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Energy Efficient Heterogeneous WSN clustering Protocol-A Comparitive study

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I.ABSTRACT:

Wireless Sensor Networks had become an economically viable solution for various applications, including critical infrastructure monitoring ,military applications ,telecommunications, power grids, agriculture, traffic networks, disaster recovery situations etc.,. Since sensor nodes were battery powered, energy consumption and conservation was a critical factor.

The sever power constraints strongly affected the existence of active nodes and consequently the network lifetime. In order to prolong the network life, one had to overcome the scarcity of energy resources and preserve the processing of the sensor nodes as long as possible. Power management approaches efficiently reduced the sensor nodes energy consumption individually.The adaptive efficient routing technique had greatly appealed a great attention in research for improving network performance.

The clustering Algorithm was a kind of key technique used to reduce energy consumption. It could increase the scalability and lifetime of the network. Energy-efficient clustering protocols should be designed for the characteristic of heterogeneous wireless sensor networks.

This paper evaluated various distributedenergy-efficient clustering schemes DEEC, DDEEC, EDEEC, TDEEC for heterogeneous wirelesssensor networkin terms of energy consumption, alive nodes, and packet transmission .

II.Introduction:

Wireless sensor networks (WSN) were beingincreasingly entering into different critical applications, such as environmental monitoring, smart offices, battlefield surveillance, and transportation traffic monitoring. In order to achieve high quality and fault-tolerant capability, a sensornetwork could be composed of hundreds or thousands of unattended sensor nodes, which were often randomly deployed inside the study area or very close to it[1]. Since WSN was usually exposed to adverse and dynamicenvironments, it was possible for the loss of connectivity ofindividual nodes. Conventional centralized algorithmsneeded to operate with global knowledge of the whole network,and an error in transmission or a failure of a criticalnode would potentially cause a serious protocol failure [2]. Onthe contrary, distributed algorithms were only executedlocally within partial nodes, thus could prevent the failurecaused by a single node. It was realized that localized algorithmswere more scalable and robust than centralized algorithms.

As each sensor node was tightly power-constrainedand one-off, the lifetime of WSN was limited. In order to prolongthe network lifetime, energy-efficient protocols shouldbe designed for the characteristic of WSN. Efficiently organizingsensor nodes into clusters was useful in reducing energyconsumption. Many energy-efficient routing protocolswere designed based on the clustering structure [3,4] Theclustering technique can also used to perform data aggregation[5,6] which combines the data from source nodes intoa small set of meaningful information. Under the condition
of achieving sufficient data rate specified by applications,the fewer messages were transmitted, the higher energy. Algorithms bring better scalability to large networks thancentralized algorithms, which were executed in global structure.

Clustering technique can be extremely effective inbroadcast and data query [7,8]. Cluster-heads would help tobroadcast messages and collect interested data within theirown clusterssaved. Localized algorithms could efficiently operate withinclusters without waiting for control messages propagatingacross the whole network. Therefore localizedalgorithms bring better scalability to large networks thancentralized algorithms, which were executed in global structure.Clustering technique can be extremely effective inbroadcast and data query[7,8]. Cluster-heads would help tobroadcast messages and collect interested data within theirown clusters.

This paper, evaluated various distributedenergy-efficient clustering scheme such as DEEC,DDEEC,EDEEC,TDEEC for heterogeneous wirelesssensor network.

In the sensor network considered here, eachnode transmitted sensing data to the base station through acluster-head. The cluster-heads, which were elected periodicallyby certain clustering algorithms, aggregate the dataof their cluster members and sent it to the base station,from where the end-users could access. It wasassumedthat all the nodes of the sensor network were equipped withdifferent amount of energy, which was a source of heterogeneity.It could be the result of reenergizing the sensor networksin order to extend the network lifetime [9]. The newnodes added to the networks would own more energy thanthe old ones. Even though the nodes were equipped withthe same energy at the beginning, the networks could notevolve equably for each node in expending energy, due tothe radio communication characteristics, random eventssuch as short-term link failures or morphological characteristicsof the field[9]. Therefore, WSN were more possiblyheterogeneous networks than homogeneous ones.

III .RADIO ENERGY DISSIPATION MODELAND NETWORK MODEL[1]

Clustering was optimal in the sense that energy consumption was well distributed over allsensors and the total energy consumption was minimum. Such optimalclustering highly depended on the energy model. For thispurpose, the present study used similar energy model asproposed in [1].

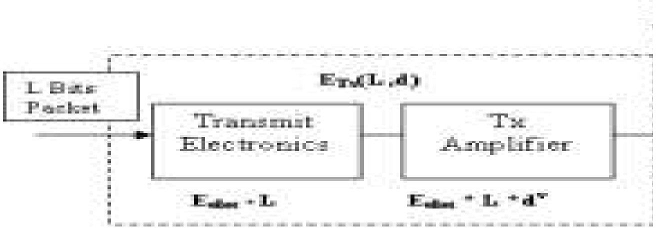


Figure 1: Radio Energy Dissipation Model.

According tothe radio energy dissipation model illustrated in figure [1]and in order to achieve an acceptable Signal-to-Noise Ratio(SNR) in transmitting an L-bit message over a distance d, theenergy expended by the radio was given by:

$Etx(L; d) =\{ LEelec + LE_{fs}d^2$ if $d < do$
(1)
$\{LEelec + LE_{mp}d^4$ if $d \geq do$

whereEelec was the energy dissipated per bit to run thetransmitter(ETX) or the receiver circuit(ERX). The Eelecdepended on many factors such as the digital coding, themodulation, the filtering, and the spreading of the signal. $E_{fs}$and E_{mp} depended on the transmitter amplifier model used, andd was the distance between the transmitter and the receiver. If this distance was less than the threshold, freespace(fs) model was used else multi path(mp) model was used.

IV.Network Model[15]

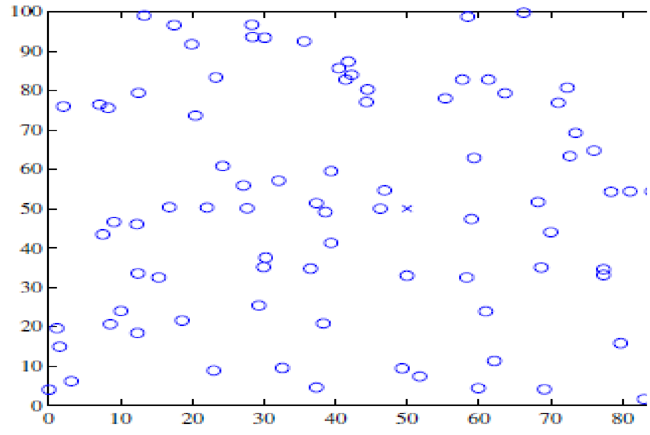


Figure 2 Network model

Network model used consisted of N nodes in M X M network fieldas shown in Figure 2. In the network model some assumptions have been made for thesensor nodes as well as for the network.Hence the assumptionsand properties of the network and sensor nodes were:

Sensor Nodes were uniformly randomly deployed in thenetwork.

- There was one Base Station which was located at the Centre of thesensing field.
- Nodes always had the data to send to the base station.
- Nodes were location-unaware, i.e. not equipped with GPScapableantennae.
- All nodes had similar capabilities in terms of processing andcommunication and of equal significance.

Sensor nodes had heterogeneity in terms of energy atdifferent energy levels. All nodes have different initialenergy; some nodes were equipped with more energy than thenormal nodes

1.Two Level Heterogeneous WSNs Model

Two level heterogeneous WSNs containedtwo energy level of nodes, normal and advanced ones. Where, E_o was the energy level of normal node and $E_o(1 + a)$ was the energy level of advanced nodes containing a times more energy as compared to normal nodes. If N was the total number of nodes then N m was the number of advanced nodes where m refered to the fraction of advanced nodes and N (1 − m) was the number of normal nodes. The total initial energy of the network was the sum of energies of normal and advanced nodes.

$$E_{total} = N (1 - m)E_o + N m(1 + am)E_o$$
$$= N E_o(1 - m + m + am)$$
$$= N E_o(1 + am)$$

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

2.Three Level Heterogeneous WSN Model

Three level heterogeneous WSNs contained 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 was equal to $E_o(1 + b)$. As N was the total number of nodes in the network, then N mm_o was total number of super nodes and $Nm(1 - m_o)$ was total number of advanced nodes. The total initial energy of three level heterogeneous WSN was therefore given by:

$$E_{total} = N (1 - m)E_o + N m(1 - m_o)(1 + a)E_o+N m_0E_0(1+b) \quad (3)$$

$$E_{total} = N E_o(1 + m(a + m_ob)) \quad (4)$$

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

*3.*Multilevel Heterogeneous WSN Model

Multilevel heterogeneous WSN was a network that containednodes of multiple energy levels. The initial energy of nodes wasdistributed over the close set [Eo,Eo(1 + amax)], where Eowas the lower bound and amax was the value of maximal energy.Initially, node Si was equipped with initial energy of Eo(1+ai), which was ai times more energy than the lower bound Eo. Thetotal initial energy of multi-level heterogeneous networks wasgiven by:

$$E_{total} = \sum_{i=1}^{N} Eo(1+ai) = Eo(N + \sum_{i=1}^{N} ai \tag{5}$$

CH nodes consumed more energy as compared to membernodes so after some rounds energy level of all the nodesbecame different as compared to each other. Therefore,heterogeneity was introduced in homogeneous WSNs and thenetworks that contained heterogeneity were more important thanhomogeneous networks.

V.The DEEC (DISTRIBUTED ENERGY-EFFICIENT CLUSTERING PROTOCOL)[11]

DEEC used the initial and residual energy level of the nodes to select the cluster-heads. To avoid that each node needed to know the global knowledge of the networks, DEEC estimated the ideal value of network life-time, which was used to compute the reference energy that each node should expend during a roundCluster-head selection algorithm based on residual energy in DEECCluster-head selection algorithm based on residual energy in DEEC

Let nidenote the number of rounds to be a cluster head for the node s**i**,(rotating epoch)

If the rotating epoch ni was the same for all the nodes as proposed in LEACH, the energy would notbe well distributed and the low-energy nodes would die more quickly than the high-energy nodes.

For DEEC

The choice was different ni based on the residual energy Ei(r) of node si at round r.

- $pi = \frac{1}{ni}$ average probability to be a cluster-head during n**i**rounds
- When nodes had the same amount of energy at each epoch, choosing the average probability pito be p_{opt} could ensure that there were p_{opt}N cluster-heads every round and all nodes die approximately at the same timeIf nodes had different amounts of energy, piof the nodes with more energy should be larger than p_{opt}.

Let $\overline{E}(r)$ denote the average energy at round r of the network, which could be obtained by

$$\overline{E}(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r) \tag{6}$$

To compute $\overline{E}(r)$ each node should have the knowledge of the total energy of all nodes in the network.

$\overline{E}(r)$ to be the reference energy,

$$pi = p_{\mathbf{opt}}\left[1 - \frac{\overline{E}(r) - Ei(r)}{Ei(r)}\right] = p_{\mathbf{opt}}\frac{Ei(r)}{\overline{E}(r)} \tag{7}$$

$\overline{E}(r)$ to be the reference energy, average total number of cluster heads per round per epoch is equal to:

$$\sum_{i=1}^{N} pi = p_{\mathbf{opt}}\sum_{i=1}^{N}\frac{Ei(r)}{\overline{E}(r)} = n_{opt} \tag{8}$$

$$\sum_{i=1}^{N} pi = \sum_{i=1}^{N}\frac{p_{\mathbf{opt}}Ei(r)}{\overline{E}(r)} = p_{\mathbf{opt}}\sum_{i=1}^{N}\frac{Ei(r)}{\overline{E}(r)} = n_{opt} \tag{9}$$

n_{opt}It was the optimal cluster-head number that to be achieve

The probability threshold, that each node siused to determine whether itself to become a cluster-head in each round, as follow

$$T(si)=\{ \frac{pi}{\left(1 - pi(r \bmod \frac{1}{pi}\right)} \quad \text{if} \quad si \in G \tag{10}$$

{ 0 otherwise

G (nodes that were eligible to be cluster heads at round r).

If node sihad not been a cluster-head during the most recent ni rounds for $si \in G$.

In each round r, when node si finds it was eligible to be a cluster-head, it would choose a random number between 0 and 1. If the number was less than threshold T(si), the node si became a cluster-head during the current round.

ni was chosen based on the residual energy Ei(r) at round r of node s**i** as follow

$$ni = \frac{1}{pi} = \frac{\overline{E}(r)}{p_{\mathbf{opt}}Ei(r)} = n_{opt}\frac{\overline{E}(r)}{Ei(r)} \tag{11}$$

Where $n_{opt} = \frac{1}{p_{\mathbf{opt}}}$ denote the reference epoch to be a cluster-head.

Eq. (11) shows that the rotating epoch niof each node fluctuates around the reference epoch.
heterogeneous nodes
Substituting Eq. (7) for pi on (9), we could get the probability threshold used to elect the cluster-heads.
The threshold was correlated with the initial energy and residual energy of each node directly.
weighted probability shown in Eq. (12)

$$p(si) = \frac{p_{\mathbf{opt}}\,\mathrm{N}(1+ai)}{N+\sum_{i=1}^{N} ai} \tag{12}$$

to replace popt of Eq. (12) and obtain the pi for heterogeneous nodes as

$$p(i) = \frac{p_{\mathbf{opt}}\,\mathrm{N}(1+a)}{(N+\sum_{i=1}^{N} ai)\overline{E}(r)} \tag{13}$$

From Eqs. (12) and (13),

$Ii = \dfrac{(N+\sum_{i=1}^{N} ai)}{p_{\mathbf{opt}}\,\mathrm{N}(1+ai)}$ expressed the basic rotating epoch of node si, (reference epoch). It was different for each node with different initial energy.

Note ni = 1/pi, thus the rotating epoch ni of each node fluctuates around its reference epoch Ii based on the residual energy Ei(r).

If $Ei(r) > \overline{E}(r)$,ni<Ii and vice versa. This implied that the nodes with more energy would have
more chances to be the cluster-heads than the nodes with less energy
estimate the average energy

$$\overline{E}(r) = \frac{1}{N}E_{total}\left(1-\frac{r}{R}\right)\mathrm{R} \tag{14}$$

was the total of rounds from the network begins to all the nodes die.

Let E_{round} denote the energy consumed by the network in each round. R could be approximated as follow

$$R = \frac{E_{total}}{\mathbf{E_{round}}} \tag{15}$$

Each non-cluster-head send L bits data to the cluster-head a round. Thus the total energy dissipated in the network during a round was equal to

$$E_{round} = L(2NE_{elec} + NE_{DA} + kE_{mp}\, d_{toBS}^{4} + NE_{fs} d_{toCH}^{2}) \tag{16}$$

E_{DA}data aggregation cost expended in the cluster-heads
k was the number of clusters
$d_{toBS}$was the average distance between the cluster-head and the base station
$d_{toCH}$was the average distance between the cluster members and the cluster-head
Assuming that the nodes were uniformly distributed, one could get

$$\mathbf{d}_{\mathbf{toCH}} = \frac{M}{\sqrt{2\pi k}}, \mathbf{d}_{\mathbf{toBS}} = 0.765\frac{M}{2} \tag{17}$$

optimal number of clusters as

$$kopt = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\mathbf{E_{fs}}}{\mathbf{E\ mp}}\frac{M}{\mathbf{d}_{\mathbf{toBS}}^{2}}} \tag{18}$$

VI. DDEEC(THE DEVELOPED DISTRIBUTED ENERGY-EFFICIENT CLUSTERING PROTOCOL)[12]

DDEEC was based on DEEC scheme, where all nodes used the initial and residual energy level to define the cluster heads. To evade that each node needs to have the global knowledge of the networks, DEEC and DDEEC estimate the ideal value of network lifetime, which was used to compute the reference energy that each node should expend during each round. It was fond that nodes with more residual energy at round r weremore probable to become CH, so, in this way nodes havinghigher energy values or advanced nodes would become CH moreoften as compared to the nodes with lower energy or normalnodes. A point came in a network where advanced nodeshaving same residual energy like normal nodes. Although,after this point DEEC continued to punish the advanced nodesso this was not optimal way for energy distribution because bydoing so, advanced nodes are continuously a CH and they diemore quickly than normal nodes. DEECintroduces threshold residual energy as in [10] and givenbelow:

$$Th\,\mathrm{Re}v = E0\left(1+\frac{aEdisNN}{EdisNN - EdisAN}\right) \tag{19}$$

When energy level of advanced and normal nodes fell downto the limit of threshold residual energy then both type ofnodes use same probability to become cluster head. Therefore,CH selection was balanced and more efficient. Thresholdresidual energy T h was given as in [19]

VII.E-DEEC(Enhanced Distributed Energy Efficient Clustering protocol)[14]

EDEEC used concept of three level heterogeneous networkas described above. It contained three types of nodes normal,advanced and super nodes based on initial energy. pi isprobability used for CH selection and popt was reference forpi. EDEEC uses different p_{opt}values for normal, advancedand super nodes, so, value of pi in EDEEC was as follows

pi={ $\frac{poptEi(r)}{(1+m(a+mo.b))\overline{E(r)}}$ if si was the normal node

pi={ $\frac{popt(1+a)Ei(r)}{(1+m(a+mo.b))\overline{E(r)}}$ if si was the advanced node (20)

pi={ $\frac{popt(1+b)Ei(r)}{(1+m(a+mo.b))\overline{E(r)}}$ if si was the Super nodenode

VIII. TDEEC[15](Threshold Distributed Energy Efficient Clustering protocol)

TDEEC used same mechanism for CH selection and averageenergy estimation as proposed in DEEC. At each round, nodesdecided whether to become a CH or not by choosing a randomnumber between 0 and 1. If number was less than threshold Tsas shown in equation 24 then nodes decided to become a CHfor the given round. In TDEEC, threshold value was adjustedand based upon that value a node decided whether to becomea CH or not by introducing residual energy and average energyof that round with respect to optimum number of CHs.Threshold value proposed by TDEEC was given as follows as

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

(21)

XI. SIMULATIONS AND DISCUSSIONS

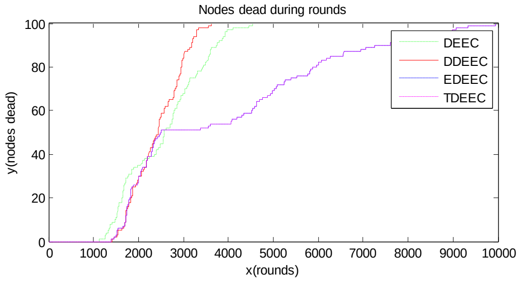
In this section, trieddifferent clustering protocols in heterogeneous WSN using MATLAB and for simulations100 nodes randomly placed in a field of dimension100m×100m. For simplicity, it was considered all nodes were eitherfixed or micro-mobile as supposed to be in [15]and ignored energy loss due to signal collision and interference between signalsof different nodes that were due to dynamic random channel conditions.

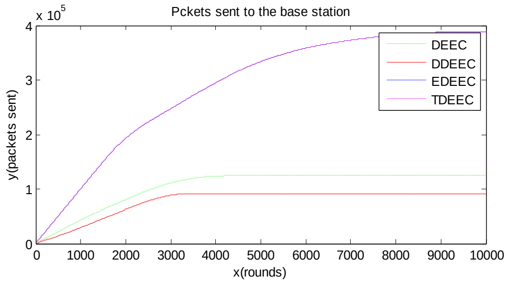
The scenarios described the values for number of nodes dead in first, tenth and last rounds as well as values for the packets sent to BS by CH at different parameters m, mo, a and b. These values were examined for DEEC, DDEEC, EDEEC and TDEEC.

The stability period of the network was the timeinterval from the start of network operation until the death of the first sensor node, unstable period of the network was the time interval from the death of the first node until the death of the last node, energyconsumption, the data sent that were received by the base station [14] and the lifetime of the network which was number of rounds until the first node die which wassimply the stability period of the network (assume all the nodes having equal importance). Morestable was the network; more was the lifetime of the network.

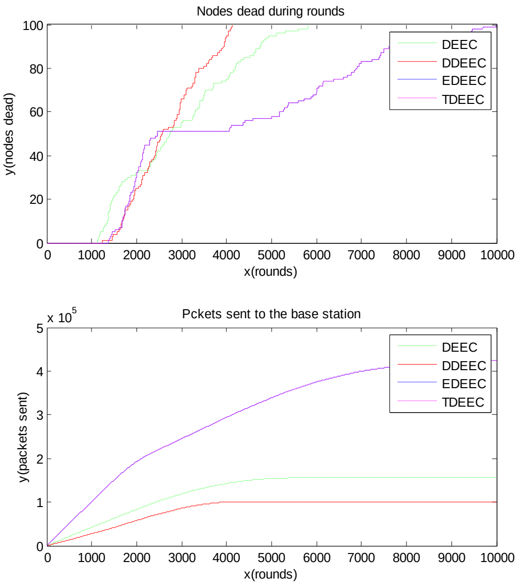
Parameters	**Value**
Network Field	(100,100)
Number of nodes	100
Eo (Initial energy of normal nodes)	0.5 J
Message Size	4000 Bits
Eelec	50nJ/bit
Efs	10nJ/bit/m2
Eamp	0.0013pJ/bit/m4
EDA	5nJ/bit/signal
do(Threshold Distance)	70m
Popt	0.1

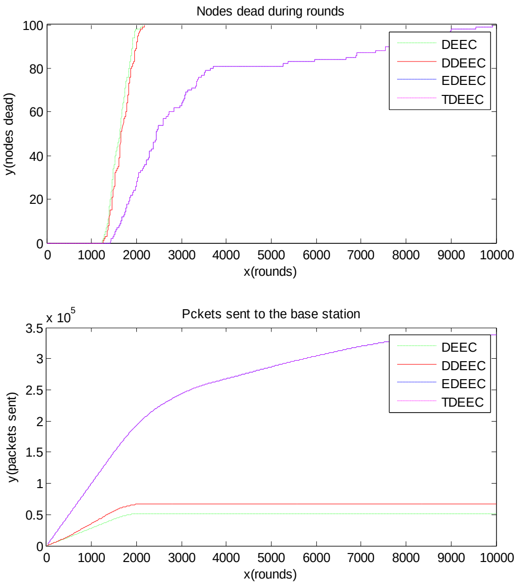
a=1.5;m=0.5;mo=0.4;b=3; deployed 20% advanced nodes deployed with 1.5 times more energy than normal nodes and 30% super nodes deployed with 3 times more energy than the normal nodes (m=0.5,mo=0.4,a=1.5,b=3).Hencemoretotal initialenergy.



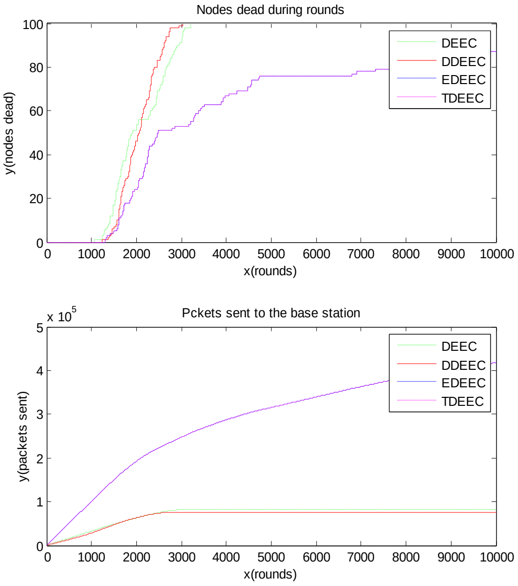


a=2;m=0.5;mo=0.5;b=3

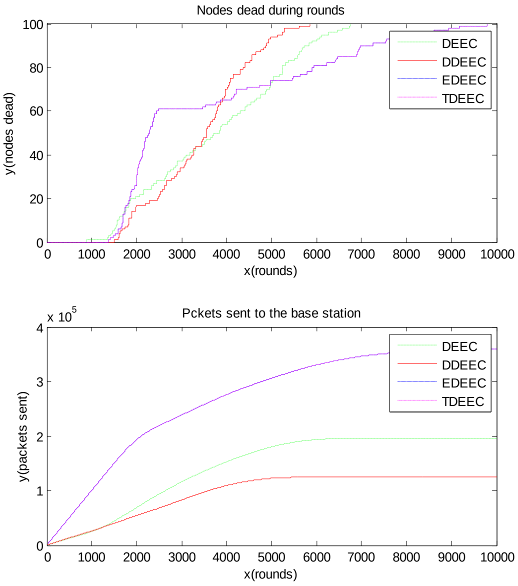




a=1;m=0.5;mo=0.5;b=4

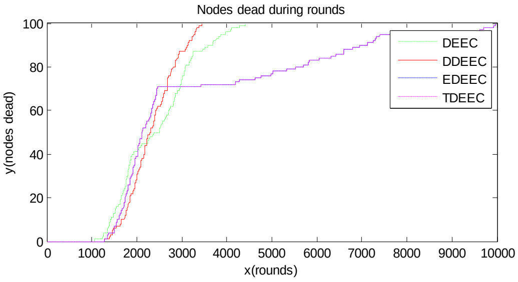


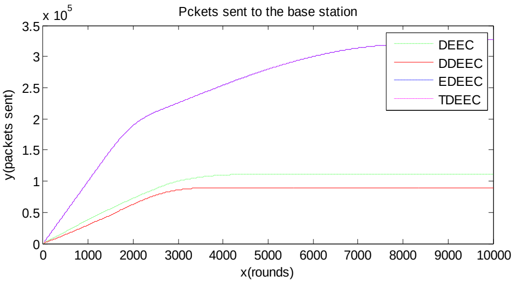
a=3;mo=0.4;m=0.5; b=1;



a=0.5;m=0.5;mo=0.4;b=3;

a=1.5;m=0.5;mo=0.5;b=4;





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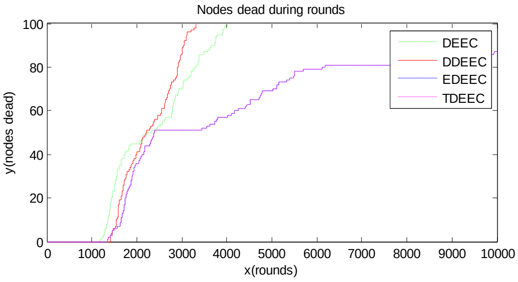
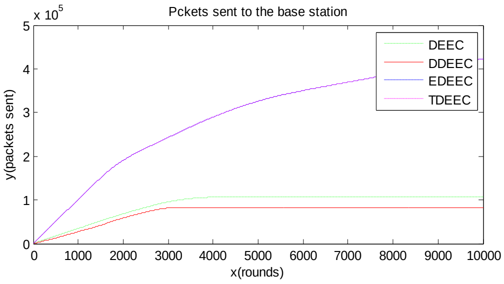
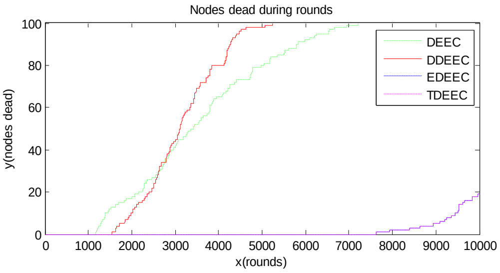
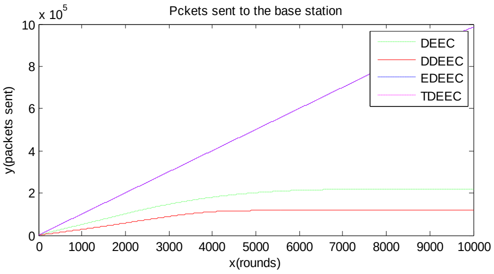




a=2.5 ,m=1.5; mo=1.5; b=5





X.CONCLUSION

DEEC, DDEEC, EDEEC and TDEEC were examined for heterogeneous WSNs containing different level of heterogeneity. Simulations proved that EDEEC and TDEEC performed well in the networks containing high energy difference between normal, advanced and super nodes. EDEEC,TDEEC had best performance in terms of stability period and life time. In a Enhanced distributed energy-efficient clustering protocol(EDEEC) lifetime might be enhanced by optimizing the probability through soft computing techniques .

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