# A New Energy Efficient Algorithm Based on LEACH Protocol

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## Abstract

In this paper, we analyse the effectiveness of LEACH protocol in extending the lifetime for energy constrained wireless sensor networks. An improved protocol is proposed based on the LEACH protocol. The proposed protocol improves the selection of cluster-head and proposes to choose relaying node when compared to LEACH. Residual energy of the nodes is considered during selection of cluster-head with the possibility of low-energy nodes being selected as cluster-head reduced. Based on both residual energy and distance to base station, relaying node is chosen from cluster heads to become the relay node between base station and other cluster-heads. The simulation results suggest that the proposed protocol could balance network energy consumption and extend the network life cycle more effectively.

**Keywords:** wireless sensor networks, LEACH protocol

## 1. Introduction

In current years, wireless sensor networks have become the furthermost exciting networking technologies to forward the sensed collected data to the base station with restricted energy capacity. Wireless sensors are micro electro-mechanical system devices that have sensing, processing and communication capabilities. A wireless sensor network system usually includes sensor nodes, base station and management node. The energy storage capacity and communication capability of sensor nodes are very limited. A large number of sensor nodes are deployed in the monitored area, constituting a network through the way of self organization. The areas are usually harsh or hostile environments. For some deployments, manual service of these sensors is not even possible. Once the battery is depleted, the sensor is considered dead and is no longer part of the network. So use of energy efficiently becomes a primary design objective for wireless sensor networks. Cluster-based routing algorithm has a better energy utilization rate compared with non-cluster routing algorithm. LEACH is a hierarchical clustering protocol that provides an elegant solution for such protocols. It uses the mechanism of cluster-head rotation, selects cluster- heads randomly, and each node has an equal chance. So LEACH algorithm balances the energy consumption of the entire network, prolongs the lifecycle of the whole network.

## 2. LEACH Algorithm

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular cluster-based routing protocols in wireless sensor networks. The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase. To reduce management consumption, the steady-state phase is much longer compared to the set-up

**2.1 Set-Up Phase**

In the set-up phase, initially the node becomes a cluster head with a probability $P$ and broadcasts its decision packet. The regular nodes choose their cluster-head based on the least communication energy to reach the cluster-head. The role of the cluster-head keeps on rotating among the nodes of the cluster to enhance the network life time.

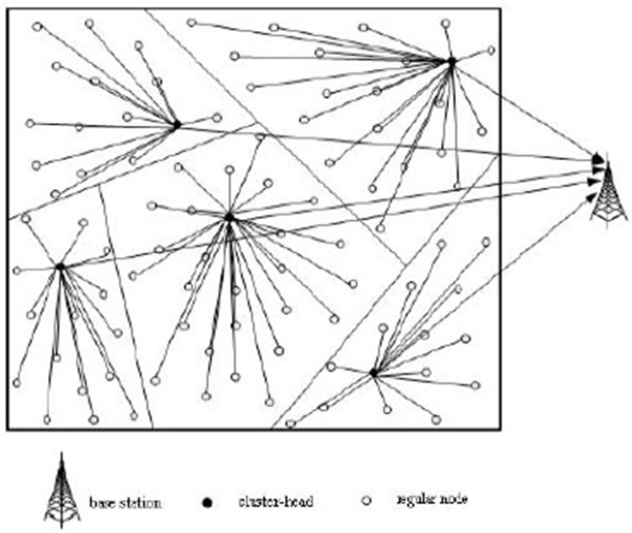


**Figure 1. Cluster Formation in LEACH**

The selection of cluster-head depends on decision made by the node by generating a random number between 0 and 1. If the number is less than a threshold $T(n)$,the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \frac{P}{1-P*r \bmod \frac{1}{P}} & if\ n \in G \\ = 0 & ;\ \text{otherwise} \end{cases} \quad (1)$$

Where $P$ equals the suggested percentage of cluster- heads, $r$ is the current round, and $G$ is the set of nodes that have not been cluster-heads in the last 1/ $P$ rounds. By using this threshold, each node will be a cluster-head at some point within 1/ $P$ rounds. During the first round ( $r$=0 ), each node has a probability $P$ of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next 1/ $P$ rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodes that are eligible to become cluster-heads. After 1/ $P$ -1 rounds, $T$ =1 for any nodes that have not yet been cluster heads, and after 1/ $P$ rounds, all nodes are once again eligible to become cluster-heads.

Once the cluster-heads have been chosen, the cluster-heads use CSMA MAC protocol to broadcast advertisement messages to the rest of the nodes. The regular nodes must keep their receivers on during this phase to hear the advertisements of all the cluster-heads. After this phase, each regular node decides which cluster to join for the current round. Then the regular node will inform the cluster-head that it will become a member of the cluster. Each regular node transmits this information back to the cluster-head again using a CSMA MAC protocol. The cluster-head receives all the messages for nodes that would like to join in the cluster. Based on the number of regular nodes in the cluster, the cluster- head creates a TDMA schedule telling each regular node when it can transmit. This schedule is broadcast back to the regular nodes in the cluster. This is the whole process of the set-up phase.

### 2.2 Steady-State Phase

After the clusters are created and the TDMA schedule is fixed, data transmission can begin. The regular node will send data during their allocated transmission time to the cluster-head according to the TDMA schedule. The radio of each regular node can be turned off until the node's allocated transmission time. The cluster-head will keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster-head performs data fusion functions to compress all the data into a single signal. After that the composite signal is sent to the base station directly by the cluster-head. Since the base station is far away, this is a high energy transmission. This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins.

## 3.System Model

### 3.1 Radio Signal Propagation Model

For this analysis, the transmission cost $E_{Tx}(l,d)$ and the receiving cost $E_{Rx}(l)$ of $l$ bits message between two nodes where their distance is $d$ are given by the following equations:

$$E_{Tx}(d,l) = \begin{cases} E_{elec} * l + \varepsilon_{amp} * l * d^2 & if\ d < d_0 \\ E_{elec} * l + \varepsilon_{amp} * l * d^4 & if\ d \geq d_0 \end{cases} \tag{2}$$

$$E_{Rx}(l) = E_{elec} * l \tag{3}$$

The parameter $E_{elec}$ is the per bit energy dissipation for transmission and reception. We also use the free-space and two-ray models according to the distance between the transmitter and receiver. $d_0$ is a threshold transmission distance and

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}} \tag{4}$$

If $d_0 < d$ , the free-space model will be employed; otherwise, the two-ray model will be employed. $\varepsilon_{fs}$ and $\varepsilon_{amp}$ are the amplifier parameters of transmission corresponding to the free- space and the two-ray models respectively.

### 3.2 The Optimal Ratio of Cluster-heads

In hierarchical routing protocols, the number of clusterheads is a key factor that affects performance of routing protocols. If the number of cluster-heads is less, each cluster head needs to cover larger region, that will lead to some cluster members being are far from their cluster-heads and consume much more energy. As the communication between cluster-heads and the base station needs much more energy than common nodes, the excessive number of cluster-heads will increase the energy consumption of the whole network and shorten the network lifetime. Therefore, it is necessary to select optimal cluster head number to make the energy consumption minimum.

Assume that *N* nodes are distributed uniformly. If there are *k* clusters, there are on average *N* / *k* nodes per cluster (one cluster-head and (*N* / *k*) - 1 regular nodes). Each cluster-head dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the Base station (BS). Since the BS is far from the nodes, presumably the energy dissipation follows the two-ray model. Therefore, the energy dissipated in the cluster head during a single frame is

$$E_{CH} = l * \frac{N}{K} * (E_{elec} + E_{DA}) + l * \varepsilon_{amp} * d_{t0BS}^4 \quad (5)$$

where $l$ is the number of bits in each data message, $d_{toBS}$ is the distance from the cluster-head to the BS, $E_{DA}$ is the energy consumption of one byte in data aggregation. Each regular node only needs to transmit its data to the cluster-head once during a frame. Presumably the distance to the cluster-head is small, so the energy dissipation follows the Friss free-space model.

## 4. Simulation Analysis

To evaluate the performance, we simulated LEACH algorithm and the proposed algorithm.

### 4.1 Network Model

- Nodes are deployed randomly in a square area. Communication within the square area is not subjected to multipath fading.
- The base station is constant and localized far from the sensors area, homogeneous and energy-constrained.
- No mobility of sensor nodes.
- The communication channel is symmetric.
- All nodes can transmit with enough power to reach the BS if needed and the nodes can use power control to vary the amount of transmit power.

### 4.2 Parameters for Simulation

We simulate proposed algorithm and Low-Energy Adaptive Clustering Hierarchy (LEACH) clustering algorithm for WSN. Results from many runs of each algorithm are recorded for random distribution of nodes. The basic parameters used are listed in Table1

**Table 1. Simulation Parameters**

| Parameter | Value |
|---|---|
| Number of nodes | 100 |
| Network grid | $100 \times 100$ |
| Base station position | (50,175) |
| Size of data packet | 500 bits |
| Initial energy of normal nodes | 1 J |
| $\varepsilon_{fs}$ | 10pJ/bit/m$^2$ |
| $\varepsilon_{amp}$ | 0.0013pJ/bit/m$^2$ |
| $E_{elec}$ | 50 nJ/bit |

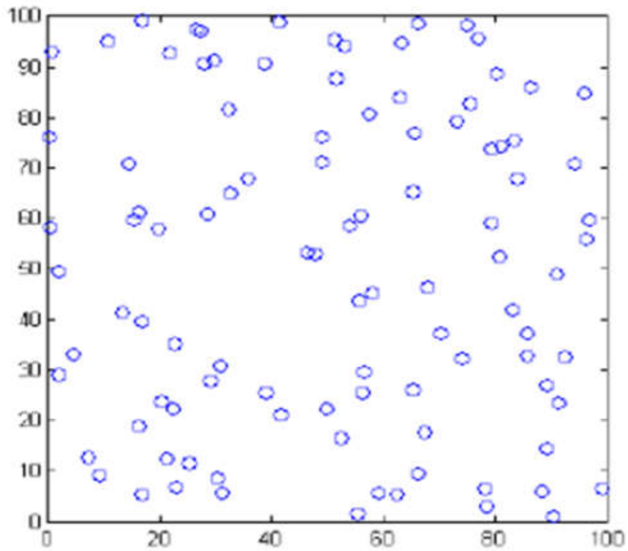


**Figure 2. Deployment of Sensor Nodes**

Figure 2 shows the deployment of sensor nodes, All nodes are deployed randomly in the 100×100 square area. The base station is at the coordinate of (50,175). And the network life time simulation is as follows

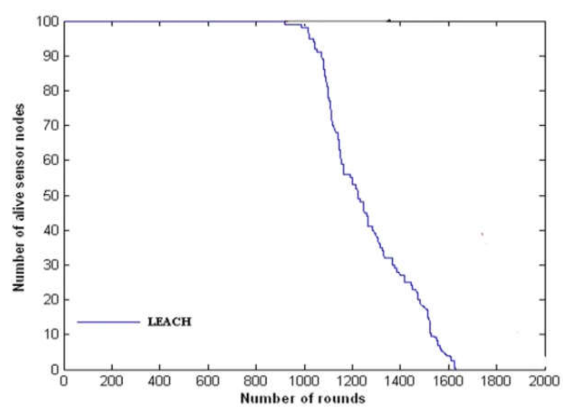


**Figure 3. Network Life Time Simulation**

Figure 3 illustrates the performance of LEACH algorithm in terms of network lifetime. As it is clear from figure, this is due to energy saving in transmission by the improvement of cluster-head selection and the relay node.

## 5. CONCLUSION

In this paper, we have proposed an improvement based on LEACH protocol to enhance the performance of life cycle in this well known and widely used protocol for clustering in wireless sensor networks. Simulation results prove the improvement in the performance in the original LEACH protocol in terms of energy dissipation rate and network lifetime

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