A Hybrid Energy Efficient Reactive Multipath Routing for Wireless Sensor Network

Neha Malgotra, Nitin Mittal, Prabhjot Singh

Abstract*: The efficiency of the wireless sensor network (WSN) can be evaluated by using various factors such as lifetime of the network, number of dead nodes, number of alive nodes, throughput of the network etc. All these factors are highly influenced by CH and route formation process as the election of right node for CH and route is quite tedious task to perform. Thus a large number of researches has been conducted in previous years. Few of the previous approaches have been discussed in this study and it is analyzed that the traditional HEEMP approach in quite effective to enhance the network lifetime but has a weak data communication and transmission strategy. Thus a novel approach is developed in this work by using the traditional HEEMP approach. The modification in the proposed work is done in terms of data gathering and data transmission strategy. Only the relevant and meaningful data packets are transmitted to the BS. The performance analysis of the proposed and traditional HEEMP protocol is compared and proposed work is found to be effective than the HEEMP protocol in terms of lifetime of the network.

Index Terms*: Wireless Sensor Network, Data packets transmission, network lifetime, cluster head, HEEMP, TEEN, CEED, and LEACH.

I. INTRODUCTION

Wireless Sensor Network is developed by using a large number of tiny sensor nodes. The number of comprised sensor nodes could be in thousands or lacks or it depends upon the type of the application for which the networks is being deployed. In the network, the location of the sensor nodes may or may not be pre-defined by the user so that it results to the topography or disaster management operations. On the contrary, this shows the way to an issue that the sensor network protocols and techniques must have the self-organizing feature. The sensor nodes in the network have an inbuilt embedded processor that performs the locally carried out calculations automatically and also enables a sensor to transmit the processed data packets instead of raw or unprocessed data [1].

The transmissions of data from one node to another node take place by applying the process of routing. In routing from source node to destination node by using the intermediate nodes, the dedicated path is formed. The model of reliable routing protocol is vulnerable to frequent route disturbance due to the sudden node failure and collision. It is essential to hold the information of routing path and the re-creation of the path will leads to the surplus energy consumption. Few of the available routing protocols are found to be quite effective for route development but fails to retain or manage the route information [3, 4-7, 8, 9, 10] and hence leads to the reduction in the system reliability. The data packets must reach to the destination node by following a reliable route or path. The solution to the unreliability of the route is multi path routing. To travel through multiple routes instead of a single dedicated route, the multipath routing is used for the allocating the data. Thus, in case of multi path routing, if the path fails or disconnected due to node failure the data can still transmitted by using various available routes in the network without having any delay in data transmission. In this manner, the system reliability is also increases. The implication of multipath routing is only possible if the network is quite dense in nature [11]. Thus by motivating from above defined statements, this study develops a novel multipath routing approach. In order to conserve the energy and for the reduction of the maintenance cost, variety of multi-hop routing protocol has been developed [12-16, 17-19].

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II. LTERATURE SURVEY

The directing principle with static sink can be arranged into various hierarchical-based, multipath-based, and location-based and hybrid routing. The network nodes in the hierarchical structure are categorized into two parts; one brains the atmosphere and other work for data collection and then sends it to the base station. The available path between a sensor and the sink purposes the multipath routing to offer the reliability to the network. In the location based routing, the sink knows the area of the source node. The sink sends the question to a paying attention location to obtain the data. The mixture of two or more above routing protocols can be identified as the hybrid routing protocol. The multipath routing is alternate routing technique to transmit the data packets from the source node to the destination node that elects more than one route. The source node to the destination node allows the sensor nodes to create the numerous paths. Because of path repetition feature, the multipath routing suffers from various issues such load balancing and the less reliability etc. So many multipath routing approaches has been projected the traditional multi-hop routing protocols had been developed with an objective to cop up with the resource limitation and load balancing of the sensor nodes with the less energy in the network. The protocol named as directed diffusion routing approach had been developed by [20].

It was a question based multipath routing protocol in which the routing process is initialized by base station. First of all the sink node sends interest for communication in the whole network. During this awareness message, all of the intermediate nodes saves the interest message received from adjacent nodes and use it for future and develop a gradient corresponding to the sender node. Through this phase, more than one path can be developed within each and every pair of source and sink pair. Then the source node transmits the data packets by using the elected paths. At this stage, the sink node continues to transmit the low rate interest messages by using the rest of the unused routes. This process is done to retain the freshness of the interest tables for the middle nodes along with the discovered paths.

In this work, if the active route of data transmission crashes due to any reason then the available paths become available for data transmission. On the basis of the implemented results, it was concluded that the protocol was quite effective to enhance the network lifetime even after evolving all of the sensor nodes in routing process.

In [21], the author had represented a braided multipath routing approach that was capable to develop the more than one route but all of the created routes were partially disjoint in nature. The proposed work facilitates the fault tolerance facility in the network. The proposed protocol creates the paths by utilizing the two path reinforcement messages. Out of these two paths, one is considered as the major path and the other is considered as alternative path. The role of the base station is to initialize the route creation process by sending the primary path support messages to the most suitable adjacent next hop towards the source node in the network. This process repeats until the primary support data packet reaches to the source node in the network. The primary node also transmits the alternate path support data packets to the next best adjacent node the origin of the node. The proposed protocol had an advantage that it develops the backup path for data transmission.

In [22], the study had suggested a routing algorithm that was distributed, scalable and localized in nature. The novelty of the protocol was that it leads to the discovery of multiple node disjoints routes within sink and other nodes. The author had used the load balancing algorithm in order to distribute the traffic load over the multiple paths. At the time when an event occurs, a node was elected from the corresponding region as a source node. Then this elected source node starts the path discovery process by sending the multiple route request packets to the adjacent nodes. This request message comprised of a unique route id to create a route disjoint path. After obtaining the first most route request message or packets from source node, the node initialize the timer. The paths that are discovered within the time limit set by the timer are considered for communication. The base station node also optimally allocates the data rate for each and every path.

III. PROBLEM FORMULATION

The routing in sensor network is a crucial task to perform, as either directly or indirectly it leads an effect to the overall performance of the network. The factors like energy of the nodes, distance of the nodes from BS, elected CH, nodes degree etc highly effects the routing decision in WSN. This study have analyzed the various traditional route and CH selection protocols in previous section and has observed that even after having such a vast variety of routing and CH election protocols there are some limitations that still need to overcome anyhow. In traditional routing approach HEEP [1], the author had developed HEEP with an objective to enhance the network lifetime by reducing the load of the nodes as the election of route from CH to sink node was performed by the sink node or BS itself. The CH election was done on the basis of the following three parameters are Residual energy of the nodes, Node degree and Initial energy of the nodes. The node with the highest rank was elected as CH. Then for route formation, a cost value was elected on the basis of the transmission energy and residual energy of the node. The node with the least cost value was elected for route formation. On the basis of these observations, it is concluded that in HEEMP all of the nodes of a cluster were participating in the communication process, whether these nodes had valid data to transit or not. Thus the transmission of irrelevant or random data to the BS leads to energy loss.

Thus the excess usage of network energy leads to the reduction in network lifetime. Therefore, there is a need to develop a novel routing approach that could be capable enough to overcome the defined issue.

IV. PROPOSED WORK

After having a review to the traditional HEEMP protocol for route formation and CH election, the present study find out various flaws in it. On the basis of the defined lacking points of the traditional work, the present work aims to develop a new route formation and CH election approach by making the modifications to the traditional approach.

As the traditional HEEP protocol was quite effective to enhance the network lifetime but the more amendments could be done to reduce the communication rounds. Thus, for this purpose, the modifications are done in the data transmission strategy of the network. By motivating from the concept of TEEN protocol, only the relevant or meaning full data packets are transmitted to the BS. Other than this the election of the CH nodes are done by using the following formulation:

$$CE = \left(\frac{Residual\ Energy}{Initial\ Enenrgy}\right) * \left(\frac{Node\ Degree}{max\ (node\ degree)}\right) \ldots\ldots (1.1)$$

After electing the CH, the route formation is done on the basis of the cost function. The cost function is as follows;

$$cf = \sum_{\forall x \in LRj} \frac{Tx(x)}{Eres(x)} \ldots (1)$$

Where, $Tx(x)$, depicts the transmission energy of the node x and $E_{res}(x)$, defines the residual energy of the node x. With this, the energy of the nodes is evaluated by using the following formulation. For energy model the transmitting energy can be evaluated by using following equation:

$$IF\ d \leq d_0\ then\ \varepsilon_{TX} = (\varepsilon_{elec} * P) + (\varepsilon_{fs} * P * d^2) \ldots\ldots (2)$$
$$IF\ d > d_0\ then\ \varepsilon_{TX} = (\varepsilon_{elec} * P) + (\varepsilon_{mp} * P * d^2) \ldots\ldots (3)$$

In above equations E_{elec} stands for amount of energy consumed for transmitting a bit/m^2

The Table 1 includes the parameters used for proposed network setup. The methodology of the proposed work is as follows.

Step 1. The first most step is to initialize the network by defining its parameters such as the area covered by the network, placement of the nodes, initial energy of the nodes, transmission energy of the nodes etc. following is the parameters used for proposed network setup:

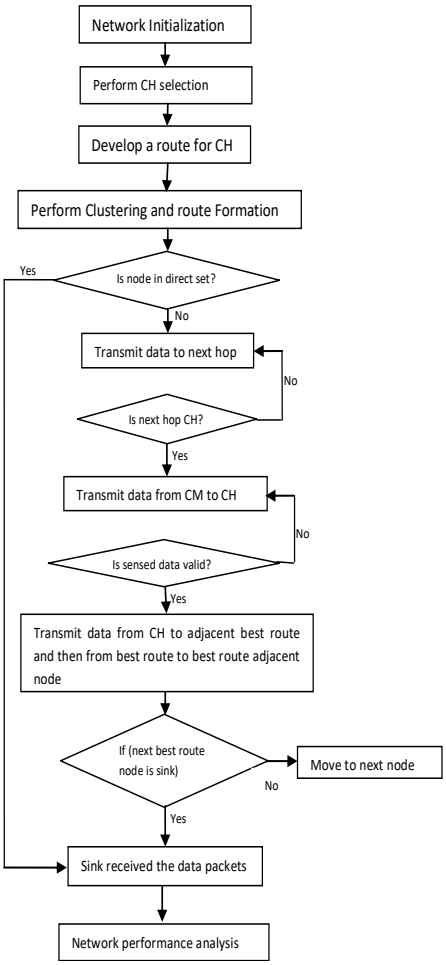

Figure 1: Framework of proposed work

Step 2. After initializing the network, the next step is o perform the CH formation by using the equation no 1 defined above.

Step 3. Then the route from CH to BS is developed by implementing the equation 2.

Step 4. While route formation, if the node is located in to be direct set then the data packet is directly transmitted to the BS otherwise go to the step 6.

Step 5. Perform data packet transmission to the next located hop in the route. If this next hop is not a CH, then perform Step 5 again. Else transmit the data CM to CH.

Step 6. If the transmitted data is valid or relevant to the BS then go to step 8 else go to step 6.

Step 7. Transfer the data packets from CH to its adjacent best route and then to best adjacent node in that particular route.

Step 8. If this best node is detected as a sink then it means that the data is reached to its final destination else go to next adjacent node.

Step 9. In this step perform the network performance evaluation in the terms of total energy consumption and alive nodes of the network are done.

V. RESULTS AND ANALYSIS

In this work, a novel approach is developed by making slight modifications to the traditional HEEMP routing protocol [1].

Table 1: Proposed network setup

Network Parameters	Values
Free Space Energy	10 pj/bit/m^2
Multipath energy (E_{fs})	0.0013 pj/bit/m^4
Transmitter energy (E_{mp})	50 nj/bit
Receiver energy ($E_{tx\text{-}elec}$)	50 nj/bit
Energy for data aggregation(E_{DA})	5 nj/bit/signal
Data Packets Size	2000 bits
Control packet size	200 bits
Initial energy	0.5 j
Communication range	30 m
Dist_threshold	60 m

This figure represents the alive nodes statics. In x-axis represents the number of rounds and y-axis represents the number of alive nodes.

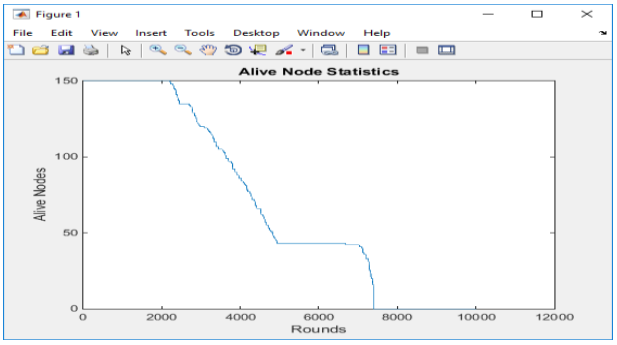

Figure 2 Alive numbers of nodes

In this figure FND sink at centre, the x-axis represents the routing protocols and the y-axis represents the number of rounds.

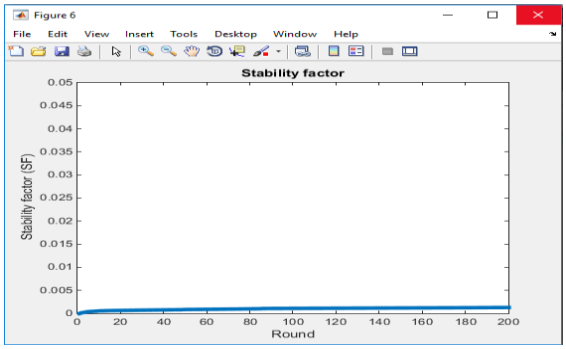

Figure 3 Stability

In this figure the Stability is defined. The x-axis represents the number of rounds and the y-axis represents the stability factor.

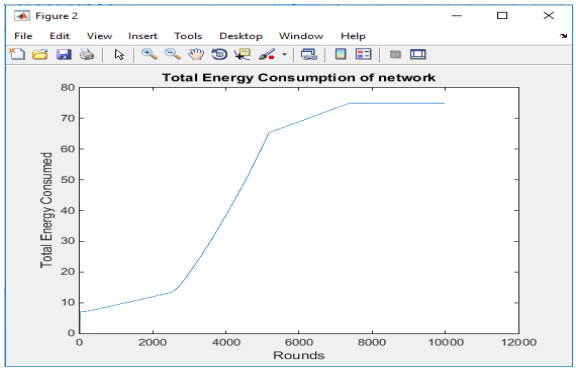

Figure 4 Total energy consumption of the network

The performed modifications are defined in previous section. This section s organized to represent the results that are observed after implementing the proposed work in MTLAB. The performance analysis of the proposed work is done to analyze the network lifetime and for this purpose, the energy consumption and the number of alive nodes in the network is measured and shown in graphical format as follows.

The graph in figure 5 depicts the comparison analysis of the proposed work and traditional HEEMP protocol in terms of energy consumed by the network.

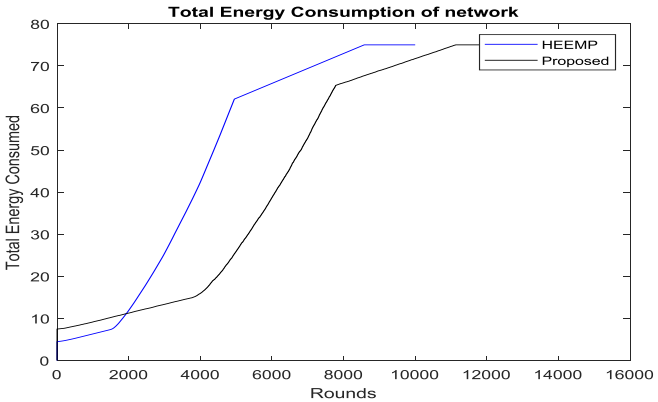

Figure 5: Total energy consumed versus rounds

Figure 4 Comparison Analysis of Total Energy Consumption in HEEMP and Propose Work.

The energy consumption is analyzed with respect to the number of rounds performed for communication. The curve in black stands for the energy consumption of proposed approach and blue curve represents the HEEMP approach. The x axis calibrates the data for energy level and ranges from 0j to 80 j. The y axis shows the count for communication rounds. The observations from the graph prove that the proposed approach has lower energy consumption in comparison to the HEEMP protocol. The observations are shown in table 1.

The graph in figure 4represents the comparison analysis for number of alive nodes in the proposed and HEEMP protocol. The alive nodes refer to the nodes in the network that still have a adequate amount of residual energy to act upon the data transmission and other operations in the network.

Table 2 Total Energy Consumption Analysis for HEEMP and Proposed work

No. of Rounds	HEEMP	Proposed
1	0	0
1000	6.3178	9.1666
2000	11.9064	11.2739
3000	25.4589	13.3524
4000	42.3739	15.9560
5000	62.2917	25.9353
6000	65.8442	38.7005
7000	69.3964	52.8591
8000	72.9495	65.9938
9000	75.0000	68.8766
10000	75.0000	71.7346

The x axis in the graph defines the number of alive nodes from 0 to 150 and y axis defines the number of communication rounds. In this graph, it has been seen that initially the number of alive nodes in projected work is slightly lower than the number of alive nodes in HEEMP protocol, but as the number communication rounds increases the number of alive nodes in proposed network also increases.

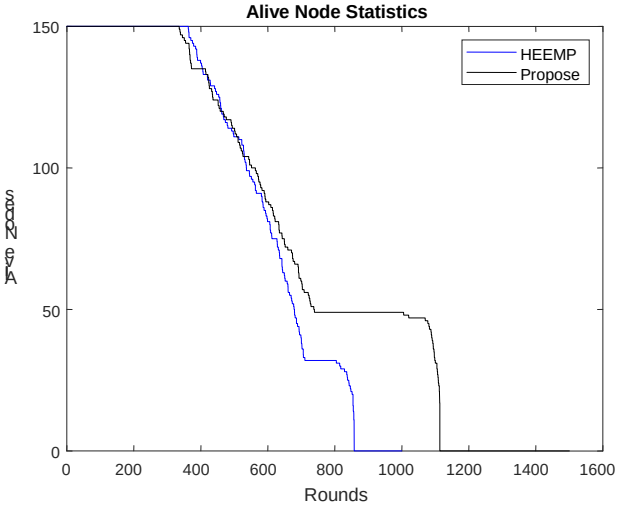

Figure 6: Alive nodes versus rounds

Figure 6 Comparison Analysis of Number of Alive nodes in HEEMP and Propose Work.

Table 3: Number of Alive Nodes Analysis for HEEMP and Proposed work

No. of Rounds	HEEMP	Proposed
1	150	150
1000	150	150
2000	150	150
3000	150	150
4000	137	135
5000	111	114
6000	81	88
7000	39	60
8000	32	49
9000	0	49
10000	0	49

As shown in table 3, the number of alive nodes in proposed approach during 1000 communication rounds is similar as of HEEMP protocol, during 5000 rounds of communication it is 114 and for proposed and 111 for HEEMP. Hence till the completion of 10000 rounds the number of alive nodes in HEEMP is 10 and in proposed approach still 49 nodes are found to be alive.

The graph in figure 4 depicts the number of alive nodes with respect to the variable size of the network corresponding to HEEMP and Proposed approach. The network size is considered from 100 to 1000 with the variation of 100. The number of alive nodes varies from 100 to 300 respectively. The graph proves that the number of alive nodes in proposed work is higher in evaluation to the HEEMP protocol. The observed facts and figures are shown in table 4 below.

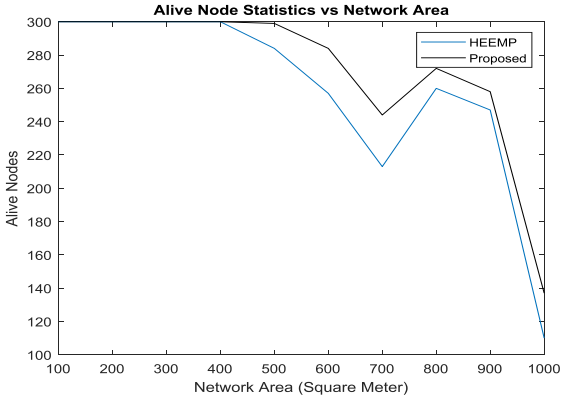

Figure 7: Alive nodes versus Network Area

Figure 4 shows the Comparison Analysis of Number of Alive nodes with respect to the variable size of network in HEEMP and Propose Work.

Table 4: Number of Alive Nodes Analysis with respect to the variable size of network for HEEMP and Proposed work

No. of Rounds	HEEMP	Proposed
100	300	300
200	300	300
300	300	300
400	300	300
500	284	299
600	257	284
700	213	244
800	260	272
900	247	258
10000	110	137

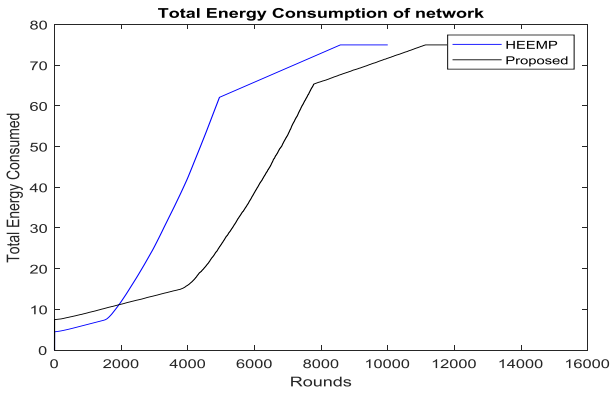

Figure 8 Comparison Analysis of Total Energy Consumption in HEEMP and Propose Work.

The performed modifications are defined in previous section. This section s organized to represent the results that are observed after executing the proposed work in MTLAB. The performance analysis of the proposed work is done to analyze the network lifetime and for this purpose, the energy consumption and the number of alive nodes in the network is measured and shown in graphical format as follows. The graph in figure 2 depicts the comparison analysis of the proposed work and traditional HEEMP protocol in terms of energy enthusiastic by the network. The energy consumption is analyzed with admiration to the number of rounds performed for communication. The curve in black stands for the energy consumption of proposed approach and blue curve represents the HEEMP approach. The x axis calibrates the data for energy level and ranges from 0 j to 80 j. The y axis shows the count for communication rounds. The observations from the graph prove that the proposed approach has lower energy consumption in comparison to the HEEMP protocol. The observations are shown in table 2.

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The graph in figure 3 represents the comparison analysis for number of alive nodes in the proposed and HEEMP protocol. The alive nodes refer to the nodes in the

network that still have a satisfactory amount of residual energy to perform the data transmission and other operations in the network. The x axis in the graph defines the number of alive nodes from 0 to 150 and y axis defines the number of communication rounds. In this graph, it has been observe that initially the number of alive nodes in proposed work is slightly lower than the number of alive nodes in HEEMP protocol, but as the number communication rounds increases the number of alive nodes in proposed network also increases.

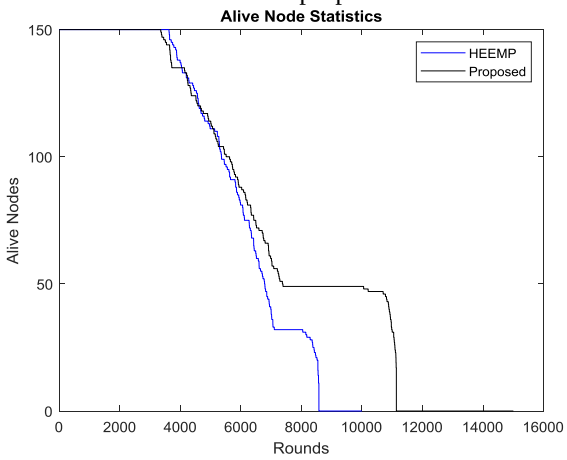

Figure 9 Comparison Analysis of Number of Alive nodes in HEEMP and Propose Work.

As shown in table 3, the number of alive nodes in proposed approach during 1000 communication rounds is similar as of HEEMP protocol, during 5000 rounds of communication it is 114 and for proposed and 111 for HEEMP. Hence till the finishing point of 10000 rounds the number of alive nodes in HEEMP is 10 and in proposed approach still 49 nodes are found to be alive.

Table 3 Number of Alive Nodes Analysis for HEEMP and Proposed work

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The graph in figure 4 depicts the number of alive nodes with respect to the variable size of the network corresponding to HEEMP and Proposed approach. The network size is considered from 100 to 1000 with the variation of 100. The number of alive nodes varies from 100 to 300 respectively. The graph proves that the number of alive nodes in proposed work is higher in evaluation to the HEEMP protocol. The observed facts and figures are shown in table 4 below.

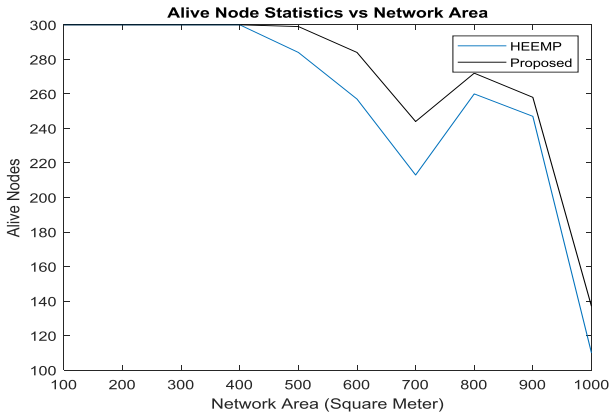

Figure 10 Comparison Analysis of Number of Alive nodes with respect to the variable size of network in HEEMP and Propose Work.

Table 4 Number of Alive Nodes Analysis with respect to the variable size of network for HEEMP and Proposed work

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200	300	300
300	300	300
400	300	300
500	284	299
600	257	284
700	213	244
800	260	272
900	247	258
10000	110	137

VI. CONCLUSION AND FUTURE SCOPE

This study has analyzed the traditional HEEMP protocol for routing and CH election process. The defined observations conclude some lacking issues in HEEMP approach. In order to overcome the flaws of HEEMP, some modifications are performed in this protocol by reducing the number of communication rounds. Then the HEEMP and proposed approach is implemented and analyzed by using the MATLAB simulation platform in terms of total energy utilization and number of alive nodes in the network.

The observations conclude the proficiency of the proposed work over traditional HEEMP approach and hence it is proved that the lifetime of the network has been increased by using the proposed approach instead of traditional HEEMP approach.

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