

Evaluating the Performance of DEEC Variants

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ABSTRACT

Wireless Sensor Networks (WSNs) have many sensor nodes having restricted battery power, which transmit sensed data to the Base Station that needs high energy consumption. Numerous routing protocols have been proposed in this regard getting energy efficiency in heterogeneous situations. Though, each protocol is inappropriate for heterogeneous WSNs. Efficiency of WSNs declines as varying the heterogeneity of sensor nodes. This paper has evaluated the performance of various Distributed Energy- Efficient Clustering based protocols like DEEC, DDEEC, EDEEC, HDEEC, EDDEEC and TDEEC under numerous scenarios; comprising various level of heterogeneity. MATLAB tool is used for experimental purpose. The comparison has shown that the EDDEEC has very effective results over other DEEC variants due to its special feature of T-absolute i.e. it treats all heterogeneous sensor nodes with same election probability when each node has lesser energy than T-absolute.

Keywords

WSNs, DEEC, heterogeneity, super nodes, T-absolute

1. INTRODUCTION

Wireless sensor networks consist of small nodes with sensing, computation, and wireless communication capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. As wireless sensor network is a collection of sensor nodes therefore these sensor nodes are grouped into clusters. Each cluster is assigned with a leader, which is also called the cluster head (CH) and usually performs the unique tasks like data aggregation, pass data to base station.

Various clustering protocols are specified in this consideration [2,3]. Every node belonging to cluster transmits their data to Cluster Head, where, Cluster Head performs the data aggregation and transmit this aggregated data to base station. In aggregation process, smaller numbers of messages are transmitted to Base Station and only some nodes have to send data to large distances therefore more energy is saved and the network lifetime is spanned. The cluster arrangement process is a two-level hierarchy process where the CH nodes make the higher level and the cluster-member nodes make the lower level. The sensor nodes at regular intervals send their data to the corresponding CH nodes. CH nodes aggregate the data and transmit them to the base station (BS) directly or through the midway communication with other CH nodes. Due to the CH nodes transmit all the time data to large distances than the member nodes; they obviously spend energy at large rates. A general solution in order to balance the energy consumption amongst all the sensor nodes is to regularly re-elect new CHs in each cluster. Low-Energy Adaptive Clustering Hierarchy (LEACH) [5], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [7], Hybrid Energy-Efficient Distributed clustering (HEED) [8] are algorithms specially designed for

homogenous WSN under thought because these protocols do not work effectively in heterogeneous circumstances as these algorithms are not capable to treat nodes in a different way in conditions of their energy. Whereas, Stable Election Protocol (SEP) [9], Distributed Energy-Efficient Clustering (DEEC) [10], Developed DEEC (DDEEC) [11], Enhanced DEEC (EDEEC) [12] and Threshold DEEC (TDEEC) [13] are algorithms designed for heterogeneous WSN.

In this paper, we study performance of heterogeneous WSNs protocols under three and multi-level heterogeneous networks. We have compared the performance of DEEC, DDEEC, EDEEC, TDEEC, EDDEEC, and HDEEC for different scenarios of three and multilevel heterogeneous WSNs. Heterogeneous WSNs contains normal, advanced and super sensor nodes where super nodes comes up with extra energy than to normal and advanced sensor nodes. We recognize each protocol focused around the extending stability phase, network life time of network alive through out rounds for a few three level heterogeneous networks. Each node having apparently equivalent proportion of normal, advanced and super nodes alongside the multilevel heterogeneous WSNs. It is observed that diverse protocols have distinctive effectiveness for three level and multilevel heterogeneous WSNs in terms of stability period, nodes alive and network life time. DEEC and DDEEC perform well under three level heterogeneous WSNs holding high energy level distinction between normal, advanced and super nodes regarding stability period. However, it is deficient in results as contrast with EDEEC and TDEEC.

The rest of the paper is ordered as follows: section 2 briefly reviews the related work. In section 3, describes the network model. In section 4, radio dissipation model is explained. Proposed overview of Heterogeneous Protocols explained in section 5. In section 6, we define the performance criteria. Section 7 shows the performance of different DEEC protocols by simulations and comparison. Finally, section 8 gives conclusion and future work.

2. RELATED WORK

W.R. Heinzelman, *et al.* [5] proposed a LEACH clustering algorithm for homogeneous WSNs in which nodes randomly choose among them to be CHs and transmit this choice criterion over the whole network to issue energy load. G. Smaragdakis, *et al.* [9] introduced SEP protocol in which each sensor node in a heterogeneous two level hierarchical network autonomously chooses itself as a CH on the basis of its initial energy relative to the other nodes of the network. L. Qing, Q. Zhu and M. Wang [10] introduced a protocol DEEC in which CH election is based on the probability of the ratio of residual energy and average energy of the network. Brahim Elbhiri, *et al.* [11] introduced a protocol DDEEC on the basis of residual energy for CH election to stable it over the whole network. So, the advanced nodes are more likely to be elected as CH for the first transmission rounds, and when their energy decreases, these nodes will have the same CH election probability like the

normal nodes. P. Saini *et al.* [12] proposed a protocol EDEEC which is extended up to three level heterogeneity by adding an extra amount of energy level known as super nodes. Parul Saini and Ajay K Sharma [13] proposed a protocol TDEEC scheme selects the CH from the high energy nodes improving energy efficiency and lifetime of the network. Ease of Use. M.Y. Khan *et al.* [14] proposed a protocol called H-DEEC. In H-DEEC, the chosen Cluster Heads (CHs) communicate the Base Station (BS) through beta elected nodes, by using multi-hopping. Logically divide the network into two parts, on the basis of the residual energy of nodes. The normal nodes with high initial and residual energy will be highly probable to be CHs than the nodes with lesser energy. N. Javaid *et al.* [15] have proposed protocol EDDEEC implements the idea of probabilities for CH selection based on initial, remaining energy level of the nodes and average energy of network.

3. HETEROGENEOUS WSN MODEL

In this segment, we suppose N number of nodes distributed in a square area of dimension M x M. Heterogeneous WSNs have two, three or multi types of nodes which are having different energy levels and are considered as two, three and multi-level heterogeneous WSNs respectively.

3.1 Two Level Heterogeneous WSNs Model

In two level heterogeneity, E_o describes the normal node's energy value and $E_o(1 + a)$ describes the advanced node's energy value where a defines the value that is this amount of value times more energy contained by advanced node compared to the normal nodes. If two level heterogeneous network N is the total number of nodes where Nm defines total number of advanced nodes and m deals with the fraction of advanced nodes and $N(1 - m)$ is the number of normal nodes. The overall initial energy of WSN is the aggregation of heterogeneous node's energy values.

$$\begin{aligned} E_{total} &= N(1 - m)E_o + Nm(1 + a)E_o \quad (1) \\ &= NE_o(1 - m + m + am) \\ &= NE_o(1 + am) \end{aligned}$$

The two level heterogeneous WSNs contain am times more energy as compared to homogeneous WSNs.

3.2 Three Level Heterogeneous WSN Model

Three level heterogeneous WSNs contain three different energy levels of nodes i.e. normal, advanced and super nodes. Normal nodes contain energy of E_o , the advanced nodes of fraction m are having a times extra energy than normal nodes equal to $E_o(1 + a)$ whereas, super nodes of fraction m_o are having a factor of b times more energy than normal nodes so their energy is equal to $E_o(1 + b)$. As N is the total number of nodes in the network, then Nmm_o is total number of super nodes and $Nm(1 - m_o)$ is total number of advanced nodes. The total initial energy of three level heterogeneous WSN is therefore given by:

$$\begin{aligned} E_{total} &= N(1 - m)E_o + Nm(1 - m_o)(1 + a)E_o + \\ &\quad Nm_oE_o(1 + b) \quad (2) \\ E_{total} &= NE_o(1 + m(a + m_o b)) \quad (3) \end{aligned}$$

The three level heterogeneous WSNs contain $(a + m_o b)$ times more energy as compared to homogeneous WSNs.

3.3 Multilevel Heterogeneous WSN Model

Multi level heterogeneous WSN is a network that holds nodes of various energy levels. The initial energy of nodes is circulated over the nearby set $[E_o, E_o(1 + a_{max})]$, where E_o the lower is bound and a_{max} is the value of maximal energy. At first, node S_i is equipped with initial energy of $E_o(1 + a_i)$, which is a_i times more energy than the lower bound E_o . The aggregate initial energy of multi-level heterogeneous networks is given by:

$$E_{total} = \sum_{i=1}^N E_o (1 + a_i) = E_o(N + \sum_{i=1}^N a_i) \quad (4)$$

CH nodes devour more energy as contrasted with member nodes so after a few rounds energy level of every last one of hubs gets diverse as contrasted with one another. Therefore, heterogeneity is presented in homogeneous WSNs and the networks that hold heterogeneity are more critical than homogeneous networks.

4. RADIO DISSIPATION MODEL

The radio energy model depicts that 1 bit message is transmitted over a distance d as in [5,6], energy exhausted is then given by:

$$E_{Tx}(1, d) = \begin{cases} lE_{elec} + l\epsilon_{fs}d^2, & d < d_o \\ lE_{elec} + l\epsilon_{mp}d^4, & d \geq d_o \end{cases} \quad (5)$$

Where, E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit. d is the separation between sender and receiver. If this distance is less than threshold, free space (fs) model is used else multi path (mp) model is used. Now, total energy disseminated in the network throughout a round is given by [5,6]

$$E_{round} = L(2NE_{elec} + NE_{DA} + k\epsilon_{mp}d_{toBS}^4 + N\epsilon_{fa}d_{toCH}^2) \quad (6)$$

Where, K = number of clusters

EDA = Data aggregation cost expensed in CH

d_{toBS} = Average distance among the CH and BS

d_{toCH} = Average distance among the cluster members and the CH

$$d_{toCH} = \frac{M}{\sqrt{2\pi}}, d_{toBS} = 0.765 \frac{M}{2} \quad (7)$$

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d_{toBS}^2} \quad (8)$$

5. OVERVIEW OF DISTRIBUTE HETEROGENOUS PROTOCOLS

5.1 DEEC

DEEC is intended to manage nodes of heterogeneous WSNs. For CH selection, DEEC uses initial and remaining energy level of nodes. Let n_i indicates the number of rounds to be a CH for node s_i . $p_{opt}N$ is the ideal number of CHs in the network throughout every round. A CH selection criterion in DEEC is focused around energy values of nodes. As in homogenous network, when nodes have equal measure of energy throughout every epoch then choosing $p_i = p_{opt}$ guarantees that $p_{opt}N$ CHs throughout every round. In WSNs, nodes with high energy are more reasonable to become CH than nodes with low energy but the net value of CHs throughout every round is equivalent to $p_{opt}N$. p_i is the probability for each node s_i to become CH, so, node with high energy has larger value of p_i as contrasted to the p_{opt} . $\bar{E}(r)$ depicts average energy of network during round r which can be given as in [10]:

$$E(r) = \frac{1}{N} \sum_{i=1}^N E_i(r) \quad (9)$$

Probability for CH selection in DEEC is given as in [10]:

$$p_i = p_{opt} \left[1 - \frac{\bar{E}(r) - E_i(r)}{\bar{E}(r)} \right] = p_{opt} \frac{E_i(r)}{\bar{E}(r)} \quad (10)$$

In DEEC the average sum number of CH during every round is given as in [10]:

$$\sum_{i=1}^N p_i = \sum_{i=1}^N p_{opt} \frac{E_i(r)}{\bar{E}(r)} = p_{opt} \sum_{i=1}^N \frac{E_i(r)}{\bar{E}(r)} = N p_{opt} \quad (11)$$

p_i is probability of every node to be a CH in a round. Where G is the set of nodes suitable to become CH at round r . If node becomes CH in recent rounds then it is from set G . Throughout every round every node selects a random number between 0 and 1. If number is minimum than threshold value as explained in equation 12 as in [10], it is appropriate to become a CH else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i(r \bmod \frac{1}{p_i})} & \text{if } s_i \in G \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

As p_{opt} is reference value of average probability p_i . In homogenous networks, all nodes have same initial energy so they use p_{opt} to be the reference energy for probability p_i . However in heterogeneous networks, the value of p_{opt} is diverse according to the initial energy of the node. In two level heterogeneous network the value of p_{opt} is given by as in [10]:

$$p_{adv} = \frac{p_{opt}}{1+am}, p_{nrm} = \frac{p_{opt}(1+am)}{(1+am)} \quad (13)$$

Then use the above p_{adv} and p_{nrm} in its place of p_{opt} in equation 10 for two level heterogeneous networks as assumed in [10]:

$$p_i = \begin{cases} \frac{p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{if } s_i \text{ is the advanced node} \end{cases} \quad (14)$$

Above model can also be extended to multi level heterogeneous network given below as in [10]:

$$p_{multi} = \frac{p_{opt} N(1+a_i)}{(N + \sum_{i=1}^N a_i)} \quad (15)$$

Above p_{multi} in equation 10 instead of p_{opt} to get p_i for heterogeneous node. p_i for the multilevel heterogeneous network is specified by as in [10]:

$$p_{multi} = \frac{p_{opt} N(1+a_i)}{(N + \sum_{i=1}^N a_i)} \quad (16)$$

In DEEC we approximate average energy $E(r)$ of the network for any round r as in [10]:

$$\bar{E}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R} \right) \quad (17)$$

R denotes total rounds of network lifetime and is estimated as follows:

$$R = \frac{E_{total}}{E_{round}} \quad (18)$$

E_{total} is total energy of the network where E_{round} is energy expenditure during each round.

5.2 DDEEC

DDEEC utilizes same strategy for estimation of average energy in the network and CH selection algorithm focused around residual energy as applied in DEEC. Distinction between DDEEC and DEEC is focused in expression that characterizes probability for normal and advanced nodes to become a CH [11] as given in equation 14. We find that nodes with more residual energy at round r are more reasonable to become CH, so, in this method node having higher energy values or advanced nodes will become CH more often as compared to the nodes with lower energy or normal nodes. At a certain point in the network where advanced nodes containing equal residual energy same as normal nodes. Although, after this point DEEC continues to punish the advanced nodes so this is not ideal way for energy allocation as by doing so, advanced nodes are constantly a CH and they die more quickly than normal nodes. To prevent this unbalanced case, DDEEC makes few improvements in equation 14 to keep advanced nodes from being penalized over and again. DEEC introduces threshold residual energy as in [11] and given below:

$$Th_{REV} = E_o \left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}} \right) \quad (19)$$

At the point when energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both kind of nodes use similar probability to become cluster head. Therefore, CH selection is balanced and more proficient. Threshold residual energy Th is given as in [11] and given below:

$$Th_{REV} = \left(\frac{7}{10} \right) E_o \quad (20)$$

Average probability p_i for CH selection used in DDEEC is as follows as in [11]:

$$p_i = \begin{cases} \frac{p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Nml nodes, } E_i > Th_{REV} \\ \frac{(1+a)p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Adv nodes, } E_i > Th_{REV} \\ c \frac{(1+a)p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Adv, Nml nodes, } E_i \leq Th_{REV} \end{cases} \quad (21)$$

5.3 EDEEC

EDEEC utilizes idea of three level heterogeneous networks as explained previously. It holds three types of nodes normal, advanced and super nodes focused on initial energy. p_i is probability used for CH selection and p_{opt} is reference for p_i . EDEEC utilizes diverse p_{opt} values for normal, advanced and super nodes, so, value of p_i in EDEEC is as follows as in [12]:

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{(1+a)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the advance node} \\ \frac{(1+b)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the super node} \end{cases} \quad (22)$$

Threshold for CH selection for all three types of node is as follows as in [12]:

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i \left(r \bmod \frac{1}{p_i} \right)} & \text{if } p_i \in G' \\ \frac{p_i}{1-p_i \left(r \bmod \frac{1}{p_i} \right)} & \text{if } p_i \in G'' \\ \frac{p_i}{1-p_i \left(r \bmod \frac{1}{p_i} \right)} & \text{if } p_i \in G''' \\ 0 & \text{otherwise} \end{cases} \quad (23)$$

5.4 TDEEC

TDEEC utilizes similar technique for CH selection and average energy approximation as suggested in DEEC. In every round, nodes make a decision whether to become a CH or not by selecting a random value between 0 and 1. If value is smaller than threshold T_s as illustrated in equation (24) then nodes choose to be a CH for the specified round. In TDEEC, threshold value is balanced and based upon that value a node chooses whether to turn into a CH or not by presenting residual energy and average energy of that round regarding to ideal number of CHs. [13]. Threshold value suggested by TDEEC is specified as follows as in [13]:

$$T(s) = \left\{ \frac{p}{1-p \left(r \bmod \frac{1}{p} \right)} * \frac{\text{residual energy of a node} * k_{opt}}{\text{average energy of the network}} \right\} \quad (24)$$

5.5 EDDEEC

In this paper protocol implements the thought of probabilities for CH choice based on initial, remaining energy level of the nodes and average energy of network. This protocol protects the super and advance nodes from over penalized, because after some rounds some super and advance nodes have same residual energy level as normal nodes due to repeatedly CH selection. EDDEEC estimates probabilities of normal, advance and super nodes. These changes are focused on absolute residual energy level $T_{absolute}$, which is the value in which advance and super nodes containing similar energy level as that of normal nodes. The thought states that under $T_{absolute}$ all normal, advance and super nodes have equal probability for CH selection. The probability for three types of nodes given by EDDEEC is specified below

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{(1+a)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the advance node} \\ \frac{(1+b)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{if } s_i \text{ is the super node} \end{cases} \quad (25)$$

Our suggested probabilities for CH selection in EDDEEC are given as follows:

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{for } N_{ml} \text{ nodes} \\ & \text{if } E_i(r) > T_{absolute} \\ \frac{(1+a)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{for Adv nodes} \\ & \text{if } E_i(r) > T_{absolute} \\ \frac{(1+b)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{for Sup nodes} \\ & \text{if } E_i(r) > T_{absolute} \\ c \frac{(1+b)p_{opt}E_i(r)}{(1+m(a+m_ob))\bar{E}(r)} & \text{for Nml, Adv, Sup nodes} \\ & \text{if } E_i(r) \leq T_{absolute} \end{cases} \quad (26)$$

The value of absolute residual energy level, $T_{absolute}$, is written as:

$$T_{absolute} = ZE_o \quad (27)$$

where, $z \in (0, 1)$. If $z = 0$ then we have conventional EDEEC. In reality, advanced and super nodes may have not been a CH in rounds r , it is also probable that some of them become CH and similar is the case with the normal nodes. So, exact value of z is not certain.

5.6 HDEEC

Hybrid-DEEC (H-DEEC), a chain and cluster based (hybrid) circulated method for proficient energy consumption in WSNs. In H-DEEC, selected Cluster Heads (CHs) communicate the Base Station (BS) from beta selected nodes, by utilizing multi-hopping. We logically partition the network into two segments, based on the residual energy of nodes. The normal nodes having more initial and residual energy will be more feasible to be CHs than the nodes with lesser energy. H-DEEC is focused around DEEC method for heterogeneous networks, in which all nodes utilize initial and residual energy level for cluster-head selection. Every node in the network has the details of every other fellow node. The HDEEC method is combination of two scenarios; clustering and chain construction.

Clustering: As specified above, fraction of the network consist of normal node will follow the clustering scenario as done in DEEC and as illustrated in Figure 1. All nodes in the network are alert of their fellow nodes energy level and location. Normal node will track the similar approach in terms of calculating average energy of the network, and CH selection algorithm, probability of each node to become CH is based on residual energy. For network of N nodes and an extra energy factor, and it is computed as:

$$p_i = \frac{p_{opt}N(1+a)E_i(r)}{(N+\sum_{i=1}^N a_i)\bar{E}(r)} \quad (28)$$

Where p_{opt} is the reference value of the average probability p_i , which decide the rotating *epoch*. $\bar{E}(r)$ is average energy of r th round and E_i is the residual energy of node s_i at round r . We can approximate average energy at r th round as given below:

$$\bar{E}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R} \right) \quad (29)$$

R depicts the number of rounds a network will be alive and is approximated as:

$$R = \frac{E_{total}}{E_{round}} \quad (30)$$

Chain Construction: Chain construction of beta nodes in our proposed situation is done based on traditional chain routing method PEGASIS. It preserves a considerable amount of energy as contrasted with the other routing protocols, because of its enhancement in delivery of data. Beta nodes will be attached by subsequent greedy algorithm. BS begins the chain constructing procedure by marking the extreme node. Farthest node finds its nearest neighbour and so on. Leader node of the chain is chosen as the beta node with least distance from BS. As chain turn around in each round based on the energy and beta node chain all the time will be redirected in the direction of the BS.

6. PERFORMANCE CRITERIA

Performance parameters are utilized for evaluation of clustering protocols for heterogeneous WSNs are lifetime of heterogeneous WSNs, number of nodes alive throughout rounds and data packets transmitted to BS.

Lifetime is a parameter used to show node of each type has not up till now spent its total energy.

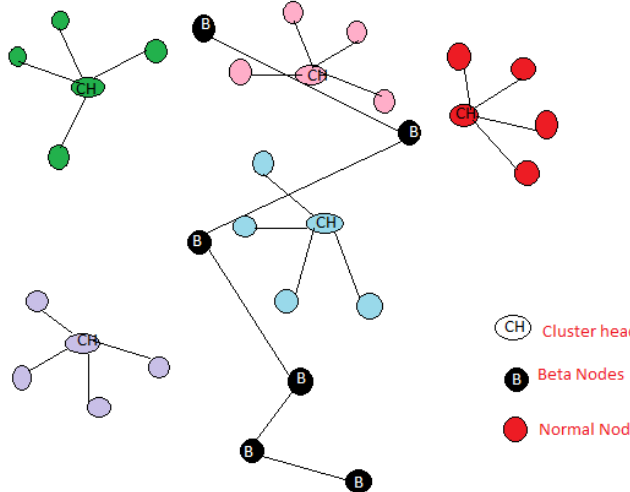


Fig 1. Network Model of HDEEC

Number of nodes alive is a parameter which defines number of alive nodes through every round.

Data packets transmitted to the Base Station is the metric which describes how many packets are received by Base Station for every round.

These parameters show stability period, instability period, energy consumption, data sent to the BS, and data received by BS and network lifetime of WSNs.

Stability period is period from start of network until the death of first node whereas; instability period is period from the death of first node until last one.

7. SIMULATIONS AND DISCUSSIONS

In this section, we simulate different clustering protocols in heterogeneous WSN using MATLAB and for simulations we

use 100 nodes randomly placed in a field of dimension 100m×100m. For ease, we suppose all nodes are either fixed or micro-mobile and avoid energy loss because of signal collision and interference between signals of different nodes that are due to dynamic random channel conditions.

Table 1: WSNs Set-up

| Parameter | Value |
|---|---------------------|
| Area(x,y) | 100,100 |
| Base station(x,y) | 50,50 or 50,150 |
| Nodes(n) | 100 |
| Probability(p) | 0.1 |
| Initial Energy | 0.1 |
| transmitter_energy | $50 * 10^{-9}$ |
| receiver_energy | $50 * 10^{-9}$ |
| Free space(amplifier) | $10 * 10^{-13}$ |
| Multipath(amplifier) | $0.0013 * 10^{-13}$ |
| Effective Data aggregation | $5 * 10^{-9}$ |
| Maximum lifetime | 2500 |
| Data packet Size | 4000 |
| m (fraction of advanced nodes) | 0.3 |
| a (energy factor between normal and advanced nodes) | 1.5 |
| m_o fraction of super nodes | 0.3 |

In this scenario, we are taking into account that, BS is located at centre of the network field. We simulate DEEC, DDEEC, EDEEC and TDEEC, EDDEEC and H-DEEC for three-level and multi-level heterogeneous WSNs. Scenarios depicts values for number of nodes dead in first, tenth and last rounds also values for the packets transmitted to BS by CH and values for packets transmitted to CH by nodes at distinct values of parameters m , m_o , a and b . These values are observed for DEEC, H-DEEC, DDEEC, EDEEC, EDDEEC and TDEEC.

In heterogeneous WSN, we utilized radio parameters stated in Table 1 for distinctive protocols placed in WSN and estimate the performance for three level heterogeneous WSNs. Parameter m refers to fraction of advanced nodes having additional amount of energy a in network whereas, m_o is a factor that refers to fraction of super nodes having additional amount of energy b in the network.

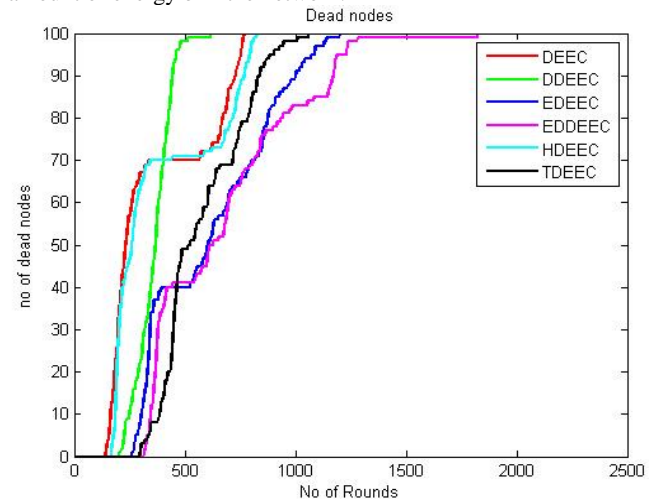


Fig. 2 Nodes dead during rounds

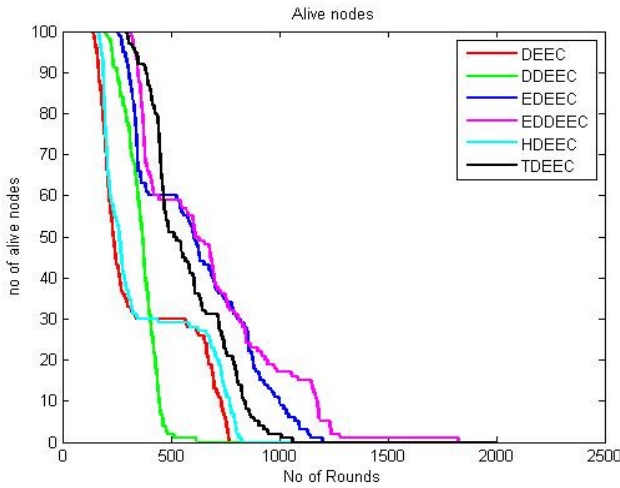


Fig. 3 Nodes alive during rounds

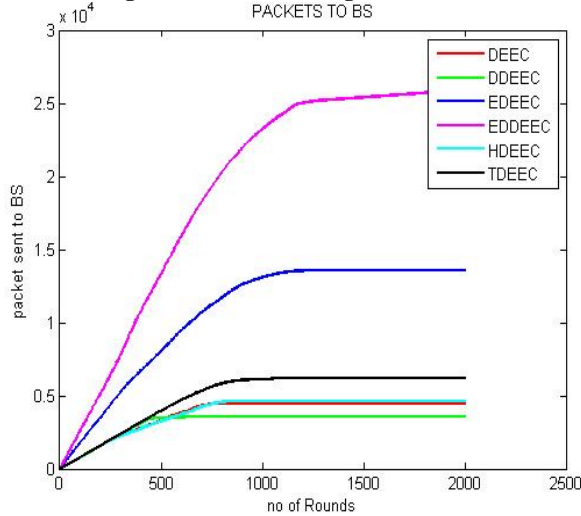


Fig. 4 Packets sent to BS

For the case of a network containing $m = 0.3$ fraction of advanced nodes having $a = 1.5$ times more energy and $mo=0.3$ fraction of super nodes containing $b = 3$ times more energy than normal nodes. From Fig. 2 and 3, we examine that first node for DEEC, DDEEC, EDEEC TDEEC, HDEEC and EDDEEC dies at 140, 201, 258,297, 166 and 315 rounds respectively. Tenth node dies at 164, 249, 303, 384, 184 and 344 rounds respectively.

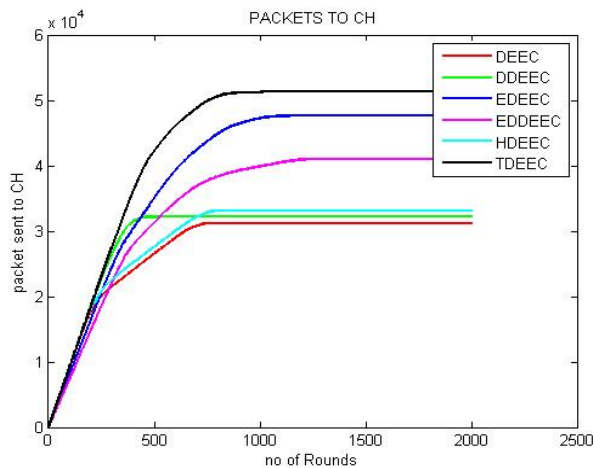


Fig. 5. Packets sent to CH

All nodes are dead at 769, 617, 1201, 1058, 825 and 1822 rounds respectively. It is obvious from the results of all protocols that in terms of stability period, EDDEEC performs best of all; TDEEC performs better than DEEC, EDEEC, DDEEC, and HDEEC but has less performance than EDDEEC. HDEEC only performs well as compared to DEEC and DEEC has least performance than all the protocols. Though, instability period of EDDEEC is best of all. EDEEC and TDEEC perform better than HDEEC, DDEEC and DEEC. The number of nodes alive in EDDEEC is quite larger than EDEEC because in EDDEEC the formula of threshold used by nodes for CH election is modified by including residual and average energy of that round. So nodes containing high energy will become CHs. DDEEC has less performance among all. Similarly, by examining results of Fig. 4, packets sent to the BS by DEEC, DDEEC, EDEEC, TDEEC, HDEEC and EDDEEC have their values at 4470, 3525, 13551, 6143, 4609 and 25721.

Now we observe that packets transmitted to BS for DEEC and DDEEC is approximately equal while, the packets transmitted to BS for EDEEC and TDEEC are approximately the equal as the probability equations for normal, advanced and super nodes is similar in both of them. Packet transmission in EDDEEC is maximum among all. Now approaching to the CHs, the packets transmitted to CHs increase throughout the beginning of the network and slowly decrease downwards the end because the nodes vanishing concurrently.

Now considering second case in which the parameters change to $a = 1.5$, $b = 3$, $m = 0.3$ and $mo = 0.3$, $area(x, y) = 50,150$. Fig. 6 shows that first node for DEEC, DDEEC, EDEEC, TDEEC, HDEEC and EDDEEC dies of each protocol at 111, 185, 158, 228, 145 and 147 rounds respectively. Tenth node dies at 132, 205, 215, 369, 180 and 203 rounds respectively.

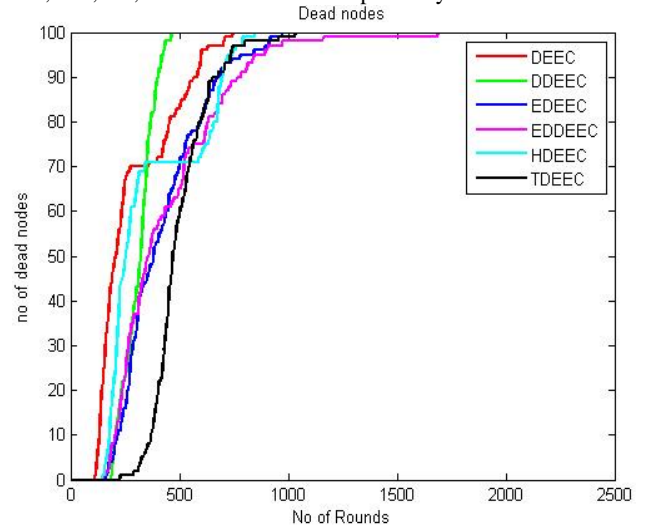


Fig. 6. Nodes dead during round (50,150)

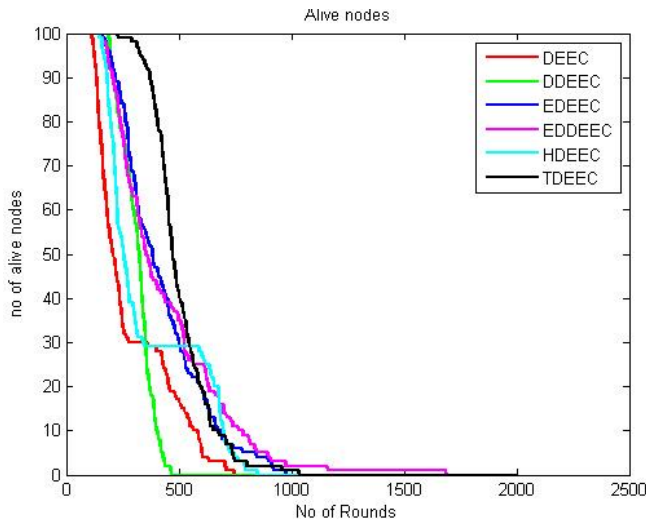


Fig 7 Nodes alive during rounds

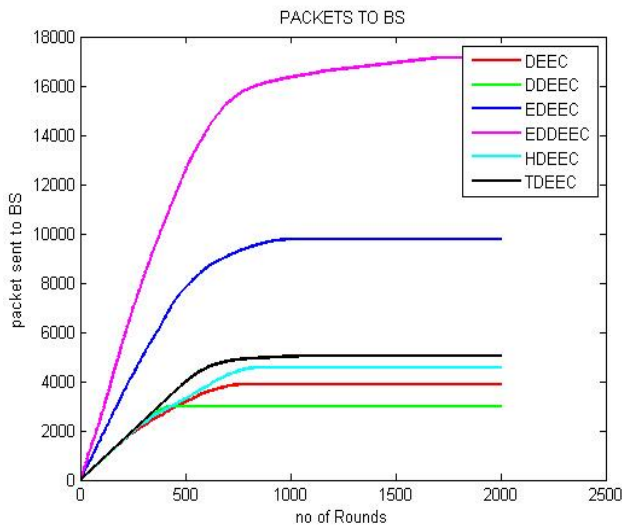


Fig.8 Packets to BS 50,150

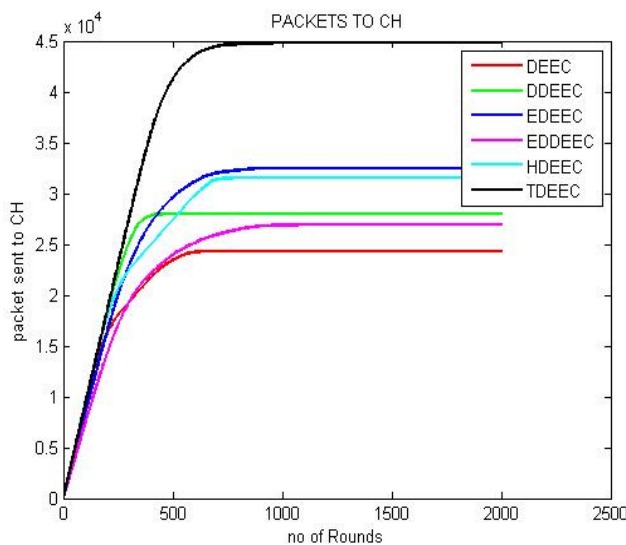


Fig. 9. Packets sent to CH

All nodes are dead at 746, 463, 972, 1034, 846 and 1689 rounds. Alive in first, tenth and all rounds is accurately the flip to the graph for number of nodes dead and is shown in Fig. 7. Result of Fig. 8 shows that packets sent to BS

by DEEC, DDEEC, EDEEC, TDEEC, HDEEC and EDDEEC are 3862, 2987, 9763, 5018, 4572 and 17128 respectively. As we see that by decreasing the values of parameters, EDDEEC still performs best among the six protocols. EDEEC performs better than TDEEC. HDEEC performs better than DEEC and DDEEC whereas, DDEEC performs worst.

8. CONCLUSION AND FUTURE WORK

This paper has evaluated and compares the well-known heterogeneous WSNs energy efficient protocols i.e. DEEC variants. The comparison has shown that the EDDEEC has quite effective results over the other DEEC variants. Although EDDEEC has shown quite significant results over existing WSNs protocols but it has neglected the use of waiting time of node to become CHs. So may some nodes will not become CHs for a long time even they have more confidence to become CHs.

So to overcome this problem in near future we will use minimum allowed distance (MDCH) and waiting nodes between two CHs to divide the sensor field among clusters in the most efficient way. MDCH will have ability to overcome the problem of the too small and too high cluster heads.

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