Load Balancing on LEACH and DEEC for Heterogeneous Wireless Sensor Network

Prachi Khare, M.Tech Scholar, Department of Computer Science & Engineering, Kanpur Institute of Technology, Kanpur, India.
Saurabh Prasad, Assistant Professor, Department of Computer Science & Engineering, Kanpur Institute of Technology, Kanpur, India.

Abstract—**A key concern in WSN technology is to enhance the network lifetime and to reduce the energy consumption of the sensor network. Wireless sensor nodes are dispersed typically in sensing area to monitor earthquake, battle field, industrial environment, and habitant monitoring agriculture field, physical atmosphere conditions and smart homes. Sensor nodes sense the environment, gather information and transmit to BS through wireless link.**
One of the most critical problem and challenging in Wireless Sensor Networks (WSNs) is to reduce energy consumption in order to prolong network lifetime of WSNs. The main aim of the project is to develop a clustering technique through which the lifetime of the nodes and throughput of the network should be increased. Network throughput and lifetime can be increased when the energy of the sensor nodes is retained for a long time. To increase the lifetime of the nodes the residual energy of the nodes should be considered. Residual energy includes many factors like nodes weight. We have developed an algorithm including nodes residual energy that will definitely increase lifetime and throughput of the network. Using DEEC formula with heterogeneous network based on average and residual energy. Then here we have compared with LEACH (Low Energy Adaptive Clustering Hierarchy), DEEC (Distributed Energy Efficient Clustering) and proposed load balancing clustering algorithm.

***Index Terms*—**WSN, Energy Efficiency, Clustering, LEACH, DEEC

I. Introduction

Wireless Sensor network is composed of many small distributed sensor nodes that provide the reliable monitoring in various environments such as military battlefield surveillance, drug identification, recognition security and civil application and automatic security. In WSN every sensor node contains specific hardware, memory & processing unit. Tiny sensor nodes process the data and send it to base station called as sink. For communication of data between nodes and sink many routing technologies are used, such as multi-hop data transmission and direct communication.

A WSN (wireless sensor networks) is a set of sensor nodes deployed in a physical area and connected through wireless links. A sensor node consists of mainly four units that are sensing, communication, processing and power supply. There are many challenges in wireless sensor networks. The key challenge is to maximize the stability as well as lifetime of network, in (WSN), have given deep attention to large scale integration and energy efficiency (energy consumption). Energy-efficient solutions can conserve valuable sensor-node energy. This is one of the main critical challenges that WSNs face, which plays a fundamental part in determining the lifetime of the network. Although, there are many WSN protocols, clustering based hierarchal routing protocols are given more consideration because of their improve scalability.

In particular, sensors are battery-powered, often limiting available energy, which is not changeable in most of the situations. One of the most common energy-efficiency sensor networks protocols is Low Energy Adaptive Clustering Hierarchy (LEACH) as source and the other technique is DEEC (Distributed Energy Efficient Clustering). But for the WSN it is not feasible to replace the batteries of hundreds or thousands of sensor nodes after deployment. In sensor network, grouping of sensor nodes into a cluster is called clustering. Every cluster has a leader called cluster head. A cluster head may be pre assigned or elected by the members of the cluster. A cluster head collects the data from the nodes within cluster and transfer to destination (base station). So that one of the techniques used to reduce energy consumption and results in prolong network lifetime of WSN is to partition the network into clusters [1].

Clustering technique has a lot of advantages in comparison with flat routing protocols in WSNs, since it adds more scalability, less load, reduce energy consumption. Scalability since only CHs nodes are responsible for data dissemination thus the size of routing table is reduced at the individual sensor node. Also, sensor node can generate redundant data therefore in Clustering algorithm CH node aggregation the received data from its member's nodes using data aggregation method, which in turn help to reduce redundant data and thus reduce the size of the data packets thus energy is saved [2, 3].

In clustering schemes, there are mainly two major phases. In first phase, some nodes are appointed as CHs and formulate different cluster while second phase is usually related to data gathering and forwarding. Within each cluster, all member nodes transfer their sensory information towards their respective CH, which perform further processing (i.e. aggregation, compression, and scheduling and resource allocation) and forward their member data towards sink node. As CHs is responsible for several functions thus consume more energy compared to ordinary nodes [4]. Therefore, CH selection plays a vital role and has great impact on network lifetime [5]. However, Most of cluster mechanism selects the CH randomly without considered important parameters where this can lead to select the deficient node as CH. Others clustering mechanisms are based on centralized approach by utilizing the base station which can affect the network scalability as every time nodes require sending its parameters such as energy, number of neighbors to the BS which in turn leads to increases network overhead. Therefore, this paper presents an energy efficient, better throughput and load balancing clustering scheme based on distributed approach.

II. Literature Review

B. Baranidharan and B. Santhi, "An Evolutionary Approach to improve the life time of the Wireless sensor network". In this paper, they worked on the approach that how energy efficiency in the wireless sensor is increased by Genetic algorithm approach? Genetics operators are applied in such a way to reduce the redundant information to the sink and conserve its energy reserves, thereby, increasing the life time of nodes.

Sujee et al (2015) proposed that Wireless Sensor Network (WSN) technology used to sense various types of physical and environmental conditions with the availability of small and low-cost sensor nodes. Main drawback in WSN is limited battery power in the sensor nodes. Here, first analyzed the basic distributed clustering routing protocol LEACH, which is in a homogeneous environment, then analyzed with the heterogeneity concept in nodes to increase the life of WSN. Simulation results were obtained using MATLAB that shows the LEACH heterogeneous environment significantly reduces energy consumption and increases the total lifetime of the WSN than LEACH homogeneous environment.

Amit Sharma et al (2014) said that In WSN, it is too difficult to initialize the sensor nodes and manage the sensor networks due to the large number of sensor nodes, which may number tens of thousands. Moreover, in order to save energy, sensor nodes carry out data aggregation and compression before sending data to the base station, and execute energy efficient routing. So in this research work amit Sharma Dr. S. N. Panda et al analyzed that cluster based routing technique is the best energy efficient routing technique comparing to any other techniques.

The WSNs have attracted several researchers because of their potential applications and related challenges. They have several applications like military applications, environmental applications, health applications, scientific exploration, area monitoring and structural health monitoring, etc. At the same time, they have numerous challenges like simplicity, coverage, connectivity, scalability, robustness, fault-tolerance, security, efficient use of energy, etc. One of the most important challenges is related to the enhancement of network lifetime so that it can observe the monitoring area for long time for the activities of objects. The network lifetime is essentially related to the efficient use of network energy. Accordingly, several approaches have been developed including various protocols. The very first protocol for increasing the lifetime in WSNs was discussed by Heinzelman et al. in 2000, which is known as low energy adaptive clustering hierarchy (LEACH) protocol [6]. Low Energy Adaptive Clustering Hierarchy (LEACH), which was proposed in [7] and it is well known as LEACH protocol. LEACH was aimed to provide a solution to resolve the energy consumption in WSN and prolong the network lifetime. LEACH is a probabilistic based on both distributed and single-hop approach. It structures the network into clusters based on the strength of receiving signals. In LEACH, nodes are either ordinary SNs or CHs. Every SN sends their sensing data to its CH. In addition, CHs node work as gateways to the BS, Initially a node in LEACH protocol, generates a random number between 0-1 to decide which node to be a CH and this is done by computed a threshold value. Generally, LEACH provides a good model for energy consumption. To reduce energy consumption in [8] proposed Power efficient gathering in sensor information systems (PEGASIS) was also proposed to form a chain of sensor nodes starting from the farthest node to closest node towards base station. Each node sends and receives data from its neighbors and takes a turn being a leader for transmission towards the base station or destination. However, such a mechanism can produce high transmission delay with an increase in chain or network size.

For past few years, the WSNs have mainly focused on technologies based on the homogeneous WSNs in which all nodes have same system resources. Recently, the heterogeneous wireless sensor networks are becoming more and more popular. The researches [9, 10] show that heterogeneous nodes can prolong the network lifetime and improve the network reliability without significantly increasing the cost. The heterogeneous nodes are more capable of providing data filtering, fusion and transport; but they are more expensive than the homogeneous nodes. A heterogeneous node may possess one or more types of heterogeneous resources, e.g., enhanced energy capacity or communication capability. Compared with the normal nodes, they may be configured with more powerful microprocessor or more memory or both. They may also communicate with the base station via high-bandwidth and long distance network. The deployment of heterogeneous nodes increases the network energy and hence the network lifetime. There have been some works that discuss heterogeneous network models. Smaragdakis et al. discuss stable election protocol (SEP) [11], an extension of LEACH, that uses heterogeneity. It is the very first protocol, which talks about heterogeneity. In this protocol, a node becomes cluster head on the basis of weighted election probability, which uses a function of the remaining energy of the nodes to ensure uniform usage of node energy. The underlying network of the SEP considers two levels of heterogeneity, consisting two types of nodes, known as normal and advanced nodes. The energy of the advanced node is higher than the normal nodes and their number is less than that of the normal nodes due to the increased cost factor Li et al. discuss the distributed energy efficient clustering (DEEC) [12] protocol by considering 2-level and multilevel heterogeneous WSNs.

III. Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low-Energy Adaptive Clustering Hierarchy is one of the most popular clustering approaches for WSN. It is an application specific architecture. In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster head and others as member nodes. All member nodes transmit their data to their respective CH, and on receiving data from all member nodes the cluster head performs signal processing functions on the data (e.g., data aggregation),and transmits data to the remote BS. Therefore, being a CH node is much more energy intensive than being a member node.

The main objective of leach is to select sensor nodes as cluster heads by rotation. In this way, the energy load of being a cluster head is evenly distributed among the nodes. The operation of LEACH is divided into rounds. Each round begins with a set-up phase followed by steady state phase. In the set-up phase the clusters are organized, while in the steady-state phase data is delivered to the BS. Initially CH is selected, based on the signal energy of nodes. The nodes with higher energy are selected as CH. Each sensor node n generates a random number between 0 and 1 and compares it to a pre-defined threshold T (n). If

random<T (n), the sensor node becomes CH in that round, otherwise it is member node. Where P is the desired percentage of CHs, *r* is the current round, and *G* is the set of nodes that have not been elected as CHs in the last 1/ *P* rounds.
LEACH is a completely distributed approach and requires no global information of network. LEACH can guarantee not only the equal probability of each node as CH, but also relatively balanced energy consumption of the network nodes.
However, there exist a few disadvantages in LEACH as follows:

1) LEACH assumes a homogenous distribution of sensor nodes in given scenario, which is not very realistic
2) Some clusters will be assigned with more number of nodes; this could makes CH nodes run out of energy quickly.
3) CH has the extra burden of performing long range transmission to the distant BS, which results in too much energy consumption.

Various modifications have been made to the LEACH protocol, which form LEACH family, such as TL-LEACH, E-LEACH, M-LEACH, LEACH-C, V-LEACH, etc

Advantages in the LEACH protocol are:

1. It is one of the mostly used hierarchical routing algorithms in sensor networks.
2. LEACH protocol erstwhile divides the total wireless sensor network into many clusters. Any node that act as a CH in present round cannot be selected as the CH again; therefore each node can share the load equally which is imposed on Cluster heads [9].
3. The cluster head node is selected randomly and chance of every node to be selected as cluster head is equally attributable to which energy consumption of whole network is averaged [18]. Thus LEACH will extend the network life cycle.

Problems within the LEACH protocol are:

1) The cluster head node is randomly selected in LEACH protocol [10]. There are some drawbacks attributable to the likelihood of every node to be selected as cluster head is same. After numerous rounds, the node with greater remaining energy and the node with smaller remaining energy have same probability to be chosen as cluster head. If the node which has smaller remaining energy is chosen as cluster head, it'll run out of the energy and die more quickly, due to which network's robustness can be affected and life of the network become short.
2) The standard LEACH Protocol divides clusters randomly, additionally results in uneven distribution of clusters simply [12]. Finally, the divided clusters might not be the simplest or best. As an example some clusters have large number of nodes than others whereas some clusters have fewer nodes. Some cluster heads may be within the relatively central of clusters whereas some clusters heads may be in the edge of clusters far away from members. These phenomena will enhance the energy consumption and make harsh impact on the total performance of the network.
3) In steady state, cluster head usually transmit information to the sink or base station directly. Cluster head that is farther from the sink communicate with the sink directly mostly spend a plenty of energy. Thus it'll crash earlier as a result of it runs out of energy. Particularly in the midst of the enlargement of the dimensions of the network, these effects have an impact on the network life seriously.

IV. Distributed Energy Efficient Clustering Protocol (DEEC)

In 2006, Q. Li, Z. Qingxin and W. Mingwen [21] projected DEEC protocol. DEEC protocol is a cluster based method for multi-level and 2 level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are chosen using the probability based on the ratio between residual energy of every node and the average energy of the network. The era of being cluster-heads for nodes are entirely different according to their initial and residual energy. The nodes with more initial and remaining energy have greater chances of the becoming cluster heads compared to nodes with low energy.

Advantages of DEEC:

1. DEEC doesn't need any universal knowledge of energy at each election round.
2. In contrast to SEP and LEACH, DEEC will perform well in multi-level heterogeneous wireless network.

Disadvantages of DEEC:

Advanced nodes always punish in the DEEC, particularly when their residual energy reduced and when they come in the range of the normal nodes. During this position, the advanced nodes die rapidly than the others.

V. Methodology

Various researches had been done on load balancing technique in WSN (Wireless Sensor Network). The standard algorithm is LEACH which is compared with various developed algorithm. Many routing protocols were also discussed in previous chapters. Increase the lifetime of the nodes and throughput of the network is the main research area in present time.
The main aim of our project is to develop a clustering technique through which the lifetime of the nodes and throughput of the network should be increased.
Network throughput and lifetime can be increased when the energy of the sensor nodes is retained for a long time. To increase the lifetime of the nodes the residual energy of the nodes should be considered. Residual energy includes many factors like nodes weight. We are trying to implement an algorithm including nodes residual energy will definitely increase lifetime and throughput of the network and then compared with standard LEACH algorithm.
This model describes a wireless sensor network that consists of three types of sensor nodes based on their energy levels. These nodes are normal node, intermediate node and advanced node. After formation of network either node becomes the cluster head for current round or the member of cluster head. Clustering is a technique to balance load of network. The clustering schemes have some characteristics. Such characteristics can be associated with the internal structure of the cluster or how it

relates to others. The parameters for cluster head selection are such as initial energy, residual energy, energy consumption rate and average energy of the network.

- In proposed clustering technique firstly, network is formed.
- Then nodes are distributed randomly all over the network and characterized as normal nodes, advanced nodes and intermediate nodes on the basis of energy distribution.
- Now for every round alive and dead node is calculated first.
- Since it is load balancing technique so residual energy and total energy of the network is calculated and we summarized it as Energy Reference Factor.
- Then probability of each kind of node is calculated on the basis of entire energy of the network.
- Then probability of each kind of node is calculated for each round to become cluster head which is based upon residual energy and average energy of the network. It's a major characteristic of a protocol named as DEEC.
- Then the throughput is calculated on the basis of packets send to BS and CH together.
- Our proposed clustering technique is compared with LEACH and DEEC.
- All the calculated graphs of alive nodes, dead nodes, Energy and throughput shows that our proposed algorithm is efficient.

The network consists of all information regarding the nodes and communication medium. So that network formation is started. The network model used in this scheme is based on some assumptions which are listed below.

- N of nodes are distributed in the square area. And Unique ID is assigned to each node.
- Base station is located at certain location.
- Base station and all the nodes are stationary
- All nodes have similar capabilities (processing/communication), but are different in terms of energies in case of heterogeneity.
- Nodes are left unattended after deployment, meaning thereby the battery recharge is not possible.
- There is only one BS located at the center in network, which has a constant power supply; thus, there are no energy, memory, and computation constraints.
- Each node has the ability to aggregate data; as a result several data packets can be compressed as one packet.
- The distance among the nodes can be computed based on the received signal strength.
- Nodes have the capability of controlling the transmission power, according to the distance of receiving nodes and the node failure is only considered due to energy depletion

The energy required for transmitting and receiving 'l' bits over a distances 'd' is calculated using the following equations

$$E_T(k,d) = \begin{cases} E_{elec}\, k + E_{fs}\, kd^2 & d < d_0 \\ E_{elec}\, k + E_{mp}\, kd^4 & d > d_0 \end{cases} \tag{1}$$

$$E_R(k) = E_{R-elec}(k) = E_{elec}\, k \tag{2}$$

Where E_{elec} is energy consumed to transmit or receive a bit, E_{fs} is transmitter amplifier energy for free space, E_{mp} is transmitter amplifier energy for multi-path.

The node residual energy is E_r; and total residual energy is En; and energy reference factor is E_{ref}.

$$E_{ref} = 2 * e^{-(E_r - \frac{En}{n})} \tag{3}$$

Here for the node distribution if node I is subset of G, if this condition is no then Node I is further participate to become CH (Cluster Head) on the basis of energy, but if condition id yes then node is advanced. But advanced node id divided in two nodes that is normal node and intermediate nodes and the energy state of these nodes is defined in equation no (4) and (5) respectively. After calculating the normal node, intermediate node and advanced node we move to find the initial energy of the nodes that depend on battery power of sensor distance of sensor from the communicating object, and the initial energy is calculated by equation (1).

After the network formation the node distribution is stared. In the proposed work for heterogeneity, it consist three types of nodes, known as normal, intermediate node and advanced nodes. The energy of the advanced node is higher than the normal nodes and their number is less than that of the normal nodes due to the increased cost factor. Let N be number of sensor nodes deployed in a monitoring area. Suppose, E_0 is the initial energy of a normal node and m is the fraction of the advanced nodes, which has a α times more energy than a normal node then Initial energy for normal nodes = Eo, and for advanced nodes,

$$Eadv = (1+\alpha). \tag{4}$$

Assume for intermediate nodes,

$$Eint = (1+\mu)\, Eo. \tag{5}$$

We write:

$\mu = \alpha/2$

The probability setting $popt$ has same value. Yet, by introducing of intermediate and advanced nodes, system entire initial energy is increased:

$$n.E_0\,(1-m-b) + n.m.\ E_0\,(1+\alpha) + n.b.\ (1+\mu)E_0 = n.E_0\,(1+ m.\alpha + b.\mu) \tag{6}$$

Where n = number of nodes, m = advanced nodes to total nodes ratio; with energy higher than remaining nodes and b = part of intermediate nodes.

For the probity manner after getting the cluster head, we calculate the alive node which are used during the round or complete cycle. Then calculate the cluster head percentage. Then calculate the Ei and Er by the equation (1) and (3) for the alive node. By introducing the intermediate node and advanced node the initial energy also increased that is shown in equation (6).

The network entire energy is increased by a part of $(1 + m.\alpha + b.\mu)$ and system new epoch must be

$$Popt: (1 + m.\alpha + b.\mu) \quad (7)$$

$$P_{nrm} = P/Popt * E_{ref} \quad (8)$$

$$P_{int} = (P) * (1 + \mu)/Popt * E_{ref} \quad (9)$$

$$P_{adv} = P * (1 + \alpha)/Popt * E_{ref} \quad (10)$$

Where, P_{opt} is the predetermined percentage of clusters. Our approach assigns weights to obtain optimal probability for each type of node. For clustering in our proposed heterogeneous network model, the total increased energy in heterogeneous networks is shown in equation (8), (9) and (10). When we get the knowledge about alive node then Calculate average energy of the network at present round.

Calculate the probability of each node to become CH based on residual energy of node and average energy of network

$$P_{\_nrm} = P_{nrm}*n*(1+\alpha)*E/(n+A)*(Ea); \quad (11)$$

$$P_{\_int} = P_{int}*n*(1+\alpha)*E/(n+A)*(Ea); \quad (12)$$

$$P_{\_adv} = P_{adv}*n*(1+\alpha)*E/(n+A)*(Ea); \quad (13)$$

Where:

A= fraction of energy enhancement of advance nodes

n= total number of nodes ; α = alpha times advance nodes have energy greater than normal nodes

For cluster head selection, the probability is calculated as follows.

$$T(P_{\_nrm}) = \begin{cases} \dfrac{P_{\_nrm}}{1-P_{\_nrm}[r \text{ x } mod(1/P_{\_nrm})]} & if\ P_{\_nrm} \in G' \\ 0 & otherwise \end{cases} \quad (14)$$

Where G' = set of normal nodes

$$T(P_{\_int}) = \begin{cases} \dfrac{P_{\_int}}{1-P_{\_int}[r \text{ x } mod(1/P_{\_int})]} & if\ P_{\_int} \in G'' \\ 0 & otherwise \end{cases} \quad (15)$$

Where G''= set of intermediate nodes

$$T(P_{\_adv}) = \begin{cases} \dfrac{P_{\_adv}}{1-P_{\_adv}[r \text{ x } mod(1/P_{\_adv})]} & if\ P_{\_adv} \in G''' \\ 0 & otherwise \end{cases} \quad (16)$$

Where G'''= set of advanced nodes

Where G'; $G''$and G''' are set of normal, intermediate, and advance nodes that have not become cluster heads within last rounds. We have evaluated the weighted election probabilities and thresholds for effective cluster head selection in order to increase the network lifetime and throughput for the proposed algorithm. Now, in the next section, we will discuss the simulation results of our heterogeneous network model and compare with the existing network models like LEECH and DEEC.

VI. RESULT AND ANALYSIS

The performance of LEECH, DEEC and proposed algorithm and compare the performance of proposed algorithm with that of the LEECH and DEEC. In our simulations, we consider random deployment of 200 sensor nodes in a square field of dimension 100 M x 100 M. The results of the existing and proposed algorithm heterogonous network models are compared in terms of rounds, the network lifetime and throughput.

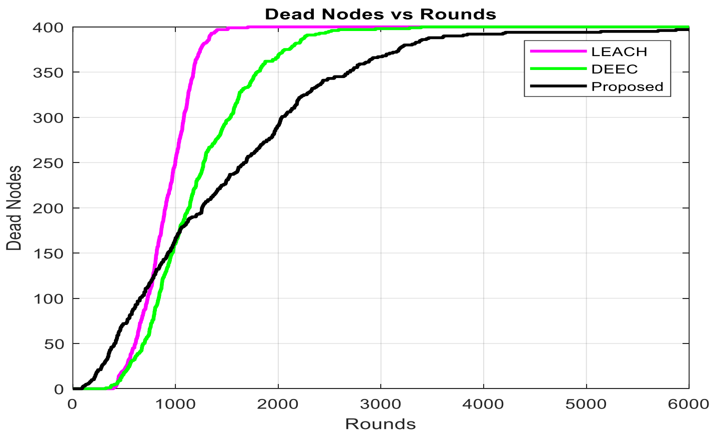

Figure 1: Number of dead sensor nodes vs. number of rounds

Figure 1 shows that proposed model provides longer lifetime as compared to the LEECH and DEEC because in proposed model the nodes die slowly as compared to the LEECH and DEEC. So that in 4000 rounds for the proposed model still nearly 10 nodes have the energy to perform or 10nodes are still alive but for the LEECH all nodes are dead till only 2500 rounds and in DEEC all nodes are dead till 2600 rounds.

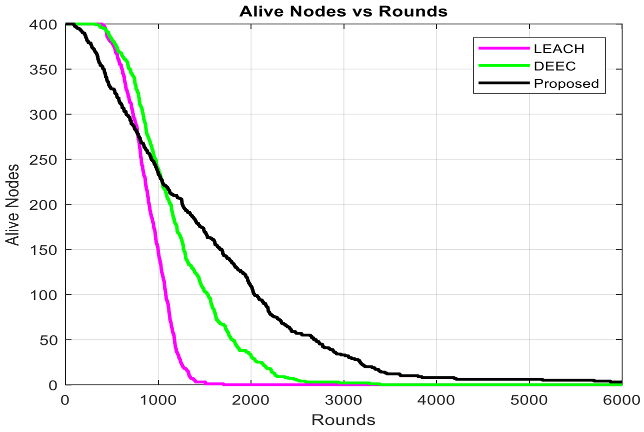

Figure 2: Number of alive sensor nodes vs. number of rounds

Figure 2 show the number of alive nodes with respect to the number of rounds for the LEECH, DEEC and the proposed model. We have included the graphs for LEECH and DEEC in order to make a comparative study of heterogeneity. This is the completely inverse plot of figure 2. In the beginning all 200 nodes are alive, but the proposed model till all 4000 rounds nearly 10 nodes are alive compare to LECCH and DEEC. In the LEECH nodes are alive till only 1500 round then all the nodes are dead. In DEEC the nodes are alive till 2500 round only.

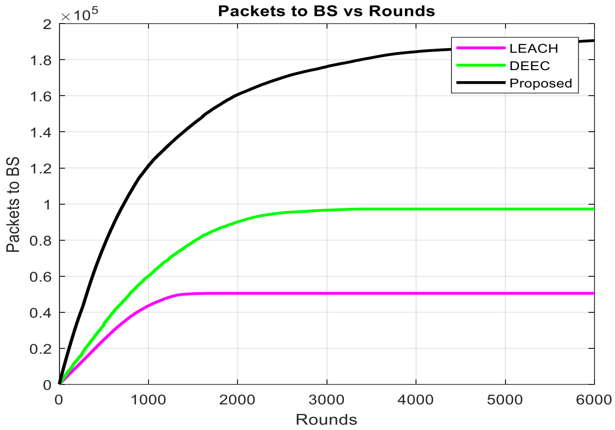

Figure 3: Packets to the base station vs. number of rounds

Figure 3 shows the number of packet transmitted to the base station with respect to the number of rounds for LEECH, DEEC and proposed model. This measure refers to the amount of information collected by the network from the sensor field and sent to the base station. The proposed model sends maximum number of packets to the base station as compared to the LEECH and DEEC.

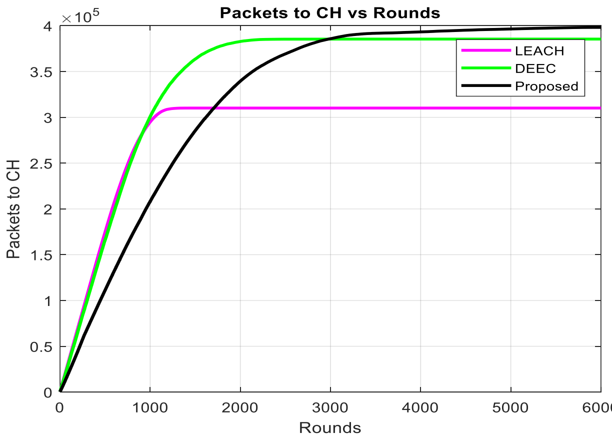

Figure 4: Packets to the Cluster head vs. number of rounds

The figure 4 shows packets send to cluster head with respect to the rounds. Here shows the graph for proposed model, LEACH and DEEC. The information send by the proposed model is much high for all the rounds but in LEACH and DEEC is less.

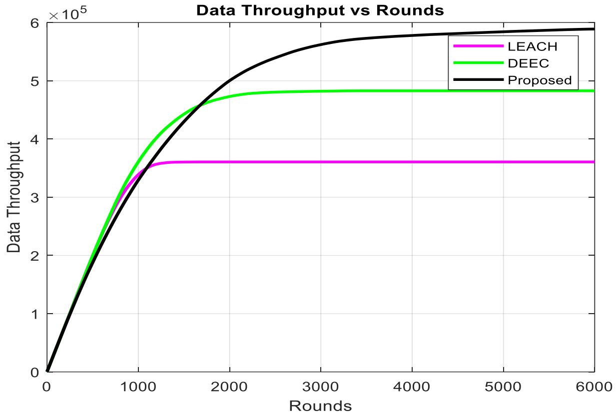

Figure 5: Throughput vs. number of rounds

The figure 5 shows throughput ((size of packets x delivered number of data packets)/ time) for the proposed model, LEACH and DEEC. Here it is shown that the throughput is better for the proposed model compare to LEACH and DEEC.

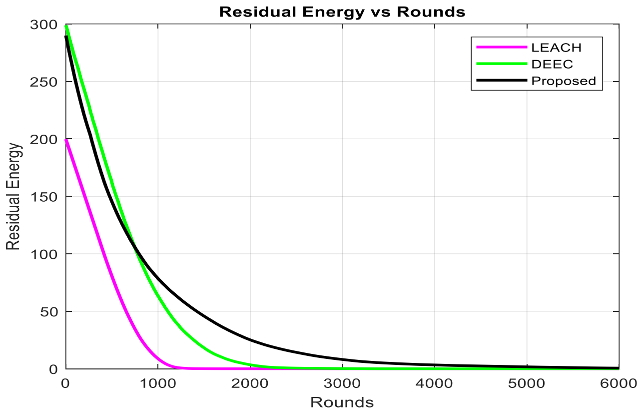

Figure 6: Average residual energy vs. number of rounds

Figure 6 shows the average residual energy with respect to rounds. This is depends on the battery life of the sensors. For the proposed model the energy is at high level and till all the rounds energy is left due to the alive nodes, but in LEACH energy is lost till 1500 rounds and in DEEC energy is lost till 2500 rounds.

VII. CONCLUSION

In this paper, an approach for load balancing in the wireless sensor network is proposed. Algorithms for cluster head selection, cluster formation, intra cluster communication and inter cluster communication in wireless sensor network are proposed. The performance of the algorithm is compared with the original LEACH algorithm DEEC algorithm with respect to the number of rounds and the dead nodes using the parameter like energy dissipation in each round per node. The results demonstrate that the proposed approach is effective in prolonging the network lifetime. The number of dead nodes and number of alive nodes that shows the energy efficiency of the proposed model that's why some nodes are alive till the last round. And the throughput of the proposed model that is more information can be transferred with this proposed model. The average energy of the model that is energy is also left till the last rounds. So that the proposed model have better life time and throughput with compared to LEACH and DEEC.

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