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Balanced Energy Efficient Clustering (BEEC) method for Heterogeneous Wireless Sensor Network using NS2

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ABSTRACT

Background/Objectives: This article presents a new method to improve the energy efficiency of the network through balanced method and stable clustering. **Methods/Analysis:** we propose a new method for heterogeneous wireless sensor network to improve the energy efficiency and balancing method for stable clustering. We compared the energy utilization with the previous LEACH and EEHRP protocols and obtained improved output result for throughput between the intervals/rounds. Compared to LEACH and EEHRP the packet delivery ratio is much higher in the proposed BEEC protocol. **Findings:** One of the methods to minimize the power utilization and improve the network lifetime of a Wireless Sensor Network is clustering. Usually Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is used to increase the network lifetime and minimize the energy utilization in WSN through clustering using homogeneous type of WSN. Sensor nodes with different characteristics are used in heterogeneous WSN. These nodes differ in their size of memory, transmission range and level of energy. There are various methods suggested already for heterogeneous WSNs. In this paper, we propose a novel approach namely Balanced Energy Efficient Clustering (BEEC) method to achieve energy efficient and minimum CH (Cluster Head) communication to reach the BS (Base Station). This causes less delay and reduces unnecessary transmission so that minimum energy is consumed. This method uses various power limit sensors to maintain stable cluster and minimize hop count using network division method and also elect CH in each cluster to transmit the data to reach BS. High energy nodes are considered as CHs which are nearer to the BS and low energy nodes are considered as leaf nodes. This will balance the energy and can achieve stable clustering. This proposed method is used for multi-hop heterogeneous WSN to enhance the lifetime, to improve the energy efficiency and to balance the energy consumption in WSN. The experimental results show the improvements obtained using the proposed method. **Applications/Improvements:** This method can be useful to improve the stability of the network, throughput, decreases delay and increase the network lifetime by using this energy efficient method.

Keywords: LEACH protocol, Base station, Cluster Head, Member nodes, clustering, topology, Network lifetime, Energy efficiency.

1. INTRODUCTION

Current scientific improvements in hardware and communication technology allow the growth of small sensors with restricted signal processing and wireless communication [1]. Normally several hundreds of unattended WSN nodes in the sensing field, which are randomly deployed spatially.WSN applications for many useful regions, include human medical care, inaccessible region sensing, military applications etc. Collecting sensitive medical data from human body is more critical when using WSN devices. Electricity grid, streetlights and water municipals are some of the few examples for utilities. Cost effective methods are used in WSN to gather medical data to improve the power utilization and efficient resource management in the network. Some of the examples for inaccessible region sensing applications are atmospheric sensing, infrastructure sensing for specific location and regions, industrial machinery sensing and event sensing. WSN nodes are tiny and working with low power backup. There is no other option to remove or renew the

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backup power of sensors when the sensors are deployed in a harsh environment. The energy inefficiency and instability of the network are the problems in WSN. At present the best way to decrease the power utilization and improve the lifetime of the WSN is to use the LEACH protocol.

LEACH is a clustering protocol in which WSN is split into many clusters and cluster heads (CH) are chosen in its every regular round. The member nodes within the cluster transfer sensed information to their CHs and the CHs do the aggregation and compression process for the received information and send the processed information to the sink nodes (Base Station) [2], [3]. LEACH uses a round to elect a CH. There is multiple numbers of rounds used to conclude whether a node will become a CH in this round. The election process is based on stochastic algorithm. LEACH assumes that each node in the network has enough radio power to communicate with the BS or closest CH. Already elected CH node should wait for its turn until the other existing nodes to become CH. This CH cannot become cluster head once again for *P* rounds, where *P* is the desired percentage of CHs. 1/*P* is the probability of a node to become CH. Thereafter, every node in the network has a chance of becoming a CH again. Non-elected member nodes join with nearby clusters and choose their CHs based on the shortest distances. Each CH then prepares a schedule for each member node in its own cluster to transmit its data. All member nodes that send information with their corresponding CH in a TDMA fashion, according to the schedule prepared by the CH. They consume very less power to send the information to reach the CH and only need to keep their transmitters on during their time slot. In cluster formation, a node generates and selects a number between 0 and 1. This number is compared with the threshold value T (n). If the number is <T (n), then the node turns out to be a CH for the present round. In each round, new CHs are chosen. The threshold T (n) is given by the following equation (1).

$$(n) = \begin{cases} \dfrac{p_{Opt}}{1 - p^*_{Opt}\left(r \bmod \dfrac{1}{p_{Opt}}\right)} & if\ n \in G \\ 0 & \text{If } n \in G \end{cases}$$

where P_{opt} is the required percentage of CHs among all nodes, r is the current round count; G is the number of non-CH sensor nodes in the last 1/Popt rounds. In this multiple 1/Popt rounds, all available nodes will be able to be a CH using this T (n).

In this heterogeneous WSN more than two types of sensor nodes are used with different characteristics than the other nodes. These nodes characteristics are different because of their cost values. The proposed BEEC method is a new energy efficient cluster based protocol, specific for heterogeneous WSN. BEEC proposes a heterogeneous based multi-hop LEACH protocol by using the primary available energy of the nodes and the average space length of the nodes from the BS. The simulation result proves that it is more capable than LEACH and EEHRP. The remaining of this paper is organised as follows. Section 2 describes the related works. In section 3 proposed Network model and energy dissipation model are discussed, Section 4 deals with BEEC protocol. Section 5 shows the simulation results and last Section 6 concludes the paper.

2. RELATED WORKS

Homogeneous and heterogeneous are the two types of clustering schemes in WSN. Same types of sensor nodes with same amount of energy are available in homogeneous clustering and more than two types of sensor nodes with different amount of energy are available in heterogeneous schemes. It is a difficult task to design a cluster based routing method for heterogeneous WSN. Hence many clustering methods are proposed for heterogeneous WSN. Some of the homogeneous clustering methods are LEACH [4], HEED [6] and PEGASIS [8].

CHs will consume high power because of doing more tasks, when compared to the non-CH nodes within the cluster, like collecting information from the member nodes, do the aggregation and then transferring the information to the BS. LEACH protocol distributes the energy and workload task to CH and to nodes available within the cluster by periodic rotation basis. LEACH protocol is best for homogeneous WSN but its functionality is reduced in the heterogeneous WSN [7].

By the use of available power each node involves the CH election process. Another important homogeneous network based protocol is Hybrid Energy Efficient Distributed protocol (HEED). In this heterogeneous WSN lower power sensor, nodes may have larger opportunity in election process than the higher power nodes. In another protocol, the BS or Sensor nodes compute the chain link form created by the protocol named PEGASIS [8].

To balance the load between the unequal clusters in the network to extend the lifetime of the network is improved by using Load Balanced Clustering Algorithm (LBCA) [9]. In LBCA, the nodes are grouped into clusters such that network is controlled by the gateway. This extends the performance of the network and improves the communication between heterogeneous sensors in the network.

In order to improve Network lifetime, Energy efficiency and Load balance in WSN, a Cluster Arrangement Energy Efficient Routing Protocol CAERP [10] is proposed. It mainly includes proficient way of node clustering and distributed multi-hop routing. In the clustering part of CAERP, they introduce an un-even clustering mechanism. CH which are closer to the BS have smaller cluster size than those farther from BS, so they can save some amount of energy in the time of inter-cluster data communication.

A new protocol for heterogeneous concerned WSN is proposed in SEP protocol. This protocol has two stages of sensor nodes and chooses its CH from its initial energy level [7]. CH is elected on the basis of probability ratio of existing available power of sensor nodes and average power of the network in DEEC [11] algorithm.

In paper [12], comparisons of more available and recent protocols are examined. In EEPSC [12], the network is split into multiple distance-based stable fixed size clusters and use CHs to circulate the load amongst the available excessive power nodes. Back up CHs are used to increase the network lifetime used in EEHCA [13]. For heterogeneous networks CH are selected using weighted election probabilities in EDGA [14]. Selection of Highest available energy path and heterogeneous based network model to transfer the data are explained in EECDA [15]. To increase the lifetime of the network authors in [16] proposed a novel distance based method (DB-SEP) for CH selection for Heterogeneous WSN. A new deployment technique for heterogeneous WSN is introduced paper [17]. Both deployment and topology control based on irregular sensor model proposed in [18]. Energy balanced algorithm of LEACH protocol in [19] described and finally a new cluster-based optimization algorithm EEHRP [20] is set up which optimizes clustering process, to successfully avoid the less-energy and distance nodes as the CH.

3. NETWORK MODEL

3.1. Heterogeneous cluster based mobile network and assumptions made.

This section illustrates the heterogeneous WSN model used in the paper. Heterogeneous WSN model includes one hundred number of sensor nodes which are arbitrarily located in a 100 X 100 square meters sensing region as shown in Figure 1.

The following assumptions are made about the heterogeneous WSN model and sensor details are as follows:

- BS is placed in the center of the sensor field.
- BS is motionless after placed. But other sensor nodes are mobile nodes.
- Each node sharing their energy level, ID and Distance to the BS.

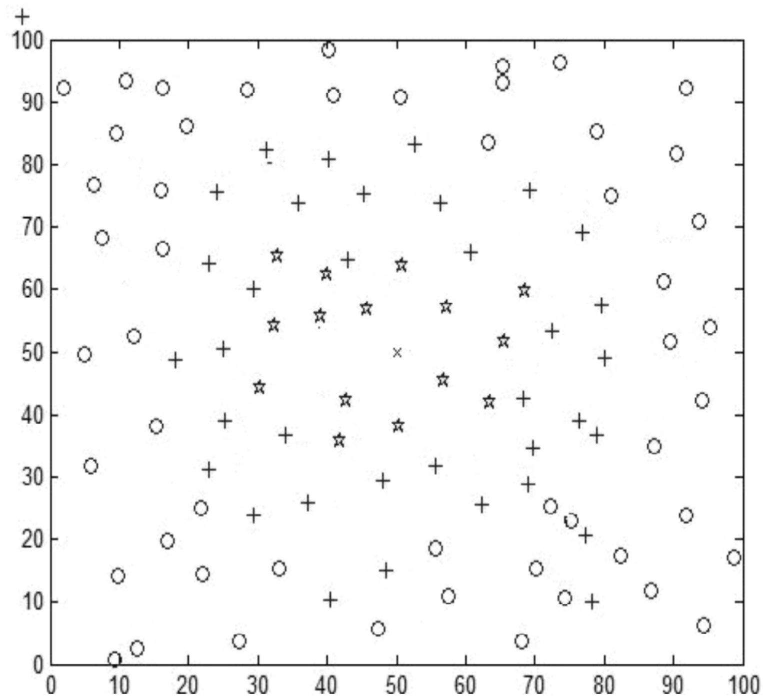

Figure 1: Sensor node deployment

- There are three categories of nodes. Each category of nodes. All nodes are of the same type and have the same characteristics.
- Nodes continuously monitor the deployed region and they can transfer the collected data to the BS or to other region CH.
- Data aggregation is done by the CH in each cluster.
- Knowledge of position value is known by any of the sensor nodes within the region.
- Each region has same type of sensor nodes with same initial power.
- Each node has a probability of p to becoming the CH in its first round.
- Distance and Data size both decide the transmission and receiving energy levels.
- Each node must know their neighbor information and the number of neighbors.
- Percentage ratio of higher energy nodes are less when compared to other nodes.
- Because of harsh ecological condition it is not possible to recharge the batteries of the nodes.

As illustrated in [7] power consumed by the CH in a round is given by (2)

$$E_{CH} = \frac{(n)}{k} LE_{ele} + \frac{n}{k} LE_{DA} + LE_{elec} + L\varepsilon_{fs}\, d^2{}_{toBS} \quad (2)$$

Where k is the count of clusters, L is the number of packet bit over a distance d, E_{DA} is the data aggregation, d_{toBS} is the average distance between the CH and the BS, E_{elec} is the power consumed per bit to run the transmitter or receiver circuit and ε_{fs} is the power consumed per bit in the channel when $d \leq do$. The power dissipated by a non-CH node is given by (3)

$$d^2{}_{BS} = \sqrt[4]{x^2 + y^2} * {}^{1}\!/_{A} = 0.765 * {}^{M}\!/_{2} \quad (3)$$

Available power level of Non-CH node is given by

$$E_{NCH} = L * (E_{elec} + \varepsilon_{fs} * d^2{}_{ch}) \quad (4)$$

In WSN, CHs are selected from all the nodes based on certain parameters. All non-CH nodes choose the nearest CH to form clusters. These nodes forward their information to the CH and CH forward these aggregated data to the base station. Let n nodes are evenly scattered within an region of M · M. It is assumed that there exist only k clusters available in the topology. Thus, on an average there will be n / k nodes per cluster. In a cluster, there will be only one CH and many (n / k 1) non-CHs.

Energy consumed by a cluster can be found out by calculating the energy consumed by non-CH in transferring information to the CH and the power consumed by the CH to send the aggregated information to the BS. Power consumed by one non-CH node in transferring K bits to the CH in a cluster is given as follows:

$$E_{non-CH} = k.E_{elec} + E_{amp}(k,d) \tag{5}$$

$$E_{CH} = \left(\frac{n}{k} - 1\right) . \; k \, . E_{elec} + \frac{n}{k} \, . k \, . E_{DA} + E_{TX_{toBS}}(k,d) \tag{6}$$

$$d^2{}_{ch} = \int\sqrt{(x^2 + y^2)} * \rho(x,y) dx \, dy = M^2/2\pi k \tag{7}$$

where d_{CH} is the distance between non-CH node and its CH node, (8) [10]. ρ (x , y) is the node deployment in x and y positions.M^2 is the region for sensing field.

In each round some amount of power is dissipated in a cluster. Equation (8) gives the total power consumption.

$$E_{Total} = E_{CH} + E_{NCH} \tag{8}$$

where E_{CH} is energy dissipated in CH and E_{NCH} is Energy dissipated in Non CH. By substituting (2) and (3) in (5), we can find out the energy dissipated during a round which is given by (9) as shown below

$$E_{Total} = L(2nE_{elec} + nE_{DA} + \varepsilon_{fs}(kd_{toBS}{}^2 + nd_{CH}^2)) \tag{9}$$

Optimal number of clusters can be obtained by differentiating E_{Total} with respect to k and equating to zero. From which we obtain

$$k_{opt} = \frac{\sqrt{\varepsilon_{fs}}}{\sqrt{\varepsilon_{mp}}} \frac{\sqrt{n}}{\sqrt{2\pi}} \frac{M}{d^2{}_{BS}} \tag{10}$$

According to [7], the average distance from CH to the BS is given by

$$d_{toBS} = 0.765 \frac{M}{2} \tag{11}$$

The optimal probability (p_{opt}) of a node to become CH is given by (12)

$$P_{opt} = \frac{1}{0.765} \sqrt{\frac{n}{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{12}$$

Figure 1. 100 sensor nodes arbitrarily located in the network (o Regular Node, + Progressive Node, * Magnificent Node, x BS)

3.2. Energy Computation Model

This paper uses the energy dissipation /computational model as described in [4]. There are two channeling models free space (d^2 power loss) and the multipath fading (d^4 power loss) used depending upon the distances between the transmitter and receiver. Free space model is used if the distance is less than a particular threshold value; otherwise a multipath loss model is used. The amount of power required to transmit L bit packet over a distance d is given by (13).

$$E_{TX}(L,d) = \begin{cases} L * E_{elec} + L * \mathcal{E}_{fs} * d^2 & if \; d \le d_{o'} \\ L * E_{elec} + L * \mathcal{E}_{mp} * d^4 & if d \ge d_{o'} \end{cases} \tag{13}$$

Where E_{elec} is the electrical power dissipated to run the transmitter or receiver. The parameters ε_{mp} and ε_{fs} are the amounts of energies dissipated per bit in the radio frequency amplifier according to the distance d_0 which is given by

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{14}$$

For receiving an L bit message, the radio expends the power and is given by

$$E_{RX}(L) = L * E_{elec} \tag{15}$$

4. BALANCED ENERGY EFFICIENT CLUSTERING (BEEC) PROTOCOL

4.1. Network Topology and Deployment

The proposed WSN network consists of three different types of sensor nodes (i.e. Regular R, Progressive P and Magnificent M, refer to Fig. 1) which are deployed arbitrarily in the sensing region. The complete sensing region is divided into three concentric circle regions called domains and nodes are arranged in a hierarchical manner. The network uses variable number of sensor nodes in each cluster. The Region-1, which is closer to the BS, consists of high-energy nodes (M nodes), Region-2, which is in the middle, consists of medium energy nodes (P nodes) and lastly Region-3 consists of low energy nodes (R nodes).

This three level hierarchy will limit the number of hops to send the information from the member node in the third region to the BS in a multi-hop manner. So, the power utilization is controlled. Due to the mobility of sensor nodes, they may change their positions within their respective regions. Route to deliver the sensed data to the BS or CH is not permanent due to the mobile nature of sensor nodes. It depends on the environmental network conditions. Our region-based concept chooses previous region node as next hop to reach the BS or CH. The route level information is updated, while clustering network is established.

4.2. Cluster creation

In this proposed model, clusters are created similar to LEACH protocol. Initially in each cluster the CH selection process is random. In the cluster creation process within the first region clusters are created with almost the same type of sensor nodes. In the first region M nodes are available. A random M node is elected as CH. This elected CH node broadcasts this information to all other nodes. In this region cluster with highest energy node becomes the CH in the next round. It continues its operation without any change until the next CH selection is made in the next round.

The responsibility of the first region CH is to collect information from its own member nodes, aggregate that information and forward that information to the BS. The second responsibility is to forward the received information from the second and third regions CHs to the BS. These M nodes consume more power to do the additional task. The time durations between the rounds in the first region clusters are long.

In the second region, only P nodes are available. The first responsibility of second region CH is to collect information from its member nodes, aggregate that information and forward the information to the first region CH. The second responsibility is to forward the received information from the third region. The time duration between the rounds in the second region, clusters are moderate.

In the third region R nodes are available. The only responsibility of this region CH is to collect information from its member nodes, aggregates the collected information and forwards the information to the second region CH. Compared to other region CHs third region CH has very less responsibility. It consumes less power when compared to other region CHs. CH closer to the BS always consumes more power as it has to handle more information. The time durations between the rounds in the third region clusters are short. This arrangement will increase the lifetime of the network and avoids the black hole concept near the BS.

In this proposed method, the number of cluster formation is not limited. The hop count to transfer information to the BS is limited. So, the energy consumption of each cluster is less. However, first region CHs consumes more power, second region CHs medium power and the third region CHs less power. The average power consumption of overall network is almost balanced because of this arrangement. The number of hop counts is minimized because of limited regions. The number of sensor nodes within the cluster is also not limited. This type of network will support all the three data delivery models (Event Driven, Query Driven and Continuous Delivery).

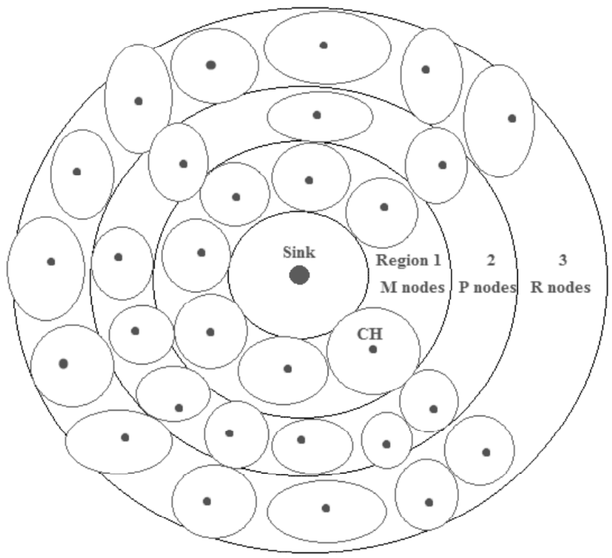

Figure 2: Cluster creation topology and deployment

Each node knows its location information. The sensor nodes used in the WSN are of mobile nodes and their movements are restricted to a particular region. These sensor nodes can share their energy levels, IDs and Distances to the BS. Sensor nodes within are particular region know their neighbor information and the number of neighbors. Therefore, each node knows its cluster, CH and the distance between CH and sensor node. Routing is done in a multi-hop fashion. The routing update is done by the CH in its CH election time. The CH knows the exact route between the CH and BS. This route is limited at the maximum of only two hops to reach BS. This will decrease the power utilization of the network. Normally, the node very nearer to the BS always consumes more energy to transfer more information to the BS. Hence, using homogeneous sensor nodes in WSN black hole are created near BS. This black hole concept is avoided by using the proposed heterogeneous method. This balanced energy distribution method improves the energy efficiency of the network and prolongs the network lifetime.

Let m be the fraction of high-energy M nodes among R nodes and m_0 is the fraction of M nodes among P nodes [13]. Let us assume that initial energy of the R node is $E_{0.}$ The initial energy each of the progressive and magnificent nodes are E_0 (1+ α) and E_0 (1+ β) where α, β means that progressive and magnificent nodes have α and β times more energy than the normal nodes. The total initial energy of the heterogeneous network is given by:

$$E_T{=}E_0{}^{*}\{(1-m)+m*\big((1-m_0)*(1+\alpha)+m_0*(1+\beta)\big\}=n^{*}E_0*(1+m^{*}(\alpha-m_0{}^{*}\,(\alpha-\beta))) \quad (16)$$

Progressive and Magnificent nodes have α and β times high energy than the Regular nodes. Progressive and magnificent nodes have more chance to become CHs than Regular nodes. The receiving power of sensor node is normally 0.01 Joules and transmission power is 0.02 Joules. Thus the system has (1+ α. (m - m0) + m_0 . β) times more energy due to heterogeneous nodes.

Initial energy of each progressive and magnificent node is

$E_0 \times (1 + \alpha)$ and $E_0 \times (1 + \beta)$ respectively,

Optimum power of each sensor node is given by

$$(1/P_{opt}) \times (1 + m \times (\alpha - m_o \times (\alpha - \beta)))$$

4.3. Calculating the Probabilities

The Regular, Progressive and Magnificent nodes weighted probabilities are

$$P_R = \frac{P_{opt}}{1+\alpha\,(m-m_0)+\beta\,m_0} \tag{17}$$

4.4. Calculating the Distance

The energy utilization is high when the distance between the transmitter and receiver is more to transfer the information. If the distance is less, then the power utilization of the sensor node will be less. The power utilization of transmitter to the receiver is proportional to the square of the distance. There is more number of considerations to become the CH to the sensor nodes, which are very close to the BS, and longer distance nodes have less number of chances to become CH. At the first time once sensor nodes are deployed in the sensing region, the BS node sends the initial request signal to the network to collect all information. Based on the signal strength each node calculates its distance from the BS. Let Di is the distance between node Si and the base station. The average distance D_{avg} [14] of the nodes can be calculated by

$$D_{avg} = \frac{1}{n}\sum_i^n D_i \tag{18}$$

According to [14] the Value of Davg can be approximated as

$$D_{avg} \simeq d_{TOCH} + d_{TOBS} \tag{19}$$

where d_{TOCH} is the average distance between the node and the associate CH. D_{toBS} is the average distance between the CH and the BS.

5. SIMULATION RESULTS

The proposed BEEC protocol is compared with LEACH and EEHRP. For evaluating the performance we have selected 100 x 100 square meters deployment region with 100 sensor nodes as shown in Fig.1.BS node is situated in the center of the sensor region.

The following symbols are used to identify the sensor nodes. We identify the R nodes by using the symbol (o), P notes with (+), M nodes by (*) and the BS node by (x).

The parameters used for the simulations are given below

1. The performance metrics used for evaluating the protocols are
   - (i) Network Lifetime: this is the time interval from the start of the operation till the last node dies.
   - (ii) Average Energy consumption: the total amount of energy consumed in a process or system, or by the network.
   - (iii) Stability Period: this is the time period between the first operation starts and the first node dead in the network.
   - (iv) Packet Delivery ratio: The ratio of packets that are successfully delivered to a destination compared to the number of packets that have been sent out by the sender
   - (v) Throughput: Total number of packets sent to the Base station with in the specific period of time.

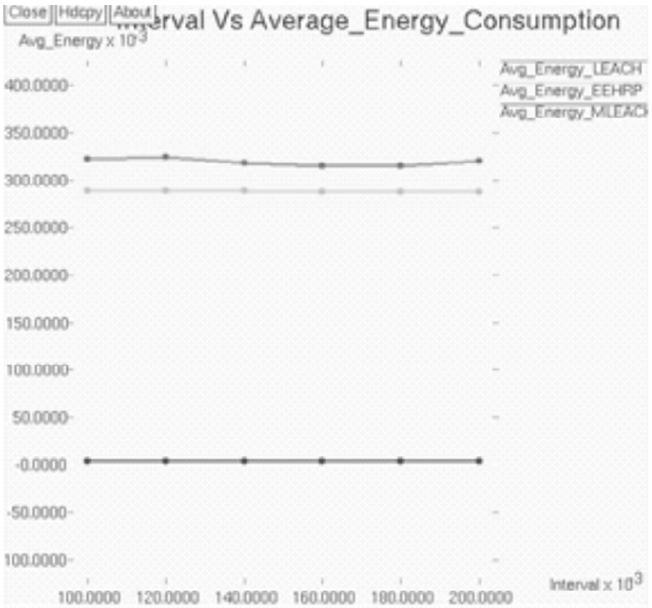

Figure 3: Average Energy Consumption in the WSN

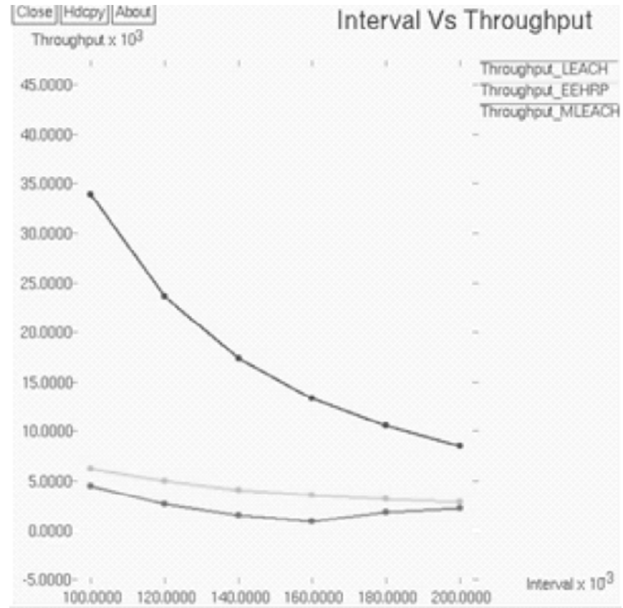

Figure 4: Output Result for throughput between the interval / rounds

The above figure is output result obtained for energy utilization in the WSN. Simulation result shows that the proposed BEEC protocol decreases the power utilization of CH and other member nodes. The energy utilization of the network is almost balanced by proper selection of CH in each round, which will enhance the lifetime of the clusters. So the whole network lifetime is increased.

The above figure shows the output result for throughput between the intervals/rounds. Compared to LEACH and EEHRP the packet delivery ratio is much higher in the proposed BEEC protocol. Hence the increased the throughput performance of the WSN. The delivery ratio is almost 30 to 40 percent increased due to limited number of hop counts to deliver the data packets to the BS node. Unlimited sizes of the cluster is also one of the reason for the improved the packet delivery ratio and hence the improved throughput.

6. CONCLUSION

A novel approach Balanced Energy Efficient Clustering (BEEC) method is proposed to achieve energy efficient and minimum CH communication to reach the BS. The proposed BEEC protocol uses three different types of nodes in heterogeneous networks enhancing the full potential of heterogeneity. To increase the energy efficiency of the network BEEC introduces a new probability scheme in the system so that the nodes, which are nearer to the base station, have the higher chances to become the CH. This has caused less delay and reduces unnecessary transmission. So that minimum energy is consumed. Various power limit sensors have been used to maintain stable cluster and minimize hop-count using network division method and elects CH in each division to transmit the data to reach BS. High-energy nodes are closer to the BS are considered as CHs and low energy nodes are considered as leaf nodes. This has balanced the energy and is able to achieve stable clustering. This proposed method has been used for multi-hop heterogeneous WSN to increase the lifetime, to improve the energy efficiency and balance the energy consumption in WSN. The experimental results show that the proposed method is energy efficient and is of high throughput capability and hence the lifetime of the network is increased.

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