# Maximizing Lifetime of Wireless Sensor Network through Extended LEACH Algorithm

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**Abstract.** Wireless Sensor Networks (WSNs) represent a new generation of real-time embedded systems that can be applied to ample of real life applications. LEACH is one of the most popular clustering mechanism in WSN; it elects a cluster head (CH) based on a probability model and rotates the cluster heads periodically to preserve maximum network coverage and lifetime. In our work we extend the LEACH's cluster head selection algorithm in WSN based on different node characteristics like, density, centrality and energy. This paper focuses on increasing the lifetime of wireless sensor networks. Appropriate cluster head selection strategy can enhance the lifetime of the network. In our work we have modified the probability calculation formula for selecting the cluster heads in each round based on three parameters of a node: density, centrality and remaining energy in the network. Simulation results demonstrate that extension of LEACH algorithm can enlarge the lifetime of the Wireless Sensor Network.

**Keywords:** Wireless Sensor Network, Cluster-head probability, LEACH, lifetime, Last Node Dies (LND).

## 1 Introduction

A Wireless Sensor Network (WSN) is a wireless network consisting of spatially distributed autonomous devices that use sensors to monitor physical or environmental conditions. In general, the Wireless Sensor Networks [7] consists of a large number of small and cheap sensor nodes with limitations, like their energy resources, dispersed in a region. Sensor networks are the key to gathering the information needed by smart environments [11, 12]. Since a WSN is composed of nodes with non-replenish able energy resources, elongating the network lifetime is the main concern.

For the reason of saving energy, a WSN is broken down into several clusters to reduce communication overhead, and then save energy [8] consumption. A WSN consists of a number of sensor nodes and a sink. Close nodes group themselves into local clusters with one node acting as cluster-head (CH). The cluster-head [4] is responsible

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for not only the general request but also receiving the sensed data of other sensor nodes in the same cluster and routing these data to the sink. Therefore, the energy consumption of the CH is higher than the other sensor nodes. A CH is responsible for not only the general request but also assisting the general nodes to route the sensed data to the target nodes. Therefore the CH selection will affect the lifetime of a WSN. The main problem is that energy consumption is concentrated on the cluster heads. In order to overcome this demerit, the issue in cluster routing of how to distribute the energy consumption must be solved. The representative solution is LEACH, which is a localized clustering method based on a probability model. In this paper, a modified method based on LEACH is proposed.

## 2 Related Work

In this section we briefly review the related works.

### 2.1 LEACH

LEACH, a communication protocol for micro sensor network [1], uses the following clustering-model: Some of the nodes elect themselves as cluster-heads. These cluster-heads collect sensor data from other nodes in the vicinity and transfer the aggregated data to the base station. Since data transfers to the base station dissipate much energy, the nodes take turns with the transmission – the cluster-heads "rotate". This rotation of cluster-heads leads to a balanced energy consumption of all nodes and hence to a longer lifetime of the network. The main idea of LEACH [10] protocol is that all nodes are chosen to be the cluster heads periodically, and each period contains two stages with construction of clusters as the first stage and data communication as the second stage. Each of these rounds consists of a set-up and a steady-state phase. During the set-up phase cluster-heads are determined and the clusters are organized. During the steady-state phase data transfers to the Base Station (BS) [9] occur.

Each node is selected to be the cluster heads according to the probability of optimal cluster heads decided by the networks. In each round, every node gets a random number between 0 and 1. If the number is less than the threshold values-T(n), the node becomes a CH for the current round [3]. T(n) is shown below:

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

$$T(n) = 0 \qquad \text{otherwise} \tag{1}$$

Where, P is the cluster-head probability, r the number of the current round and G the set of nodes that have not been cluster-heads in the last 1/P rounds. Thus, after (1/P - 1) rounds, T*(n)* =1 for all nodes that have not been a cluster-head. This algorithm ensures that every node becomes a cluster-head exactly once within 1/P rounds.

The radio model used is similar to[1] with $E_{elec}$ = 50 nJ/bit as the energy dissipated by the radio to run the transmitter or receiver circuitry and $\varepsilon_{amp}$= 100 pJ/bit/m$^2$ as the energy dissipation of the transmission amplifier. The energy expended during transmission and reception for a $k$-bit message to a distance $d$ between transmitter and receiver node is given by:

$$E_{T_x}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^{\lambda} \quad (2)$$

$$E_{R_x}(k) = E_{elec} * k \quad (3)$$

Where, λ is the path loss exponent and λ≥2.

### 2.2 Modified LEACH Algorithm

Handy et al. [2] proposed an algorithm for reducing the power consumption of the wireless sensor network. The stochastic method of selecting cluster-heads in the LEACH approach was extended by adding a deterministic component. They propose to make it energy efficient by multiplying the factor $\frac{E_{n\_current}}{E_{n\_max}}$ in Eq. (4).Where, $E_{n\_current}$ is the current energy and $E_{n\_max}$ is the initialenergy of the node. Hence the new threshold is:

$$T(n) = \frac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} \frac{E_{n\_current}}{E_{n\_max}} \qquad \text{if } n \in G$$

$$T(n) = 0 \qquad otherwise \quad (4)$$

Their simulations show that such a modification of the cluster-head threshold can increase the lifetime of a LEACH micro sensor network by 30 % for First Node Dies (FND) and more than 20 % for Half Node Alive (HNA).

### 2.3 LEACH-FL System Model

Ge Ranet al. [5] proposed an algorithm which improves LEACH protocol using Fuzzy Logic. This algorithm takes battery level, distance and node density into consideration. The LEACH-FL system has three parts, four fuzzification functions, an inference engine (conclude 27 rules) and a defuzzification module. The form of the rules is: IF A and B and C THEN D. A, B, C and D represent battery level, node density, distance and probability respectively. The rules are based on the following formula.

$$Probability = batterylevel * 2 + nodedensity + (2 - distance) \quad (5)$$

After aggregating the conclusions obtained by each rule, a defuzzification method is still needed to get the crisp value. They compared LEACH-FL with LEACH and Gupta’s method.

Indranil Gupta et al. [3] proposed a new approach for cluster-head election for WSNs. In this paper the cluster-heads are elected by the base station in each round by calculating the chance. Each node has to become the cluster-head by considering three fuzzy descriptors – node concentration, energy level in each node and its centrality with respect to the entire cluster.

## 3 Proposed Extended LEACH Algorithm

Increasing network lifetime, scalability and load balancing are important factors for Wireless Sensor Networks. Here a new method of clustering algorithm is proposed which prolongs network lifetime by using energy, density and centrality factors [6]. Simulation results demonstrate that using the proposed method offers significant improvement in clustering especially in network lifetime in comparison with the LEACH and Modified Leach methods.

In this proposed algorithm all network nodes are divided into clusters. There are three important factors [6] in the proposed algorithm. Weights can be given to them or use fuzzy logic to count their average amount. These factors are:

1. Density: The density factor of every node reveals the number of nodes around that node such that their distances are less than a threshold Distance. It'll be very good if we choose cluster heads from nodes that have the greatest density factors.
2. Centrality: Sometimes a node has a good density factor meaning that there are lots of near nodes around it but they are all on one side of that node. It is desirable to choose cluster heads from those nodes at the center of their neighbors.
3. Energy: Cluster Heads should be chosen from those nodes with enough remaining energy.

### 3.1 How Algorithm Works

Setup Phase.

Phase 1

In this phase all nodes should calculate their densities. Each node is aware of its coordinates. After some rounds, some nodes will die and consequently node densities will change. For calculating densities, all nodes send their id and geographical coordinates to other nodes around by broadcasting locally. It is clear that local broadcast doesn't need so much energy. Nodes can broadcast their messages according to geographical coordinates in different time slices to avoid overhead problem. Then they compute density factor (de). Each node can compute its distance from other nodes by knowing its own coordinates and that of the sender node. If the computed distance is less than a range the node increases its density field. At the end of this phase all nodes would know their densities.

**Algorithm to calculate the density factor (de):**

**Step 1:** [Initialize] NOOFNODES= NULL.
**Step 2:** Initialize the no of nodes, N.
**Step 3:** Initialize the area with in which the Base Station computes the density for each node, RANGE.
**Step 4:** Repeat steps (5), (6) and (7) for i= 1 to N.
**Step 5:** Repeat steps (6) and (7) for j= 1 to N.
**Step 6:** Calculate distance between two nodes.
DISTANCE = sqrt ((S(i).xd - S(j).xd)^2 + (S(i).yd -S(j).yd)^2);
**Step 7:** If DISTANCE < RANGE
NOOFNODES = NOOFNODES+1.
[End of If structure]
[End of Step (5) inner loop.]
[End of Step (4) outer loop.]
**Step 8:** End.

Phase 2
In this phase if the density of node is more than a threshold amount and also if it isn't a border node, it computes its centrality factor (ce). On the assumption that n is the number of network nodes and by using the following algorithm the centrality factor can be computed. Proposed algorithm for computing centrality factor (centrality algorithm):

**Algorithm to calculate the centrality factor (ce) :**

**Step 1:** Initialize the no of nodes, N.
**Step 2:** Initialize the initialize the area with in which the Base Station computes the centrality for each node, RANGE.
**Step 3:** Repeat steps (4), (5), (6) and (7) for i= 1 to N.
**Step 4:** [Initialize] COUNTLEFT= NULL and COUNTRIGHT= NULL.
**Step 5:** Repeat steps (6) and (7) for j= 1 to N.
**Step 6:** Calculate distance between two nodes.
DISTANCE = sqrt ((S(i).xd - S(j).xd)^2 + (S(i).yd - S(j).yd)^2);
**Step 7:** if((S(j).xd>=S(i).xd) && (S(j).xd<=S(i).xd+20))
COUNTRIGHT = COUNTRIGHT+1
if((S(j).xd>=S(i).xd-20) && (S(j).xd<=S(i).xd))
COUNTLEFT = COUNTLEFT+1
[End of If structure]
[End of Step (5) inner loop.]
[End of Step (3) outer loop.]
**Step 8:** S(i).ce=abs(COUNTLEFT- COUNTRIGHT)
**Step 9:** End.

Phase 3
Now all nodes are aware about their density factors (de), centrality factors (ce) and their energy or remaining energy. In this phase each node calculate their cluster head probability factor using the equation (6)

$$P_{new} = a * de + b * \left(\frac{1}{ce}\right) + c * de \quad (6)$$

Where, $P_{new}$ is the cluster head probability factor, de is the density factor, ce is the centrality factor and e is the remaining energy of each node. a, b and c are coefficients for giving weights to density factor, centrality factors and energy respectively.

Phase 4
Now, each node knows its probability factor and then calculates threshold value using their cluster head probability factor (Equation (6)). In order to select cluster-heads each node $n$ determines a random number between 0 and 1. If the number is less than a threshold $T_{new}(n)$the node becomes a cluster-head for the current round. So, the new threshold equation is:

$$T_{new}(n) = \frac{P_{new}}{1 - P_{new}\left(r mod \frac{1}{P_{new}}\right)} \frac{E_{n_{current}}}{E_{n_{max}}} if n \in G$$

$$T_{new}(n) = 0 \qquad \text{otherwise} \quad (7)$$

Steady State Phase
In the steady state phase the cluster-heads collect the aggregated data and performs signal processing functions to compress the data into a single signal similar to the steady state phase of LEACH. This composite signal is then sent to the base station.

## 4 Simulation Result

To test and analyze the algorithm, experimental studies were performed. To compare LEACH, Modified LEACH and Extended LEACH (Proposed) Algorithms, algorithms were simulated and executed in the MATLAB environment. Here energy consumption in WSN is modeled as given in Equations (2, 3). To define the lifetime of the sensor network we used the metric HNA (Half Node Alive) and LND (Last Node Dies). We also use the metric Total no of Node dies at a given round to test for the lifetime of the WSN.

The reference network consists of 100 nodes randomly distributed over an area of 100X100 meters. The Base Station is located at the coordinate 50, 50. The radio model is shown in Table 1. Now three algorithms LEACH, Modified LEACH and Extended LEACH (proposed) algorithm are compared in this network.

**Table 1.** Radio Model

| OPERATION | ENERGY DISSIPATED |
|---|---|
| Initial Energy | 0.02 J |
| Transmitter Electronics | $E_{elec}$=50 nJ/bit |
| Receiver Electronics | $E_{elec}$=50 nJ/bit |
| Transmit Amplifier | 100 pJ/bit/m$^2$ |

Figure 1, shows the density calculation for the network with a random distribution of nodes. Figure 2, shows the centrality calculation for the network with a random distribution of nodes. From Fig.2 it can be observed that many of the nodes have 0 centrality factors. That means those node are in the central position with in a given range.

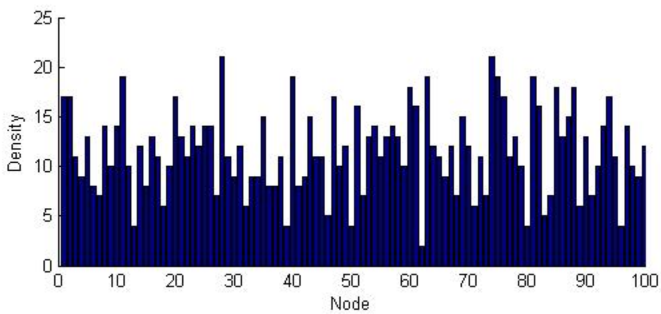


**Fig. 1.** Calculation of Density for the network cluster

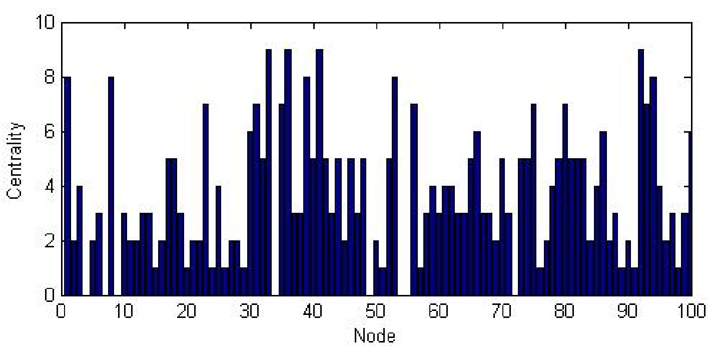


**Fig. 2.** Calculation of centrality for the network cluster

Simulation shows that modification of the threshold equation can increase the lifetime of a LEACH micro sensor network. In case of LEACH and Modified LEACH probability is chosen as 0.1. But in the proposed algorithm probability factor of cluster head election is depend on three factors. These are Density factor, Centrality factor and node's remaining energy. On the basis of these factors it can be shown that lifetime of the micro sensor network has been increased using our proposed algorithm.

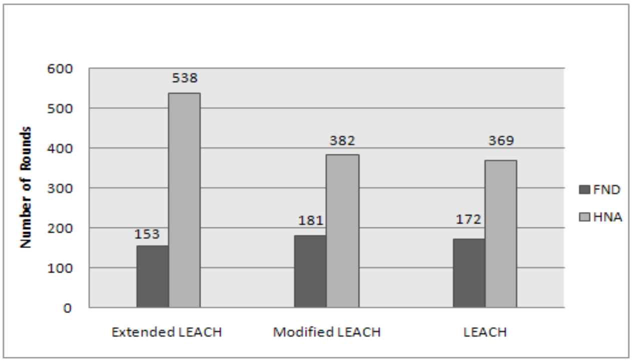


**Fig. 3.** Simulation Result (FND, HNA) of the Sample Network for 1000 Rounds

Figure 3, 4 and 5 illustrates simulation results of the sample network. In Fig. 3 FND means First Node Dies and HNA means Half Node Alive. The proposed algorithm is compared with the original LEACH and Modified LEACH. From the Figure 3 it can be shown that Proposed Algorithm gives the better result in terms of maximizing network lifetime.

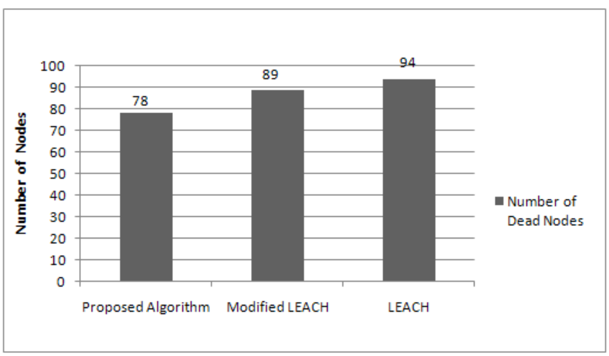


**Fig. 4.** Simulation Result (No. of Dead Nodes) of the Sample Network for 1000Rounds

Figure 4 shows the total number of node dies after 1000 rounds. In case of LEACH Algorithm total number of node dies after 1000 rounds are 94 and of Modified LEACH the number of node dies is 89. Extended LEACH shows that after 1000 rounds number of node dies are 78. Fig.5 shows the network life time of three algorithms. From figure 5 it can be shown that Extended LEACH Algorithm gives the better network life time of the sensor network in compare to other two algorithms.

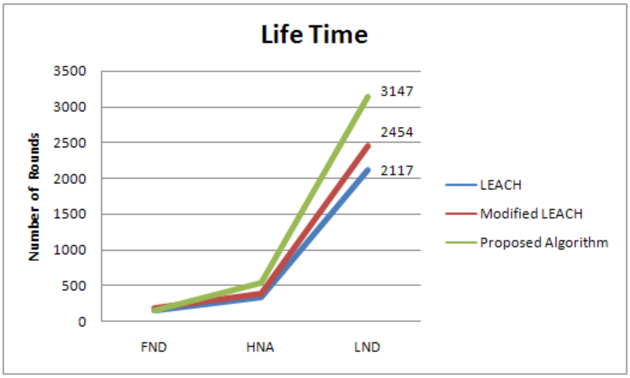


**Fig. 5.** Network Life time Comparison between LEACH, Modified LEACH and Proposed Algorithm, LND – Last Node Dies

## 5 Conclusion

In WSN Cluster Head selection is an important issue that must be considered. Objective of this work is to design a routing protocol based on LEACH which increase the network lifetime of the Wireless Sensor Network. This paper discussed a modification of LEACH's probability factor. With this modification increase of lifetime of micro sensor networks can be accomplished. The node themselves calculate their probability factor to become cluster head and using their probability factor, the threshold value is calculated. Though our proposed algorithm performs better than the LEACH algorithm, a considerable computational overhead in the network may occur due to calculation of the probability factor of each node in the network.

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