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Energy Efficient Dynamic Multi-Hop Routing Technique in Wireless Sensor Networks

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Abstract**:** ***In Wireless Sensor Networks (WSNs) main focus is on energy conservation and thus it is most researched area. The energy in WSN is highly consumed during data transmission. That's why, many routing protocols are developed as their sole purpose is to consume less energy during data transmission. Dynamic Multi-Hop Routing (DMR) and Static Multi-Hop Routing (SMR) has provided efficient approach by forwarding nodes data to Base Station (BS) by splitting whole sensor network into several levels and each node acts according to its position and status but network suffers from hotspot problem for large area applications. This paper aims to present a new technique to avoid hotspot problem in by introducing Relay Cluster Head (RCH), node whose sole purpose is to relay the data for multi hop routing in WSN and to improve the Cluster Head (CH) selection in the existing techniques by incorporating energy and distance factors. The network is divided into levels and nodes in a cluster send their data to CH and CH in each level forwards its data to the RCH of the lower level (near to BS). It is observed from simulation results that proposed technique improves the lifetime, stability and throughput of the network as compared to the DMR and SMR techniques.***

Keywords: clustering; lifetime; stability; throughput; wireless sensor networks

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is a collection of different sensor nodes and each sensor node has battery and computing capabilities A wireless communication via RF or lasers connects these nodes to each other. These sensor nodes cover the region to be tracked. The sensors in the nodes are sensing and processing the physical environment and sending it to the base station. The base stations are a gateway between the nodes and the end user. The information is sent by the sensor node via single or multiple hops to the base station. The nodes can be moving or stationary depending on the implementation Sensor nodes consist of processing unit with restricted computing capability, environment monitoring sensors and wireless trans receiver to send data packets. The primary aim is to create multifunctional, low-power and low-cost systems that can be used in actual world applications [1].

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Recent advancements in the growing technological world have also captured the revolution in the sensing technology [2]. It has enabled to generate different sensors that can execute distinct activities devoted to countless applications. These sensors are deployed depending on distinct topological deployment situations. Most of the time, these sensors are implemented randomly to prevent any difficulty in the deployment of the nodes [3]. The profile of these sensor nodes differs from temperature sensor to vibration, humidity and multiple other forms depending on the applications for which they are being used. Over the years, owing to their self-configured nature, the sensor nodes have discovered them irreplaceable alternatives for severe surveillance of the surroundings. The sensor nodes operate on the easy procedure that they sense the environment and the gathered information is transmitted to the base station or sink where the information is processed for further activities [4].

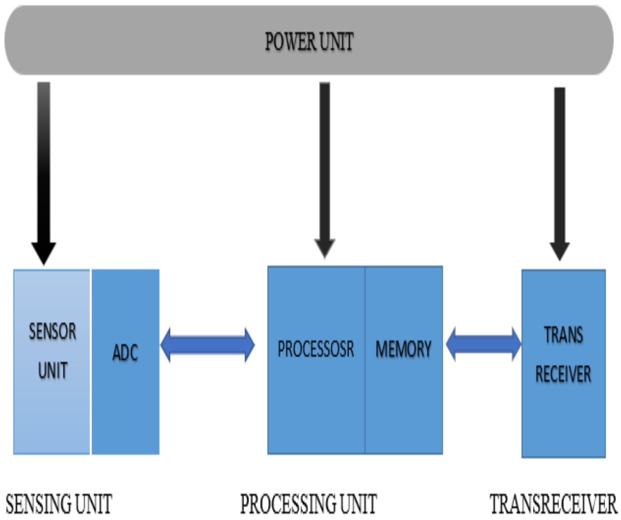

Fig.1. Architecture of Sensor Node

Fig1 shows the node architecture consisting battery power which is limited. Sensor unit comprises of various sensors required according to the application. The processing unit is a microcontroller that processes the data and the transceiver to transmit and receive data packets. Each unit consumes power to operate and the battery as a source of power is limited and must be used as minimally as possible. Various Energy efficient protocols are designed to increase the network lifetime. Routing protocols are designed so that data packets send from source to destination with consuming minimum power. WSN is utilized in various applications like in military, agriculture, industrial and commercial.

In military, it is used for intruder detection or monitoring of soldiers, battlefield surveillance, biological, chemical and nuclear attack detection, monitoring and surveillance of borders. Forest fire detection where nodes in the forest are equipped with sensors to measure gases and temperature that are produced during fire, if node detects it, then it sends alarm message. WSNs also used for air pollution and Water quality monitoring.

Land slide detection also possible using wireless sensor nodes [5]. In Medical Field the use of WSN is tracking and monitoring patients and doctors inside the hospital. And Drug administration. Industrial applications provide conservation, efficiency, control and safety by reducing the cost of energy by optimized manufacturing processes, identify an inefficient operation or some poorly performing equipment. To decrease user intervention, it helps to automate remote sensor information acquisition. To improve the preventive maintenance programs, it provides the detailed data [6]. Most common problem of multi hop WSN is the relay of data among the CH nodes. While relaying the data, the CH nodes consumes a lot of energy and eventually dies. This problem is termed as hot-spot as hot-spot is created at the place where node is dead [7]. Consequently, the no-connection zone is created between the nodes and sink. There have been various methods that have tried to overcome this problem.

II. II. Multi-Hop Routing Techniques

Heinzelman et al. [8] proposed LEACH protocol. LEACH is one of the first routing protocol which is entirely based on the clustering topology. There are basically two phased, the set up phased and steady state phase in which the protocol is operated. During the set up phased the network is established and clustering is performed. In clustering process, the nodes are selected as Cluster Heads in the network. Once the Cluster Heads are declared, they will be sending the advertisement message in the entire network. The nodes which receive the declaration message, they join the cluster heads on the basis of received signal strength. Thereafter the steady state phased comes into operation. In which the nodes will have TDMA schedule to send data to the Cluster Head. This is done so that there is no packet drop due to collision or traffic.

Alnawafa and Marghescu [9] proposes protocol Enhancing Dynamic Multi-Hop LEACH (EDMT - LEACH). In this protocol, routing table of Cluster Heads established based on a cost function and arrange routes on their cost functions. Lowest cost route is chosen and during the round routing table of CHs is updated. The dynamic routing method is used outside the clusters, whereas direct data transmission is used within the clusters as in the LEACH protocol.

Wu et. al. [10] presents routing with non-uniform node distribution assuming Nodes deployed in a circular area and the sink is located at the center of the area that addresses the WSN energy hole problem. The entire network is divided into coronas and more nodes are assigned to the inner corona. It is observed that the network achieves high energy efficiency using non uniform node distribution and 15 percent less energy is wasted. It also has advantage in network lifetime and data delivery ratio. The disadvantage of this strategy is cost of sensor nodes and requirement of a perfect MAC layer that handles channel problem among the nodes.

Wang et.al [11] presents Distance-based Energy Aware Routing (DEAR) algorithm. This protocol improves Network Lifetime and reduces Energy Consumption. It optimizes each individual distance in this routing algorithm so that all sensors consume their energy at a comparable pace. But Hot-Spot problem prevails.

Gong et al. [12] has proposed a multi hop routing protocol with unequal clustering (MRPUC) to acquire the objective of enhanced network lifetime in WSN. The relay nodes are used to forward the data to the base station by the CHs who have collected data from their respective clusters. Moreover, there are many measures that are considered by the MRPUC algorithm. These measures include the selection of nodes as CH which have higher energy and in addition to it, it also makes the clusters smaller in size which are placed nearer to the sink as compared to ones which are far located. The distance factor is also considered along with the energy. The selection of relay node is done in a way that it consumes least energy while forwarding the data and also have the more residual energy as compared to other nodes which might have been selected for same

Yang and Zhang [13] Presented an energy balancing unequal clustering protocol (EB-UCP) for wireless sensor networks. EB-UCP accomplished better lifetime efficiency by using the notion of unequal clustering and balancing the network's energy consumption. To shape clusters, an unequal clustering algorithm is used. The size of the cluster varies depending on the cluster range from the base station. The cluster nearer to the base station is smaller in size to preserve the energy to forward the data to the base station. Furthermore, the distribution of sensor nodes is carried out according to the energy balancing algorithm and therefore the energy consumption in each layer is almost equal. Simulation have shown that EB-UCP outperforms EEUC and LEACH protocols

Nurhayati [14] has proposed an Energy Efficient based on Mechanism Unequal Clustering Routing Protocol Wireless Sensor Networks. This enabled the energy dissipation among the Cluster Head nodes, thus increasing network lifetime. In this routing hierarchical structure and multi-hop, before clustering is processed. The different of this routing algorithm are the nodes with the highest energy Chooses as Cluster Head Leader Node. The network field divided into levels and unequal cluster nodes. Each cluster chooses one node as Cluster Head. The Cluster Head sends the data to Cluster Head Leader Node. The finally Cluster Head Leader Node send data to the Base Station

Rani et al. [15] suggested the Chain Based Cluster Cooperative Protocol (CBCCP). CB CCP gathers information from inaccessible areas by factorizing the region into sub-areas (clusters) and assigning cluster heads in each sub-area. Routing is based on the predefined path. Using cluster coordinators for inter-cluster communication and CH within the cluster minimizes the transmission distance. Hari et al. in [16] proposed unequal clustering routing protocol mechanism. The UCMR protocol has distinct cluster sizes depending on the spectrum of its base station. In this unequal clustering protocol, cluster head choice is based on residual energy, node degree and distance from the centroid. In this protocol, multi-hop transmission can enhance QoS parameters such as error rate and data rate.

Alnawafa and Marghescu in [17] proposed an approach where whole network is divided into numerous levels. It is the position and the status that decides how the sensor node has to act. Two routing strategies; static and dynamic have been proposed that decides for the route between the nodes. Static Multi-Hop Routing Technique (SMR) offers a static method for transmitting information to the BS along the network level. The static method presents a fresh static strategy for conveying node information to the CHs and then to the BS, which relies entirely on selecting paths with the smallest distances.

Dynamic Multi-Hop Routing Technique (DMR) assumes that, during the same round, all network nodes that own an amount of routes in their RTs can use separate routes. For this reason, all network nodes organize available routes on the basis of a cost function developed for this purpose. It is noted through simulations that the suggested method outperforms the other methods in terms of throughput, network lifetime and numerous other metrics. This algorithm, however, could not save itself from the hot-spot issue.

III. III. PROPOSED TECHNIQUE

A. Network Model

There are few network assumptions which must be taken into consideration. These are stated as following.

- All nodes are stationary including the base station.
- The homogeneous nodes are considered. Therefore, the network is homogeneous in terms of different factors.
- The physical factors like interference, mixing, refraction or reflection are not taken into consideration.
- The nodes are energy limited and once they are exhausted off their energies, they can't be replaced with other nodes.
- The connectivity link between the nodes is symmetrical.
- No security issues are considered. The whole network is assumed to be already secured.
- The energy of the base station or sink is unlimited.
- The physical damage to the nodes is not taken into consideration

B. Radio Energy Model

The nodes consume their energies based on the radio energy model which has been same for the various routing protocols developed so far. It is due to the similar wireless communication characteristics of the nodes considered.

The energy consumption in transmitting and receiving data per bit is given by equations (1) and (2), respectively.

E_{tx} (l,d)=lE_{elc}+lE_{efs} d^2 for d<do (1)
E_{tx} (l,d)=lE_{elc}+l$E_{_efs}$ d^4 for d>do (2)

The distance between the two nodes and between sink and node is represented by 'd' and the threshold distance is being given by do. The energy consumed in the reception of data per bit is given by the equation (3).

E_{rx} (l)=lE_{elec} (3)

The process of data aggregation also consumes some energy given by equation (4.4).

Edx (l)=mlE_{da} (4)

In the equations given above, E_{tx} is the amount of energy consumed for transmitting the 1-bit data at distance d, E_{efs} is amount of energy used for the free space model, for reception of 1-bit data the energy consumed is represented by $E_{rx.}$ Moreover, the process of data aggregation also consumes energy represented as E_{da}. Similarly, the for-l bit data, and for transmitting m number of packets, the total energy consumed in data aggregation is represented by E_{dx} .

C. Proposed Technique

- In Initial Phase, clusters are formed and Cluster Heads (CHs) are elected. The proposed network scenario The Relay CH(RCH) is introduced in each cluster. The cluster which is nearest to the base station (BS), will have supporting CH (SCH) that too in number which depends upon the number of clusters forwarding their data to it.CH, RCH and SCH are selected based on their energy level .CH is elected as highest energy node and the node whose distance w.r.t to other nodes is shortest. RCH and SCH are selected based on their energy level are equal or slightly lower than CH.
- The whole network is divided into levels such as the Clusters Heads which are within distance from $d_0/2$ consider at level 1 and Clusters Heads which are from distance $d_0/2$ to d_0 consider at level 2 and so on. The data is transferred along the network level to the base station (BS).
- In Announcement Phase, CHs, Nodes, RCHs declare themselves to each other by broadcasting messages. RCH acts as normal node inside a cluster.
- Routing Table is formed to select the routing path for the nodes. Table is formed based on shortest distance and energy level of RCH/SCH. Table is updated after every round.
- Cluster's in last level(n) don't have RCH, their CHs directly send their as well as their Cluster members (CM) data directly to RCH of (n-1) level Cluster which is at the minimum distance with them and so on.
- Example CH of cluster at level 3 collect the data of their members and send it to the RCH of the cluster at level 2. RCH which is at shortest distance is selected. And from there to RCH or SCH at level 1, whichever is available forward data to the BS.

IV. SIMULATION AND RESULT

The simulation table for the proposed work is given in Table 3.1. These simulation parameters are used in MATLAB for simulation purpose.

Table 1 Simulation Table

Parameters	Values
BS coordinates(X1,Y1)	150m,450m

Initial energy(E_0)	0.5
The %age of CH(p)	0.2
Relative weight(α)	100
Eelec	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^2
T_{min}	0.03
Data aggregated energy (EDA)	5nJ/bit
Control packet size	200 bit
Data packet size	6400 bit

Table 2 The experiment #1 simulation scenario

Number of nodes	BS Coordinates (X1,Y1)	Environmental Dimensions (X2,Y2)
200	(150m,450m)	(280m x 350m)
200	(150m,450m)	(300m x 300m)
200	(150m,450m)	(350m x 200m)

Table 3 The experiment #2 simulation scenario

Number of nodes	BS Coordinates (X1,Y1)	Environmental Dimensions (X2,Y2)
100	(150m,450m)	(300m x 300m)
200	(150m,450m)	(300m x 300m)
300	(150m,450m)	(300m x 300m)

The proposed technique is compared with DMR, SMR and EDMT-LEACH protocols.

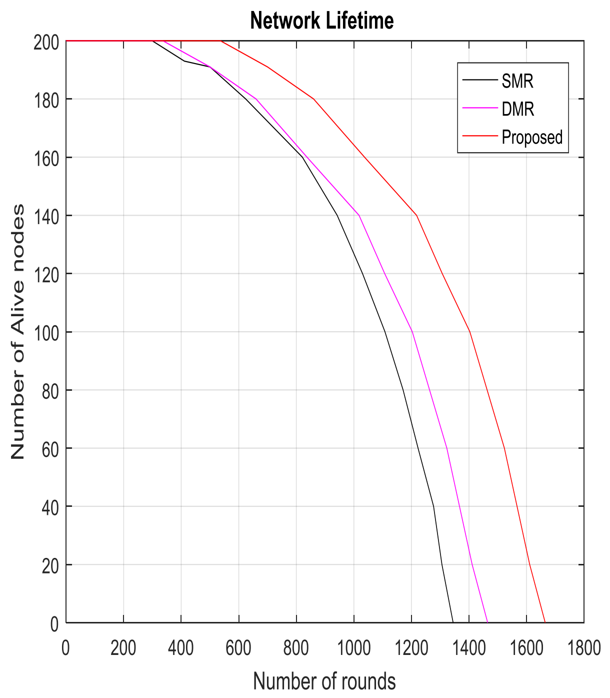

Fig. 2 Number of alive nodes comparison between Proposed, DMR and SMR approaches.

In Fig. 2, For this case, the 200 nodes are deployed in the network in the area (300 X 300) square meter in which base station is placed at the location coordinates (150 X 450) meter. It is seen that the proposed protocol shows tremendous improvement over the DMR and SMR protocols.

In fig.3 result shown for different network size.(as shown in table 2)

In fig .4 result is shown for different number of nodes(from table 3). For the first two cases, 100 and 200 nodes are taken into consideration. The proposed protocol covers 1800 rounds for the first case, i.e., for 100 nodes, showing the improvement of 39.2% over the DMR protocol. When 200 nodes are deployed, the percentage improvement is 145.73%. For the third case when 300 nodes are used, the number of rounds covered by the proposed protocol are 3900 rounds whereas the DMR only covers 1789 rounds and SMR covers 1670 rounds. Therefore, it can be said that the proposed protocol covers 2111 rounds more as compared to the DMR protocol. Moreover, the proposed protocol covers 2230 rounds more as compared to the SMR protocol. The performance improvement in the network lifetime in above three cases is due to load balancing and sharing the load distribution in the cluster.

It is also observed from the Fig. 5. the proposed protocol shows the stability period of 631 rounds whereas DMR only acquires the stability period of 336 rounds and SMR achieves only 299 rounds. Therefore, the percentage improvement in the proposed protocol as compared to the DMR and SMR is given by 87.79% and 111%, respectively. The inclusion of supporting CH in the cluster nearest to the network helps in reducing the burden of the relay traffic which eventually delivers this performance in stability period of the network.

In Fig. 6, it is seen that number of packets that are sent to the CHs for the different number of rounds during the whole operation is more as compared to the DMR, SMR and EDMT-LEACH protocols. The reason behind such improvement is the data forwarding to the Supporting and Relay CH of the network. The selection of CH is energy efficient, that makes the reduced effective distance from the CH from the cluster nodes.

As stated for Fig.7.the no. of packets sent to the BS in case of proposed protocol are more than the other protocol namely DMR and SMR respectively. It is related to the reason mentioned for the increased number of packets sent to the CHs, as the packets received are more, the greater no. of packet forwarding is done to the base station in terms of various rounds.

The proposed protocol has shown the great improvement over the DMR, SMR and EDMT-LEACH protocols in terms of network lifetime and stability period . The different regions are considered for the performance evaluation of the proposed work. The percentage improvement over the stability period is 87% as compared to the DMR protocol. The no. of packets sent to the CHs and BS are observed for different number of rounds to show the overall growth of the proposed protocol over the passage of various rounds.

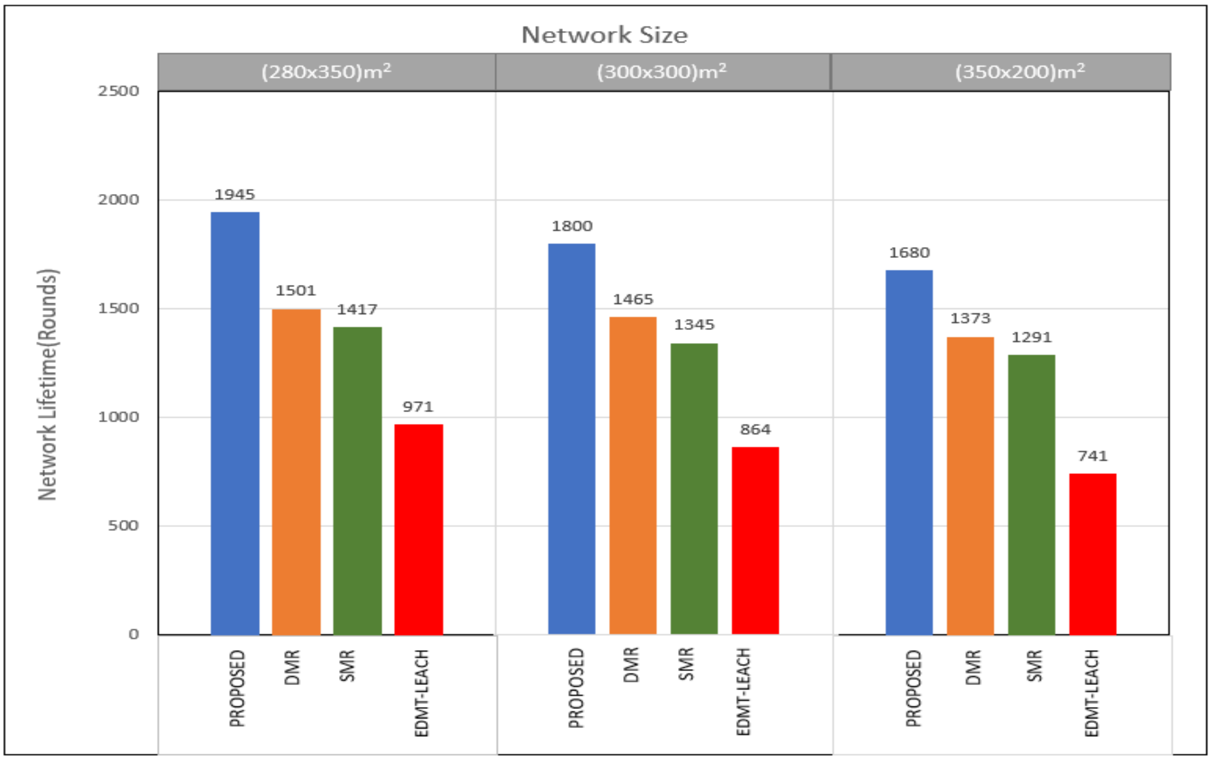

Fig. 3 Network Lifetime comparison for different regions of the network

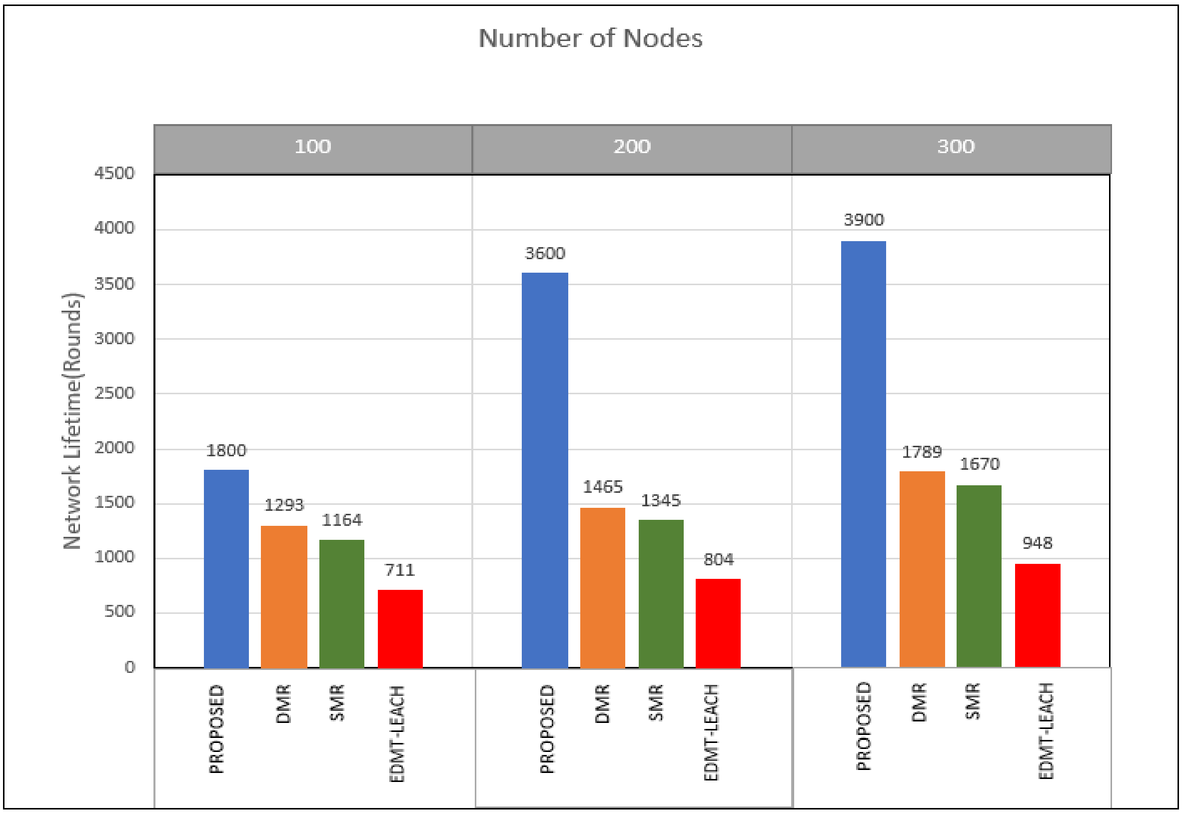

Fig. 4. Network Lifetime comparison for different number of nodes in the network

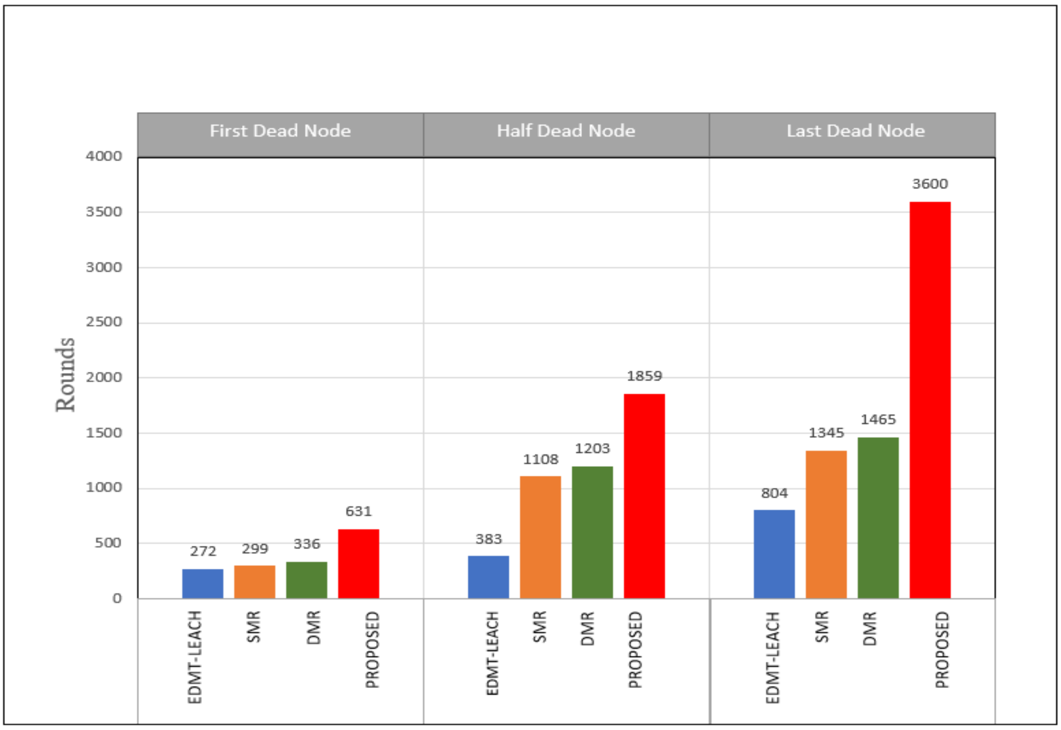

Fig. 5 Network performance comparison for stability period, HND and network lifetime

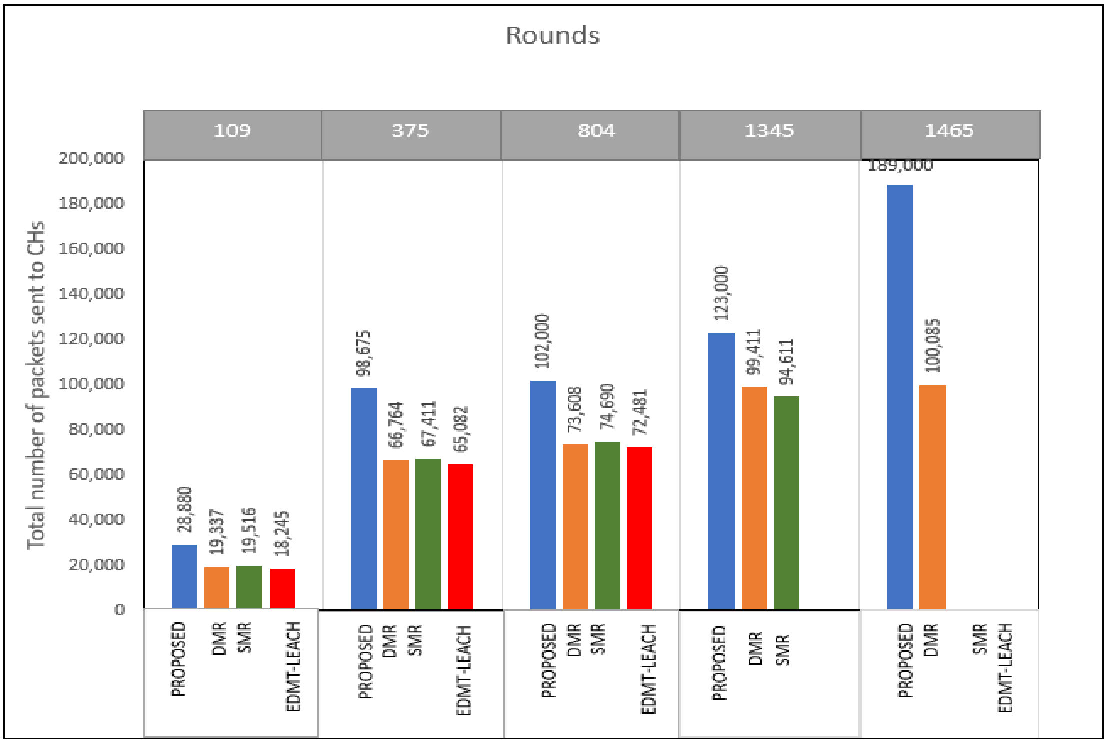

Fig. 6 Number of packets sent to CHs over different number of rounds

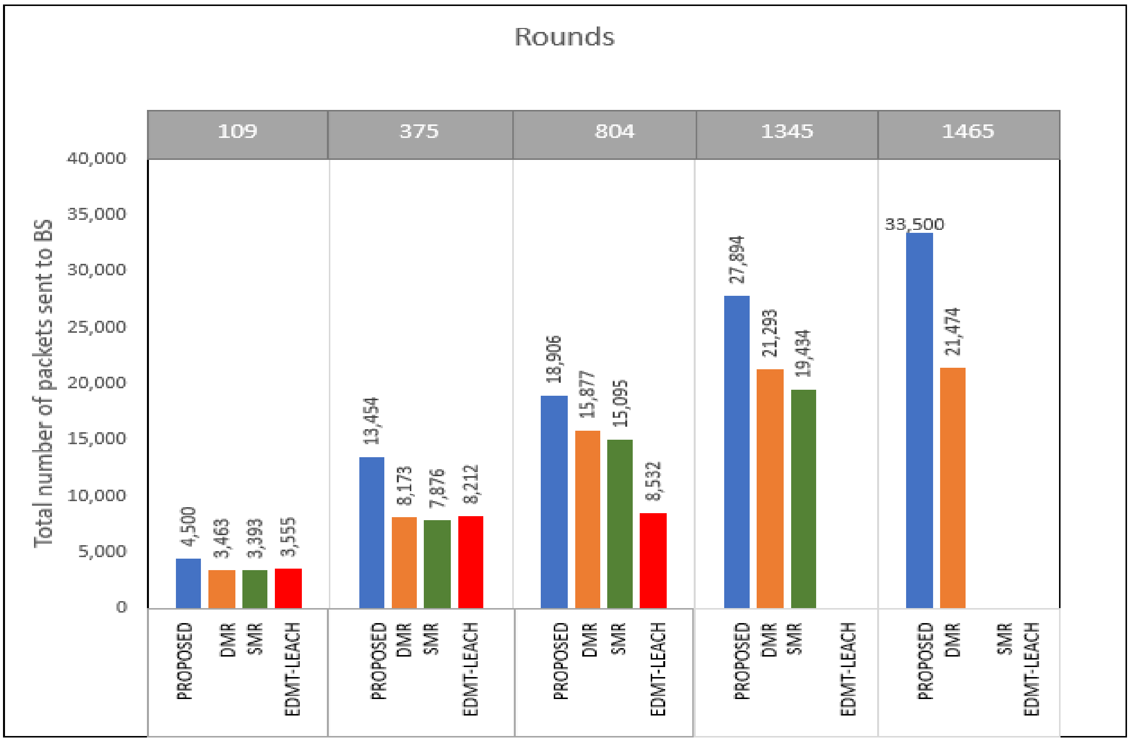

Fig. 7. Number of packets sent to BSs over different number of rounds

V. CONCLUSION

In this paper we introduced new technique for routing the data in the network by introducing RCH. Network is divided into levels. The proposed protocol has shown the great improvement over the DMR, SMR and EDMT-LEACH protocols in terms of network lifetime, stability period and throughput.

The proposed protocol shows the stability period of 631 rounds whereas DMR only acquires the stability period of 336 rounds and SMR achieves only 299 rounds. Therefore, the percentage improvement in the proposed protocol as compared to the DMR and SMR is given by 87.79% and 111%, respectively.

Different number of nodes and different network size is taken into consideration for network lifetime. The proposed protocol covers 1800 rounds for for 100 nodes, showing the improvement of 39.2% over the DMR protocol. In case when 200 nodes are deployed, the percentage improvement is 145.73%. For the third case when 300 nodes are used, the number of rounds covered by the proposed protocol are 3900 rounds whereas the DMR only covers 1789 rounds and SMR covers 1670 rounds. Therefore, it can be said that the proposed protocol covers 2111 rounds more as compared to the DMR protocol and 2230 rounds more as compared to the SMR protocol.

The number of packets sent to the CHs and BS are observed for different number of rounds to show the overall growth of the proposed protocol over the passage of various rounds.

The result proved that the new technique prolonged network lifetime as compared to SMR and DMR. As the energy consumption of CH is reduced as it not forwards the data of another CH, for relaying the data RCH is introduced. This reduces the burden on CH.

VI. FUTURE WORK

In future, the work can be extended where the sink can be moved in the network. When the network area is very large, hot spot problem still exists in the network. Therefore, if the sink is made to move in network for the data collection, the data collection will become more reliable. Introducing the number of relay CHs and supporting CHs will also lead to the increase in the number of overheads. This process also leads to the energy consumption of the network. Therefore, an attempt can be reported to increase the load balancing in the network.

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