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Analysis of EDEEC and its types using different parameters

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Abstract: The clustering Algorithm is a kind of technique used to reduce energy consumption. It can increase the scalability and lifetime of the network. Many routing protocols on clustering structure have been proposed in recent years. Every protocol is not suitable for heterogeneous Wireless sensor networks. Efficiency of protocol degrades while changing the heterogeneity parameters. In this paper, we first determine DEEC,DDEEC,EDEEC under several different scenarios. We observe thoroughly regarding the performance based on stability period, instability period, cluster heads per round, number of nodes alive, data packets sent to base station.

1. Introduction

Wireless sensor networks are the network consisting of hundreds of compact and small sensor nodes which senses physical environment in terms of light, temperature, sound, vibration, etc. These sensor nodes gather the data from sensing field and send this information to the end user. Current wireless sensor network is working on the problems of low power communication, sensing, energy storage. Hierarchical based routing is a cluster based routing in which high energy nodes are randomly selected for processing and sending data whereas low energy nodes are used for sensing and send information to the cluster heads. Clustering technique increases the energy consumption of the sensor network and hence the lifetime.

Clustering can be done in two types of networks, homogeneous and heterogeneous. Homogeneous have same initial energy while heterogeneous networks are those in which nodes have different initial energy. Low Energy Adaptive Clustering Hierarchy (LEACH) , Power Efficient Gathering in Sensor Information Systems, Hybrid Energy-Efficient Distributed clustering are algorithms designed for homogenous WSN under consideration so these protocols do not work efficiently under heterogeneous scenarios because these algorithms are unable to treat nodes differently in terms of their energy.SEP is designed for two level heterogeneous networks, so it cannot work efficiently in three or multilevel heterogeneous network. SEP considers only normal and advanced nodes where normal nodes have low energy level and advanced nodes have high energy. In this paper, we study performance of heterogeneous WSN protocols under three and multi level heterogeneous networks. We compare performance of DEEC, DDEEC, EDEEC for different scenarios of three and multilevel heterogeneous WSNs. Three level heterogeneous networks contain normal, advanced and super nodes whereas super nodes have highest energy level as compared to normal and advanced nodes.

2. HETEROGENEOUS WSN MODEL

In this section, we assume N number of nodes placed in a square region of dimension M×M. Heterogeneous WSNs contain two, three or multi types of nodes with respect to their energy levels and are termed as two, three and multilevel heterogeneous WSNs respectively.

A. Two Level Heterogeneous WSNs Model

Two level heterogeneous WSNs contain two energy level of nodes, normal and advanced nodes. Where, Eo is the energy level of normal node and Eo(1 +a) is the energy level of advanced nodes containing a times more energy as compared to normal nodes. If N is the total number of nodes then N m is the number of advanced nodes where m refers to the fraction of advanced nodes and N(1−m) is the number of normal nodes. The total initial energy of the network is the sum of energies of normal and advanced nodes.

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

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

B. 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 Eo, the advanced nodes of
fraction m are having a times extra energy than normal nodes equal to Eo(1 +a) whereas, super nodes of fraction mo are having a factor of b times more energy than normal nodes so their energy is equal to Eo(1 +b). As N is the total number of nodes in the network, then
Nm.mo is total number of super nodes and N m(1−mo) is total number of advanced nodes.
The total initial energy of three level heterogeneous WSN is therefore given by:

$$E_{total} = N(1-m)E_o + Nm(1-m_o)(1+a)E_o + Nm_oE_o(1+b) \quad (2)$$

$$E_{total} = NE_o(1 + m(a + m_ob)) \quad (3)$$

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

C. Multilevel Heterogeneous WSN Model

Multi level heterogeneous WSN is a network that contains nodes of multiple energy levels. The initial energy of nodes is distributed over the close set[Eo, Eo(1 +amax)], where
Eo is the lower bound and amax is the value of maximal energy.Initially, node Si is equipped with initial energy of Eo(1+ai) which is ai time more energy than the lower bound
Eo. The total 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 consume more energy as compared to member nodes so after some rounds energy level of all the nodes becomes different as compared to each other. Therefore, heterogeneity is introduced in homogeneous WSNs and the networks that contain heterogeneity are more important than homogeneous network.

3.RADIO DISSIPATION MODEL

The radio energy model describes that l bit message is transmitted over a distance d energy expended is then given by:

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

Where,
Eelec is the energy dissipated per bit to run the transmitter or the receiver circuit. d is the distance between sender and receiver. If this distance is less than threshold, freespace model is used else multi path model is used. Now, total energy dissipated in the network during a round is given by [5,6]:

$$E_{round} = L(2NE_{elec} + NE_{DA} + k\varepsilon_{mp}d^4_{toBS} + N\varepsilon_{fs}d^2_{toCH}) \quad (6)$$

Where, K= number of clusters
EDA= Data aggregation cost expended in CH
dtoBS= Average distance between the CH and BS
dtoCH= Average distance between the cluster members and the CH

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

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

4. OVERVIEW OF DISTRIBUTED HETEROGENOUS PROTOCOLS

A.DEEC

DEEC is designed to deal with nodes of heterogeneous WSNs. For CH selection, DEEC uses initial and residual energy level of nodes. Let ni denote the number of rounds to be a CH for node si. popt N is the optimum number of CHs in our network during each round. CH selection criteria in DEEC is based on energy level of nodes. As in homogenous network,
when nodes have same amount of energy during each epoch then choosing pi=popt assures that poptN CHs during each round. In WSNs, nodes with high energy are more probable to
become CH than nodes with low energy but the net value of CHs during each round is equal to poptN. Pi is the probability for each node si to become CH, so, node with high energy
has larger value of pi as compared to the popt. E(r) denote average energy of network during round r which can be given as in [10]:

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

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

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

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

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

pi is probability of each node to become CH in a round.

Where G is the set of nodes eligible to become CH at round r. If node becomes CH in recent rounds then it belongs to G. During each round each node chooses a random number between 0 and 1. If number is less than threshold as defined in equation 12 as in [10], it is eligible to become a CH else not.

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

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

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

Then use the above padv and pnrm instead of popt in equation 10 for two level heterogeneous network as supposed in [10]:

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

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

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

Above pmulti in equation 10 instead of popt to get pi for heterogeneous node. pi for the multilevel heterogeneous network is given by as in [10]:

$$p_i = \frac{p_{opt}N(1+a)E_i(r)}{(N+\sum_{i=1}^{N} a_i)\bar{E}(r)} \qquad (16)$$

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

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

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

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

Etotal is total energy of the network where Eround is energy expenditure during each round.

B.DDEEC

DDEEC uses same method for estimation of average energy in the network and CH selection algorithm based on residual energy as implemented in DEEC. Difference between DDEEC
and DEEC is centered in expression that defines probability for normal and advanced nodes to be a CH [11] as given in equation 14. We find that nodes with more residual energy at round r are more probable to become CH, so, in this way nodes having higher energy values or advanced nodes will become CH more often as compared to the nodes with lower energy or normal nodes. A point comes in a network where advanced nodes having same residual energy like normal nodes. Although, after this point DEEC continues to punish the advanced nodes so this is not optimal way for energy distribution because by doing so, advanced nodes are continuously a CH and they die more quickly than normal nodes. To avoid this unbalanced case, DDEEC makes some changes in equation 14 to save advanced nodes from being punished over and again. DEEC introduces threshold residual energy as in [11] and given below:

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

When energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both type of nodes use same probability to become cluster head. Therefore, CH selection is balanced and more efficient. Threshold residual energy is given as in [11] and given below:

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

C. EDEEC

EDEEC uses concept of three level heterogeneous network as described above. It contains three types of nodes normal, advanced and super nodes based on initial energy.pi is probability used for CH selection and popt is reference for pi. EDEEC uses different popt values for normal, advanced and super nodes, so, value of pi in EDEEC is as follows as
in [12]:

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

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

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_{i(rmod\frac{1}{p_i})}} & if p_i \epsilon G' \\ \frac{p_i}{1-p_i(rmod\frac{1}{p_i})} & if p_i \epsilon G'' \\ \frac{p_i}{1-p_i(rmod\frac{1}{p_i})} & if p_i \epsilon G''' \\ 0 & otherwise \end{cases} \quad (23)$$

5. PERFORMANCE CRITERIA

Performance parameter used for evaluation of clustering protocols for heterogeneous WSNs are lifetime of heterogeneous WSNs, number of nodes alive during rounds and data packets sent to BS.
Stability Period is the time duration between the expiry of very first sensor node and very last sensor node of the network..
Instability Period is the time duration between the expiry of very first sensor node and very last sensor node of the network.
Number of nodes alive is a parameter that describes number of alive nodes during each round.
Data packets sent to the BS is the measure that how many packets are received by BS for each round.

6. 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 simplicity, we consider all nodes are either fixed or micro-mobile as supposed in [14] and ignore energy loss due to signal collision and interference between signal of different nodes that are due to dynamic random channel conditions. In this scenario, we are considering that, BS is placed at center of the network field. We simulate DEEC, DDEEC, EDEEC for three-level and multi-level heterogeneous WSNs. Scenarios describe values for number of nodes dead in first, tenth and last rounds as well as values for the packets sent to BS by CH at different values of parameters m, mo, a and b. These values are examined for DEEC, DDEEC, EDEEC.

TABLE I
VALUE OF PARAMETERS

Parameters	Values
Network field	100 m,100 m
Number of nodes	100
E_o(initial energy of normal nodes)	0.5J
Message size	4000 bits
E_{elec}	50nJ/bit
E_{fs}	10nJ/bit/m2
E_{amp}	0.0013pJ/bit/m4
EDA	5nJ/bit/signal
d_o(threshold distance)	70m
P_{opt}	0.1

In heterogeneous WSN, we use radio parameters mentioned in Table 1 for different protocols deployed in WSN and estimate the performance for three level heterogeneous WSNs. Parameter m refers to fraction of advanced nodes containing extra amount of energy a
in network whereas, mo is a factor that refers to fraction of super nodes containing extra amount of energy b in the network.

For the case of a network containing m=0.5 fraction of advanced nodes having a= 1.5 times more energy and m0 =0.4 fraction of super nodes containing b = 3 times more energy than normal nodes. Figure 1 and Table 2 depicts that in which round the first, fiftieth, all nodes are dead and numbers of packets station to the base station.

Case 1:- a=1.5,b=3,m=0.5,m0=0.4

Table 2

Nodes	EDEEC	DDEEC	DEEC
FIRST	1360	1255	1090
50TH node	1617	1554	1436
All dead nodes	9540	4326	4267
Packets sent to base station	396908	86940	126192

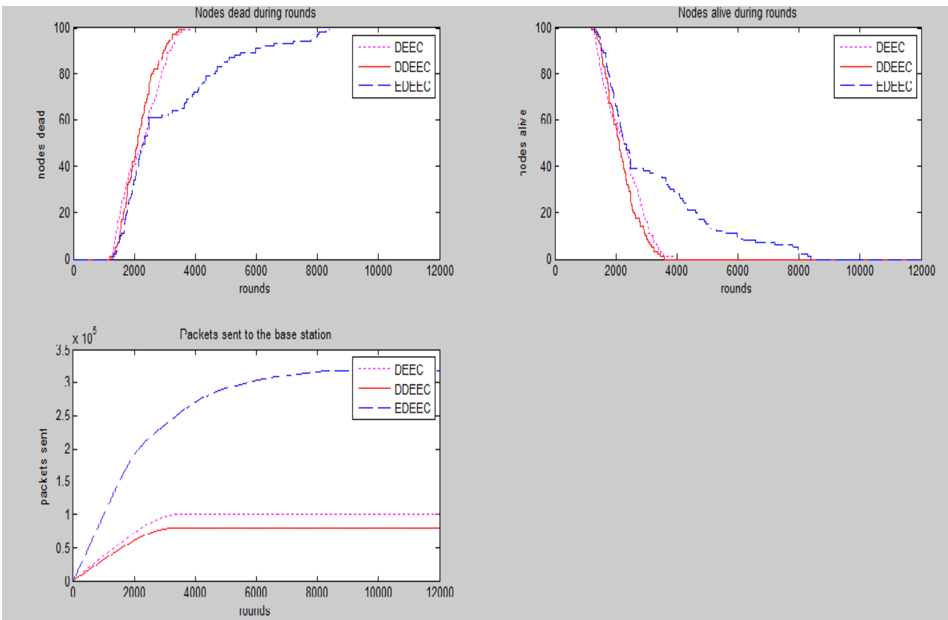

Figure1

Case 2:- a=1.2,b=2.5,m=0.4,m0=0.3

Table 3

Nodes	EDEEC	DDEEC	DEEC
FIRST	1296	1328	943
50TH node	1532	1556	1362
All dead nodes	8385	3456	3877
Packets sent to base station	317307	79975	87256

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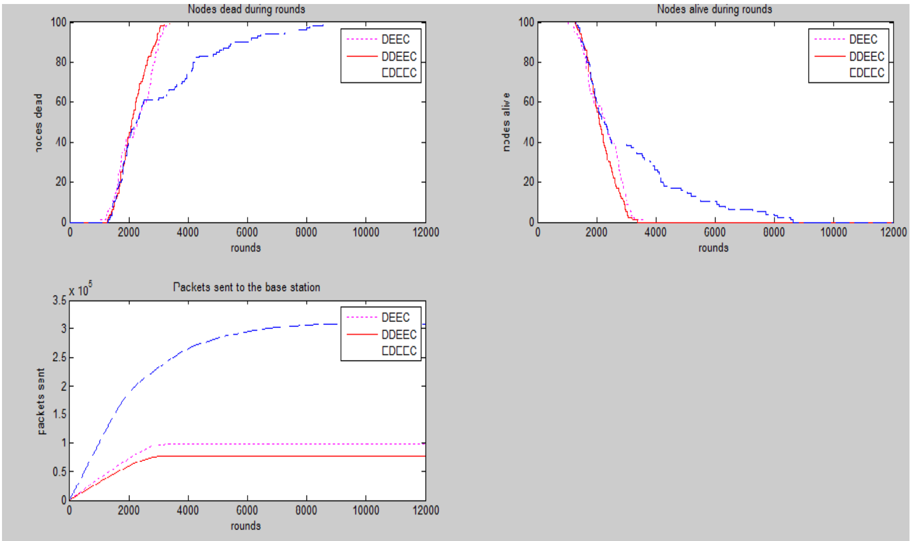

Figure 2

Case 3:- a=1.6,b=3.2,m=0.6,m0=0.5

Table 4

Nodes	EDEEC	DDEEC	DEEC
FIRST	1303	1450	1579
50TH node	2530	2515	1897
All dead nodes	8687	3610	3857
Packets sent to base station	308142	79314	100660

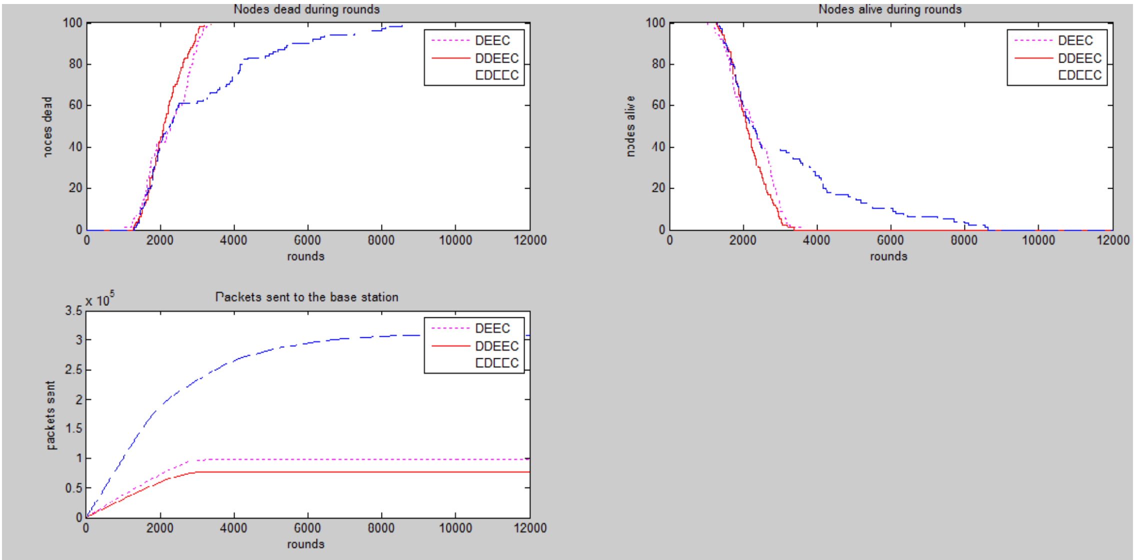

Figure 3

Case 4:- a=1.7,b=3.4,m=0.7,m0=0.6

Table 5

Nodes	EDEEC	DDEEC	DEEC
FIRST	1462	1649	1864
50^{TH} node	1607	1699	2819
All dead nodes	10869	4529	4373
Packets sent to base station	569107	95372	115699

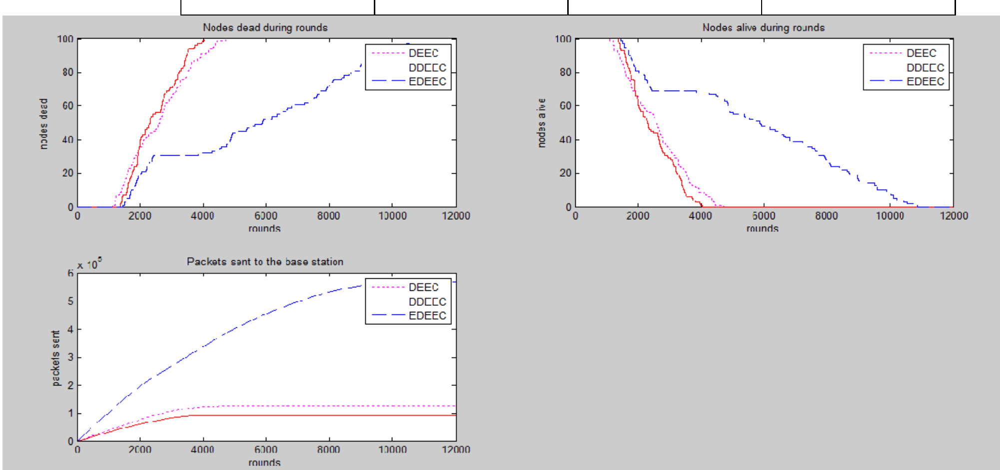

Figure 4

It is observed from all the above cases or scenarios that for first case of three level heterogeneous WSN considering a = 1.5,b= 3,m= 0.5 and mo= 0.4 EDEEC performs better than DDEEC and DEEC where DDEEC performs better than DEEC in terms of stability period. For EDEEC instability period is higher as compared to DDEEC and DEEC. When values of a, b, m, mo are decreased linearly further in second scenario, same results as in first scenario are found for all protocols. In third and fourth scenarios when a, b, m,moare increased linearly it is found after larger number of simulations that in some cases DEEC performs better than DDEEC. Stability period DDEEC and EDEEC is almost the same. In last case ,it is observed that EDEEC performs better than DDEEC and DEEC.In terms of stability period DDEEC performs better than DEEC. For EDEEC instability period is higher as compared to DDEEC.

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