Performance Evaluation of Distributed Energy Efficient Clustering Protocols in Wireless Sensor Networks

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Abstract:- Wireless Sensor Networks (WSNs) consist of sensor nodes having limited amount of battery power. Sensor nodes sense the data and transmit this data to base station that needs high energy consumption. Numerous routing protocols have been proposed in this regard getting energy efficiency in heterogeneous situations. Efficiency of WSNs declines as changing the heterogeneous parameters of sensor nodes. In this paper, performance of various Distributed Energy- Efficient Clustering based protocols like DDEEC, EDEEC, TDEEC and TADEEC under various scenarios. Performance of these protocols is observed based on stability period, network life time and throughput. MATLAB simulator tool is used for this experiment scenario. TADEEC performs better than TDEEC and EDEEC in all scenarios. TDEEC performs better than EDEEC in terms of stability period and network lifetime. EDEEC performs better than DDEEC in all parameters under all scenarios. Performance of TADEEC is best among all these protocols for each parameter in all scenarios.

Keywords— *WSNs, heterogeneity, TADEEC, threshold.*

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I. INTRODUCTION

Wireless sensor networks consist of sensor nodes with capabilities of sensing, computation and wireless communication. Sensor nodes have limited amount of battery power which is major issue in wireless sensor networks. WSN consists of hundreds or even thousands of sensors which are randomly deployed inside the area of interest[1]. Sensor nodes send the sensed data to base station from where users can access this data. It is not possible to replace or recharge the battery of node which is already deployed. Sensor nodes can be far away from base station, so it is not feasible to send this data to base station due to limited energy in nodes. Clustering can be used to decrease the power consumption. Cluster is collection of senor nodes, in which each node in cluster sends the sensed data to cluster head. Some clustering protocols have been proposed in this view[2,3]. Cluster head collects and aggregates this data and sends to base station[4]. Cluster head eliminates the redundant and unwanted information under aggregation process. The cluster arrangement process is a two-level hierarchy process where the CH nodes form higher level and receive the sensed data from cluster member nodes, which form the lower level. The sensor nodes send their data to the corresponding CH nodes at regular interval. Cluster head nodes transmit collected data to large distances than the member nodes, so they obviously spend more energy. A proper solution in order to balance the energy consumption amongst all the sensor nodes is to re-elect new CHs in each cluster at regular intervals. Clustering can be performed in two types of networks which are homogenous and heterogeneous networks. Nodes having same energy level are called homogenous network and nodes having different energy levels called heterogeneous network. Various algorithms such as Low-Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS) [5], Hybrid Energy-Efficient Distributed clustering (HEED) [6] are designed for homogenous WSN. On the other side, some algorithms like Stable Election

Protocol (SEP) [7], Distributed Energy-Efficient Clustering (DEEC) [8], Developed DEEC (DDEEC) [9], Enhanced DEEC (EDEEC) [10], Threshold DEEC (TDEEC)[11] and Threshold Sensitive Advanced DEEC (TADEEC)[12] are designed for heterogeneous WSNs. SEP is designed for two level heterogeneous networks, so it cannot work efficiently in three or multilevel heterogeneous network. Normal and advanced nodes exist in SEP where normal nodes have low energy level and advanced nodes have high energy. DEEC, DDEEC, EDEEC, TDEEC and TADEEC are designed for multilevel heterogeneous networks and can also perform efficiently in two level heterogeneous scenarios.

In this paper, Performance of various clustering protocols under three and multi level heterogeneous networks is studied. Performance of DDEEC, EDEEC, TDEEC and TADEEC 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. TADEEC implements functionality of EDEEC and TEEN[13]. It is observed that TADEEC protocol performs well among these protocols in stability period, network lifetime and throughput because four different energy level nodes are there. In TADEEC, heterogeneity level is increased to four.

The rest of the paper is ordered as follows: In section 2, related work is discussed. In section 3, network model is explained. In section 4, overview of clustering protocols for Heterogeneous networks are proposed. In section 5, Performance criteria are defined. Section 6 demonstrates the performance of different variants of DEEC protocols by comparison. Finally, in section 7 conclusion and future work are given.

II. RELATED WORK

A. Manjeshwar and D. P. Agarwal proposed TEEN protocol which is designed for reactive networks. G. Smaragdakis, *et al.*

[7] 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 [8] 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.* [9] 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.* [10] proposed a protocol EDEEC which is extended to three level heterogeneity by adding an extra amount of energy level known as super nodes. Parul Saini and Ajay K Sharma [11] proposed a protocol TDEEC scheme selects the CH from the high energy nodes improving energy efficiency and lifetime of the network. Anamika Chouhan and Amit Kaushik [12] proposed a protocol TADEEC in which functionality of EDEEC and TEEN protocol is implemented.

III. HETEROGENEOUS WSN MODEL

Heterogeneous WSN consist of sensor nodes having different energy levels. This kind of sensor network contains two, three or multi types of sensor nodes with respect to their energy levels.

A. Two Level Heterogeneous WSNs Model

Two level heterogeneous WSNs contain two different energy level of nodes i.e. normal and advanced nodes. E_O is the energy level of normal node and $E_O(1 + a)$ 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 Nm 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 energy levels of normal and advanced nodes.

$$E_{total} = N(1-m)E_O + Nm(1+a)E_O$$

$$E_{total} = NE_O(1 + am) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{eq.}(1)$$

B. Three Level Heterogeneous WSNs Model

Three level heterogeneous WSNs contain three different energy levels of nodes i.e. normal, advanced and super nodes. Normal nodes contain energy 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:

$$E_{total} = N(1-m)E_O + Nm(1+a)E_O + Nm_OE_O(1+b)$$

$$E_{total} = NE_O(1 + m(a + m_Ob)) \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{eq.}(2)$$

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 $[E_O, E_O(1 + a_{max})]$, where E_O is the lower bound and a_{max} is the value of maximal energy. Initially, 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.

IV. OVERVIEW OF DISTRIBUTED CLUSTERING PROTOCOLS FOR HETEROGENOUS NETWORK

A. DEEC

In DEEC, the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster-heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the nodes with low energy.

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.

It is found that nodes with more residual energy at round *r* are more probable to become CH, so, in this way nodes having higher energy level 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. It is not optimal way for energy distribution because advanced nodes are continuously becoming a CH and they die more quickly than normal nodes. To avoid this unbalanced problem, DDEEC introduces threshold residual energy, which is given below:

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

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, selection of CH is balanced and more efficient.

Average probability P_i for CH selection used in DDEEC is as follows as in:

$$P_i = \begin{cases} \dfrac{P_{opt}\,E_i(r)}{(1+am)\bar{E}(r)} & \text{for Nml nodes, } E_i(r) > Th_{REV} \\ \dfrac{(1+a)\,P_{opt}\,E_i(r)}{(1+am)\bar{E}(r)} & \text{for Adv nodes, } E_i(r) > Th_{REV} \\ \dfrac{(1+a)\,P_{opt}\,E_i(r)}{(1+am)\bar{E}(r)} & \text{for Ad, Nm nodes, } E_i(r) \le Th_{REV} \end{cases}$$

Where $E_i(r)$= Energy of node at round r.
$\bar{E}(r)$= Average energy of network

C. EDEEC

EDEEC uses concept of three level heterogeneous networks. It contains three types of nodes normal, advanced and super nodes based on initial energy. It is evaluated[14,15] that EDEEC performs well than DDEEC. The energy levels of normal, advanced and super nodes are E_0, $E_0(1+a)$ and $E_0(1+b)$ respectively. P_i is probability which is used for CH selection and P_{opt} is reference for P_i. EDEEC uses different P_{opt} values for normal, advanced and super nodes, so, value of P_i in EDEEC is as follows:-

$$P_i = \begin{cases} \dfrac{Popt\, E_i(r)}{(1+m(a+m_0b))E`(r)} & \text{if node is normal node} \\ \dfrac{(1+a)\, Popt\, E_i(r)}{(1+m(a+m_0b))E`(r)} & \text{if node is advanced node} \\ \dfrac{(1+b)\, Popt\, E_i(r)}{(1+m(a+m_0b))E`(r)} & \text{if node is super node} \end{cases}$$

:

Threshold value for CH selection for all three types of node is as follows as:

$$T(S_i) = \begin{cases} \dfrac{P_i}{1-P_i(r*mod(1/P_i))} & \text{if } P_i \text{ belongs to G} \\ \dfrac{P_i}{1-P_i(r*mod(1/P_i))} & \text{if } P_i \text{ belongs to G`} \\ \dfrac{P_i}{1-P_i(r*mod(1/P_i))} & \text{if } P_i \text{ belongs to G``} \end{cases}$$

Where G`,G``and G``` are sets of nodes which have not become cluster heads till ate specific round number r.

D. TDEEC

TDEEC uses same mechanism for CH selection and average energy estimation which are implemented in DEEC. At each round, nodes decide whether to become a CH or not by choosing a random number between 0 and 1. If number is less than threshold T_S which is shown below, then node become CH for the given round. In TDEEC, threshold value is adjusted and based on that value a node decides whether to become a CH or not by introducing residual energy and average energy of that round with respect to optimum number of CHs. Threshold value which is proposed in TDEEC is given as follows :

$$T(s) = \frac{P}{1-P(r*mod(1/P))} * \frac{\text{Residual energy of a node}*K_{opt}}{\text{Average energy of network}}$$

E. TADEEC

TADEEC protocol is configured to work in a reactive mode in a heterogeneous network. It is enhancement of EDEEC because heterogeneity is increased to four. In TADEEC, four types of nodes i.e. normal , advanced, super and superadvanced are there. It implements functionality of TEEN protocol as hard and soft threshold are used for overcome the problem of sending data again and again. It is best suited as it combines the best of both approaches[16] i.e. heterogeneous and thresholds constrained network. It uses same strategy as used in LEACH for cluster head selection. The nodes are distributed according to m and m0 factor. Energy level and distribution of these nodes are given as follows

$E_{normal} = E_0$; No. of normal nodes = (1-m)*n;
$E_{adv} = E_0(1+a)$; No. of advanced nodes =(1-m0)*m*n;
$E_{super} = E_0(1+b)$; No. of super nodes =(m0*m*n)/2;
$E_{supadvanced} = E_0(1+c)$; No. of superadvanced nodes =(m0*m*n)/2;

The probabilities for election of cluster head for normal, advance, super and superadvanced nodes are as follows as:

$$P_i = \begin{cases} \dfrac{Popt^*\, E_i(r)}{(1+m*a-m_{0*}m*(a-(b+c)/2))*E`(r)} & \text{if node is normal node} \\ \dfrac{(1+a)*Popt^*\, E_i(r)}{(1+m*a-m_{0*}m*(a-(b+c)/2))*E`(r)} & \text{if node is advanced node} \\ \dfrac{(1+b)^*\, Popt^*\, E_i(r)}{(1+m*a-m_{0*}m*(a-(b+c)/2))*E`(r)} & \text{if node is super node} \\ \dfrac{(1+c)^*\, Popt^*\, E_i(r)}{(1+m*a-m_{0*}m*(a-(b+c)/2))*E`(r)} & \text{if node is superadvanced node} \end{cases}$$

Threshold value for electing the cluster head is as follows as:

$$T(S_i) = \begin{cases} \dfrac{P_{norm}}{1-P_{norm}(r*mod(1/P_{norm}))} & \text{if i is normal and belongs to G} \\ \dfrac{P_{adv}}{1-P_{adv}(r*mod(1/P_{adv}))} & \text{if i is advanced and belongs to G`} \\ \dfrac{P_{super}}{1-P_{super}(r*mod(1/P_{super}))} & \text{if i is super and belongs to G``} \\ \dfrac{P_{supadv}}{1-P_{supadv}(r*mod(1/P_{supadv}))} & \text{if i is superadv and belongs to G```} \\ 0 & \text{Otherwise} \end{cases}$$

Where G,G',G''and G''' are set of nodes which have not become cluster heads till round.

V. PERFORMANCE PARAMETERS

Various clustering protocol for heterogeneous networks are compared on basis of parameters which are as follows:

1. Alive nodes: It shows number of nodes which exist till the last round, so it is better to be alive nodes higher.
2. Dead nodes: It determines number of dead nodes get died till last round, so lesser will be dead nodes better will be network performance.

3. Packets send to base station: This computes the data sent per round to the base station by the cluster head. If more packets will be sent to base station, throughput will be higher also.

VI. SIMULATIONS AND DISCUSSIONS

In this section, various clustering protocols for heterogeneous network are simulated. These simulations are performed in MATLAB[17]. Various parameters for protocol simulation are given in table 1. We have taken 100 nodes for simulation which are randomly deployed in network field of dimension 100m*100m. It is considered that basestation is located at center of network field for this scenario. We have simulated DDEEC, TDEEC, EDEEC and TADEEC under different scenarios by varying energy level of sensor nodes and changing the fraction factor of respective node. We have taken a, b, c, m and m0 as varying parameters. we have taken the hard threshold in TADEEC as 100 degree Celsius and also soft threshold is taken as 2. Current sensed value should be differ from previous sent value by 2 only then data would be sent to the cluster head. Parameter *m* refers to fraction of advanced nodes containing extra amount of energy *a* in network whereas, m_O is a factor that refers to fraction of super nodes containing extra amount of energy *b* in the network. In TADEEC, parameter *c* is used which refers extra amount of energy in superadvanced nodes in network.

Table 1: List of various simulation parameters

Parameters	Values
Area	100*100 square meters
Basestation location	(50,50) (in meters)
Number of nodes	100
Initial Energy	0.5J
Message Size	4000 bits
Transmission Energy	50nJ/bit
Receiver Energy	50nJ/bit
Free space(E_{fs}) energy	10pJ/bit/m^2
Multipath amplification energy	0.0013pJ/bit/m^4
Aggregation Energy	5nJ/bit/packet
Number of rounds	25000
Hard threshold	100 degree Celsius
Soft threshold	2 degree Celsius
P_{opt}	0.1

These protocols are studied and compared with respect to dead nodes, network lifetime and throughput of the network. DDEEC protocol is involved in heterogeneous mode with normal and advanced nodes. EDEEC is enhancement of DDEEC with normal, advanced and super nodes. TDEEC is same as EDEEC in terms of heterogeneity but threshold value for cluster head selection is changed. The TADEEC is involved in the reactive mode in the heterogeneous mode with normal, advanced, super and super advanced nodes. The comparison of given all protocol is shown in graphical form.

Consider the case of a network where m = 0.3, m_0=0.6, a=1, b=1.5, c=2. From Fig. 1 and 2, it is examined that first node for DDEEC, EDEEC, TDEEC and TADEEC dies at 1197, 1297,1408 and 3231 rounds respectively. Tenth node dies at 1439, 1534, 1536 and 4775 rounds respectively. All nodes die at 3282, 6205, 5716 and 16585 rounds respectively. It is clear from the results of all protocols that in terms of stability period, TADEEC performs best of all and TDEEC performs better than EDEEC and DDEEC has least performance at all. It can be said from examining alive nodes that TADEEC has good network lifetime, whereas lifetime of EDEEC and TDEEC is approximate equal. From Fig. 3, it is examined that packets sent to base station for DDEEC, EDDEC, TDEEC and TADEEC is 81009, 258550, 258612, and 333286 respectively. It is found that TADEEC performs well in all protocol, whereas EDEEC and TDEEC have equally performance.

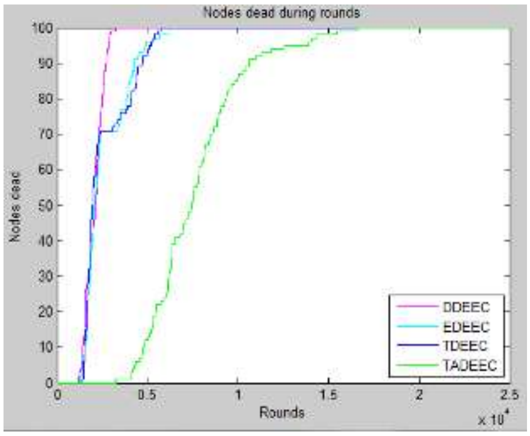

Fig 1: Nodes dead during rounds

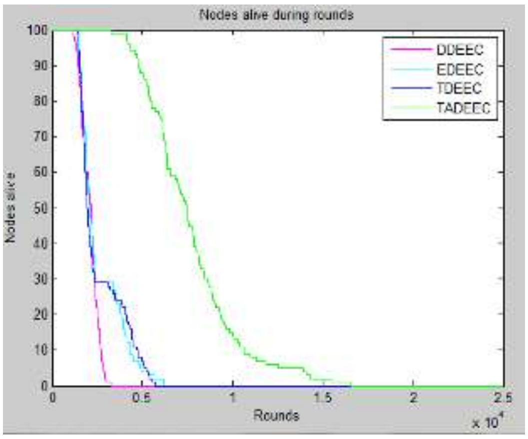

Fig 2: Nodes alive during rounds

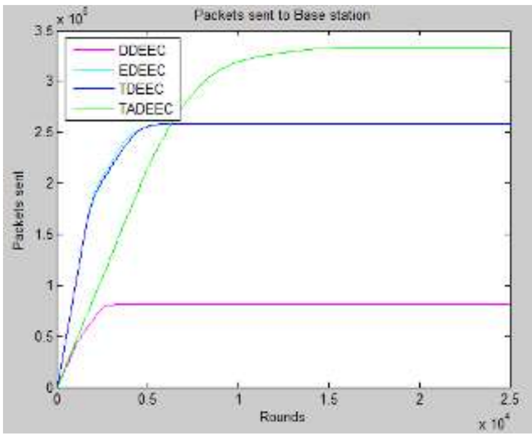

Fig 3: Packets Sent to base station

Now, consider another case of network where m = 0.6, m_0=0.3, a=1.2, b=2.5, c=2.8. From Fig. 4 and 5, it is examined that first node for DDEEC, EDEEC, TDEEC and TADEEC dies at 1205, 1304,1492 and 3791 rounds respectively. Tenth node dies at 1444, 1657, 1682 and 4822 rounds respectively. All nodes die at 3919, 8727, 8512 and 21551 rounds respectively. It is clear from the results of all protocols that in terms of stability period, TADEEC has good performance among all and TDEEC performs better than EDEEC and DDEEC has least performance at all. By examining above figures, it can be said that TADEEC has good network lifetime among all given protocols because its last node die at 21551th round. From Fig. 6, it is examined that packets sent to base station for DDEEC, EDDEC, TDEEC and TADEEC is 97888, 368744, 375366 and 397142 respectively. It is clear that throughput(packets/round) is highest for TADDEC. TDEEC performs well than EDEEC in respect to throughput.

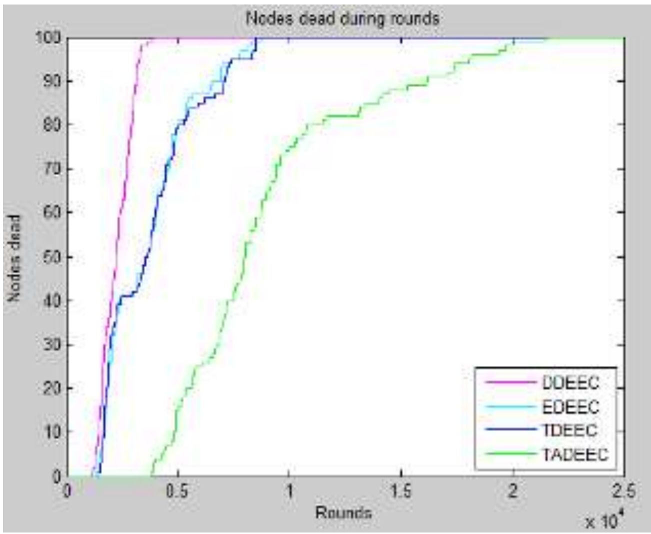

Fig 4: Nodes dead during rounds

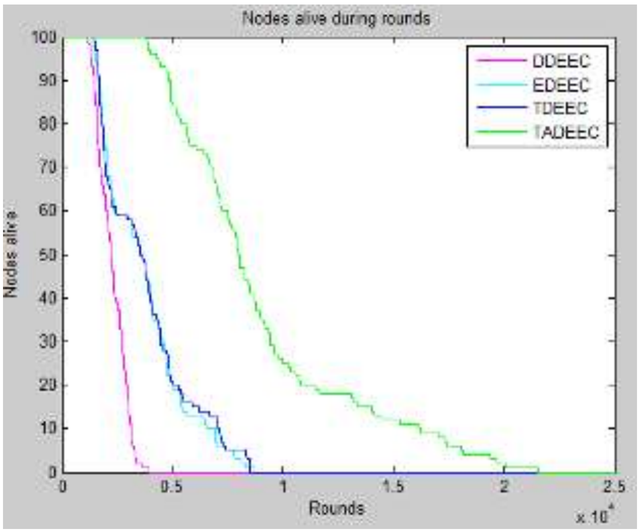

Fig 5: Nodes alive during rounds

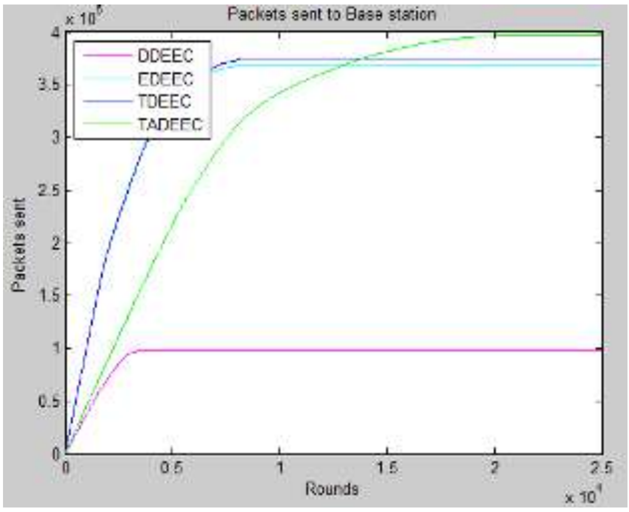

Fig 6: Packets Sent to Base station

Now, consider another and last case of network where m = 0.8, m_0=0.5, a=1.8, b=3.4, c=3.8. From Fig. 7 and 8, it is examined that first node for DDEEC, EDEEC, TDEEC and TADEEC dies at 1298, 1456,1464 and 6172 rounds respectively. Tenth node dies at 1615, 1819, 1787 and 8163 rounds respectively. All nodes die at 4415, 10730, 10894 and more than 25000 rounds respectively. It is obvious from the results of all protocols that with respect to stability period, TADEEC has good performance among. It is more interesting point here that last node in TADEEC does not die till 25000 rounds, so network lifetime is best in TADEEC among all protocols. It can be seen by examining alive nodes during rounds. From Fig. 9, it is examined that packets sent to base station for DDEEC, EDDEC, TDEEC and TADEEC is 175942, 585554, 607502 and 653830 respectively. It can be said that more packets are sent in TADEEC compared to remaining protocols. TDEEC has higher throughput(packets/round) than EDEEC and DDEEC. DDEEC has lower throughput among all.

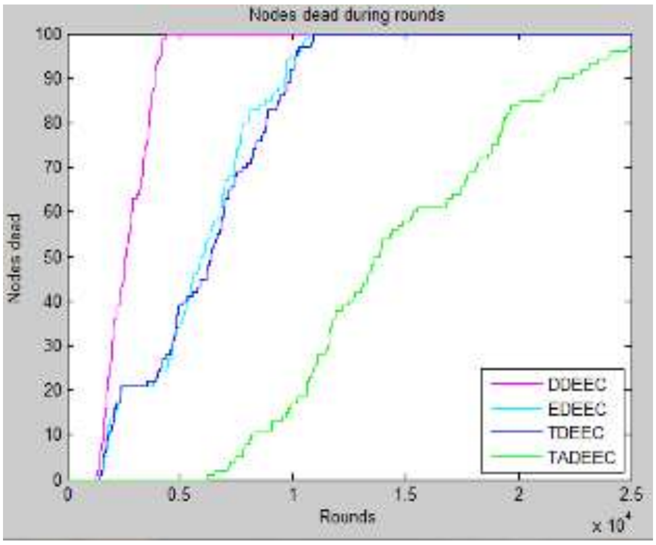

Fig 7: Nodes dead during rounds

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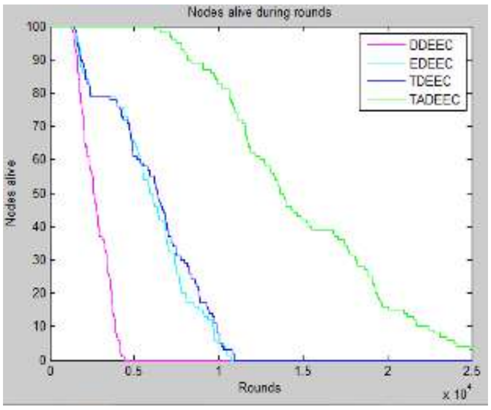

Fig 8: Nodes alive during rounds

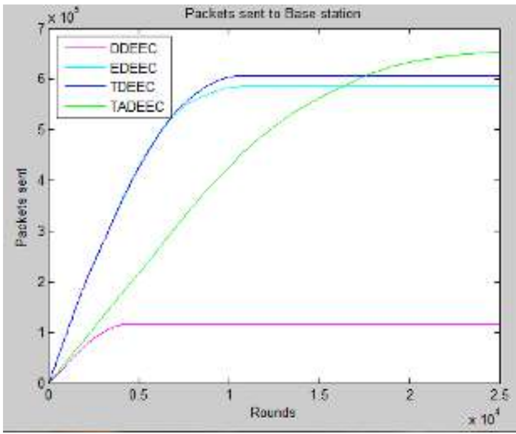

Fig 9: Packets Sent to Base station

VII. CONCLUSION AND FUTURE SCOPE

In this paper, various clustering protocols i.e. DDEEC, EDEEC, TDEEC and TADEEC are compared for three and multilevel heterogeneous WSN. By examining all results under different scenario it can be said that TADEEC performs well among all in terms of all parameters. It can be seen that in most cases TDEEC performs better than EDEEC, but in some cases both perform equal where difference between energy level of super node and normal node is less. DDEEC performs least among all protocols. Performance can be improved in such cases when there is optimal distribution of sensor nodes among cluster because it affects stability period, network lifetime and throughput. Research can be done on above given issues.

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