

# Performance Comparison of Energy Efficient Clustering Protocol in Heterogeneous Wireless Sensor Network

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## **Abstract**

Wireless sensor network consists of small battery powered sensors. Therefore, energy consumption is an important issue and several schemes have been proposed to improve the lifetime of the network. In this paper we propose a new approach called energy-driven adaptive clustering hierarchy (EDACH), which evenly distributes the energy dissipation among the sensor nodes to maximize the network lifetime. This is achieved by using proxy node replacing the cluster-head of low battery power and forming more clusters in the region relatively far from the base station. Comparison with the existing schemes such as LEACH (Low-Energy Adaptive Clustering Hierarchy) and reveals that the proposed EDACH approach significantly improves the network lifetime.

## **Keyword:**

Wireless Sensor Network (WSN), Normal Node, Advanced Node, Cluster Head (CH), Base Station, proxy node.

## **Introduction**

A wireless sensor network consists of spatially distributed sensor nodes, which are connected without use of any wire. In a WSN, sensor nodes sense the environment and use their communication components in order to transmit the sensed data over wireless channels to the other nodes and to a designated sink point, referred to as the Base Station (BS). Now days in most wireless sensor network (WSN) applications the entire network must have to the ability to operate unattended in harsh environments. Harsh environments, refers to in which pure human access and monitoring cannot be easily scheduled or efficiently managed or it's even not feasible at all. Based on this critical expectation, in many significant wireless sensor network (WSN) applications, the sensor nodes are often deployed randomly in the area of interest by relatively uncontrolled means. [3]

In wireless sensor network, sensor nodes are making group naturally and cluster is formed. Clustering forms hierarchical network structure. Each cluster has a leader, which is called as Cluster head (CH) and it always perform special tasks. The several common sensor node is called as member node (MN). In this cluster head form higher level and cluster member node form lower level. Cluster

head (CH) nodes aggregate the data and transmit them to the base station (BS) either directly or through the intermediate communication with other CH nodes. However, because the nodes send all the time data to higher distance than member nodes, they naturally spend energy at higher rates. Therefore some issues like Energy consumption and network lifetime comes into picture. The power consumed due to various kind of data is transmitted from the node to the sink i.e. BS which limits the network lifetime. The battery of the node is difficult to change. Hence it become important to consideration of number of cluster, cluster head as well as distance between cluster head and other sensor node for minimizing energy consumption and maximize network lifetime. [4]

Thus energy efficient protocols for wireless sensor network come into existence .One of the popular clustering protocol is the Low Energy Adaptive Clustering Hierarchy (LEACH) which handles the distributed information from the clusters. Low Energy Adaptive Clustering Hierarchy (LEACH) randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy consumption among the sensors in the network

## Energy Efficient Protocols

### 1] Low Energy Adaptive Clustering Hierarchy (LEACH):

In the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, sensor nodes of the network will be organizing themselves into local clusters, with one of the nodes of them acting as the cluster head (CH).The operation of LEACH is carried out into multiple rounds, where each round is categorize into two phases,[1]

- (i) Set-up phase
- (ii) Steady-state phase.

#### (i) Set-up phase

In Set-up phase each node considers itself as CH for the current round but it is decides based on the predefined percentage of CHs and how many times the node has been a CH in previous rounds. The decision is taken by the node choosing a random value from 0 and 1. The node will consider as a CH if the value is less than the given threshold value for current round.

$$T(S)=\begin{cases} \frac{p}{1-p(r \bmod (1/p))} & \text{if } S \in G \\ 0 & \text{Otherwise} \end{cases} \dots\dots\dots(1)$$

Where,

r = current round number

G =set of nodes that have not become cluster head within the last 1/p rounds

#### ( ii) Steady state phase

In steady state phase, the member nodes start sensing and transmitting data to the CHs according to the TDMA schedule, and the fused information by the CH is sent to the BS. At the end of a given round, a new set of nodes become CHs for the subsequent round and the process repeats.

LEACH has advantage that node that select as a CH in particular round will not selected at the CH next round, so all nodes can equally share the load in the network and TDMA avoids unnecessary collision of CHs.

But it have drawback such as it sends data directly from CHs to the BS without intermediate node which utilizes more energy for Transmission and Because probabilistic approach of CH selection, CH may select having low energy in it .Cluster head cause failure because of energy deficiency. If a failure occurs at the cluster-head, the network has to be re-clustered and a new schedule is transmitted to the sensors. Also, the sensor network has to stop data processing and communication in order to perform re-clustering, which requires network setup and bootstrapping. Consequently, frequent failures will result in large reclustering overhead of energy and time. Lifetime of a sensor network and its energy efficiency are thus greatly affected by the frequency of reclustering. Therefore, in this paper,

Propose the energy-driven adaptive clustering hierarchy (EDACH) approach that Puts more number of cluster-heads in the region relatively far from the base station [5].

### 2] Energy Driven Adaptive Clustering Hierarchy (EDACH):

In EDACH, Each round of communication in the proposed scheme begins with the set-up phase where the clusters are organized, followed by the self-organized data collection and transmission phase where data transfer to the base station occurs. The second phase also includes the proxy node selection process and Indicator Control Message (ICM) advertisement process.

#### (i) The Set-Up Phase

In this phase partition the entire area of the sensor network into three segments as near, medium, and far segment . The values of  $P$  for the nodes belonging to different segments differ from each other. That is, the  $P$  value for the nodes in the near, medium, and far segment is  $(1-x)P$ ,  $P$ , and  $(1+x)P$ , respectively, where  $0 < x < 1$ . With this arrangement the nodes relatively close to the base station will have smaller threshold value and thus smaller chance to become a cluster-head.

When a node is selected as a cluster-head, it generates a cluster-head token. Then, the selected cluster-head advertises its token by CSMA/CA MAC protocol to all its neighbours. After the remaining nodes receive the advertisements, they compare the strengths of the received signals. It

keeps only the token with the strongest signal in every comparison, and broadcasts the topology reply packet by CSMA/CA MAC protocol back to the cluster-head. In the reply packet the node's position (NP) and remaining energy (RE) level are included. When the cluster-heads receive the reply packets, they set up a schedule for the nodes in their cluster. Based on the number of nodes in the cluster, the cluster-head creates a TDMA schedule indicating when each node in the cluster can transmit.

**(ii)The Self-organized Data Collection and Transmission Phase**

After the set-up phase, the self-organized data collection and transmission phase starts. Every sensor node collects the data and then sends a packet to the cluster-head in its scheduled transmission time. The radio of a node is turned off when it is outside its scheduled time slot in order to save the energy. Each cluster-head keeps its receiver on to collect data from the nodes in its cluster and continuously updates the table listing the energy of the nodes based on the received packets. When the data from all the nodes have been received, the cluster-head executes the function for data fusion to aggregate the received data into one packet. After the data fusion, the cluster-head sends it to the base station. As a cluster-head needs to receive many packets and consume large power for long range transmission, its energy is used up more quickly than other nodes in the cluster. Therefore, a cluster-head can cause a failure because of energy deficiency. If a failure occurs at a cluster-head, the network has to be re-clustered and a new schedule needs to be transmitted to the sensors. This will significantly reduce the network lifetime. In order to solve this problem, a proxy node is selected if the battery power of the cluster-head becomes smaller than the threshold explained next.

**Calculation of the Threshold Value:**

The threshold value,  $E_{TH}$ , plays a very important role in the data transmission phase. It is calculated when a cluster-head is selected. If the energy of the cluster-head drops below the threshold, the proxy node selection process begins. We assume that all sensors are identical and produce data at the same rate. The following equations are used to compute the threshold value.

$$k_j = M \text{bit} \sum_{i=1}^{[n/k]-1} k_{ij} \dots\dots\dots(2)$$

$$E_{CH(j)} = E_{ele} \times k_j + \epsilon_{amp} \times k_j \times d_{CH(j)}^2 \dots\dots\dots(3)$$

$$E_{TH} = 1/k \sum_{j=1}^{[n/k]-1} E_{CH(j)} \dots\dots\dots(4)$$

Here  $k_j$  is the length of the aggregated message in the cluster-head and  $d_{CH}$  is the distance between the cluster-head and base station. Since  $E_{TH}$  changes with time, it is recalculated in every self-organized data collection and transmission phase. When the energy level of the cluster-head falls below the threshold, a proxy node is selected using the RE and NP value of the reply packets received in the set-up phase. After a node is selected as a proxy node, the cluster-head broadcasts an indicator control message (ICM) containing the address of the proxy node and a new TDMA schedule for the member nodes. The member nodes receiving the ICM send a confirmation message to the proxy node. When the proxy node receives the confirmation message, it keeps the node IDs of the member nodes. After the message exchanges are over, the member nodes resume data transmission.

**Simulation Parameters**

In this work, the sensor network with 100 Sensor nodes which are randomly distributed over the  $100 \times 100 \text{ m}^2$  area. The sink or base station is located at central and boundary condition. The packet size that the nodes send to their cluster heads as well as the aggregated packet size that a cluster head sends to the sink is set to 4000 bits. The initial energy of each normal node is set to 1J. The proposed approach has been implemented in MATLAB R2012a. All the parameter values including the first order radio model characteristic parameters are mentioned in the table 1.

**Table 1:** Various parameters and their values

Parameter	Value
Number of nodes	100
Network Size	$100 \times 100 \text{ m}^2$
Location of BS	(50,50)
Cluster head probability	0.05
Data Packet Size	4000bits
Initial Energy of node	1J
Unit Energy consumed by the electronics to process one bit data ( $E_{elec}$ )	50 nJ/bit
Energy for Data Aggregation EDA	5 nJ/bit/Signal
Amplifier factor for free space ( $\epsilon_{fs}$ )	10 pJ/bit/ $\text{m}^2$
Amplifier factor for multipath model ( $\epsilon_{mp}$ )	0.0013 pJ/bit/ $\text{m}^2$

## Network Model

There are two types of network on the basis of energy; homogeneous and heterogeneous. In former type of network, nodes having same energy levels are deployed, whereas, in lateral type, nodes possess different initial energy levels. The heterogeneous network is considered in our work. We divide network into two energy levels of nodes. The nodes with higher energy level are called advanced nodes and the nodes with low energy level are called normal nodes. The percentage of advanced nodes is  $m$ . Each advanced node possesses  $\alpha$  times more energy than a normal node.[5]

Energy of Normal node is,

$$E = E_0 \quad \dots\dots\dots(5)$$

Energy of Advanced node is,

$$E = E_0 (1 + \alpha) \quad \dots\dots\dots(6)$$

Where,  $E_0$  = Energy of a normal node

## Simulation Results

The Simulation result gives comparison of Energy efficient EDACH protocol with LEACH based on following parameters:

- I) Packet rate
- II) Network Lifetime
- III) Energy Consumption rate
- IV) Death rate
- V) Number of cluster heads per round

### I] Packet rate

Figure 1 shows number of packet sent to base station per round. The amount of data received by the base station describes the rate of the accuracy of the nodes. The more data received means high accuracy. The EDACH uses proxy node in case of cluster head failure occurred. Therefore EDACH sent more number of packets as compares to LEACH as shown in figure 1.

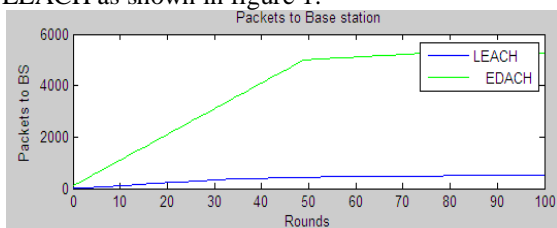


Figure 1. Packet sent to base station

### II] Network Lifetime

Figure 2 shows number of alive nodes per round with base station at central position. The network lifetime of the sensor network is the lifetime of the network from the starting of the network to the end of the network. It means the time from where the network starts its operation till the phase network has completed its operation. The operation is measured in terms of the rounds. The network lifetime is measured in terms of number of alive

nodes. Figure 2 shows that, for EDACH all nodes alive up to 30 round and for LEACH it is up to 2 round, then goes to becoming dead, also EDACH contains more number of alive node as compares with LEACH.

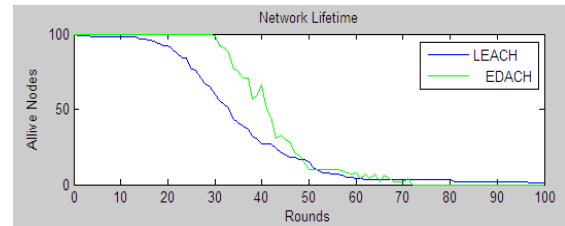


Figure 2. Network Lifetime

### III] Energy Consumption Rate

Fig 3 shows that energy of network per round. Energy of network for EDACH remains for longer period than LEACH.

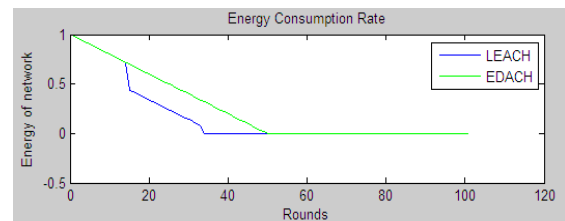


Figure 3. Energy Consumption Rate

### IV] Death Rate

Figure 4 shows number of dead nodes per rounds. It is seen that for EDACH node start to becoming dead after 30 round and for LEACH it start after 2 round.



Figure 4. Death Rate

### V] Number of cluster heads per round

Figure 5 shows number of cluster heads per round. It is seen that EDACH contains more number of cluster heads per round as compares with LEACH.

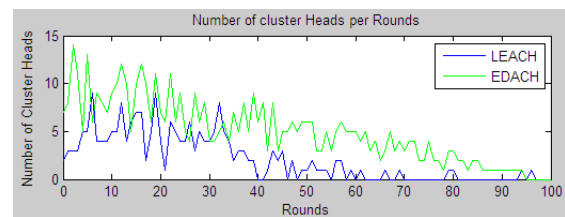


Figure 5. Number of cluster Heads per round

**Table 2.** Values of packet to base station, number of cluster head, first node die.

Parameter	LEACH	EDACH
Packet to BS	521	5250
Number of cluster heads	9	14
First node dead after(round)	2	30

**Table 3.** Comparison between LEACH and EDACH

Parameter	LEACH	EDACH
Packet to BS	minimum	maximum
Network Lifetime	minimum	maximum
Energy Consumption Rate	maximum	minimum
Death Rate	maximum	minimum

## Conclusion

This paper gives performance analysis of Energy Driven Adaptive Clustering Hierarchy (EDACH) with Low Energy Adaptive Clustering Hierarchy (LEACH). EDACH use proxy node in case of cluster head failure and data transmission is occurred successively. From the result it can be concluded that EDACH increases network lifetime with minimum energy consumption rate than LEACH. Also it send maximum packet to BS than LEACH

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