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Performance Analysis of Clustering Protocols in WSN

Sofiya.I
Department of Computer Science and Engineering
Manonmaniam Sundaranar University
Tirunelveli, India

Sundareswaran.P
Department of Computer Science and Engineering
Manonmaniam Sundaranar University
Tirunelveli, India

Abstract: Wireless Sensor Network (WSN) is the network of finite potential observing gadgets called sensors. The resource constraint behavior of WSN entails diverse problems in its motif and performance that reduces its execution. Wireless sensor network be unlike to other networks in phrase of accession of aggregation of energy, because at the time of sensors observing and sending the observed data to other sensors, which are covered by the network, a reasonable amount of energy gets reduced. So to overcome this, several routing, potentially organized and data broadcasting protocols are particularly constructed, in which energy devouring is an important design issue that conserves the durability of the network, thereby the lifetime of WSN gets increased. Hierarchical routing protocols which follows an approach of clustering such as Low Energy Adaptive Clustering Hierarchy (LEACH), Stable Election Protocol (SEP), Distributed Energy Efficient Clustering (DEEC) and Threshold Sensitive Energy Efficient Networks (TEEN) are well known for the purpose of keeping up the energy effective. Here we compare these four protocols in phrase of number of nodes dead, packet delivery ratio, number of nodes alive and packets delivered to cluster heads.

Keywords: WSN; packet delivery ratio; energy efficiency; hierarchical routing, LEACH; DEEC; TEEN; SEP

I. INTRODUCTION

The Wireless Sensor Network (WSN) is randomly allocated independent sensors to monitor materialistic or situational state like atmospheric condition, noise, adversity and so on [14] and after monitoring, it transmits the data via the network to the receiving end. Wireless sensor network got developed by the cause of military application. From then it is being used in industrial and consumer application etc. Composition of WSN includes hundreds of node in which each node will be connected to each sensor. Composition of each node in the network include parts like radio identification device attached with internal or external antenna, a microcontroller and an electronic circuit for the integration of sensors, then a source of energy in the form of battery. Size of a sensor node ranges from the size of a rat trap to the size of a small dust. Instead operational speck of authentic microscopic magnitude are still to be found. The cost of a sensor node may range from a little amount to hundreds of dollar, which relies on the difficulties in each sensor node. Because of the variations in price and size of a sensor node there is a detention on various resources like energy, storage, functional speed and bandwidth for communications. Dispersion technique between skitter of a network could be routing [14]. The rapid increase of manufacturing of minimal cost, minimal power, multi functional sensors made WSN an essential data collection template to extract some of the scales of interests. In these applications, usually sensors will be too dense and they will be diffused randomly over an area to be sensed and some are left without attending since they are in remote location that makes difficulties in recharging and replacing their batteries. When sensors form as independent organization the sensors which are closer to base station or data sink get drained sooner than others because of relaying traffic [16]. After all the sensors surrounding the data sink drains its energy, connection among the network and communication cannot be assured. The concept of clustering indicates the structure of non overlapping hierarchical clusters of the nodes. A firm clustering method is essential for a self organizing wireless sensor network. An efficient clustering protocol confirms the development of clusters with same radius and cluster heads that are located in best position in the particular cluster. As each and every node in a cluster is directed to the cluster head, all the cluster heads in a network must have a route discovery to establish acceptable route in the network. All the energy effective algorithms[17] will select some cluster heads randomly for saving energy but latter if the selected cluster heads get reduce in its functionality and fails in good connectivity and if they become unstable, the repetition of transmission and dropping of packets will minimize the performance of the network. Hence the overall energy gets wasted. The solution of this kind of network which has a goal of reducing energy fusion is analyzing a trust worthy communication. The decision of lifetime of the network must not rely on time taken for death of first and last node alone but also on the time interval of the network's withstanding capacity to provide its entire service and operation. Usually the network is crowded and nodes present in it are repetitious and because of this even death of some nodes will not affect the network. Hence network lifetime and its performance are linked [15].

A. Taxonomy of Energy Efficient Techniques

The causes of energy getting wasted by a wireless sensor network are explained below. Then some of already present energy effective solutions are proposed considering the resource restricted behavior of sensors.

- ***Causes of energy wasted by a sensor:***

In wireless sensor networks, the sensors spend its power during encountering or observing, operating, sending or getting data for the satisfaction of target needed by that work. It is apparent that reducing information drawn out in transducer has the capacity of saving energy of so constraint sensors. Repetitious essential behavior of wireless sensor network gives result of many such report of WSN to charge routing network to base station. Solutions of analysis show that subsystem of communication is confirmed and it is acquisition of energy source diffusion. Giving attention for

communication is alone not enough because a huge quantity of energy also gets wasted.

Overhearing:

At the time of transmitter sending a packet, it is ready to be accepted by every node which are present in its range of communication, though those nodes are not located in its advised landing place. Hence here some energy gets wasted by the node since it receives packets of other nodes.

Control packet overhead:

Low amount of packets which have control must be utilized for permitting data communication. One of parts of power diffusion is abandoned observation. This occurs at the time of a node observing for an abandoned channel, for the purpose of getting feasible traffic.

- ***Types of energy efficient techniques***

Energy efficient methods can be divided into five main types. They are data reduction, protocol overhead reduction, energy efficient routing, topology control and duty cycling.

Protocol overhead reduction:

Main goal of protocol overhead reduction is to higher the effectiveness of a protocol by lessening overhead. Common time interval of messages is altered by the network's stability or the path of the resource of communicated data. In common, a cross layering approach authorizes best utilization of transmission protocols, which also look for requirements of an application. Minimized flooding also reduces the overhead.

Data reduction:

The main goal of this method is lessening the quantity of information produced, operated and sent. Examples of this method are data aggregation and data compression.

Energy efficient routing:

The design of a routing protocol must satisfy the aim of increasing lifetime of the network using minimization of energy consumption by a peer-to-peer communication and neglecting sensors with less remaining energy. Few algorithms are adept, considering uses of establishing behavior of wireless transmission, to minimize the power absorbed by transmission to base station.

II. RELATED WORK

Aseri *et al.* [2] presented an analysis on heterogeneous clustering protocols. The author made analysis over the performance of the heterogeneous clustering protocols based on lifetime of the network and amount of messages received by the base stations.

Analysis of clustering protocols by Mariam alunuaimi *et al.* [7] highlighted the challenges in clustering a large WSN, also discussed few clustering protocols and they are classified based on clusters development method and the technique of aggregation of data to the sink position. It also looked a case of border monitoring and they simulated these protocols and compared those using different scenarios.

A performance analysis of clustering protocols was given by Sachin gajjar *et al.* [1]. The author of that analysis simulated and referred some of the referred protocols which significantly control life time of the network based on quantitative (network throughput, network overhead, network setting time etc.) and qualitative (fairness, heterogeneity, time synchronization etc.) performance metrics which can also be used as construction or designing guidelines for the implementation of new clustering protocols in WSNs. Some of the weak points of the clustering protocols are discussed to facilitate researchers to overcome in their work.

Energy efficient clustering in wireless sensor networks was proposed by chandrasekaran *et al.* [3]. It gives a novel approach on energy efficient clustering for single hop WSN which would suit periodical data gathering applications. The proposed approach was also compared with some other protocols. The assumption of single hop is removed here and multi hop hierarchical routing is an important technique for energy consumption. The cluster setup analysis is mainly focused here.

Amritkaur *et al.* [8] presented a method to prolong network lifetime using cluster based routing protocols. The author studied cluster approached routing protocol, that the remaining energy of nodes are considered for the extension of life time of the network. It also looked for different parameters such as size of a packet and positioning of Base station for comparison of various protocols.

Survey by sheik dawood *et al.* [5] studied general grouping of clustering schemes and analysis was made on present day classification, analysis was also based on metrics such as energy efficiency, clustering stability, location awareness node mobility and QOS support.

Comparison of energy optimization clustering protocols by manpreet kaur *et al.* [9] made a discussion on the classification and overview of clustering algorithms and performance analysis of clustering algorithm is made on time complexity and node mobility.

Another survey on cluster based routing protocol was given by santar pal singh *et al.* [6]. This survey discussed design challenges of routing protocols in WSN, classification of routing protocols in WSNs and merits and limitations of some of the cluster based algorithm. It also compares some of the cluster schemes based on energy efficiency, delivery delay, clusters stability, scalability, load balancing and algorithm complexity and finally it discusses an issues in cluster based routing protocols.

Review analysis of the routing protocols for energy optimization by Lakshmi sudha *et al.* [4] presented a review on network layer protocols for optimum routing, life time and energy efficiency. Comparisons are made between proactive, reactive and hybrid routing protocol, direct communication, flats and clustering protocols, hierarchical routing, data centric and location based protocols.

Apart from all these analysis our analysis differs in a way of comparing two homogeneous protocols separately and two heterogeneous protocols separately and also because of some of the distinct characteristic

III. METHODOLOGY

A. Homogeneous sensor networks

If all the nodes are said to have similar characteristics, hardware and processing capabilities it denotes homogeneous sensor network. This makes every sensor to turn into a CH.

- ***LEACH***

LEACH [10] (Low-Energy Adaptive Clustering Hierarchy) is a TDMA based MAC protocol. The main aim of this protocol is to extend the duration of lifetime of the network by reclustering periodically and making a change in the network topology. The operation of LEACH can be classified in to two and they are clustering phase and steady state phase. To minimize the amount of data that is to be sent to the base

station from clusters, LEACH will undergo local data fusion. By doing this energy wastage can be reduced, thereby extending the duration of network lifetime. The process of election of cluster head by a sensor itself, starts with assuming certain probability followed by establishing the status of the particular sensor to other members in that network. When each round gets started, a sensor will select a number between 0 and 1 randomly and the selected number is compared with the calculated value of the threshold T(n). When the number selected by the sensor node is higher than T(n), the particular sensor node gets the chance of becoming cluster head (CH) for that round. To calculate T(n) we use the following formula:

$$\mathbf{T(n)} = \begin{cases} \dfrac{P}{1 - p\ (r \bmod (\frac{1}{p}))} & if\ n \in G \\ 0 & otherwise \end{cases}$$

where p denotes ratio of total quantity of cluster heads to total quantity of nodes, r denotes number of rounds, then G denotes the set of nodes that are not selected as cluster heads for the last 1/p rounds. Let T(n) be equal to p for the first round (r=0), and all nodes will have equal rights of becoming cluster head. When value of r gets neared to 1/p, T(n) value increases and nodes that are not selected as cluster heads for last 1/p rounds will have more priority of becoming cluster head. After 1/p -1 rounds T(n) is equal to 1, denotes that all the nodes left over are selected as CH. Hence, after 1/p rounds all the nodes have a chance to become a cluster head once. Being the cluster-head will put an extensive burden on the sensor nodes, which is to make sure that the network has no overloaded node that runs out of energy sooner than the others.

The phases of LEACH

Advertisement phase

An advertisement message will be broadcasted to other nodes by a self elected cluster-head for a particular round. In this phase CSMA MAC protocol is used by cluster-heads. The transmit energy used by all the cluster-heads in this process is the same. The receivers of ordinary nodes which are not selected as cluster head are to be kept on to get advertisements from every elected cluster-head nodes. Once the phase gets over, each member node of the network will decide a cluster where it should be. The decision is made relying on the signal strength received from the advertisement.

Cluster setup phase

The cluster-head node must be informed by each node once it decides like it would be a part of that cluster. Each member sends that information to CH via a MAC protocol named CSMA. At this phase also, the receivers of all the nodes which are elected as cluster heads are kept on.

Schedule Creation

Nodes that are willing to be a part of the particular cluster, receives a message by the cluster head node. The responsibility of cluster head node includes creation of a TDMA schedule considering the quantity of nodes present in the cluster. This informs each node, when to transmit and latter establishes it to each and every node in the cluster.

Data Transmission

This phase starts after creating a cluster and after the fixation of TDMA schedule. When a node gets a data to be sent, the transmission of the data to CH is done only at its allocated time. This transmission of data consumes little energy level.

- ***TEEN***

TEEN [13] (Threshold Sensitive Energy Efficient Sensor Network Protocol) protocol is meant for network which are reactive and which uses a hierarchical clustering scheme of LEACH. A hierarchy of clusters is formed and the sensor node transmits its sensed data to its corresponding cluster head. This leads heads nodes of the cluster to form a hierarchy. The cluster heads at lower level transmits its data to heads of the cluster at higher level. The heads of a cluster at topmost level nodes sends its data directly to the BS. Thus the root of a hierarchy is the Base station. According to this protocol, at the time of change of each cluster, along with attributes, two more parameters are also broadcasted by cluster-heads to their members. They are

Hard Threshold (HT): Hard threshold is the value of a threshold. If the value of a sensed attribute as sensed by any sensing node, found greater than or equal to this hard threshold then the transmitter will be turned on and the cluster heads are informed.

Soft Threshold (ST): Soft threshold points out every small variation that happens in a sensed attribute's value, which thereby will make that node to switch on its transmitter by itself and start transmission.

Nodes sense the surroundings simultaneously and if value of any parameter of the attribute set is found to be the same as the hard threshold value of that parameter, transmitter is turned on by the node and transmits the sensed data. In the internal variable (SV) of the sensor this sensed value of the parameter gets stored. Next time the nodes start sending data only at the time of currently observed value of the observed attribute becomes higher than hard threshold. It must also vary from observed value by a quantity that is equal or greater than soft threshold. The number of transmissions is decreased via the hard threshold by letting the nodes to send at the time only when the observed attribute is in a range. The quantity of transmissions is further decreased through the soft threshold by removing all the transmissions that occurs even when there is small or no variation in the sensed attribute. The number of packet transmissions can be controlled by both the soft and hard threshold. These values have an effect over TEEN.

B. Heterogeneous Sensor Networks

In heterogeneous sensor networks, various nodes with various battery energy levels are utilized. Heterogeneous network is a complicated network as it uses different topologies. Heterogeneous sensor network has variety of network nodes along with various functionalities and battery power is used. The need of extra battery energy and more complex hardware is embedded in some cluster heads leads to the real motivation behind the heterogeneous networks. Thus this reduces the overall cost of the hardware for the remaining sensor network.

- ***SEP***

In SEP [11] (Stable Election Protocol) the stable region is increased using the behavioral parameters of heterogeneity, in the process of clustering hierarchy. The behavioral parameters are part of advanced nodes (m) and energy in addition to normal and advanced nodes (α). Some attempts are taken by SEP for maintaining energy consumption in a well balanced manner to increase stable region. Without conscious reason advanced nodes take up the role of cluster head more frequently than normal nodes that lead to a balanced consumption of energy. Latest settings in heterogeneous does not affect the network's spatial density. Hence initial setting made on P_{opt} is not changed, but the overall power or energy of the whole network is changed. If each normal sensor has E_o as initial energy. Then advanced node has $E_o.(1+\alpha)$ energy. So, the overall (initial) energy of the latest heterogeneous framework is

$$n\cdot(1-m)\cdot E_o + n\cdot m\cdot E_o\cdot(1+\alpha) = n\cdot E_o\cdot(1+\alpha\cdot m)$$

Hence the addition made on network is improved using the factor of 1+α.m. Increasing the sensor network's epoch proportionate to increment in energy is the first modification to the already known LEACH. Weighted selection of state of being probable for normal node is P_{nrm} and weighted selection of state of being probable for advanced nodes are $P_{adv.}$ To keep up least energy absorption in every iteration inside an epoch, the median amount of CHs for each iteration for each epoch should retain constant nature and must be same as $n\times P_{opt}$. Normal node has initial energy equal to nodes with $n\times(1+\alpha\cdot m)$ energy. $n\cdot(1+\alpha\cdot m)\times P_{nrm}$ is equal to median count of cluster head for each round for each epoch in a heterogeneous system. Weighted states of being probable of advanced and normal nodes are

$$P_{adv} = \frac{P_{opt}}{1+m\alpha} \quad (1+\alpha)$$

$$P_{nor} = \frac{P_{opt}}{1+m\alpha}$$

Every normal node gets a chance of becoming cluster head exactly utmost $1/P_{opt}\cdot(1+\alpha\cdot m)$ iterations for each time. Normal nodes for each round for each epoch has a median count of $n\cdot(1-m)\times P_{nrm}$ cluster heads. Every advanced node get a chance of becoming cluster head exactly once utmost $(1/P_{opt})\cdot(1+\alpha\cdot m/1+\alpha)$ iterations. This time interval is defined as sub-epoch. Every epoch will have 1+ α sub epochs. At last within an epoch the role of advanced nodes to become cluster head is exactly 1+ α times. The median of count of cluster head which are advanced nodes for each round for each epoch and sub epoch is $n\cdot m\times P_{adv}$. Operations of heterogeneous epoch and sub epoch is defined as x = r mod $1/P_{opt}$ and $x=r.\mathrm{mod}1/P_{nrm}$, where r denotes current round. Hence median overall count of cluster heads of every iteration and for each heterogeneous epoch is

$$n\cdot(1-m)\times P_{nrm} + n\cdot m\times P_{adv} = n\times P_{opt}$$

- ***DEEC***

The DEEC [12] protocol (Distributed Energy Efficient Clustering protocol), is also an energy effective protocol and it comes under heterogeneous clustering, it is based on distribution. DEEC relies on basic LEACH algorithm but differs in method of cluster head election. The selection of cluster head is based on probability based ration between each node's residual energy and system's average energy. DEEC can also be implemented on the multi level heterogeneous wireless sensor network since it supports the distributed property. Nodes are of two type namely normal nodes and advanced nodes which help in cluster head selection and it is known from SEP protocol. But it fails in a multi-level heterogeneous network environment. So, DEEC uses the probability basis ration between each node's residual energy and system's average energy. Having a global knowledge on system's average energy to a single node is difficult. Hence, DEEC will assume an ideal value for the network lifetime. The ideal value is utilized for the reference energy calculation with which each node expand in each round. The only limitation in using DEEC is that the advance nodes always get penalized when the residual energy gets reduced and become equal to that of the normal node. On such conditions advance nodes will drain soon than other normal nodes.

IV. PERFORMANCE ANALYSIS

A. Performance measures

Mat Lab version 2013(b) is used as the simulation platform and comparison is done for both homogeneous and heterogeneous clustering protocols. Performance measures which are used to analyse performance of clustering protocols are given below

Stability Period: It is the time interval between the start of network operation and death of the first sensor node.

Network lifetime: It is the time gap from a start of the operation (operation of sensor network) to the death of a last alive node.

Number of cluster heads per round: It is a prompt measure that reflects the count of nodes that send the information aggregated from its cluster members directly to the sink.

Packet delivery ratio: It is the ratio of count of packets transmitted from the source end to the count of packets that are got at the destination. Higher the value of PDR indicates comparatively higher functionality of the protocol.

B. Simulation and results

- ***Simulation parameters***

In this section, the comparison is made between two homogeneous clustering protocols, LEACH and TEEN and two heterogeneous protocols SEP and DEEC. Simulation parameters for the comparison are shown in Table 4.1.

Table 4.1 Simulation parameters for Homogeneous and heterogeneous sensor network

Simulation parameters	***Values***
Simulation area	100x100 m
Sink position	50x50 m
Number of nodes	100
Transmitter amplifier energy dissipation	E_{fs}= 10*0.0000000000001 J E_{mp}= 0.0013*0.000000000001 J
Channel type	Wireless
Cluster head selection probability	0.1
Data aggregation	5*0.000000001

Energy model	Battery
Initial energy	0.5J
Transmit power	$0.5*10^{-7}$
Receiver power	$0.5*10^{-7}$
Maximum number of rounds	3000
Percentage of advanced nodes	0.1
Energy enhancement of advanced nodes	1

- ***Performance analysis of homogeneous sensor networks***

Figures shows experimental comparison results of the two protocols, LEACH and TEEN in the aspect of number of nodes dead, number of nodes alive and packets sent to Base station and packets sent to Cluster heads.

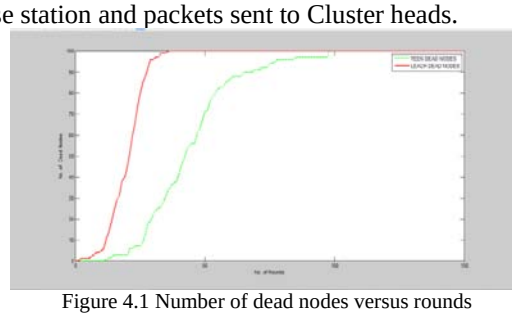

Figure 4.1 Number of dead nodes versus rounds

Figure 4.1 implies that all nodes LEACH dies much sooner than TEEN which leads to shorter lifetime for LEACH

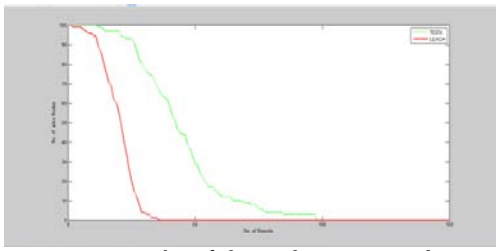

Figure 4.2 Number of alive nodes versus rounds

Figure 4.2 implies that TEEN will have more alive nodes in the later rounds than LEACH which leads to better scalability.

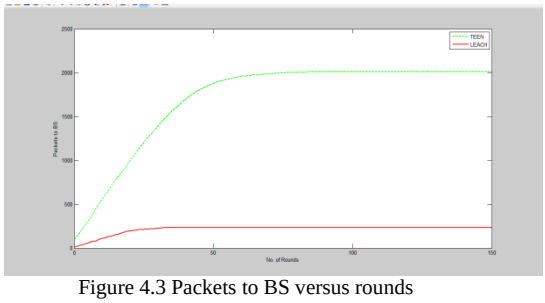

Figure 4.3 Packets to BS versus rounds

Apart from lifetime of the network, there is another metric to analyse the effectiveness of a clustering protocol i.e., throughput of that network. The effectiveness of a clustering protocol is confirmed by the base station that receives more data packets. Throughput mostly depends on lifetime of the network. With the simulated results from figure 4.3 we can conclude that the maximum throughput is achieved by TEEN

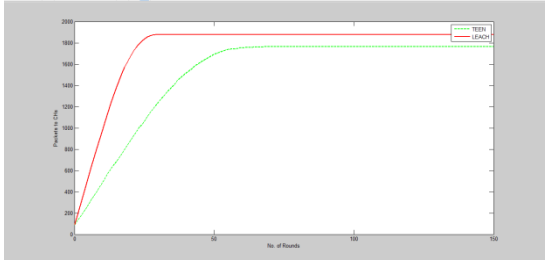

Figure 4.4 Packets to CHs versus rounds

Figure 4.4 implies the gradual expansion of the network scale of TEEN protocol which is better when compared to LEACH which leads to the stability of the protocol. From the above figures and their implications it is clearly understood that TEEN performs better than LEACH i.e., TEEN has higher energy effectiveness than LEACH that it effectively prolong the network lifetime.

- ***Performance analysis of Heterogeneous sensor networks***

Figures show experimental comparison results of the two protocols, SEP and DEEC in the aspect of nodes dead, nodes alive and packet delivery ratio.

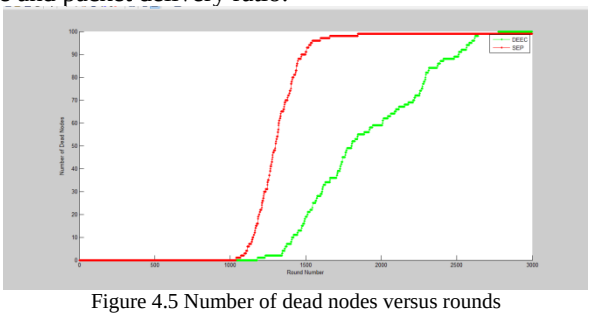

Figure 4.5 Number of dead nodes versus rounds

Figure 4.5 indicates that the first node of SEP dies faster than the first node of DEEC which implies, the stable region of DEEC is higher than the stable region of SEP.

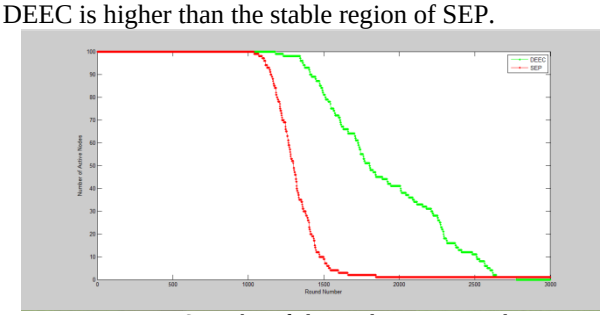

Figure 4.6 Number of alive nodes versus rounds

Figure 4.6 implies, all nodes of SEP get drained merely from round 2000 but in case of DEEC all nodes get drained only after round 2600.So DEEC can withstand much more time than SEP.

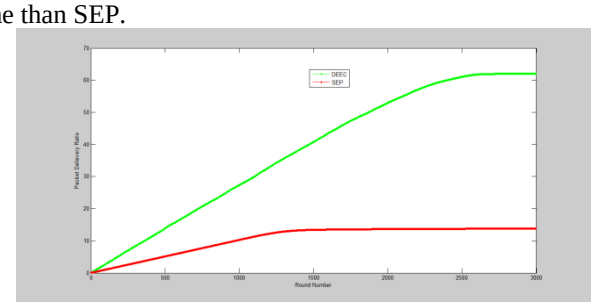

Figure 4.7 Packet delivery ratio

Figure 4.7 clearly shows that the numbers of packets of DEEC received in destination are greater than the number of packets of SEP. So DEEC gives the better performance than SEP.

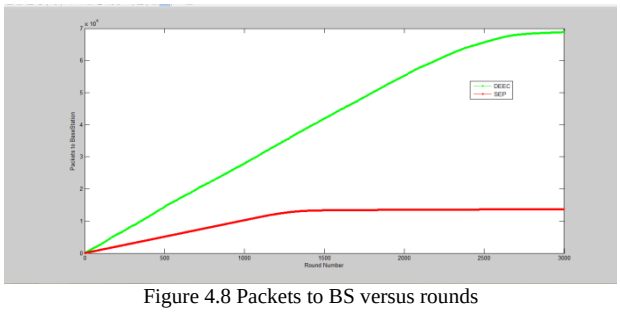

Figure 4.8 Packets to BS versus rounds

The effectiveness of a clustering protocol is confirmed by a base station that receives more data packets. With the simulated results in Fig 4.8, we can conclude that maximum throughput is achieved by DEEC. Throughput mostly depends on lifetime of the network.

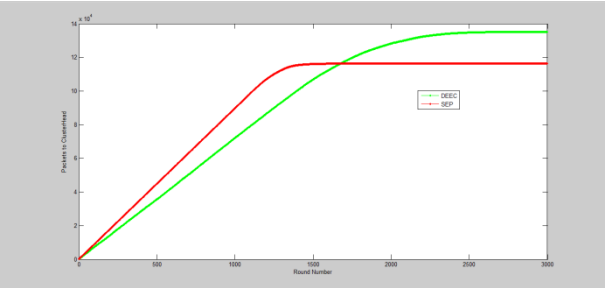

Figure 4.9 Packets to CHs versus rounds

Figure 4.9 implies the gradual expansion of the network scale of DEEC protocol which is better when compared to SEP which leads to the better stability of the protocol. From the above figures and their implications, it is clearly understood that DEEC performs better than SEP i.e., DEEC is more energy efficient than SEP that it effectively prolong the network lifetime.

V. CONCLUSION

Network life time is an important factor in WSN, since recharging or replacing the batteries in the sensors is difficult and expensive. The challenge which the design of a clustering protocol in WSNs undergoes is energy efficiency. Major amount of energy in the sensor is used for data transmission and reception. Hence whatever clustering based protocol designed or proposed for wireless sensor network should be highly energy effective so that, the network can extend its duration to a long time. Many clustering protocols have been proposed for the issue. In this paper we simulated and analyzed Homogeneous clustering protocols, LEACH and TEEN and Heterogeneous clustering protocols, SEP and DEEC. Through the analysis made on LEACH and TEEN, it is concluded that TEEN performs comparatively well than LEACH because TEEN provides energy efficiency by having higher number of alive nodes in the later iterations and thus extending the duration of life time of the network. And through the analysis made on SEP and DEEC, it is concluded that DEEC performs comparatively well than SEP because DEEC provides energy efficiency by having higher stability region than SEP which leads to higher reliability and thus extending the duration of life time of the network.

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