Performance Analysis of LEACH Protocol in Wireless Sensor Network

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***Index Terms*—LEACH, wireless sensor network, WSN, cluster head**

Abstract—**Wireless Sensor Networks (WSN) are distributed network of sensors or micro-sensors. It has ability to sense the parameter around it, like temperature, moisture, humidity, etc. WSN has application in various field like engineering, medical, environment monitoring, industrial automation, military surveillance. Wireless sensor network consists of three main components: Sensing element(Node), Process unit(Base station) and Power unit(Battery). WSN sense data, process data and communicate with base station which includes data transmission. In WSN, energy efficiency is always a main issue since batteries die out very soon. In wireless sensor networks, sending data consumes energy, which affects the lifetime of the network. Therefore, we need a solution to reduce energy consumption. Thus, routing protocol comes into picture. From last few years, there have been increasing effort to minimize energy consumption via algorithms, different techniques in different layer, i.e. hardware layer, network layer and application layer. One of them is the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. In this paper we propose LEACH protocol. LEACH is an energy efficient hierarchical-based routing protocol. Our prime focus is on the implementation and analysis of LEACH. Simulation in MATLAB is done to study and analyze various parameters**

I. Introduction

A variety of modern devices and equipment depend on data sense from the real world around it. Wireless Sensor Networks (WSNs) consist of several sensor nodes which monitor physical or environmental conditions, such as temperature, vibration, pressure, sound and then collectively send this information to a central hub system, called the Base Station (BS) or Sink. Figure 1 : shows wireless sensor network how node can communicate with base station [1] . It is pictorial representation of WSN.

Different routing protocols govern the movement of this information. The routing protocols can be broadly classified as flat-based routing, hierarchical-based routing and location-based routing. LEACH (the Low Energy Adaptive Clustering Hierarchy), a hierarchical based routing protocol that minimizes energy dissipation in WSN [2]. The key features of WSN are:

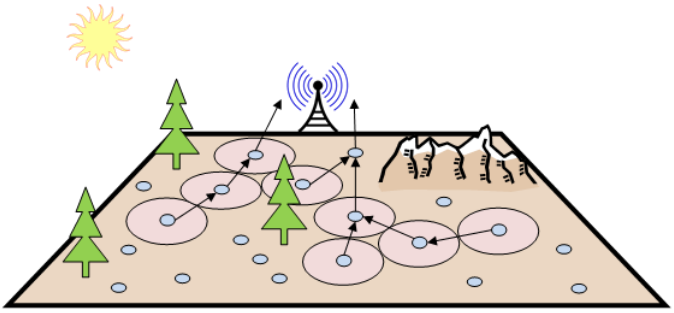

Fig. 1. Wireless Sensor Network

- Randomly formation of clusters and allocation of cluster head.
- Evenly distributed energy consumption in the network.
- Lifetime is more.

LEACH performs better than classical clustering algorithm by using adaptive clustering and rotating cluster heads allowing distributed energy consumption among all the sensors. LEACH is able to achieve reduction in dissipation by using adaptive hierarchical approach.

II. LEACH: Low Energy Adaptive Clustering Hierarchy

LEACH organizes nodes in the system into small bunches called as clusters and picks one of them as the group head called as cluster head (CH). In the event that the cluster heads were picked an earlier and fixed all through the system lifetime, as in traditional clustering formation method it is simple to see that the sensors picked to be cluster heads would die rapidly, finishing the helpful lifetime of all nodes considered having a place with those cluster [3]. In this way LEACH randomized rotation of the high-energy cluster head position such that it rotates among the different sensors so as to not deplete the battery of a solitary sensor [2] . Sensors choose themselves to be cluster heads at random time with a specific probability. These cluster head nodes communicate or advertise their status to alternate sensors in the system. Every sensor node decides to which cluster it needs to have a place by picking the cluster head that requires the less communication energy.

Figure 2 : shows formation of cluster and communication between sensor node to cluster head and cluster head to base

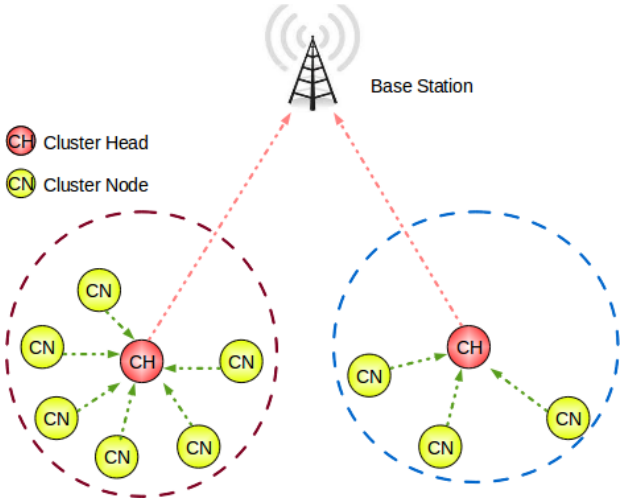

Fig. 2. LEACH Protocol

station. When all the nodes are arranged in its cluster, each cluster head generates a time-slot for the nodes in its cluster. The schedule creation stage is performed, where the cluster heads allocate the time duration which the sensor node can send information to the cluster heads. This allocation depends on a Time Division Multiple Access (TDMA) approach. This permits the radio segments of each non-cluster head node to be turned off at all times except during its transmission time. A cluster member in a cluster is active only during its allocated time slot in this way it limits the energy dissipation in the individual sensors. Sensor nodes sense data and send it to cluster head of that particular cluster. Sensor node first detects its objective and after that sends the important data to its cluster head, then the cluster head totals and compresses the data got from every one of the node and sends it to the base station of network.

III. LEACH Operation

The operation of LEACH is controlled through rounds, which consist of two phases:

1) Setup Phase
2) Steady Phase

In the setup phase, clusters are formed and cluster head (CH) is elected for each cluster. In steady phase, data is detects, aggregate, compressed and transmit to base station. Figure 3 : shows phases present in LEACH protocol, which we discuss below:

A. Setup Phase

In setup phase process of election of cluster heads, formation of clusters, schedule creations are taking place. We discuss these processes as follows:

1) Election of cluster heads: Every node decides whether or not to become a cluster-head for the current round. This decision depends on the recommended rate of cluster heads set out toward the network (decided from the earlier) and the

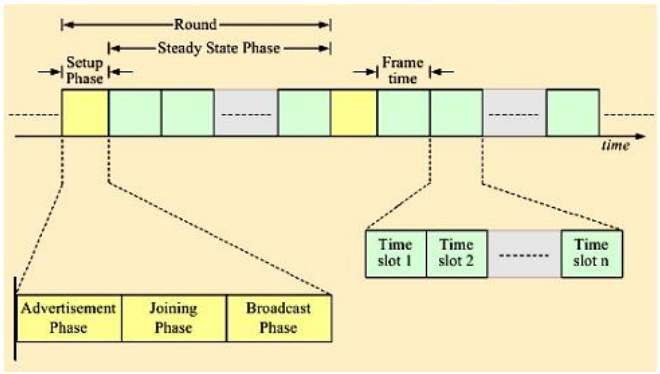

Fig. 3. Phases of LEACH Protocol

number of times the node has been a cluster head during before rounds. Election of cluster heads are depends on threshold value (Tn). The formula is as follows [4] :

$$T(n) = \frac{P}{1 - P[rmod\,(\frac{1}{P})]} \quad \forall n \in G$$
$$T(n) = 0 \quad \forall n \notin G \qquad (1)$$

Where n is a random number between 0 and 1.

P is the cluster head probability

r is the current number of rounds

G is the set of nodes that were not cluster heads in previous 1/P rounds

T(n) depends upon desired rate of cluster heads of network. Each node who wants to be the cluster head select value, somewhere in the range of 0 and 1. If this arbitrary number is less than T(n), the node turns into the cluster head for that particular round. The nodes that are cluster heads in current round cannot be cluster head till next $1/P^{th}$ round.

2) Cluster formation: Every node that has chosen a cluster head for the current round communicates and send advertisement message to the rest of the nodes for formation of cluster. This is also called 'cluster-head-advertisement' phase. If non-cluster-head node receives high signal strength advertisement message then it needs minimum energy for data transmission with that cluster head so, non-cluster-head nodes make decision to form cluster on the basis of signal strength of advertisement message of cluster head.

3) Schedule creation: As we discuss above cluster head generates time-slot for all nodes. Only in that time slot nodes can transmit a data to cluster head. Schedule Creation is on the basis of total number of nodes present in network. TDMA (Time Division Multiple Access) determines when node transmits the data to cluster head [5] .

B. Steady Phase

During steady state stage, the sensor nodes i.e. the non-cluster head nodes begins sensing information and send it to their cluster head as per their TDMA plan. The cluster head gather information from every one of the nodes in cluster and

compress the information at that point then send it to base station or sink.

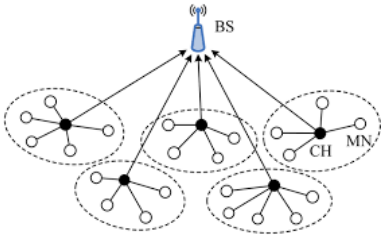

Fig. 4. Hierarchical clustering

Figure 4 shows hierarchical clustering representation of nodes, in which all cluster heads communicate directly with base station. To diminish interference, each cluster imparts utilizing distinctive CDMA code [5] . Subsequently, when a node chooses to become a cluster head, it is picked arbitrarily using Equation (1). After completion of steady state, network goes in setup phase again.

IV. Simulation Model

The proposed network model represents implementation of LEACH algorithm including clustering and routing. In our proposed simulation, we will have considered 100 nodes with equal initial energy. The nodes are considered to be immobile. We considered single-hop communication between both cluster head and base station; sensing node and cluster head. Sensors periodically sense the environment and send the data to the Base Station. Following Table I shows the parameters used for simulation.

TABLE I
Simulation Parameters

Paramaters	Value
Network size	100 x 100
Base station co-ordinates	x=50, y=50
Etx and Erx	50nJ
εfs	100pJ/bit/m^2
Number of nodes	100
Eaggregation	5nJ/bit/signal
Packet size of normal node(pn)	200 bits
Packet size of cluster head(pCH)	6400 bits
Initial energy of each node	1J
Broadcast range	50

Following Simulation diagram gives knowledge about location of nodes, base station, cluster heads as well as number of nodes are live and dead and current number of round. Figure 5 shows operation of round 1 in network. In it can see location of nodes, base station and cluster head. Figure 6 shows last round operation in network which is 2372th round, there is no cluster head is present.

V. Energy Equations

A. For normal nodes

$$E(n) = E(n^{j}) - \{(pn * Etx) + (E\,fs * pCH * mD2) + [(Erx + Eagg) * pCH]\}$$

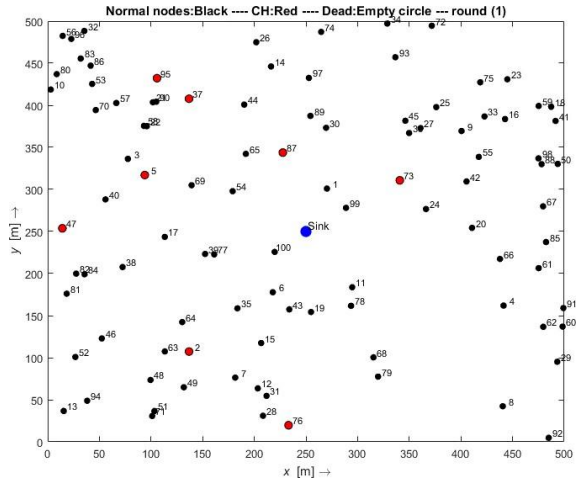

Fig. 5. Simulation in 1st round

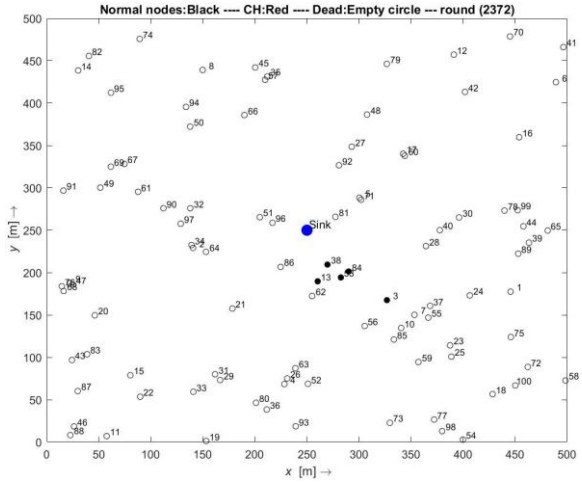

Fig. 6. Simulation in 2372th round

Here,

E (n) =Updated energy of node.
E (n') =energy of node in simultaneous rounds.
pn =Packet size for normal node per round (bits).
Etx =Energy for transmitting one bit.
Erx =Energy for receiving one bit.
Efs =Energy of free space model amplifier.
Eagg =Data aggregation energy.
mD =minimum distance between node and cluster head.

B. For cluster head

$$E(CH) = E(CH^{j}) - \{[(Etx + Eagg) * pCH] + (E\,fs * pCH * D2) + [pn * Erx * round(N/numClust)]\}$$

Here,

E (CH) =Updated energy of CH.
E (CH') =Energy of CH in simultaneous rounds.
pCH =Packet size for cluster head per round (bits).

pn = Packet size for normal node per round (bits).
Etx =Energy for transmitting one bit.
Erx =Energy for receiving one bit.
Efs =Energy of free space model amplifier.
Eagg =Data aggregation energy.
D =distance between cluster head and sink (base station).
numClust = number of clusters in particular round.
N =number of nodes i.e.100.

VI. Results and Analysis

To measure the performance of LEACH protocol, we took the following three parameters in consideration:

1) Throughput
2) Lifetime of network
3) Total energy dissipated

These parameters gave us a basic idea about lifespan of WSN. By using MATLAB we get following results shown inTable II.

TABLE II
Results

	Time(s)	No. of nodes alive	Throughput(bits)
1	$1.5x10^4$	90	$4.1x10^7$
2	$2.2x10^4$	77	$5x10^7$
3	$2.7x10^4$	30	$5.6x10^7$

A. Throughput

Throughput is maximum rate of successful message delivery at the base station. We measure throughput in terms of data packets(bits).Figure 7 shows throughput in network. In our proposed system we considered size of data packet for normal node to be 200 bits/round and size of data packet for cluster head to be 6400 bits/round. After the simulation, we got throughput of 5.85_X10^7 bits(approx.) during the lifetime of network.

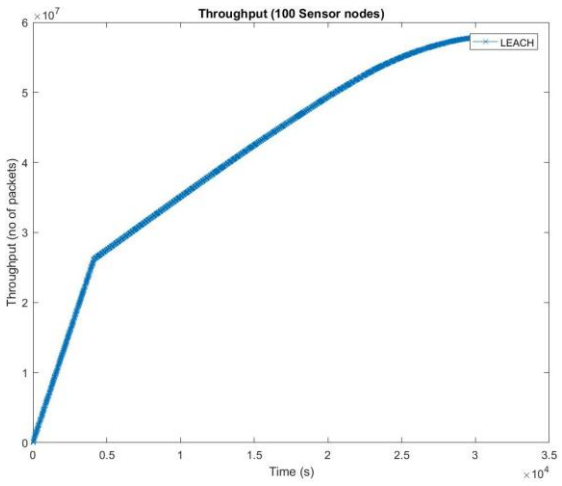

Fig. 7. Throughput

B. Lifetime of Network

Lifetime of sensor nodes describes how many nodes are alive and how many nodes are dead(out of all the nodes present in system). Lifetime of network indicates the number of nodes that are alive at periodic interval of time. Lifetime of network decreases slowly with increasing in time. In our proposed system, lifetime of network is of $3.2_X 10^4$ seconds approx. Figure 8 shows lifetime of network.

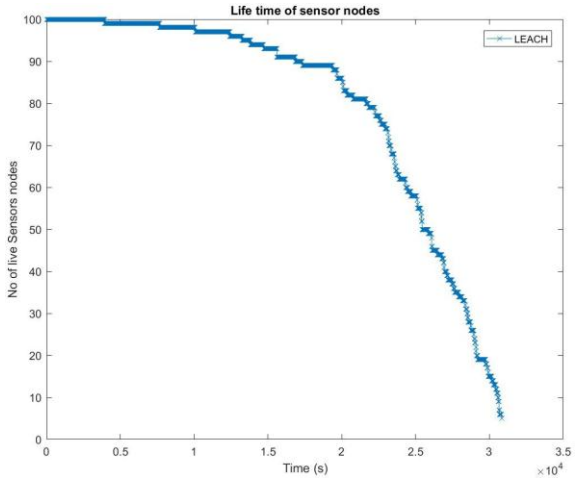

Fig. 8. Lifetime of network

C. Total energy dissipation

Total energy dissipated in network at periodic interval of time is shown in Figure 9. In LEACH protocol, network simulation is continued till the total energy of all the sensor nodes is fully consumed(which is 100J in our case).

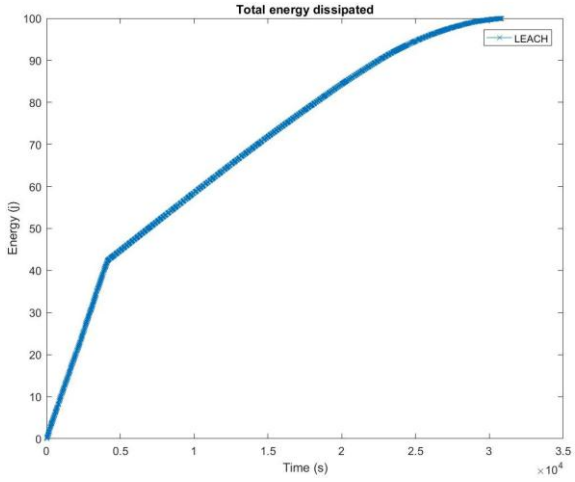

Fig. 9. Total energy dissipation

VII. Conclusion

Being one among the many hierarchical routing protocols, LEACH is the simplest yet efficient. Simple and adaptive nature of LEACH is what makes it eligible to be used as a base for various other protocols, and also which inspired us to study LEACH protocol. In order to implement and analyze LEACH, we have used MATLAB. Compared to traditional routing protocols, we can conclude that LEACH is more efficient in terms of lifetime, throughput and energy dissipation [4]. As cluster heads are elected among the number of sensor nodes, the energy utilization of each node is uniformly distributed and reduced. Thus, cluster-based hierarchical approach of LEACH improves the vitality and proficiency of WSN.

References

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