from Sink Node to all CHs is defined as rounds. Here, error rates are minimized using GEOR algorithm so that transmission of data packets becomes maximum. The proposed GEOR algorithm is used to ensure high quality performance results in WSNs. Energy consumption reduction and throughput enhancement are the prime focus area in the current research using sink node-cluster head configuration in WSNs. Existing WSNs have multiple issues such as high computational complexity, low throughput, large error rates. However, proposed GEOR algorithm handles these problems efficiently. A transmission route is selected with maximized energy and strong linkage to send data packets with minimum error rate in WSNs.

Moreover, $MATLAB^{TM}$ simulation platform is used to obtain performance results. Here, computational complexity is significantly minimized using GEOR algorithm. The performance efficiency is evaluated using proposed GEOR algorithm on 64-bit windows 10 OS with $INTEL\ (R)$ core $(TM)\ i5-4460$ processor. Performance is simulated using 16 GB RAM and $3.20\ GHz\ CPU$. Moreover, simulation results are obtained considering 100 sensor nodes and 20 sensor nodes are selected as CHs among those 100 sensor nodes. Several network parameters and dynamics are considered

Figure 1 shows a graphical representation of Node deployment in WSNs. Total number of nodes considered are 100. Here, plus sign is referred for advanced nodes and circle represents normal nodes. All the advanced nodes has higher energy than the normal nodes and CHs selection is done among those advanced nodes.

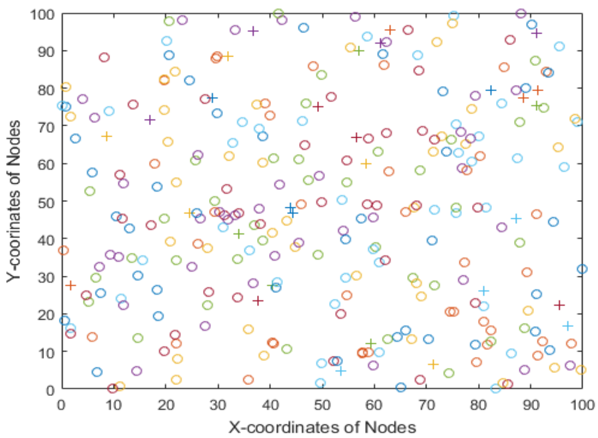

Figure 1 Node Deployment in WSNs

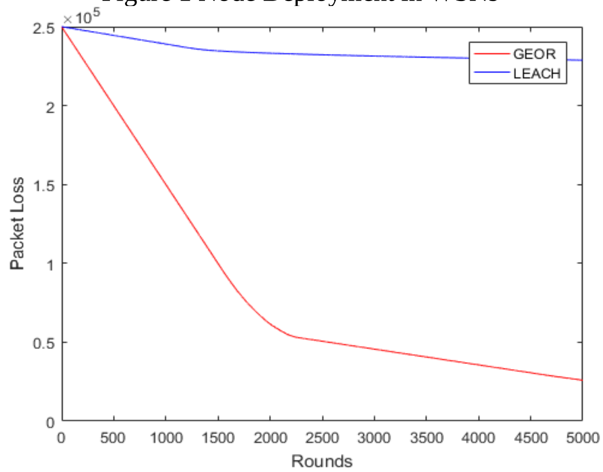

Figure 2 Packet Loss against Number of Rounds

Figure 2 shows a plot between numbers of data packet lost while transmission against number of iterations using proposed GEOR algorithm against traditional LEACH approach and the number of iterations considered are 5000 to evaluate performance efficiency in terms of packet loss in a sensor network.

It is analyzed from Figure 2 that number of packet loss are relatively less in number in comparison with traditional

LEACH approach. Therefore, overall data packet transmission rate is massively enhanced in proposed GEOR algorithm and can provide transmission for larger time-period.

Figure 3 shows a graphical representation of mobility cost function versus number of iterations. Total number of iterations used are 100 to determine mobility cost function. Mobility cost is utilized to allocate CHs and improve resource utilization efficiency in WSNs. Based on mobility cost energy, transmission of data packets is achieved through a strongly linked route.

Likewise, Figure 4 shows a plot between throughput versus number of iterations using proposed GEOR algorithm against traditional LEACH approach and the number of iterations considered are 5000 to evaluate performance efficiency in terms of throughput of a sensor network. It is analyzed from Figure 4 that throughput is relatively higher in case of proposed GEOR algorithm in comparison with traditional LEACH approach and till 2000 rounds, the throughput is massively enhanced compare to classical LEACH algorithm and after 2000 rounds, the obtained throughput shows satisfactory performance using proposed GEOR algorithm. Thus, overall efficiency of sensor network is massively improved in case of proposed GEOR algorithm compare to their counterpart LEACH approach.

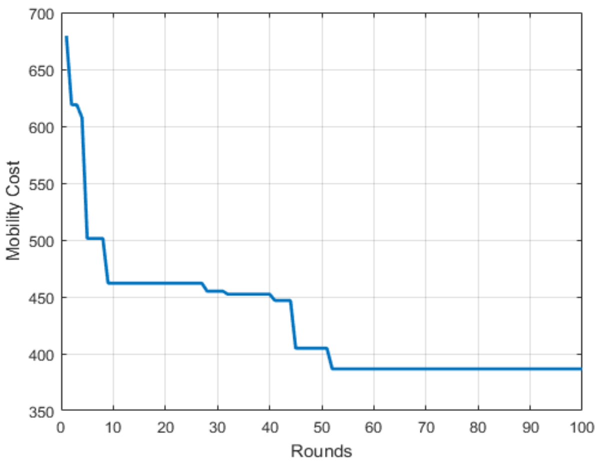

Figure 3 Mobility cost function Energy against Number of Rounds

Figure 5 shows a graph between Network Lifetime versus number of rounds and the number of iterations considered are 5000. The network lifetime is obtained considering 100 sensor nodes and it is analyzed from Figure 4 that lifetime of sensor network is much higher for initial number of rounds. However, after 2000 rounds, lifetime of sensor nodes start decreasing. Thus, the simulation results shows superiority of proposed GEOR algorithm in terms of mobility cost, packet transmission loss, network lifetime and throughput.

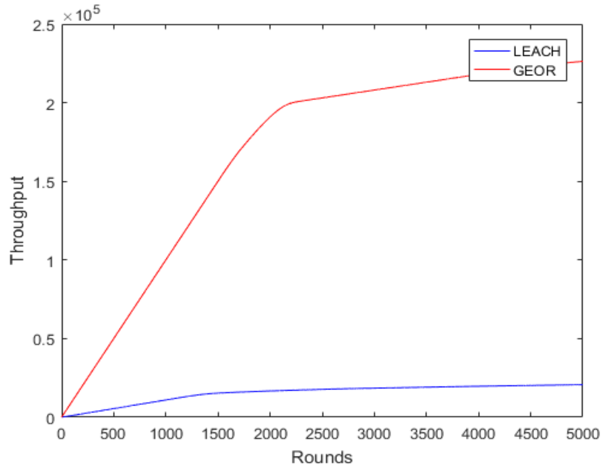

Figure 4 Throughput against Number of Rounds

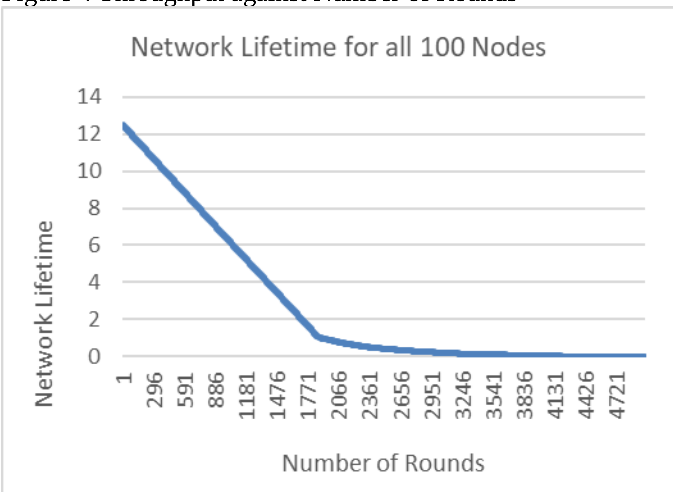

Figure 5 Network Lifetime Vs Number of Rounds

IV. CONCLUSION

Reduction of energy consumption and lifetime enhancement of sensor network are major challenges in WSNs. Therefore, in this article, Graph enabled Energy Optimized Routing (GEOR) algorithm is presented to maintain balance between sensor network lifetime enhancement and energy consumption in WSNs. The proposed GEOR algorithm works on the principle of cluster formation and Cluster Head (CH) selection so that data packets can transmit efficiently from CHs to the mobile Sink Node. Multiple clusters are constructed inside the sensor network and nodes are strongly linked to each other based on Graph Theory. Exploitation of mobility concept in mobile sink node has provided improved sensing results with higher accuracy. A detailed mathematical modelling for cluster formation, cluster boundaries construction and selection of CHs and efficient data transmission based on Energy Optimized Routing using Graph Theory. Training matrices like mobility cost, packet transmission loss, network lifetime and throughput are selected using proposed GEOR algorithm to analyze performance efficiency. Simulation results are obtained considering 100 sensor nodes and 20 sensor nodes are selected as CHs among those 100 sensor nodes. Performance results shows superiority of proposed GEOR algorithm in comparison with traditional LEACH algorithm.

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