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Improved &Modified DEEC protocol for Energy Efficient Clustering in WSN's

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ABSTRACT

In this work, we propose M-DEEC (Modified Distributed Energy Efficient Clustering) protocol, a new variant of DEEC for WSN's. We propose this M-DEEC for three different segregation for the nodes to elongate the stability & lifetime of the network. Hence, it increases the heterogeneity & energy level of the network. Our proposed M-DEEC scheme is based on DEEC with the extension of new types of nodes named super nodes. We have extended the DEEC to three-level heterogeneity. These super nodes have more energy than normal & advanced nodes & respective probabilities. Different simulation for the various values of a, b, m & mo has been carried out. For all the combination the proposed M-DEEC outperforms other protocol, as well as classical DEEC.

Keywords: *Clustering, Energy Efficient Routing, WSN, DEEC, M-DEEC*

1. INTRODUCTION

Wireless Sensor Networks (WSN) are able to perform data collection, aggregation and communication from an environment through many distributed individual sensor nodes through radio communications. By sensing the environmental events within their respective ranges, the sensor nodes collect data of interest and communicate the data through the nodes until the data finally reaches to the base-stations (BSs) for final processing. WSNs have become increasingly useful in a variety of critical applications, such as environmental monitoring, smart offices, battlefield surveillance, and transportation traffic monitoring [1].

In a sensor network, each node is both a sensor and a router, and its computing capability, storage capacity and communications ability are limited. Moreover, in many WSN applications, sensor nodes are deployed in harsh environments, which make the replacement of failed nodes either difficult or expensive. Thus, in many scenarios, a wireless node must operate without battery replacement for an extended period of time. Consequently, energy efficiency is the most critical issue when designing a network routing protocol with the objective of prolonging the network lifetime. [2].

The basic features of a sensor network are self-organizing capability, dynamic network topology, and limited battery power, short range broadcast communication, nodes mobility, routing and large scale of deployment. Due to the capability of self-organization and wireless communication, sensor networks are expected to be used in civil, commercial and military applications such as surveillance, climate and habitat monitoring, vehicle tracking, disaster management, medical observation and acoustic data gathering. There are many challenges in wireless sensor networks. The key challenge is to maximize the stability as well as lifetime of network. It is not feasible to replace the batteries of hundreds or thousands of sensor nodes after deployment. In sensor network, grouping of sensor nodes into a cluster is called clustering. Every cluster has a leader called cluster head. A cluster head may be pre assigned or elected by the members of the cluster. A cluster head collects the data from the nodes within cluster and transfer to destination (base station). The clustering techniques widely perused by researchers increase the lifetime as well as scalability objectives. Many clustering protocols can be use to create hierarchical structure that reduces the path cost when communicating with the base station.

2. RELATED WORK

Under the constrains of limited energy, bandwidth and computation capabilities, many routing protocols are designed to improve network efficiency. The LEACH protocol is one of the most well-known WSN clustering protocols, which selects a CH based on a predetermined probability of rotating the CH role among the sensor nodes so as to avoid fast depletion of the CH's energy. However, the selection of CHs is random. As a result, a node with low energy may be chosen as the CH, and the CHs may not evenly distributed [1]. Furthermore, the LEACH protocol requires that the transmission between the CHs and the BS be completed via a single hop, which consumes a large amount of energy and destroy the energy balance of nodes if the CHs are located far away the BS. The LEACH-centralized (LEACH-C) protocol is proposed as an improvement over LEACH, which uses a centralized clustering algorithm to form the clusters. LEACH-C enhances network performance through creating better clusters by dispersing the CHs throughout the network. The information on the residual energy of the nodes is taken into account in the probability formula, so the nodes with higher energy are more likely to be selected as the CHs [1].

DEEC protocol is a cluster based method for multi level and 2 level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are chosen using the probability based on the ratio between residual energy of every node and the average energy of the network. The era of being cluster-heads for nodes are entirely different according to their initial and residual energy. The nodes with more initial and remaining energy have greater chances of the becoming cluster heads compared to nodes with low energy [11].

The limited battery supply of a sensor node is one of the most important factors that limit the lifetime of the WSNs. As a consequence, increasing the lifetime of WSNs through energy efficient mechanisms has become a challenging research area. Previous studies have shown that instead of implementing direct transmission or multi-hop routing, clustering can significantly improve the total energy dissipation and lifetime of a WSN. The traditional LEACH and LEACH based algorithms have evolved from this idea. In this paper, authors proposed a fixed clustering routing algorithm for WSNs which selects the node with maximum residual energy for the following rounds according to a threshold level [1]. Some of the advantages of DEEC protocols are:

1. DEEC doesn't need any universal knowledge of energy at each election round.

2. In contrast to SEP and LEACH, DEEC will perform well in multi-level heterogeneous wireless network.

3. PROPOSED METHODOLOGY

The major problem in all the previous WSN routing protocol is energy consumption. In case of multi-level heterogeneous networks other performs poorly. SEP protocol was evolved for two-level of heterogeneity, in which two types of nodes advance nodes & normal nodes according to the initial energy, were incorporated. The rotating epoch & election probability is based on the initial energy of nodes. But this protocol has drawback of poor performance in multi-level heterogeneous networks. This problem was overcome by the introduction of DEEC protocol, in which initial & residual energy level of the nodes is used for the selection of cluster-heads, but for this also another problem was that each node should know the global knowledge of the networks. The solution of this drawback is the proposed M-DEEC which estimates the ideal value of network life-time, which is used to compute the reference energy that each node should expend during a round. The proposed M-DEEC is an energy-aware adaptive clustering protocol which used in heterogeneous WSN, in which every sensor node individually elects itself as a cluster-head based on the initial & residual energy. To hold the energy consumption of nodes with adaptive scheme, the proposed M-DEEC uses the avg. energy of the network as the reference energy. Thus, proposed M-DEEC does not require any global knowledge of energy at every election round.

Energy model for the radio hardware energy consumption, where the transmitter requires energy for the functioning of radio electronics & the power amplifier, & the receiver requires energy for the functioning of radio electronics is shown in Figure 1.

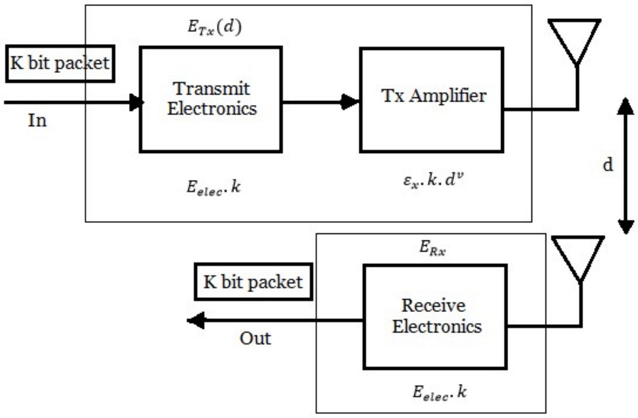

Figure 1: Network Model diagram

Here both the free space (d^2 power loss) & the multipath fading (d^4 power loss) channel models were used, depending on the distance between the transmitter & receiver [9]. Power controlling is used to invert this loss by make changes in the setting of the power amplifier, when the distance is below threshold d_o, free space model is opted; for other cases, the multipath model is opted. Hence, for transmission of k-bit message at a distance, the radio expends. Hence, to transmit k bits, the energy expended can be given as:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-} \quad (k,d)$$

$$= \begin{cases} kE_{elec} + kE_{f_s}d^2 if d < d_o; \\ kE_{elec} + kE_{amp}d^4 if d \geq d_o; \end{cases}$$

This electronics energy E_{elec} is dependent upon the various factors like digital coding, spreading, filtering, & modulation of the signal, & the amplifier's energy, $E_{f_s}d^2$ or $E_{amp}d^4$, is dependent upon the distance to the receiver & the acceptable BER [9].

Where; $d_o$is the distance threshold for swapping amplification models, can be computed as;

$$d_o = \sqrt{\frac{E_{f_s}}{E_{amp}}}$$

To receive a k-bit message, the radio will expand;

$$E_{Rx}(k) = kE_{elect}$$

It is also further assumed a symmetric radio channel i.e., the same amount of energy is required to transmit a k-bit message from node A to B & vice versa.

Sensor network is used with N nodes in M X M network field as shown in Figure 2. There are three types of sensor nodes [11, 12]. They are normal nodes, advanced nodes & super nodes. Let m be the fraction of the total number of nodes N, & mo is the percentage of the total number of nodes which are equipped with b times more energy than the normal nodes, called as super nodes, the number is $N.m.mo$. The rest $N.m(1 - mo)$ nodes are having with more energy compared the normal nodes; called as advanced nodes & remaining $N.(1 - m)$ as normal nodes.

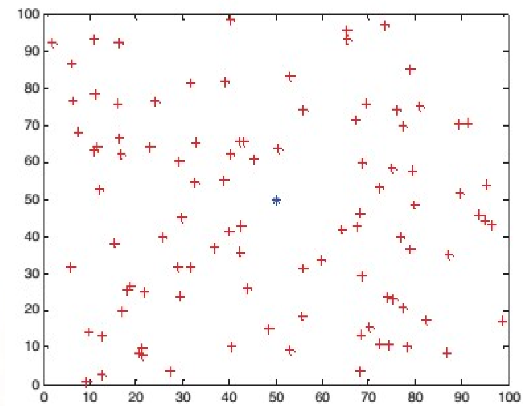

Figure 2: MxM network field

The total initial energy of the three-level heterogeneous networks is given by:

$$E_{total} = N.(1 - m).E_o + N.m(1 - mo),$$

$$(1 + a)E_o + N.m.mo.E_o(1 + b)$$

$$= NE_o(1 + m(a + mo.b)$$

Therefore, the three-level heterogeneous networks have $(1 + m(a + mo.b)$ times more energy or we can say that the total energy of the system is increased by a factor of $(1 + m(a + mo.b)$[11].

Cluster Formation

The formation of the clusters is done using a distributed algorithm. The main idea is for the sensor nodes to elect themselves in accordance to their energy levels sovereignty. The main aim is to minimize the communication cost & maximizing network resources in order to ensure succinct information is sent to the sink. Each node transmits data to its imminent cluster head & the cluster heads do the data aggregation. Now, to move ahead the indicator function of chose n a cluster head & assuming an optimal number of clusters c present in each round. It is conjectured that as a cluster head expended energy is more than as a cluster member. Each node can become cluster head with a probability P_{opt}& every node must become cluster head once every $1/P_{opt}$ rounds. Hence, now we have nP_{opt} clusters plus cluster heads in the each round. Now, assuming the non-elected nodes were a member of set G in the last previous $1/P_{opt}$ rounds.

For each round sensor node chooses a random number between 0 & 1. If this is lower than the threshold for node $n, T(n)$, the sensor node develop into a cluster head. Then the threshold $T(n)$ is given by:

$$T(n) = \begin{cases} \dfrac{P_{opt}}{1 - P_{opt}[rmod(1/P_{opt})]} if n \in G; \\ 0 \qquad otherwise \end{cases}$$

Where, P_{opt}, r, & G represent, respectively, the desired percentage of cluster-heads, the current round number, & the group of nodes which were not became cluster-heads in the last 1/p rounds. By using this threshold, each of the node will be elected as a cluster head, but only once within 1/p rounds.

Assume nodes are uniformly & randomly distributed in an area of m^2. On average there would be n/c nodes per cluster, one cluster head &$\left(\frac{n}{c} - 1\right)$ non-cluster head. Each cluster head should dissipate energy receiving k bits of data packet from associated cluster members & transmitting to the sink. Also, data aggregation before the transmission also uses energy, which is s E_{DA}, per bit. In all, the energy consumed by each cluster head is:

$$E_{CH} = kE_{elec}\left(\frac{n}{c} - 1\right) + kE_{DA}\frac{n}{c} + E_{Tx}(k, d_{toSink})$$

Where; d_{toSink} is the distance from cluster head node to the sink. For non-cluster head, the energy expended will be to transmit k bits of data to the respective cluster heads, also a free space power loss $d^2$is taken due to, $d_{toCH} < d_o$in equation given below:

$$E_{no} \qquad = kE_{elec} + kE_{f_s}d_{toCH}^2$$

Where;d_{toCH} is the distance from each node to their respective cluster heads. The average value of d_{toCH} can be estimated as $M/\sqrt{2\pi c}$[8].

The energy consumed in a cluster per round is estimated as;

$$E_{cluster} \approx E_{CH} + \frac{n}{c}E_{nonCH}$$

The total energy consumed per round is the sum of the energy consumed by all clusters, i.e.;

$$E_{total} = cE_{cluster}$$

If the average of d_{toSink} is greater than do, the total energy can be calculated as:

$$E_{total} = \left(kE_{elec}\left(\frac{n}{c} - 1\right) + kE_{DA}\frac{n}{c} + kE_{elec} + k \in_{mp} d_{toSink}^4\right) + \left(kE_{elec} + k \in_{f_s} M^2/2\pi c\right)$$

Otherwise, when $d_{toSink} < d_o$ applies, the total energy becomes,

$$E_{total} = k\left(2nE_{elec} + nE_{DA} + \in f_s(cd_{toSink}^2 + nd_{toCH}^2)\right)$$

The optimal number of clusters can be found by letting $\frac{\delta E_{total}}{\delta c} = 0$. the different forms of the E_{total} calculation will lead to different optimal c settings.

In the three levels heterogeneous networks there are three types of nodes normal nodes, advanced nodes & super nodes, based on their initial energy. Therefore, the reference value of p is distinguishing for all these types of nodes. The probabilities of normal, advanced & super nodes are:

$$P_i = \begin{cases} \dfrac{P_{opt}E_i(r)}{(1 + m(a + mo.b))\bar{E}(r)} if s_i is the normal node \\ \dfrac{P_{opt}(1 + a)E_i(r)}{(1 + m(a + mo.b))\bar{E}(r)} if s_i is the advanced node \\ \dfrac{P_{opt}(1 + b)E_i(r)}{(1 + m(a + mo.b))\bar{E}(r)} if s_i is the super node \end{cases}$$

Threshold for cluster head selection is calculated for normal, advanced, super nodes by putting above values in given equation:

$$T(s_i) = \begin{cases} \frac{P_i}{1-P_i(r mod \frac{1}{P_i})} if P_i \in G' \\ \frac{P_i}{1-P_i(r mod \frac{1}{P_i})} if P_i \in G'' \\ \frac{P_i}{1-P_i(r mod \frac{1}{P_i})} if P_i \in G''' \\ 0 \quad\quad\quad\quad\quad Otherwise \end{cases}$$

where G' is the set of normal nodes that haven't been acted as cluster heads in the last $1/P_i$ rounds of the time span where s_i is normal node,$G''$is set of the advanced nodes that have not become cluster heads within the last $1/P_i$ rounds of the time span, at where, s_i is advanced node, $G'''$is the set of super nodes which haven't been acted as cluster heads in the last $1/P_i$ rounds of the epoch where s_i is super node.

M-DEEC is also based on the similar sort of approach for the estimation of the energy in the network as defined in the conventional DEEC. Since the probabilities which were computed before, are dependent upon the avg. energy of the network for round r, therefore this has to be calculated. This average energy is estimated as:

$$\bar{E}(r) = \frac{1}{N} E_{total}(1 - \frac{r}{R})$$

Where R denotes the total no. of rounds of the lifetime. R can be computed as:

$$R = \frac{E_{total}}{E_{round}}$$

$E_{round}$is the energy debauched in the network in around.

The overall energy debauchedE_{round} is;

$$E_{round} = L\big(2NE_{elec} + NE_{DA} + kE_{amp}d_{toBS}^4 + NE_{fs}d_{toCH}^2\big)$$

Where, k is number of clusters,

d_{toBS} is the avg. distance from cluster head to the base station,

d_{toCH} is avg. distance from the cluster members to the cluster head.

$$\text{Now, } d_{toCH} = \frac{M}{\sqrt{2\pi k}}, d_{toBS} = 0.765\frac{M}{2}$$

From the derivative of E_{round}w.r.t. k to 0, optimal number of clusters can be given as;

$$k_{opt} = \sqrt{\frac{N}{2\pi}\frac{M}{d_{toBS}^2}}\sqrt{\frac{E_{fs}}{E_{amp}}}$$

Hence, the energy consumed per round can be find out by last three equations. Due to the heterogeneity factors R is taken as 1.5 R; since $\bar{E}(r)$ will be huge at the end, few of them will not be died till last.

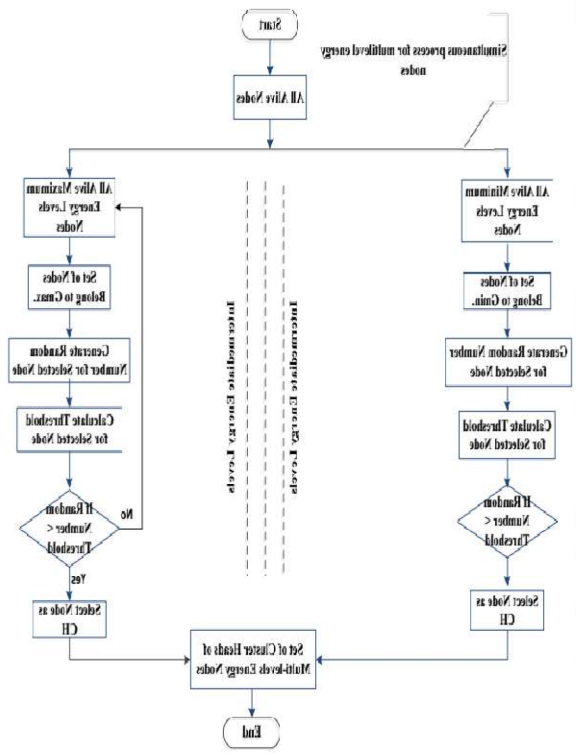

Figure 3: Flow chart of Proposed Methodology

4. SIMULATION RESULTS & DISCUSSIONS

The performance parameters which are generally used to evaluate the WSN clustering protocols are as follows:

- Data Packets at base station.
- Number of nodes alive.
- Number of nodes dead.
- Remaining network energy.

The above mentioned metrics give us the idea to conclude about the stability period of the network which is the time period from the start of network operation till the first sensor node is dead, unstable period of the network which is the time period from when first node is dead to when last node is dead, energy consumption, the data send that are received by the base station & the lifetime of the network which is number of rounds until the first node die which is simply the stability period of the network (it is assumed that all nodes having equal priority). More the network stability means more the network lifetime.

For the simulation in MATLAB following parameters are taken as the benchmark:

Network Parameters	Value
Network Field Size	$100 \times 100\ m^2$
Number of Nodes	100
Initial Energy of Sensor Nodes (E_o)	0.5 J
Packet / Message Size	4000 bits
Transceiver idle state energy consumption (E_{elec})	50 nJ/bit
Data Aggregation/ Fusion Energy consumption (E_{fs})	10 nJ/bit/report
Amplification Energy (Cluster to BS) (E_{amp})	0.0013pJ/bit/m2
Energy Consumption of Data Gathering Cluster Head (E_{DA})	5nJ/bit/signal
Threshold Distance (d_o)	70 m
P_{opt}	0.1

Table 1: Parameters for simulation of our proposed M-DEEC implementation

4.1 Network Life Time / DEAD & Alive Nodes

To examine the performance of wireless sensor networks some characterization parameters are generally used. These parameters are related to number of nodes, alive or dead & network life time span. Some of them are:

FND (First Node Dead): The time span from start to when the first node dead is called FND (First Node Dead).

HND (Half number of Nodes Dead): What's more, the rounds when half of the nodes die are called HND (Half number of Nodes Dead).

LND (Last Node Dead): Another measure is LND (Last Node Dead), which is the time span from the time zero to when there is no alive node in the network.

In the simulation of this proposed heterogeneous WSN routing protocol M-DEEC, the radio parameters mentioned in Table 1 are used & estimation of the performance for three level heterogeneous WSNs is done along with the comparison with Classical DEEC. The Parameter m which refers to part of advanced nodes have excess portion of energy in the network. Further, mo is the quantitative factor which refers to part of super nodes, those contains excess portion of energy b in the network.

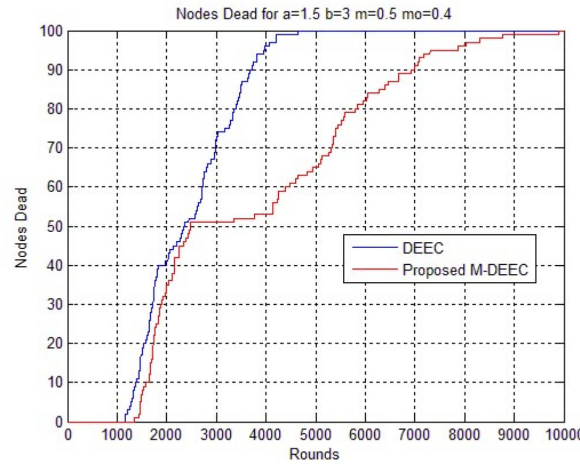

Figure 4: Number of Dead Nodes during Rounds for a=1.5, m=0.5, b=3, mo=0.4

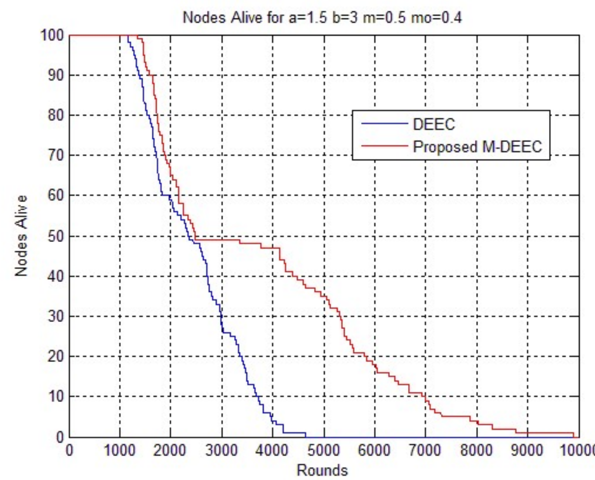

Figure 5: Number of Alive Nodes during Rounds for a=1.5, m=0.5, b=3, mo=0.4

For the case for a network having m = 0.5 fragment of advanced nodes have a = 1.5x greater energy portion & mo=0.4 fragment of super nodes having b = 3 times more energy content than normal nodes. From figure 4 it can be seen that first node for classical DEEC & M-DEEC dies at 1117 & 1613 rounds respectively. Tenth node dies at 1315 & 1825 rounds respectively. All nodes for the classical DEEC are dead at 4588 & for M-DEEC are dead at 9883 rounds. Figure 5 for number of nodes alive in first, tenth & for all the rounds is explicitly the inverted case of the graph for number of nodes dead which is shown in Figure 4.

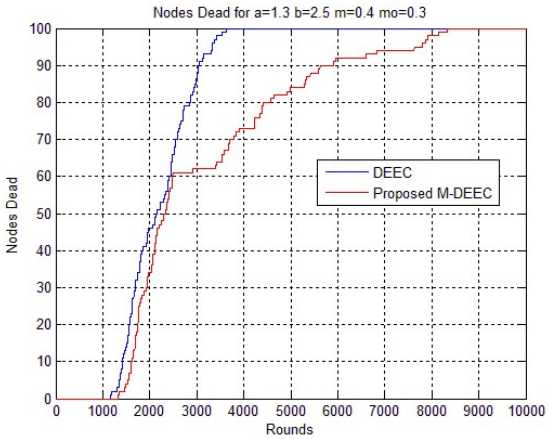

Figure 6: Number of Dead Nodes during Rounds for a=1.3, m=0.4, b=2.5, mo=0.3

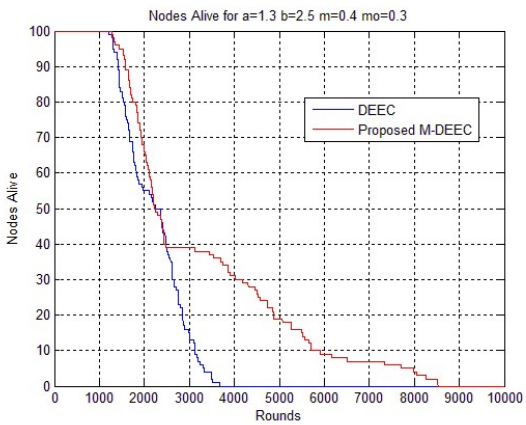

Figure 7: Number of Alive Nodes during Rounds for a=1.3, m=0.4, b=2.5, mo=0.3

For the case for a network having m = 0.4 fragment of advanced nodes having a = 1.3 times more energy content & mo=0.3 fragment of super nodes having b = 2.5 times more energy content than normal nodes. From figure 6.3 it can be seen that first node for classical DEEC & M-DEEC dies at 1100 & 1300 rounds respectively. Tenth node dies at 1205 & 1720 rounds respectively. All nodes for the classical DEEC & M-DEEC are dead at 3400&8700 rounds respectively.Figure7 for number of nodes alive in first, tenth & for all the rounds is explicitly the inverted case of the graph for number of nodes dead which is shown in Figure 6.

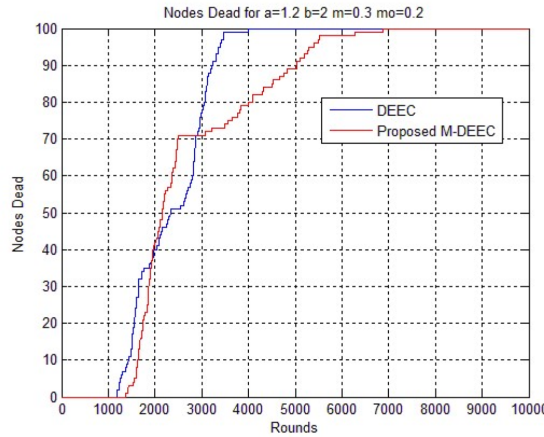

Figure 8: Number of Dead Nodes during Rounds for a=1.2, m=0.3, b=2, mo=0.2

For the case for a network having m = 0.3 fragment of advanced nodes have a = 1.5x greater energy portion & mo=0.2 fragment of super nodes having b = 2 times more energy content than normal nodes. From figure 8 it can be seen that first node for classical DEEC & M-DEEC dies at 1100 & 1300 rounds respectively. Tenth node dies at 1380 & 1600 rounds respectively. All nodes for the classical DEEC & M-DEEC are dead at 3400 & 6900 rounds respectively. Figure 9 for number of nodes alive in first, tenth & for all the rounds is explicitly the inverted case of the graph for number of nodes dead which is shown in Figure 8.

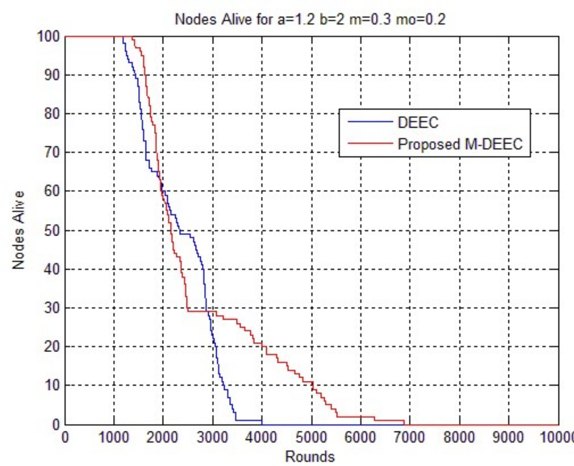

Figure 9: Number of Alive Nodes during Rounds for a=1.2, m=0.3, b=2, mo=0.2

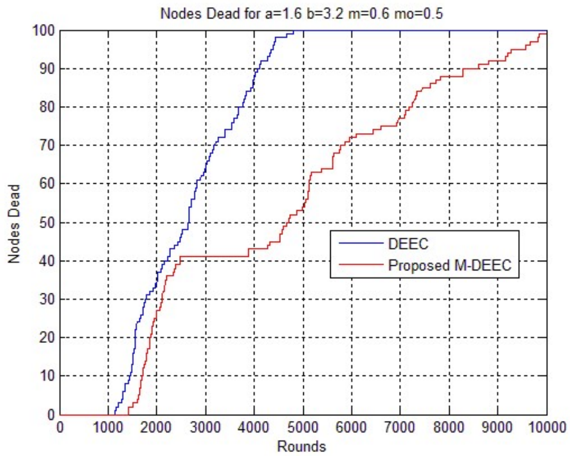

Figure 10: Number of Dead Nodes during Rounds for a=1.6, m=0.6, b=3.2, mo=0.5

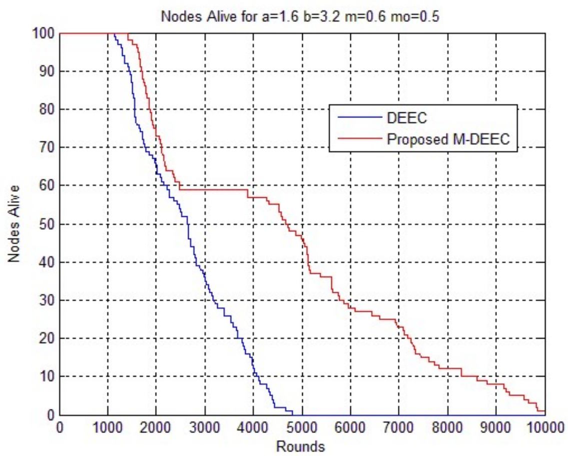

Figure 11: Number of Alive Nodes during Rounds for a=1.6, m=0.6, b=3.2, mo=0.5

For the case for a network having m = 0.6 fragment of advanced nodes have a = 1.5x greater energy portion & mo=0.5 fragment of super nodes having b = 3.2 times more energy content than normal nodes. From figure 10 it can be seen that first node for classical DEEC & M-DEEC dies at 1070 & 1480 rounds respectively. Tenth node dies at 1500 & 1830 rounds respectively. All nodes for the classical DEEC & M-DEEC are dead at 4900 & 9999 rounds respectively. Figure11 for number of nodes alive in first, tenth & for all the rounds is explicitly the inverted case of the graph for number of nodes dead which is shown in Figure 10.

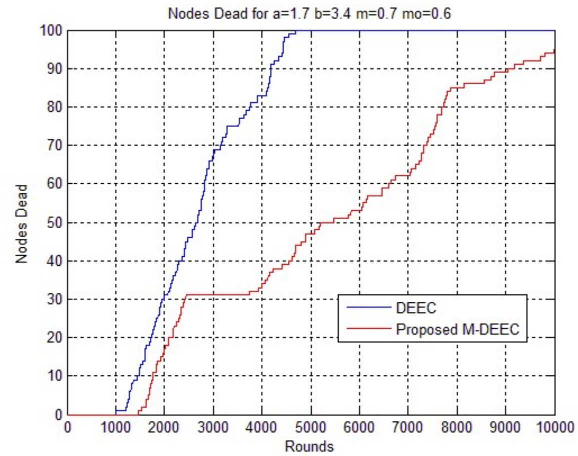

Figure 12: Number of Dead Nodes during Rounds for a=1.7, m=0.7, b=3.4, mo=0.6

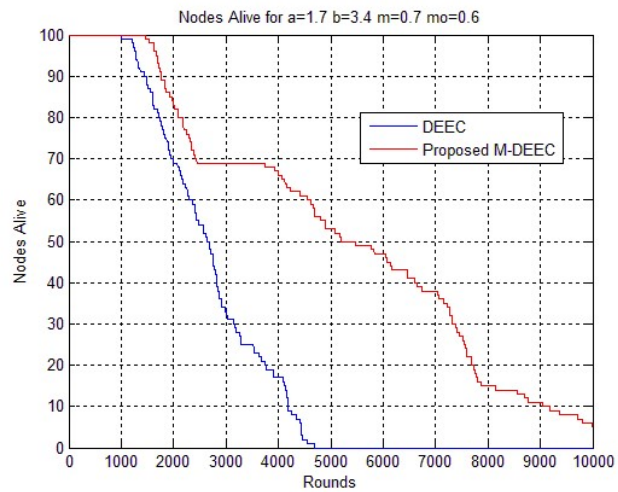

Figure 13: Number of Alive Nodes during Rounds for a=1.7, m=0.7, b=3.4, mo=0.6

For the case for a network having m = 0.7 fragment of advanced nodes having a = 1.7 times more energy content & mo=0.6 fragment of super nodes having b = 3.4 times more energy content than normal nodes. From figure 12 it can be seen that first node for classical DEEC & M-DEEC dies at 1000 & 1450 rounds respectively. Tenth node dies at 1300 & 1850 rounds respectively. All nodes for the classical DEEC & M-DEEC are dead at 4800 & more than 10000 rounds respectively. Figure 13 for number of nodes alive in first, tenth & for all the rounds is explicitly the inverted case of the graph for number of nodes dead which is shown in Figure 12.

It can be concluded from the simulation results that proposed M-DEEC protocol is better than classical DEEC in terms of stability period, because of the fact that the probabilities in M-DEEC are defined distinguishly for different nodes i.e. normal, advanced & super nodes.

4.2 Simulation Result Summary

In this work, we propose M-DEEC (Modified Distributed Energy Efficient Clustering) protocol, a new variant of DEEC. We propose this M-DEEC for three different segregations for the nodes to elongate the stability & lifetime of the network. Hence, it increases the heterogeneity & energy level of the network. Different simulation for the various values of a, b, m & mo has been carried out. For all the combination the proposed M-DEEC outperforms classical DEEC protocol, as shown in table 3.

CASE	FND		HND		LND	
	Classical DEEC	Proposed M-DEEC	Classical DEEC	Proposed M-DEEC	Classical DEEC	Proposed M-DEEC
a=1.7, m=0.7, b=3.4, mo=0.6	1000	1500	2750	5200	4700	9999
a=1.3, m=0.4, b=2.5, mo=0.3	1300	1340	2430	2400	3800	8500
a=1.2, m=0.3, b=2, mo=0.2	1200	1400	2200	2400	4000	6900
a=1.6, m=0.6, b=3.2, mo=0.5	1100	1480	2700	4700	4800	9999
a=1.7, m=0.7, b=3.4, mo=0.6	1000	1500	2750	5200	4700	9999

Table 3: Simulation result summary for FND, HND & DND

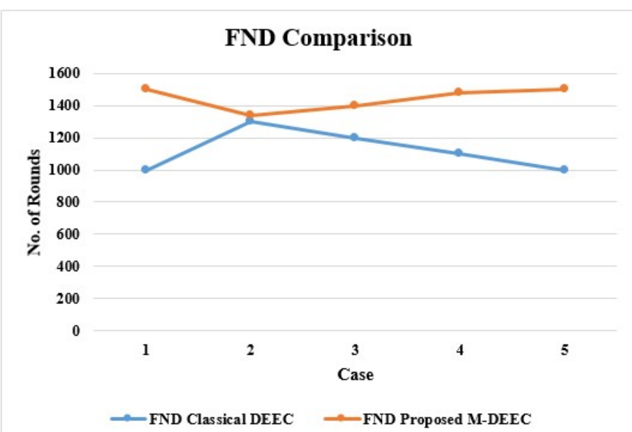

Figure 14: Network Lifetime First Node Dead comparison

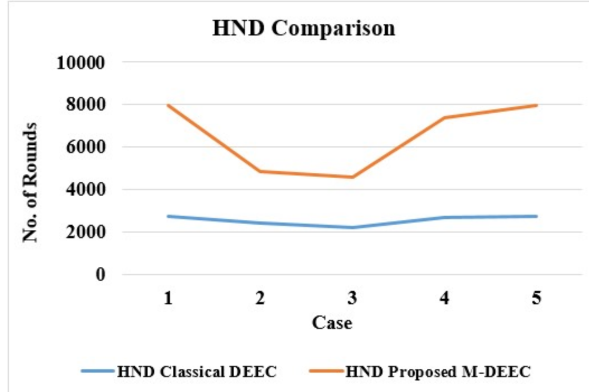

Figure 15: Network Lifetime Half Node Dead comparison

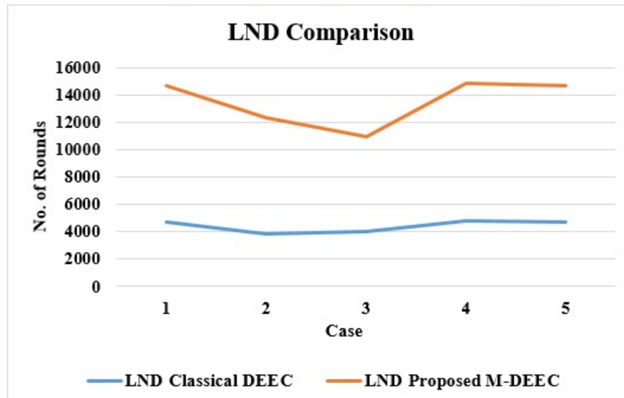

Figure 16: Network Lifetime Last Node Dead comparison

4.3 Results Comparison

In literature many routing protocols have been implemented for increasing network lifetime, for the comparison purpose of network lifetime more oftenly LND parameter is used. In [1], [2] the results of network lifetime are mentioned in terms of last node dead. Table 4 shows the comparison of network lifetime with respect to LND performance of our proposed M-DEEC with other existing protocols.

LND Performance	Protocol					
	Classical DEEC [1]	Improved PSO [2]	LEACH [1]	MOD LEACH [1]	MESA [1]	Proposed M-DEEC
Number of Rounds	4000	2495	3700	3900	5500	6900

Table 4: Comparison of LND performance for various Protocols

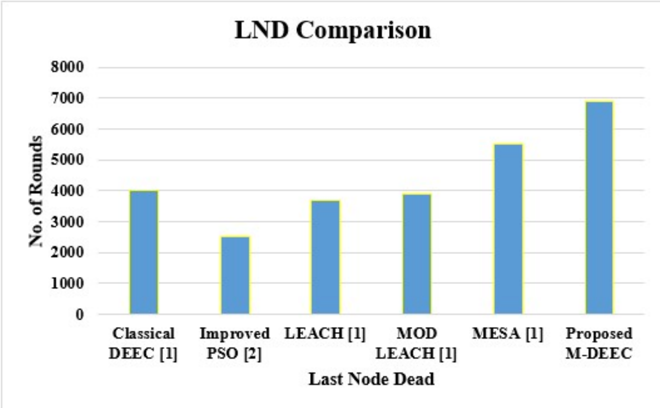

Figure 17: Comparison of LND performance for various Protocols

5. CONCLUSION

In this work, we propose M-DEEC (Modified Distributed Energy Efficient Clustering) protocol, a new variant of DEEC. We propose this M-DEEC for three different segregations for the nodes to elongate the stability & lifetime of the network. Hence, it increases the heterogeneity & energy level of the network. Our proposed M-DEEC scheme is based on DEEC with the extension of new types of nodes named super nodes. We have extended the DEEC to three-level heterogeneity. These super nodes have more energy than normal & advanced nodes & respective probabilities. Different simulation for the various values of a, b, m & mo has been carried out. For all the combination the proposed M-DEEC outperforms other protocol, as well as classical DEEC.

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