

Behavior Analysis of LEACH Protocol

Prashant Maurya
Research Scholar
Centre for CST
Central University of Punjab
Bathinda, India
prashant.glaitm@gmail.com

Amanpreet Kaur
Assistant professor
Centre for CST
Central University of Punjab
Bathinda, India
pandheraman@gmail.com

Rohit Choudhary
Research Scholar
Centre for CST
Central University of Punjab
Bathinda, India
rohitchoudhary67@gmail.com

Abstract: A wireless sensor network (WSN) is an emerging field comprising of sensor nodes with limited resources like power, memory etc. It is used to monitor the remote areas where recharging or replacing the battery power of sensor nodes is not possible. So, energy is a most challenging issue in case of WSN. Low-Energy Adaptive Clustering Hierarchy (LEACH) is the first significant protocol which consumes less amount of energy while routing the data to the base station. In this paper LEACH protocol has been analyzed with different percentage of cluster heads at different locations of base station in the network.

Keywords: LEACH, Energy Efficient Routing, Lifetime Optimization, WSN.

I. INTRODUCTION

A sensor network is an infrastructure that consists of mobile or static nodes which are able to communicate with each other for transferring data more efficiently and autonomously. Nodes used in Wireless Sensor Network (WSN) are affordable and multifunctional with the capability of detecting characteristics of various physical phenomena such as heat, pressure, humidity etc. This type of network is characterized by energy efficient operation of involved wireless sensor nodes and is suitable for use in a wide range of potential applications including environmental monitoring, industrial diagnostics and critical infrastructure protection. The network gives an administrator the ability to instrument, observe and react to events in a specified environment. The main objective of WSN is to reliably detect and estimate event features from the collective information provided by sensor nodes [1]. An infrastructure of a wireless sensor network is shown in Figure 1.

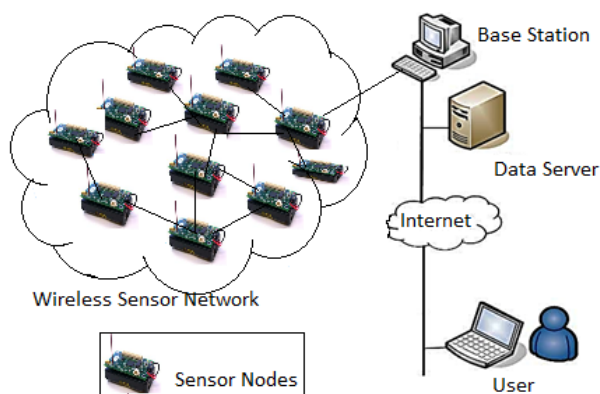


Figure 1: Architecture of Wireless Sensor Network

Various applications of Wireless Sensor Networks include Home Applications, Civil Applications, Environmental Applications, Industrial Applications, and Medical Applications.

II. ISSUE OF ENERGY EFFICIENCY

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery and have very low energy resources. This makes energy optimization more complicated in sensor networks because it involves not only reduction of energy consumption but also prolonging the life of the network as much as possible. This can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is incorporated into groups of communicating sensor nodes of entire network and not only in the individual nodes. Energy saving is an important concern because limited energy source is the most challenging issue in sensor networks. Hence, it is desirable to develop energy-efficient processing techniques that minimize power requirements. The main goal of any Energy Efficient Routing (EER) protocol for WSN is to maximize network lifetime by minimizing energy consumption in end-to-end transmission. WSNs are largely application-specific which implies that routing protocols are also dependent on applications [2].

A. Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol

LEACH is a distributed clustering protocol which utilizes randomized rotation of local Cluster Heads (CHs) to evenly distribute energy utilization between the nodes of WSNs. It uses one-hop inter-cluster communication towards sink. The whole operation of the LEACH protocol is divided into rounds. Each round consists of two phases as set-up phase (clusters are organized) and steady state phase (data transmission) [1].

In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the data transfer to the sink or base station takes place. The duration of the setup phase is smaller than steady state phase in order to minimize overhead. A predetermined fraction of nodes, p , elect themselves as CHs during the setup phase. A sensor node chooses a random number, r , between 0 and 1. If this random number is less than a threshold value, $T(n)$, the node becomes a cluster-head for the current round. The threshold value is calculated based on the equation given below:

$$T(n) = \frac{p}{1 - p \left(r \bmod \left(\frac{1}{p} \right) \right)} \quad \text{if } n \in G \quad (1)$$

Where G is the set of nodes that have not been selected as cluster head in last $(1/p)$ rounds, p is percentage of

nodes to be selected as cluster head and r is the previous round number.

Each elected Cluster Head broadcast an advertisement message to the rest of the nodes in the network. After receiving this advertisement, all the non-cluster head nodes, decide about the cluster, to which they want to attach. This decision is based on the distance of the node from the cluster head which directly depends on the signal strength of the advertisement. Based on the total number of sensor nodes that want to be a part of the cluster, the head node creates a TDMA (Time Division Multiple Access) schedule. It assigns each node a time slot during that, nodes can transmit. This schedule is broadcast to all the nodes in the cluster (Heinzelman et.al., Oct. 2000).

In steady state phase, the sensor nodes start sensing the data in field and can send data to the cluster-heads. When cluster-head node receives all the data, it aggregates it and sends it to the base-station. After certain time, which is called round, the network again starts setup phase again and enters into another round (Heinzelman et.al., Oct. 2000).

III. RELATED WORK

Authors in [3] proposed centralized LEACH (LEACH-C) in which selection of CH is controlled by base station. In this protocol the base station receives information from all sensor nodes about its state, location and remaining energy. Mean value of network nodes energy is calculated at the base station. After calculation of mean value of energy BS selects higher energy level node as a CH. Though it enhances the lifetime but requires GPS involvement.

Authors in [4] proposed Two-Level LEACH (TL-LEACH) Protocol using two types of CHs in the network as first level cluster heads and second level cluster heads. Each node decides to be a primary (second level CH), secondary (first level CH) or simple node (SN). Data transfers from first level CH to the BS via second level CH. First level CH decides which second level CH it will join; similarly each simple node also decides which first level CH it will join.

Authors in [5] proposed V-LEACH (Vice-LEACH) protocol which has an alternative cluster heads (Vice-CH) along with active CH in each cluster. Vice-CH becomes CH to avoid isolation of cluster nodes from network in case CH dies. It insures the availability of cluster nodes and does not select a new CH each time when the CH dies.

Authors in [6] proposed MRLEACH (Multi-hop Routing with LEACH) which uses multi-hop data transmission technique to send data from CH to BS. At the beginning of a round and before cluster formation each node builds a table which holds the information like node's ID, residual energy level, and node's status. The table of each CH holds the nodes ID's of its member nodes. Status of a node can be one of three values: unknown, cluster member or CH. CH is selected by using residual energy of node. CHs which are near to BS are layer-one CHs and which are away from BS are layer-two CHs.

Authors in [7] proposed far-zone LEACH (FZ-LEACH) as an enhancement of LEACH protocol to make

it for large area network. This protocol creates a far zone of sensor nodes placed away from BS and have lesser energy than the threshold energy level to transfer the data. This threshold value is decided by the average of the minimum reachability power of every node.

Authors in [8] proposed cell-LEACH protocol. In cell-LEACH protocol a cluster is divided into seven sections which are called as cells. These seven clusters are divided using one central cell of hexagonal shape and other six cells at each face of central hexagonal shape with their own cell heads which can communicate to each other directly. Cluster head is chosen among all nodes of seven cells of a single cluster and cell heads forwards the aggregated cell data to CH. These clustering and celling is static and hence remain there for network lifetime. The only thing which changes is cell heads and cluster heads.

Authors in [9] proposed a Fuzzy Logic LEACH (FL-LEACH) as an extension to LEACH protocol which uses Fuzzy-Logic to find out the optimal number of CHs. Mamdani's fuzzy inference method is used in fuzzification to determine the fuzzy sets or membership values by taking the number of nodes and network density as crisp values of the input variables. The fuzzified inputs are applied to the antecedent and consequent parts of each fuzzy rule for rule evaluation. Then aggregation is done at the output fuzzy sets using the output variable. Finally, Defuzzification of output is done at last step to get the crisp value of the output.

Authors in [10] proposed K-LEACH protocol which optimizes the LEACH protocol by using K-Medoids clustering algorithm. K-Medoids algorithm provides highly uniform clustering of nodes. This protocol considers Least distant from the center of cluster is considered as a criterion for the selection of CHs. A highly uniform clustering will reduce the energy consumption efficiently.

IV. BASIC ASSUMPTIONS OF NETWORK

Following are the basic assumption of Sensor Network:

- The Network is homogeneous i.e. all sensor nodes have equal energy.
- Sensor nodes are randomly and uniformly distributed in the area.
- Sensor nodes are immobile i.e. they are static.
- All sensor nodes are eligible to calculate its current energy level.
- Nodes do not have location information.
- Base station is also immobile.
- Each sensor node knows the location of sink or Base station.
- Dimension of the sensor field is fixed.
- Sink or Base Station is not energy limited.
- All sensor nodes participate in network sensing.
- Data aggregation is done at the cluster head only.

The Wireless Sensor Network will be analyzed under following scenario:

Table 1: Simulation Parameters

| Parameters | | Value |
|-------------------------|-------------------------|-------------------------------|
| Number of Sensor Nodes | | 100 |
| Field Dimension (m*m) | | 100*100 |
| Initial Energy per Node | | 0.5 Joule |
| Energy | Transmitter Electronics | 50 nJoule/bit |
| | Receiver Electronics | 50 nJoule/bit |
| | Transmit Amplifier | 100 pJoule/bit/m ² |
| | Data Aggregation | 5 nJoule/bit |
| | In free space/air | 0.01 pJoule |

V. SIMULATION RESULTS

In this part LEACH Protocol has been analyzed with different percentage of cluster heads at different location of base station.

A. LEACH under different Percentage of CH

In this section LEACH has been analyzed at different percentage of cluster heads. Figure 2, Figure 3 and Figure 4 represents amount of energy consumed, throughput and number of Dead Nodes respectively at various percentage of CHs. It is clear from output results that change in percentage of cluster heads affects the performance of LEACH Protocol. LEACH performs better if CH percentage is 5% and performance degrades if CH percentage is taken too low or too high.

B. LEACH under different location of BS

In this section LEACH has been analyzed at different location of base station. Figure 5, Figure 6 and Figure 7 represents amount of energy consumed, throughput, number of dead nodes respectively and Figure 8 represents FND, HND and LND at various locations of BS. These results show that performance of LEACH gets degraded with increase in distance of base station from the sensor field.

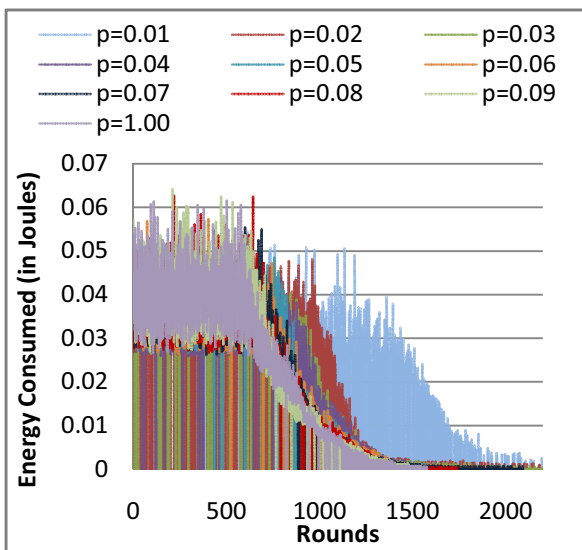


Figure 2: Energy Consumption under different Percentage of CH

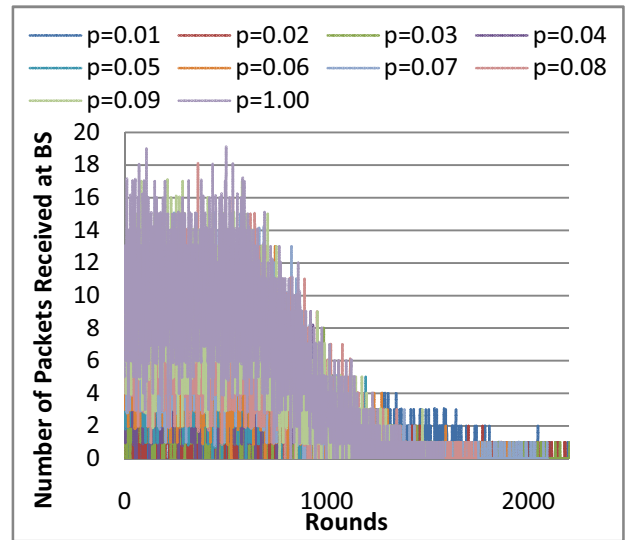


Figure 3: Throughput under different Percentage of CH

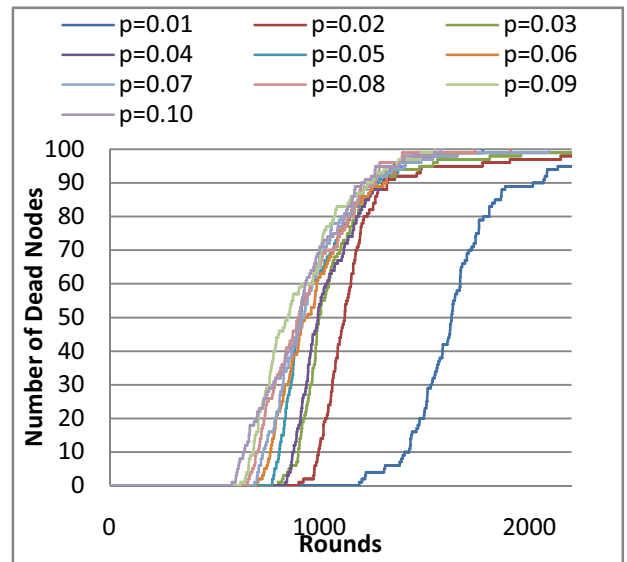


Figure 4: Dead Nodes under different Percentage of CH

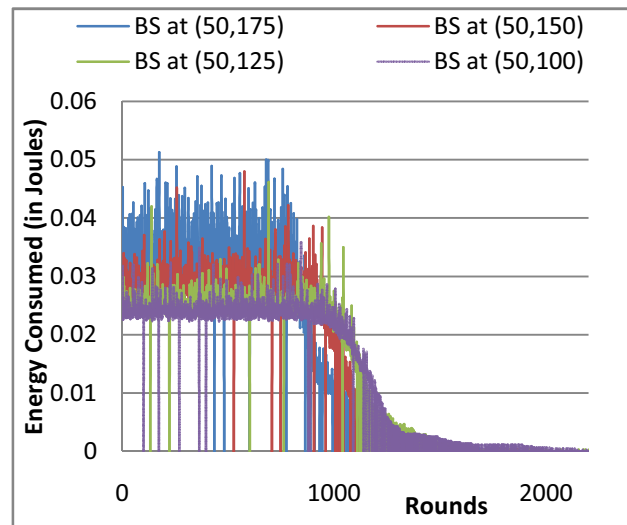


Figure 5: Energy Consumption under Different Location of BS

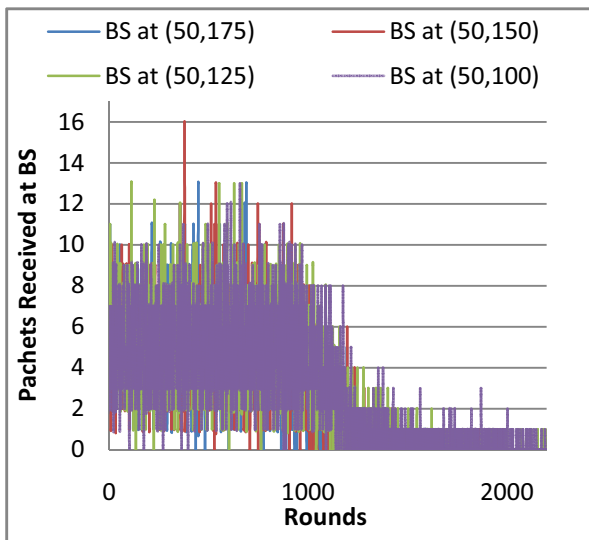


Figure 6: Throughput under Different Location of BS

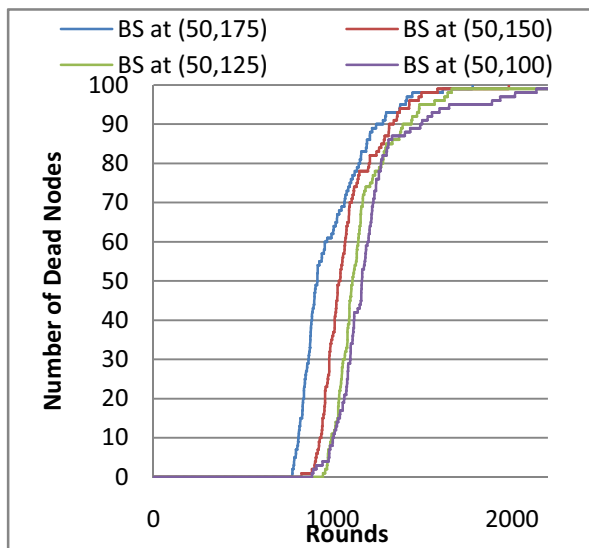


Figure 7: Dead Nodes under different location of BS

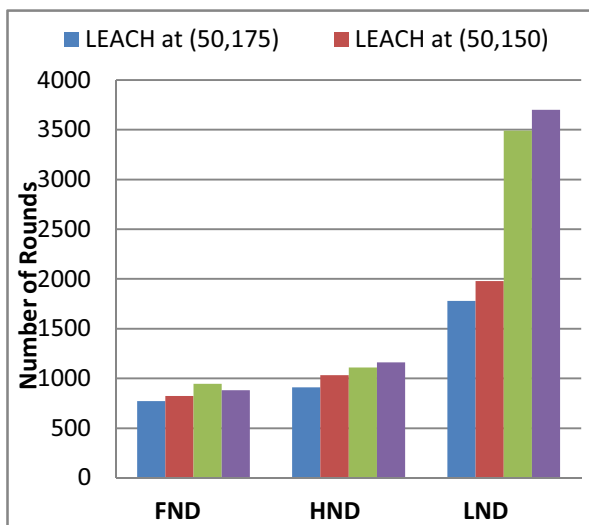


Figure 8: FND, HND and LND under different location of BS

Wireless Sensor Network has sensor nodes which can sense the environment and send the data to the base station for decision making. All sensor nodes are dependent on limited battery power and can not be recharged or replaced because they are deployed in remote locations like in underwater, forests, volcanic areas etc. During transmission of data from sensor nodes a lot of energy is wasted. In this paper LEACH Protocol has been simulated on MATLAB and analyzed. The output results of LEACH Protocol shows that throughput and energy consumption gets affected if location of base station or percentage of cluster head nodes is changed. On changing percentage of cluster head nodes it has been observed that LEACH is performing better if percentage is moderate. On changing the location of base station LEACH performs better if it is located near the target area. Results also show that LEACH protocol performance is stable till FND (Round when First Node Dies) and after that performance degrades. So, it can be concluded that performance of LEACH Protocol depends on distance of base station from target area and percentage of cluster heads. All research work to improve LEACH focuses on diminishing energy consumption while transmitting data to base station. Cluster Head percentage and distance of Base Station from target area are very important factors which affect the performance and lifetime of LEACH Protocol. So, an optimal percentage of Cluster Head and a better distance of Base Station should be chosen to improve LEACH Protocol.

VII. REFERENCES

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