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Threshold Based Chain-Leader Election Scheme for Mobile Sink improved energy-efficient PEGASIS-based Routing Protocol

Wei-Xin Kang, Raja-Asif Wagan, Jing-De Li, and Cheng-Cheng Zhang
College of Information and Communication Engineering
Harbin Engineering University
Harbin, 150001, China
kangweixin@hrbeu.edu.cn, rajuwagan@gmail.com
lijngde1314@sina.com, 410565802@163.com

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Abstract. *There are various routing protocols proposed on clustering algorithms along with vital research goals of energy reducing transmission delay, energy efficiency, network lifetime, fault tolerance and reliability. In this paper mobile sink energy-efficient PEGASIS-based routing protocol (MIEEPB) which uses mobile sink to acquire data from chain of sensors. The chain-leader selection is based on distance and residual energy. This study uses distance and energy threshold chain-leader election scheme to enhance the performance with sink mobility.*
Keywords: Mobility, Energy consumption, Optimization, Ubiquitous Computing, Wireless sensor networks

1. **Introduction.** The wireless sensor networks embedded in our life, which are mainly used for monitoring physical and environment surrounding situations like sound, motion, weather, pollution etc. These devices which are deployed in physical environment are distributed and networked to each other wirelessly. They acquire data from real environment and transmit it to the sink or base station. The nodes or sensors used in the WSN are tiny and in order to disseminate information they use battery which requires them to be smart in nature of energy consumption. The size, cost, memory, speed, bandwidth and energy are main concerns in this field.

The WSNs are widely used in various applications such as health care monitoring, landslide detection, air pollution monitoring, forest fire, water monitoring, flood monitoring, machine monitoring. WSNs are coping with issues of power consumption, cross layer design, failures of node, easy usage, mobility, scalability and heterogeneity of nodes.

2. **Related Work.** The sensor network is categorized in two types related the capabilities of sensor heterogeneous or homogeneous. The PEGASIS proposed in [18] is renowned routing protocol which is chain-based. In this routing protocol the sensors are structured into the chain by using the greedy algorithm and sensors with sink. The chain is formed and later the data is transmitted to the sink after aggregating from the sensors in the chain. PEGASIS protocol has difficulties in the route discovery and any node fails the path is re-routed to transmit towards sink. The main motive of the protocol is to improve the lifetime of the network. As it uses the greedy algorithm to construct the chain formation unbalanced energy consumption can occur in case sensors having communication of long distance, thus can lead to efficiency concerns in the network lifetime [7]. During every

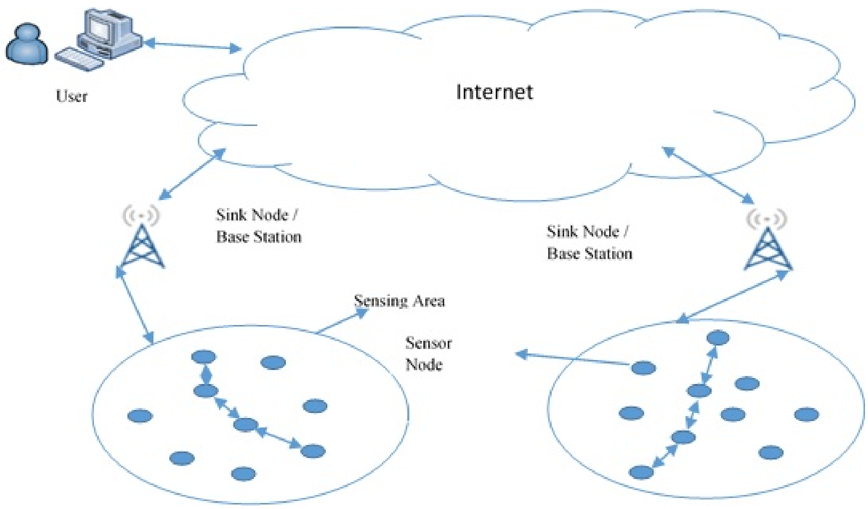

Figure 1. Typical WSN network

round one sensor node is selected as chain leader that is responsible for collect data from the chain nodes the member nodes of chain will transmit data from one node to another node towards the chain leader. Throughout the data collection phase each sensor node collects and chain leader fuses own data collected data to sink. The communication takes place in the chain with neighbors along with selection of chain leader node which reduces the energy consumption in every round. The usage of greedy algorithm does not allows to revisit the member nodes of chain thus loops are prevented. The distance between nodes as increases the consumption of energy consumption increases in the communication as WSN has limited energy and that is directly related to the network lifetime which declines. The SEP proposed in [11] is well-known routing protocol which stability of the region of WSN with the help of various heterogeneous parameters of the WSN network that enables the prolonged network lifetime by using the levels of the nodes. These constraints are based on the energy where the advanced nodes uses fraction of m and normal nodes has normal residual energy. The stability of the WSN region is improved by using this technique to reduce the consumption of energy. In the SEP protocol the energy of the system is increased (1 + a.m) for the balancing of the energy in the advance nodes for the cluster head selection as compare to the nodes which are normal. The probability for SEP includes 1/popt (1 + a.m) epoch for supplying and implementing more energy. At the initial stage the Popt is the probability for the cluster head selection criteria.

2.1. **MIEEPB.** This protocol stands for Mobile sink improved energy-efficient PEGASIS-based routing protocol (MIEPB). This protocol is proposed in [12] where the previously IEEPB protocol is improved to achieve maximum life time of the network by using the mobility of the sink. The mechanism of multi-chain PEGASIS same approach is used to create the chain where the sink transmits packet to across the network to determine nodes information, the sink uses distance calculation to locate the farthest node and later chain establishment is initiated from the farthest node considering the distance between nodes which is near to each other. The chain leader is selected according to the weight of Q assigned to each node which is the available energy and distance from the base station. This comparison provides the parameters for the selection of the chain leader.The mobility of sink in MIEEPB is assumed to have bulk amount of energy and mobility is uses pre-defined trajectory to move in the 4 regions defined and sojourn algorithm is used for mobility. The sojourn location are fixed and sojourn time is also defined. The sink moves to region at sojourn location and waits for sojourn time. When sink reaches at the specified location it collects data from the leader of chain.

2.2. **Motivation.** Clustering approach is very useful for acquiring and disseminating data packets in wireless sensor networks. The cluster heads are helpful to broadcast and aggregate data from their clusters. In this study we have studied performance of clustering algorithm for improving energy consumption in heterogeneous wireless sensor networks. Usually in wireless sensor networks the network uses sensors to transmit sensing data towards base station by using cluster heads. The cluster heads are aggregating the data from members of their cluster and finally sent to base station, eventually reaching end user. In this study we have assumed that sensor network is equipped with various power and energy that makes it heterogeneous. This approach is helpful in uplifting the network lifetime for long lasting network. In beginning the nodes of network are having same energy but later which nodes are added will have more energy as compare to resident nodes that makes it energy not equally distributed or had by nodes. Therefore, wireless sensor networks are ought to be more heterogeneous as compare to other networks. The routing protocols made and proposed for WSN are supposed to have these properties and attributes. There are numerous protocols proposed for heterogeneous networks to reduce the energy consumption and to avail best clustering approach. Currently few routing protocols such as DREEM-ME [1], SCEDH [7], BEENISH [14] and REECH-ME [17] has incorporated heterogeneity in their routing algorithms. These routing protocols uses clustering mechanism to fetch data and information from and send it towards base station. However the nature of the wireless sensor networks enable the mobility into network. The TEEN [14], SEP [11] and PEGASIS [18] are proposed as energy efficient routing protocols which has to have the characteristics of heterogeneity. Moreover the MIEEB protocol was introduced the mobility in the routing protocol while taking into count the energy efficiency. In [12] authors proposed clustering scheme which maximized the lifetime of multi-Chain PEGASIS by using sink mobility, the mobility of sink brought issues of region and clustering therefore regions were made for the simplicity of mobility of the sink. The mobile sinks moves on specified locations predefined locations in the four clusters to fetch data. In this paper we introduced the three levels of heterogeneity which categorizes nodes according to their residual energy and distance to the sink. The sink is mobile in the four regions for acquiring data. The heterogeneity incorporation which provided in the distance threshold based chain scheme with energy levels will solve the clustering and cluster head selection problem. This scheme addressed issue of different heterogeneous network which has various levels of residual energy by choosing and selecting least distance node for the communication to take place. In this study we incorporated proposed scheme for distance and heterogeneity of nodes for cluster head selection.

3. Network Model.

3.1. **Energy Dissipation Model.** In this study simple first order radio model is assumed which is employed by [1, 14, 15, 17] to use and estimate the energy consumption in the wireless sensors transmission. As illustrated in Figure 2 the radio energy dissipation model the equations as in [1, 12] which transmits k-bit message to d distance. The general formulas used for the transmitting and receiving are following

$$Etx(k,d) = Etx - elec(k) + Etx - amp(k,d) \tag{1}$$

$$Erx(k) = Etx - elec(k) \tag{2}$$

$$EDA(k) = EDA - elec(k) \tag{3}$$

Where per bit energy consumption for transmitting or receiving by circuit is known as E_{elec}, the mp is multipath model, d is distance and k is number of bits. E_{DA} is the data aggregation cost used in CH.

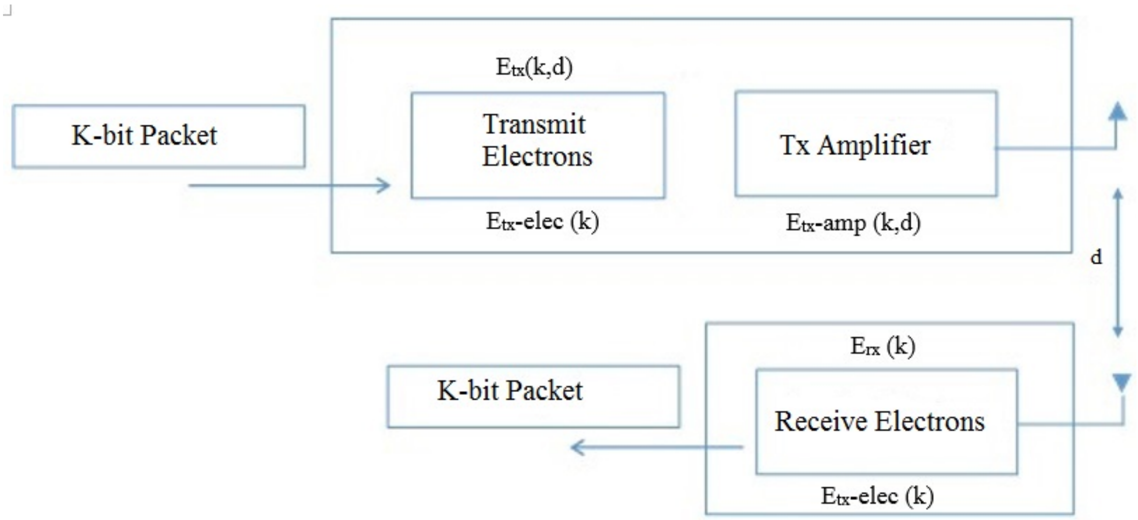

FIGURE 2. First order radio model

3.2. **Distance Threshold based Chain Scheme with energy levels.** The SEP enhances the stability of region by using parameters of heterogeneity for nodes by using nodes m additional energy factor of α within normal and advanced nodes, this enables it to balance the consumption of the energy in network. The SEP increases energy by (1 + αm) times. For stabilizing and enhancing the energy the advanced nodes have to selected cluster heads more than as compare to normal nodes. For implementation of this epoch 1/p_{opt} (1 + αm) because the network has more energy and nodes αm times. In the beginning cluster head selection probability is p_{opt}.
In heterogeneous networks sensor nodes are having two levels of energy called as advanced and normal nodes. To compute total energy initial energy equation used in [19] where E_0 is the energy for normal nodes and m is fraction of advanced nodes which is having α times more energy as compared to normal nodes therefore mN becomes advanced nodes having initial energy with E_0 (1+ α) and (1-m)N for the normal nodes is E_0. The formula for total energy given in [19] as follows

$$E_{total} = N(1-m)E_0 + NmE_0(1+a) = NE_0(1+am) \quad (4)$$

The multi-level heterogeneous networks are having randomly distributed initial energy $[E_0, E_0(1+a_{max})]$, in that the E_0 is the lowest minimum energy and a_{max} is the maximum energy provided. The node s_i is having initial energy in starting as $E_0(1+a_i)$, that is a_i times more than the energy given for the lowest E_0. The formula for total energy given in [19] as follows

$$E_0 = \sum_{i=1}^{N} E_0(1+a_0) = E_0(N + \sum_{i=1}^{N} a_i) \quad (5)$$

The selection of cluster head is for node si is used in LEACH si (i= 1,2, ..., N) to get every cluster head n_i=1/p_{opt} is used where in DEEC protocol p_i = 1/n_i the cluster head selection through si as probability threshold in [19]

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i(rmod\frac{1}{p_i})} & if\ si\ \in\ G \\ 0 & otherwise \end{cases} \tag{6}$$

The weighted probabilities for the S_i is given below:

$$p(s_i) = \frac{p_{opt}N(1+a_i)}{(N+\sum_{i=0}^{N} a_i)} \tag{7}$$

The p_{opt} is used to get value for the average probability of p_i, this provides changing value of n_i and threshold value for the $T(s_i)$ which belongs to the node s_i.

The chaining processes helps to transfer data towards sink by the chain-leader. The selection of chain-leader from the nodes in the region or in chain is based on weight of distance and energy. The nodes expected to be chain leader can have different level or energy and distance. The levels presented in [11] are modified and included distance to gain optimized threshold value for better performance.
Let B the threshold, D_0 is the distance from the node source point s to the base station. So, we have:

$$\frac{d_{si}}{D} = \frac{\sqrt{(x_s-x_i)^2+(y_s-y_i)^2}}{D_0} \tag{8}$$

By embedding distance into threshold

$$T(s_i) = \begin{cases} \frac{p}{1-p.(rmod\frac{1}{p})} * \frac{\sqrt{(xs-xi)^2+(ys-yi)^2}}{D0} & \text{if s } \in \text{ G} \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

In case of two level heterogeneity the normal node and strong node probabilities are:

$$P_i = \begin{cases} \frac{Popt\ \ Ei(r)}{(1+am)\ \bar{E}(r)} = \frac{Popt.Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+am)\ \bar{E}(r)} & \text{if si is normal node} \\ \frac{Popt\ (1+\text{a})\ Ei(r)}{(1+am)\ \bar{E}(r)} = \frac{Popt.(1+a)Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+am)\ \bar{E}(r)} & \text{if si is advance node} \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

In case of three level heterogeneity the normal node, strong node and herculean node probabilities are:

$$P_i = \begin{cases} \frac{Popt\ Ei(r)}{(1+m.(a+mo.b))\bar{E}(r)} = \frac{Popt.Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mo.b))\ \bar{E}(r)} & \text{if si is normal node} \\ \frac{Popt\ (1+\text{a})\ \bar{E}i(r)}{(1+m.(a+mo.b))\bar{E}(r)} = \frac{Popt.(1+a).Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mo.b))\ \bar{E}(r)} & \text{if si is strong node} \\ \frac{Popt\ (1+\text{b})\ \text{E}i(r)}{(1+m.(a+mo.b))\bar{E}(r)} = \frac{Popt.(1+b).Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mo.b))\ \bar{E}(r)} & \text{if si is herculean node} \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

Formation of Cluster: The process of cluster formation is divided into four regions where four clusters are created then to find optimum cluster head first mobile sink transmits initial packet to whole nodes for acquiring their information. The sink compares distance of nodes and elects the node having high distance the it start making network between nodes till reach end later every nodes compares distance between near nodes and makes the chain while the i nodes is parent and j is child node.

Cluster Head Election: The clustering approach is widely used to reduce the consumption of energy in WSN. In clustered networks, the network is portioned into chunks or small groups known as cluster, each cluster residing in the network will have a cluster head at a time mostly known as cluster-head (CH). The other remaining nodes will join as member of the cluster. The cluster members will disseminate data packets towards cluster head where the processing and forwarding to base station is done. The cluster head selection and election from the sensor nodes in a cluster is carried out by pre-assigned weight. The cluster head is assigned a role to acquire information from other sensors in cluster sensed data that may compress and aggregate before transition towards base station. The redundancy is eliminated by data aggregation which reduces size of data packet. In case of changes in topology occurred due to node failure insertion and deletion makes clustering robust and scalable with efficient bandwidth.

TABLE 1. Factors related in cluster head selection

S.No	Initial Energy	Residual Energy	Dsi to neighbor node	Dsi to mobile sink	Chance
1	Low	Low	Close	Close	Small
2	Medium	Medium	Adequate	Adequate	Medium
3	High	High	Far	Far	Large

Distance threshold based chain scheme with energy levels is aware of heterogeneity of network therefore, it extends network lifetime by assigning weighted probabilities to the nodes for cluster head election. The cluster head is chosen on weight W of hold by every node in network. As shown in Table 1 decision of cluster head selection is dependent on the residual energy and distance to mobile sink and neighbor node. By adding distance D_{si} which distance from source to sink node to distance to neighbor node which is D_n by adding with residual energy E_i we get the weight W_i for the decision for election for cluster head.

$$W_i = \frac{D_n + D_{si}}{E^i} \tag{12}$$

Where E_i is residual energy of current node i , D_n is distance to neighbor node and D_{si} is distance from source to sink node

4. **Simulation results and performance analysis.** In order to simulate proposed modifications in the MIEEPB we used MATLAB software for the performance evaluation of the protocol. The simulation contained N=100 sensor nodes. The 100x100 meters network size is used, the WSN sensor field is divided into the four regions where 25 nodes are deployed in each region. The chains are formed and chain-leader is selected specific criteria. The aggregated data is transmitted to sink, to make the heterogeneous network the nodes are provided more energy and divided into the normal, intermediate and advance nodes. Moreover modified compared with SEP protocol. To conduct this simulation we used following parameters shown in Table 2.

As illustrated in Figure 3 and Figure 4 the simulation results of modified MIEEPB and SEPE where the heterogeneity case of the network is m=0.2 m0=0.5 and a=1.5 and b=3 that enables nodes to have 300% and 150% increased energy for advance and intermediate nodes as compare to normal nodes which means there are 10% advance and intermediate nodes.

Table 2. Simulation Characterizes used in our simulation

S.No	Parameters	Values
1	E_{elec}	50nJ/bit
2	Data Packet Size	4000 bits
3	P_{opt}	0.1
4	P	0.7
5	E_{amp}	0.0013pJ/bit/m^2
6	E_{DA}	5nJ/bit/signal
7	E_0	0.5J
8	E_{fs}	10pJ/bit/m2
9	BS sojourn locations	(33m,25m), (33m,75m), (66m,25m), (66m,75m)

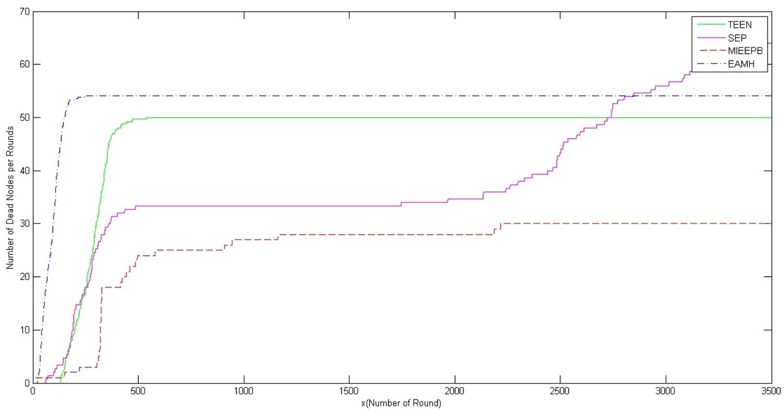

Figure 3. Case 1 of dead nodes with parameters such as a=1.5, b=3, m=0.2 and m0=0.5

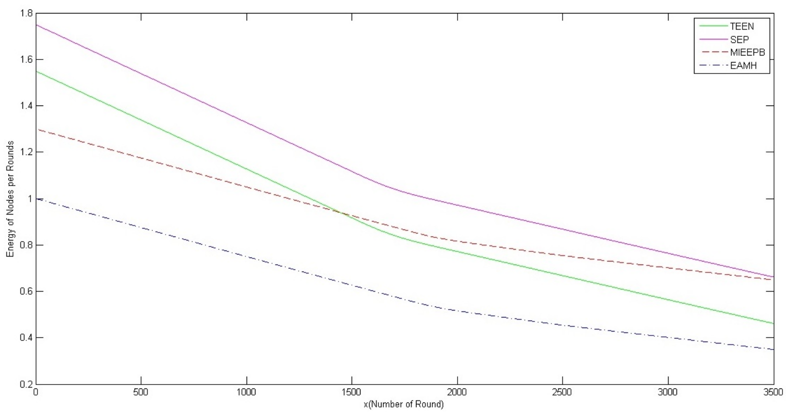

Figure 4. Case 1 of Energy of nodes with parameters such as a=1.5, b=3, m=0.2 and m0=0.5

Accordingly the figure number 5 and Figure 6 illustrates result of the values of heterogeneity as m=0.5, m_0=0.4, a=1.5 and b=3 which enables network to have 50% normal nodes , 20% intermediate and 30% advanced nodes, the energy increase is kept as before the normal nodes having 150% and advanced nodes having 300% excessive energy.

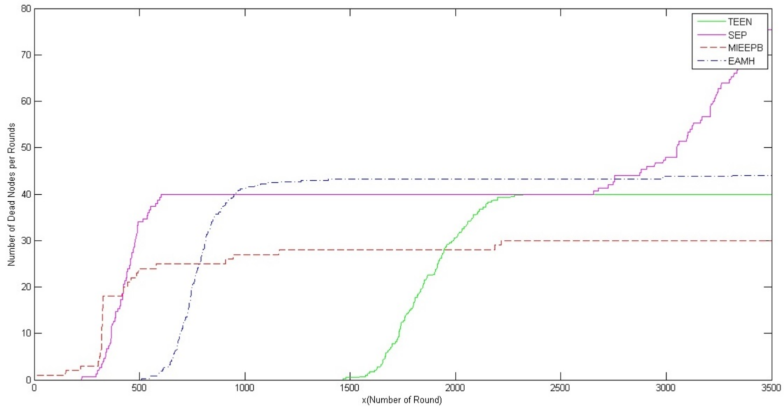

FIGURE 5. Case 2 of dead nodes with parameters such as a=1.5, b=3, m=0.5 and m0=0.4

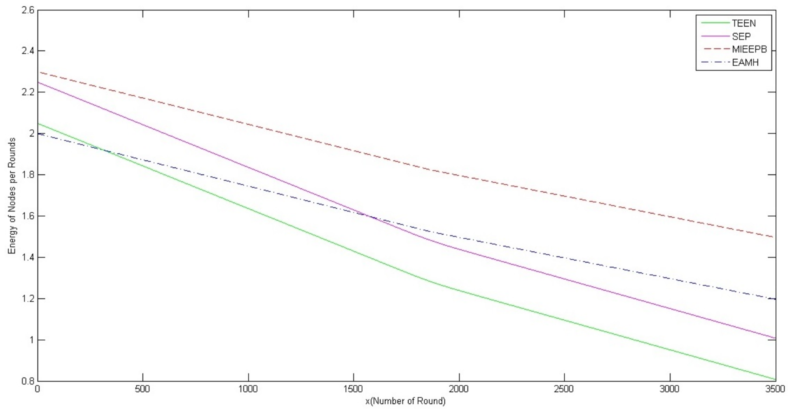

FIGURE 6. Case 1 of Energy of nodes with parameters such as a=1.5, b=3, m=0.5 and m0=0.4

The simulation results are demonstrating the vital and substantial improvement after modification in MIEEPB, the lifetime of the network is increased after running 7000 rounds of the simulation the nodes die faster in the SEPE protocol. This shows that the approach of using heterogeneity levels which are effecting the performance of network in terms of the energy and lifetime.

5. **Conclusions.** This study explored the enlightened the particulars of heterogeneous network in MIEEPB protocol based on distance and energy heterogeneous levels. These three level threshold constraints shown important effect on achieving longer lifetime of the network. This threshold scheme we evaluated by using simulation and comparing with other protocol. This scheme offers enhances optimization. After running comparative simulations in MATLAB we obtained results for the dead nodes.

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