

Implementation of LEACH, Hetero-LEACH, SEP and EEHC Protocols using MATLAB in Wireless Sensor Network

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Abstract: In this paper we have proposed different models and implementation of different energy efficiency protocols in Wireless Sensor Networks (WSN). We have analyzed as well as optimized the performance of the heterogeneous LEACH protocol for different parameters. In this paper, the proposed models have been applied on the n-node network and the performance of the same has been calculated and shown with the help of results. Analysis of heterogeneous LEACH simulation network is done. Performance of a clustering protocol is also determined by duration of stable and unstable period. Network Lifetime of Heterogeneous LEACH Protocol for $\epsilon_{ft1}=1$ is much stable. Result prove that energy consumption remains almost same until the death of first node and after that it starts decreasing. In SEP cluster head of advance node is frequent become the cluster head than the normal node. Instability period of SEP has reduced from that in heterogeneous LEACH and there is also improvement in stability period. With decrease in number of nodes, packets transmission reduces. Throughput is improved as; consumption per round in SEP. energy consumption has reduced in case of SEP than that in LEACH and Heterogeneous LEACH.

Keywords: LEACH, SEP, WSN

1. INTRODUCTION

A heterogeneous wireless sensor network consists of a large number of normal nodes and some heterogeneous nodes. The main task of normal nodes is sensing and issuing data report. However, heterogeneous nodes have advanced energy capacity or communication capability. In comparison with normal nodes, these nodes may be configured with more memory and more powerful microprocessor/microcontroller. There are three types of resource heterogeneity [1] in WSNs: computational, link and energy heterogeneity. The main impact of the heterogeneous WSNs [18] is increasing network lifetime, reliability in data transmission and reducing latency. WSNs suffer from several limitations related to network resources, among which energy is the most important resource because it determines the lifetime of the sensor network. Sensor nodes are usually powered through batteries, which must be recharge or replaced when depleted. But sensor nodes are usually deployed in hostile environments where it is impossible to access them and replace their batteries. For these non-rechargeable batteries, a sensor node should be able to operate until its mission time has passed or the battery can be replaced. The length of the

mission time depends on the application type, for example, sensor in a battlefield may only be needed for few hours or few days while glacial movements monitoring may need sensors that can operate for several years. As a consequence, the most important design challenge for a wireless sensor network is energy efficiency. This requirement pervades every aspect of sensor node and network design. For instance, the choices made at physical layer may affect the energy consumption of the entire device and the design of higher level protocols. The MAC layer is accountable for providing sensor nodes access to the wireless channel. Some MAC approaches are contention based, that is, nodes can access the medium at any time, leading to collision among several nodes. Drawbacks of such approaches include energy overheads and delays brought by the collisions and recovery mechanisms and also sensor nodes may have to listen to the medium all the times to ensure that no transmission is missed. To overcome this problem contention-free MAC protocols can be used in which access to the medium is regulated, eliminating collisions and allowing the sensor nodes to shut down their radios when no communications are expected.

The main role of cluster head is to provide the communication between different sensor nodes and the base station efficiently. Another way is the prolong lifetime of network, to insert a percentage of heterogeneous nodes. Heterogeneous sensor network consists of different ability sensor nodes, like different computing power and sensing range. They are very much useful in real deployments because they are more close to real life situations.

there are many existing techniques of clustering exist such as LEACH which is consider to be homogeneous sensor networks where all the sensor nodes are designed with the same battery energy. The energy saving schemes when applied to heterogeneous wireless sensor network do not perform efficiently. Thus, Energy clustering protocols must be designed for the heterogeneous wireless sensor networks. According to the way that data is collected, WSNs can be classified into two types: homogeneous and heterogeneous sensor networks.

A homogeneous network consists of sink and sensor nodes equipped with equal capabilities, like computational energy and storage capacity. Data gathering and

dissemination in homogeneous networks is done using flat and hierarchical [19] topologies

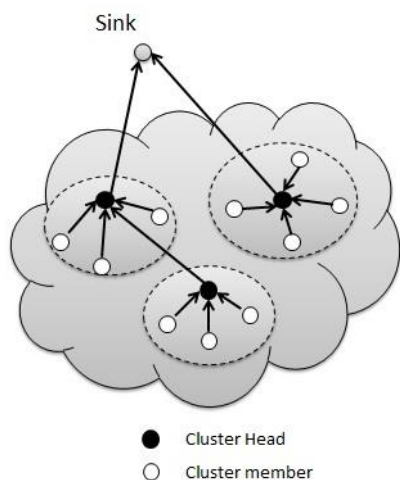


Figure 1.1: Hierarchical Network Architecture

A heterogeneous sensor network consists of sink which may be fixed or mobile, normal sensor nodes and advanced sensor nodes. Advanced sensor nodes are the nodes with advances embedded processing and communication capabilities as compared to normal nodes. Figure 1.2 shows the heterogeneous sensor network architecture. Since data fusion is done at cluster heads, so energy consumption at cluster heads will be more than that on cluster members. So advance nodes with higher energy can be elected as cluster heads to prolong network lifetime.

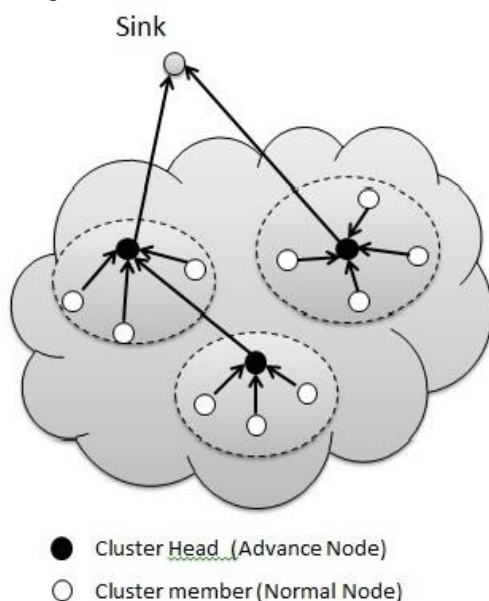


Figure 1.2: Heterogeneous Network Architecture

2. MOTIVATION OF RESEARCH WORK

In the past years, many algorithms have been proposed for various protocols in the wireless sensor networks. According to the survey, A heterogeneous wireless sensor network consists of a large number of normal nodes and some

heterogeneous nodes. The main task of normal nodes is sensing and issuing data report. A wide range of applications. network for Heterogeneous LEACH protocol. Loscri et.al [20] had proposed another LEACH based protocol which used two level hierarchies. In this, instead of one cluster head, two cluster heads were elected, primary and secondary. Cluster head collects data from other cluster member as in LEACH, but instead of transferring data directly to the base station, it used one of the cluster heads lying between the cluster head and the base station as a relay station. Data was sent from each sensor node to its secondary cluster head. Then aggregated data from secondary cluster head were sent to its primary cluster head. Transmit distance for nodes had been reduced, so less energy was consumed and data aggregation could be done both on primary and secondary levels to further improve the energy efficiency. Qing et.al [2] had described another protocol for heterogeneous wireless sensor networks. It is a distributed energy efficient clustering protocol based on clustering. Cluster heads were elected on the basis of probability based on ratio between residual energy of each node and average energy of the network. The epochs of being CH for each node was different depending upon its initial and residual energy. The nodes with high initial energy had more chances to become CHs than the nodes with less initial energy. DEEC had prolonged network lifetime as well as the stability period.

3. ENERGY EFFICIENT CLUSTERING PROTOCOLS

3.1 EEHC

Energy Efficient Hierarchical Clustering (EEHC) [3] is a randomized, distributed clustering algorithm that prolongs the network lifetime. In this algorithm sensor nodes are organized into clusters with a hierarchy of cluster heads as shown in figure 3.10. the CHs collect the information from the nodes within their clusters and send the aggregated data to the BS through the hierarchy. This algorithm is based on two stage clustering: single-level and multi-level clustering.

At the single-level clustering stage, each sensor node becomes a CH on the basis of a pre-defined probability p and announces itself as the volunteer CH to its neighbors within k -hops distance. Any node which receives this announcement becomes member of the closest cluster. If a node does not hear any announcement within a preset time interval t , then it will become a forced CH. This time interval t is calculated on the basis of the duration for a packet to reach a node that is k -hops away. The energy consumed for sending the information to the sink depends on the parameters p and k .

At the second stage, same process is applied from bottom-up to multilevel clustering. Assume there are h levels in a clustering hierarchy, among which level-1 being the lowest one and level- h being the highest one. Then level-1 aggregates the data from its cluster members and send it to level-2 CHs, and so on. Finally the level- h CHs send the aggregated data to the base station. The cost of transmitting the information to the base station is the power consumed by sensor nodes to send data to level-1, then energy used by level-1 CHs to the base station via $h - \text{hop}$ CHs at different hierarchical levels.

The EEHC algorithm can be run periodically for load balancing or triggered as the energy level of the CH falls below a certain threshold level.

3.2 DEEC Protocol

Distributed Energy Efficient Clustering (DEEC) [2] protocol is an energy efficient clustering protocol for heterogeneous wireless sensor networks. The idea of DEEC protocol is to elect the cluster heads using probability based on the ratio of the residual energy of each node to the average energy of the network.

If n_i is the number of rounds for a node and s_i to be a cluster-head, to guarantee an average of $p_{opt} \times n$ cluster heads as in homogeneous network like LEACH, for each node s_i must become cluster-head every $n_i = \frac{1}{p_{opt}}$ rounds. But in a

heterogeneous network the epoch and the probability of the nodes to become cluster head must be different for high energy nodes. Thus the probability p_i is chosen as:

$$p_i = p_{opt} \left[1 - \frac{E(r) - E_i(r)}{E(r)} \right] = p_{opt} \frac{E_i(r)}{E(r)} \quad \dots\dots\dots(3.6)$$

where $E_i(r)$ is the residual energy of node i at round r and $E(r)$ is the estimated average energy of the network at round r given by:

$$E(r) = \frac{1}{n} E_{total} \left(1 - \frac{r}{R_T} \right) \quad \dots\dots(3.7)$$

where $R_T = \frac{E_{total}}{E_{round}}$; the total round of the network life-time, n is the number of nodes in the network, E_{total} is the total energy at beginning of the network and E_{round} is the energy consumed in the network each round.

4. SIMULATION MODELS

We have implemented the various models and compared their performance in wireless sensor networks which are being used for the proposed work

4.1. LEACH

LEACH is Low Energy Adaptive Clustering Hierarchy and it is self-organizing clustering protocol that uses randomized select the cluster heads to distribute the energy load among the sensor nodes. The main features of LEACH are:

- Localized coordination and control for data transfer,
- Randomized, self-configuring and adaptive formation of clusters,
- Low energy media access, and
- Data processing, such as data aggregation to reduce global communication.

The operation of LEACH is divided into two rounds, where each round begins with setup phase in which cluster

formation takes place, followed by steady state phase in which data transfer to sink takes place. In order to reduce overhead, steady state phase is kept longer than the setup phase.

4.2.1 Set-up Phase

For cluster formation, each node initially decides whether to become a CH or not for the current round. This decision is made by the node by choosing a randomly a number between 0 and 1. If the number is less than a threshold, the node becomes a CH for the current round. The threshold equation for CH formation is given by

$$T(n) = \begin{cases} \frac{p_{opt}}{1 - p_{opt} \left[r \bmod \left(\frac{1}{p_{opt}} \right) \right]}, & \text{if node } n \in G \\ 0, & \text{otherwise} \end{cases} \quad \dots(4.1)$$

where p_{opt} is the desired percentage of cluster heads, r is the current round and G is the set of nodes which have not become cluster heads in last $(1/p_{opt})$ rounds. Using this threshold, each node will be cluster head at some point within rounds. This $(1/p_{opt})$ number of rounds during which each node has become cluster head once is called epoch.

Each node which selects itself as a CH broadcasts an advertisement message to all non-CH nodes. The receiver of non-CH should be kept on to hear the advertisement message from all the CH nodes. The non-CH on the basis of received signal strength decides which CH to join. After each node has decided which cluster to join, it should confirm the CH for its status as cluster member. Each node sends a join-request message to their respective CHs. At this time all the CHs must keep their receivers on.

Based on the number of cluster member in a cluster, CH node sets up a TDMA schedule to ensure that there are no collisions during data transmission and this also allows non-CH nodes, to turn off the radio at all times except during their transmit time, thus minimizing the energy consumption by the individual sensors. This schedule made by CH is broadcast back to all the members in the cluster. A flow chart of cluster formation algorithm is shown in figure 4.2

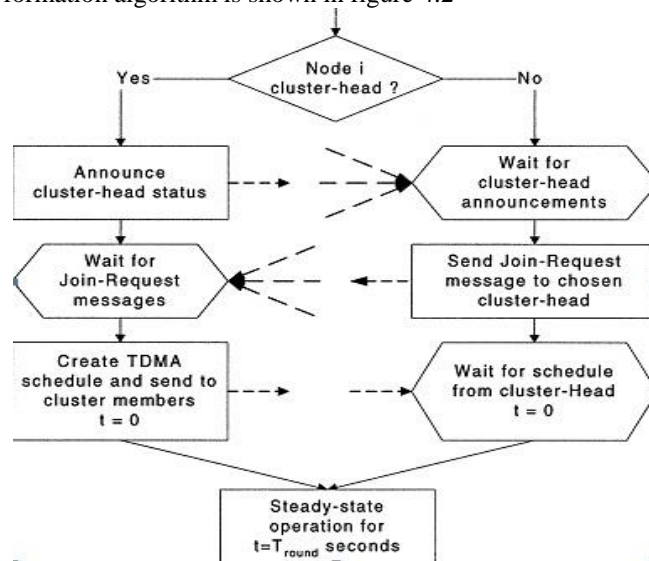


Figure 4.2: Flow Chart of the Cluster formation Algorithm for LEACH [3]

4.2.2 Steady State Phase

Once the cluster formation takes place and TDMA schedule is fixed, data transfer can take place. Steady state operation is broken into frames. Nodes send their data to the CH at most once per frame during their allocated time slot. The time of a frame of data transfer depends upon the number of cluster members in the cluster. To reduce energy consumption, each node uses power control to set the amount of transmit power based on RSS of the CH advertisement. Further, the radio of each node is turned off until its allocated transmission time.

The CH must keep its receiver on to receive all the data from the cluster members. When all the data has been received, the CH node process the data to compress the data into a single signal and this compressed signal is then sent to the BS. Flow chart of steady state operation is shown in figure 4.2. Figure 4.3 shows the timeline for a single round of LEACH.

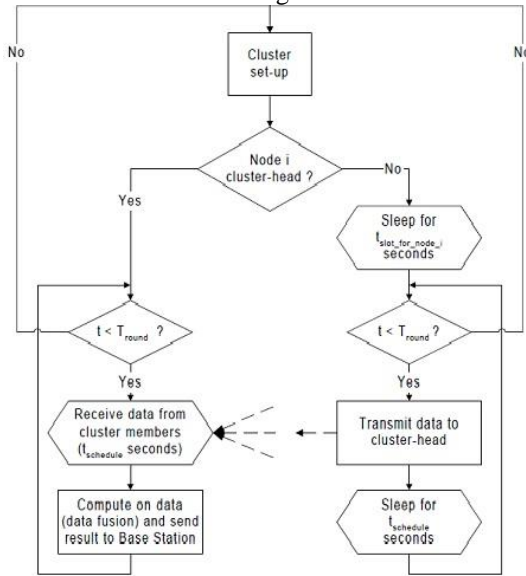


Figure 4.3: Flow Chart of the Steady State Operation of the LEACH [1]

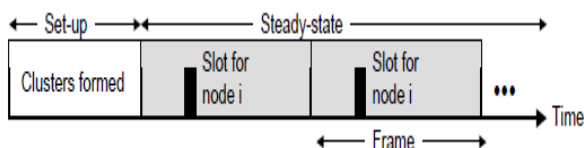


Figure 4.4: Timeline for a Single Round of LEACH [1]

4.2.3 Optimal Number of Clusters

To reduce inter-cluster interference, each cluster communicates using direct sequence spread spectrum (DS-SS). Each cluster uses a unique spreading code sequence and all the nodes in that cluster communicate using that code.

Clustering is said to be optimal in the sense that energy consumption is well distributed among all the sensor nodes and energy consumption should be minimum. Assume there are N nodes in an $M \times M$ region. If there are k clusters, then there will be on an average N/k nodes per cluster with one CH and $(N/k)-1$ non-CH nodes. Energy dissipated at cluster head node during a frame is given by the formula:

$$E_{ch} = \frac{N}{k} * l * E_{elec} + \frac{N}{k} * l * E_{DA} + l * \epsilon_{two-ray-amp} * d_{to BS}^4 \quad \dots(4.2)$$

where E_{DA} is the data aggregation energy and $d_{to BS}$ is the distance from cluster head to base station. If distance between CH and the BS is larger than crossover distance, then energy dissipation follows multipath model (i.e. d^4 power loss). The energy dissipated at non-cluster head is equal to:

$$E_{non-ch} = l * E_{elec} + l * \epsilon_{friss-amp} d_{to CH}^2 \quad \dots(4.3)$$

where $d_{to CH}$ is the distance from non-cluster head to cluster head. Assuming that nodes are uniformly distributed, it can be shown that:

$$E[d_{to CH}^2] = \iint (x^2 + y^2) \rho(x, y) dx dy = \frac{M^2}{2 \cdot \pi \cdot k} \quad \dots(4.4)$$

Therefore E_{non-ch} becomes:

$$E_{non-ch} = l * E_{elec} + l * \epsilon_{friss-amp} \frac{M^2}{2 \cdot \pi \cdot k} \quad \dots(4.5)$$

So energy dissipated in a cluster during a frame is:

$$E_{cluster} = E_{ch} + \frac{N}{k} E_{non-ch} \quad \dots(4.6)$$

and the total energy of the frame is:

$$E_{total} = k E_{cluster} \quad \dots(4.7)$$

Substituting value of from equation (4.2), (4.5), (4.6) in equation (4.7) and by setting the derivative of E_{total} with respect to k equal to zero, optimal number of clusters can be obtained. Therefore, optimum number of clusters, k is given by:

$$k = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{friss-amp}}{\epsilon_{two-ray-amp}} \frac{M^2}{d_{to BS}^2}} \quad \dots(4.8)$$

5. RESULTS AND DISCUSSION

5.1. Heterogeneous LEACH

Figure 5.2(a) shows the test network for Heterogeneous LEACH protocol. There are two types of nodes used with different energy. Normal nodes are represented by 'o' and advanced nodes are represented by '+' and base station is represented by 'x'. Cluster formation is shown in figure 5.2(b) in which cluster heads are represented by '*'.

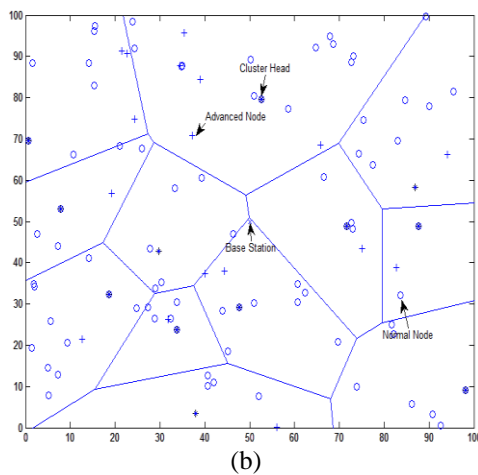
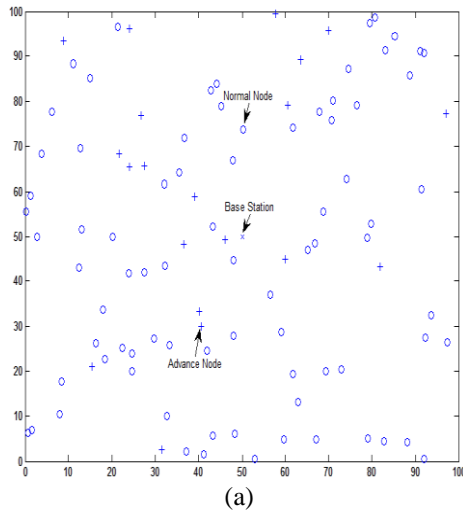


Figure 5.1: Heterogeneous-LEACH Simulation Network (a) Test Network Model (b) Cluster Formation

5.5.1 Network Lifetime

Network lifetime is determined by the number of nodes alive per round as shown in figure 5.2. Lifetime for both types of nodes separately is also shown in figure 5.2. Performance of a clustering protocol is also determined by duration of stable and unstable period. Analysis of network lifetime shows the round number for the death of first normal, last normal, first advanced and last advanced node.

Table 5.1: Network Lifetime Analysis of Heterogeneous LEACH for $\epsilon_{ft1} = 1$

Round for first node dead	Round for first 10 nodes dead	Round for half of the nodes alive	Round for all nodes dead	Stability Period	Instability Period
1046	1122	1234	4011	1046	4011-1046=2965

In this protocol, since there are 2 types of nodes used but the threshold equation for cluster head election is kept same for both types of nodes, due to which instability in the cluster head formation takes place. As it can be seen from the table 5.1.1 and table 5.1.2, that instability period is much longer

than the stability period, which does not represent an efficient clustering. This large unstable period is due to unstable cluster head formation when population of nodes decreases.

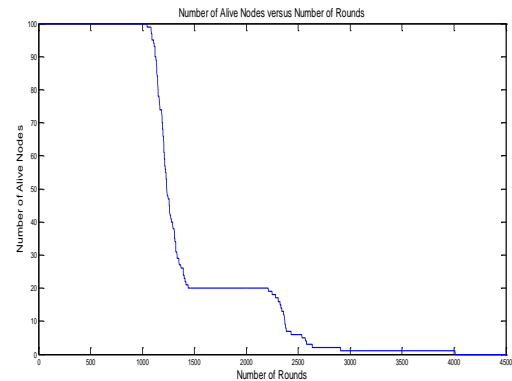


Figure 5.2: Network Lifetime of Heterogeneous LEACH Protocol for $\epsilon_{ft1} = 1$

5.5.2 Throughput

Throughput for Heterogeneous LEACH protocol is again represented in term of packets sent from nodes to cluster head and then from cluster head to base station. Throughput of Heterogeneous LEACH is shown in figure 5.3.

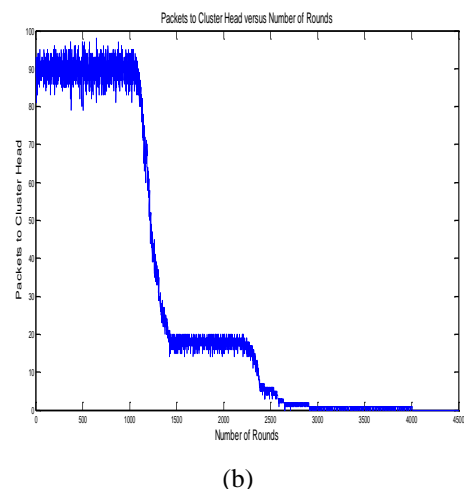
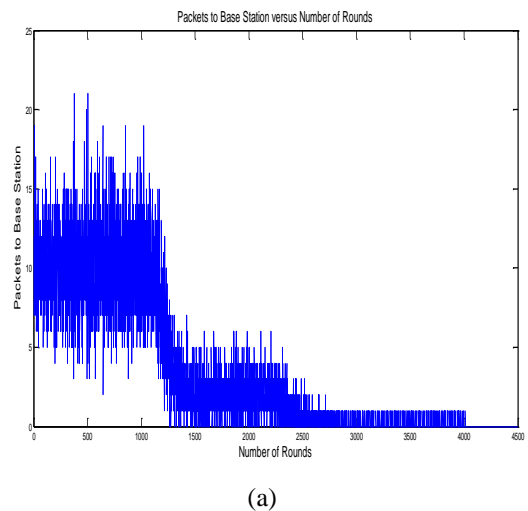


Figure 5.3: Throughput of Heterogeneous LEACH Protocol: (a) Packets to Base Station versus Number of Rounds (b) Packets to Cluster Head versus Number of Rounds

5.5.3 Energy Consumption

It can be seen from figure 5.4, energy consumption remains almost same until the death of first node and after that it starts decreasing.

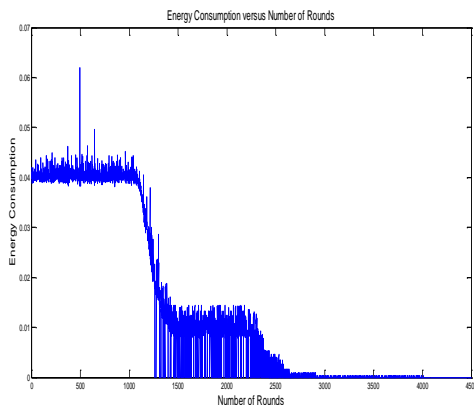


Figure 5.4: Energy Consumption versus Number of Rounds of Heterogeneous LEACH Protocol

5.2 SEP

Figure 5.3(a) shows the test network of Stable Election Protocol. There are two types of nodes used with different energy. Normal nodes are represented by 'o' and advanced nodes are represented by '+' and base station is represented by 'x'. Cluster formation is shown in figure 5.3(b) in which cluster heads are represented by '*'.

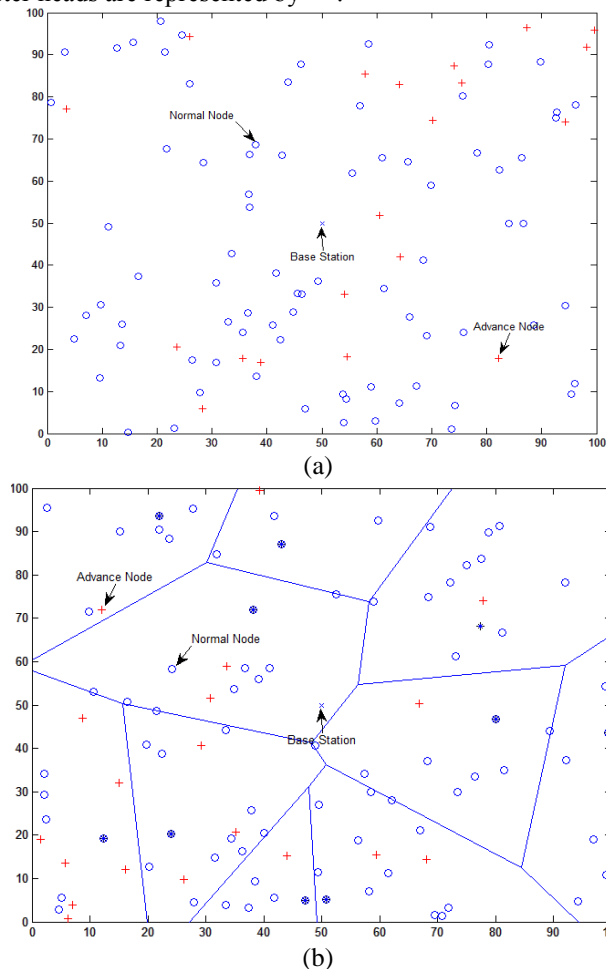


Figure 5.5: SEP Simulation Network (a) Test Network Model (b) Cluster Formation

5.2.1 Network Lifetime

Network lifetime is determined by the number of nodes alive per round as shown in figure 5.2. As in heterogeneous LEACH, in this protocol also there are 2 types of nodes used but the threshold equation for cluster head election for both types of nodes is kept different so that advance nodes could become cluster head more frequently than normal nodes. It can be seen from table 5.2 that instability period of SEP has reduced from that in heterogeneous LEACH and there is also improvement in stability period.

Table 5.2: Network Lifetime analysis of SEP

Round for first node dead	Round for first 10 node dead	Round for half of the nodes alive	Round for all nodes dead	Stability Period	Instability Period
1152	1220	1353	3226	1152 rounds	3226-1152 = 2074 rounds

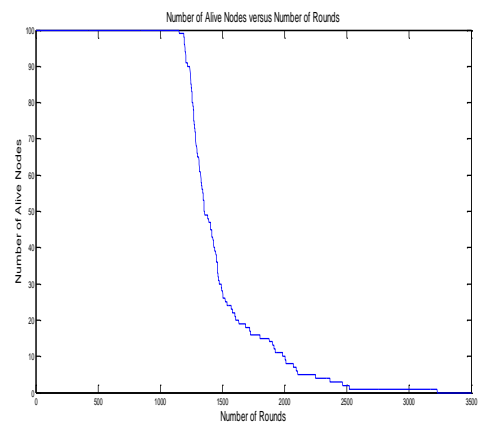
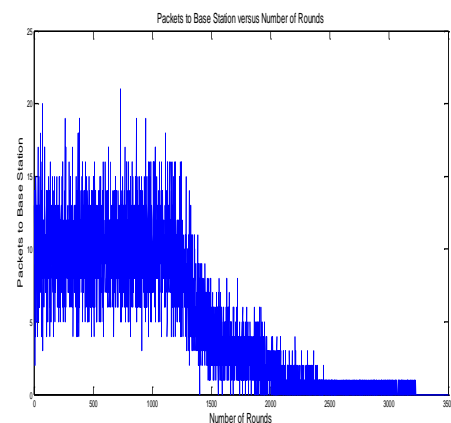


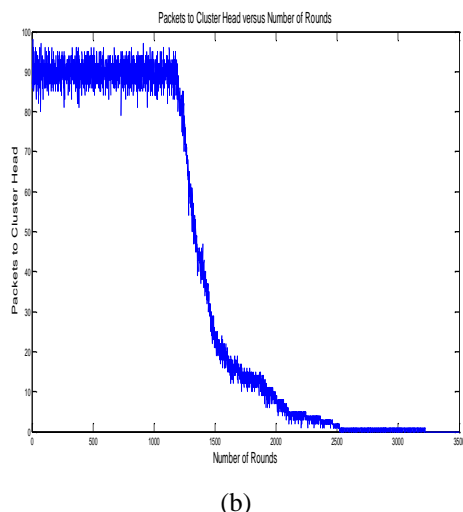
Figure 5.6: Network Lifetime of SEP

5.2.2 Throughput

Throughput in terms of packets transmitted from nodes to cluster heads and cluster heads to base station is shown in figure 5.7. With decrease in number of nodes, packets transmission reduces.



(a)



(b)

Figure 5.7: Throughput of SEP Protocol: (a) Packets to Base Station versus Number of Rounds (b) Packets to Cluster Head versus Number of Rounds

5.2.3 Energy Consumption

Figure 5.8 shows graph for energy consumption per round in SEP. energy consumption has reduced in case of SEP than that in LEACH and Heterogeneous LEACH.

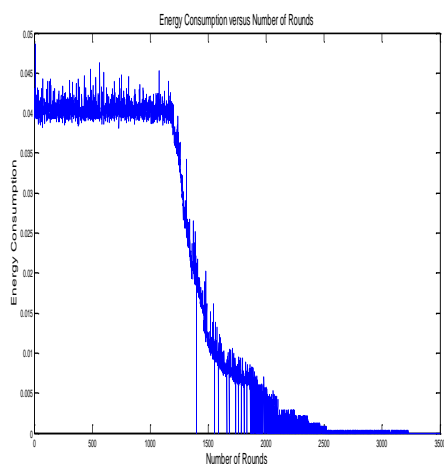


Figure 5.8: Energy Consumption versus Number of Rounds of SEP

1. CONCLUSION

In this paper we have proposed different models and implementation of different energy efficiency protocols in Wireless Sensor Networks. We have analyzed that the heterogeneous LEACH protocol and optimized the performance of the protocol for different parameters. In this paper the proposed models have been applied on the n-node network and the performance of the same has been calculated and shown with the help of results. Analysis of heterogeneous LEACH simulation network is done. Performance is also determined by duration of stable and its unstable period. Network Lifetime of Heterogeneous LEACH Protocol for $\epsilon_{fl}=1$ is much stable. It shows that energy consumption remains almost same until the death of first node and after that it starts decreasing. In SEP cluster head of advance node is frequent become the cluster head than any other normal node.

Instability period of SEP has reduced from that in heterogeneous LEACH and there is also there is improvement in stability period. With decrease in number of nodes, packets transmission reduces. Throughput is improved as; consumption per round in SEP. energy consumption has reduced in case of SEP than that in LEACH and Heterogeneous LEACH.

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