

# Energy Saving in Heterogeneous Wireless Sensor Networks

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**Abstract:** In Wireless Sensor Network (WSN) the sensor nodes are very much sensitive to the energy consumption. The success of the wireless sensor network applications highly depends on the reliable communication among the sensor nodes. One of the major problems in WSN environments is the limitation of the physical resource that is energy resources. More energy is consumed in transmitting and receiving the data as compared to other processing done. Therefore we can use cluster based (Hierarchical) protocols in which the set of nodes are divided into different groups called clusters. For each cluster a cluster head is selected which is responsible for all the communication between the nodes in the cluster and the base station. Instead of homogeneous nodes some high energy nodes can be used to handle the clusters for a longer time. This paper uses concept of heterogeneous nodes to save some energy required for setup phase as in case of LEACH and alike protocols.

**Keywords-** wireless sensor network, dynamic clustering, cluster head, energy efficiency, heterogeneous nodes.

## 1. INTRODUCTION

One of the most important characteristics of wireless sensor networks is that sensor nodes' battery power is quite limited and they are not easy to recharge. Clustering protocol divides the network into different clusters where each cluster has a node as the cluster head (CH) and several nodes as the cluster members. The CH is responsible for collecting the data from all the cluster members, aggregating the data and transmitting fused information to sink nodes. A suitable clustering protocol could balance the energy consumption of all nodes and to prolong network lifetime. In the conventional cluster architecture, clusters are formed statically at the time of network deployment. The attributes of each cluster, such as the size of a cluster, the area it covers, and the number it possesses, are static. In spite of its simplicity, the static cluster suffers from bad scalability [1][2]. Dynamic cluster architecture, on the other hand, offers desirable features such as survivability and scalability. Formation of a cluster is triggered by certain events of interest. The proposed method uses some high energy, high priority node to work as the cluster heads so that life time of the network increases. The network model [3] used for implementation purpose is mentioned below.

## 2. II. RELATED WORK

In case of non-clustering protocols more energy is needed finding the path from source to sink in multi-hop communication since the WSN consist of large number of nodes and more energy is consumed in transmitting and receiving the data as compared to other processing done. Therefore we can use cluster based (Hierarchical) protocols.

In clustering, the whole sensor network is divided into small regions known as cluster. In each cluster, one node is elected as Cluster Head (CH). Elected CH is responsible for aggregating sensed data from its cluster member node(s) and propagate/forward it to base station or to the next CH. As CH has to relay the data of all member node(s), and will deplete energy if continuously selected as a CH. So, the phenomenon of CH selection is periodically divided in rounds [8]. In each round, responsibility of CH is alternatively taken by different cluster member node(s) in a cluster. New CH is selected randomly or based on the parameters like residual energy, distance from base station, connected nodes, topology etc [4]. For forwarding data to the BS, CH is multi-hop CH communication. In which every CH sends sensed data to other CH in its neighborhood which is near to the BS. In this way sensed data is forwarded by CHs using multi-hop communication and ultimately it reaches the BS.

*LEACH [Low-energy adaptive clustering hierarchy]-*

LEACH is hierarchical routing approach for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed [2]. The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head.

LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network [2]. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically.

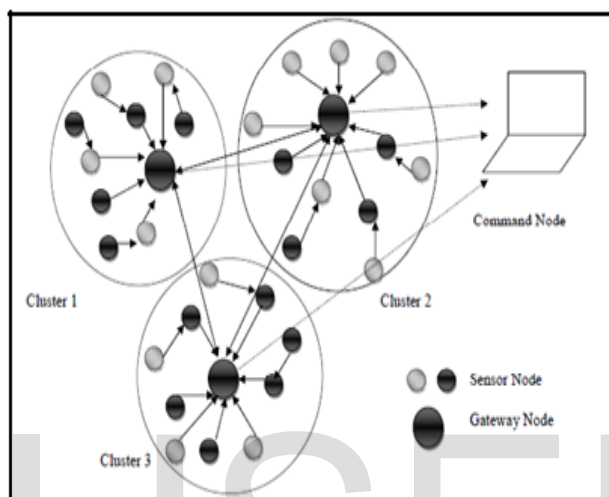


Figure 1: Hierarchical or cluster-based routing

The operation of LEACH is separated into two phases, the setup phase and the steady state phase [4]. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

During the setup phase, a predetermined fraction of nodes,  $p$ , elect themselves as CHs as follows. 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 an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last  $(1/P)$  rounds, denoted by  $G$ . It is given by:

$$T(n) = \frac{p}{1 - p \left( r \bmod \left( \frac{1}{p} \right) \right)} \quad \text{if } n \in G \quad (3)$$

Where  $G$  is the set of nodes that are involved in the CH election. Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads.

During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster head node, after receiving all the data, aggregates it before sending it to the base-station. After a certain time, which is determined a priori, the network goes back into the setup phase again and enters another round of selecting new CH.

### 3. MODEL DESCRIPTION

To develop the algorithm following network and energy models are used:

#### 3.1. Network Model

The network model of the dynamic clustering protocol we proposed is composed as follows:

- 1) The nodes in the network are heterogeneous. The high priority nodes have more energy as compared to the other nodes. The sink node is having unlimited power and the transmit power can be adjusted in an available range.
- 2) The nodes are immobile and their locations have been known with the help of GPS or node self-localization algorithms.
- 3) There is only one sink node and it's immobile. The distance between node in the network and the sink node has been known through exchanging information. Its not far away from the network.
- 4) CHs use a multi-hop communication to the sink node and Cluster Member(CM) nodes use one-hop communication with CHs.
- 5) Sensors are sensing the environment at a fixed rate and thus always have data to send to the BS.

### 3.2. Energy Model

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. Both the free space ( $d^2$  power loss) and the multipath fading ( $d^4$  power loss) channel models are used in this paper, depending on the distance between the transmitter and receiver. If the distance is less than a threshold  $d_0$ , the free space model is used; otherwise, the multipath model is used.

Thus, to transmit a  $k$  bit message a distance  $d$ , the radio expends[3]:

$$E_{Tx}(k, d) = \begin{cases} kE_{elec} + k\epsilon_{fs}d^2 & d < d_0 \\ kE_{elec} + k\epsilon_{mp}d^4 & d \geq d_0 \end{cases} \quad (1)$$

and to receive this message, the radio expends:

$$E_{Rx}(k) = kE_{elec} \quad (2)$$

Where,  $E_{elec}$  is the electronics energy;  $\epsilon_{fs}$  and  $\epsilon_{mp}$  are the amplifier energy of the free space model and the multipath model.

### Issue Description

An effective dynamic clustering protocol should follow some principles as follows:

- 1) The detected signal of the sensor should be strong. A strong signal means the sensor is near the target. It can get more credible information and the output of data aggregation can be more accurate.
- 2) The CH should have much residual energy. The CH performs the task of maintaining the cluster and communication. Thus, it will consume more energy.
- 3) The CH should be near the sink node. The CH sends the result of data aggregation to the sink node. If the CH is far from the sink node, there will be too much energy consumption in communication. If possible in the application the sink node can be placed in the center of the sensor area.
- 4) The cluster size should be acceptable. In a big size cluster, the communication between boundary cluster member and the CH consumes too much energy. Otherwise, too many cluster members may cause more collision. On the other hand, a small size cluster has a small detection range and the CH changes too frequently which also would cause additional energy consumption. Thus, it requires confining the cluster size in order to insure the locality of the cluster.

We can achieve 1) ~ 3) by setting a desirable back-off timer and gives an adaptive method for cluster size setting based on the task to achieve 4).

## 4. THE PROPOSED METHOD

The proposed method uses high energy, high priority nodes to become cluster heads so that energy consumed during cluster head selection can be reduced. At fixed time interval cluster head's residual energy will be checked which should be greater than a predefined minimum  $E_{min}$ . If this energy goes below  $E_{min}$  then only next cluster head selection round will take place. This will save the energy required for cluster head selection and member solicitation frequently. The next priority node can then be elected as the cluster head and the priority of earlier CH is set to minimum priority. Number of priority levels can be selected according to requirement of the application of the sensor network. Presently three levels are selected. Priority 1 and 2 are for high energy nodes and priority 3 is the minimum one for remaining member nodes.

#### 4.1. Simulation Parameters

The parameters for simulation and study purpose are as mentioned in Table 1.

Table 1: Simulation Parameters

Parameters	Value
Network size	100m x 100m
Sink coordinates	x = 0; y = 0
Eelec	50 nJ/bit
efs	100 pJ/bit/m <sup>2</sup>
emp	0.0013 pJ/bit/m <sup>4</sup>
Number of nodes	100
Broadcast packet size	25 bytes
Eaggregation	5 nJ/bit/signal
Data packet size	250 bytes
Packet header size	25 bytes
Initial energy	.8J/node with priority 3, 8J/2nd priority nodes, 16J / 1st priority nodes
Broadcast range	50 m
Max transmission of CH	100 m
Time for each round	20 sec

#### 4.2 The Algorithm:

The network contains 100 nodes in the area of 100 x 100 m<sup>2</sup>. According to standard criteria by Heinzelman 5% of nodes should become the cluster heads. Therefore 5 nodes with priority 1 and 5 nodes with priority 2 will be present. Rest 90 nodes will be kept as normal or common nodes with priority 3. While deployment of nodes care should be taken that one highest and one higher priority node is always associated with set of common nodes. For initial experiment purpose the energy assignments are as follows:

- Priority 1 node: 16J
- Priority 2 node: 8J
- Priority 3 node: 0.8J

At the time of initialization the nodes with priority 1 will declare themselves as CHs and start with the member solicitation phase. According to the received signal strength the common nodes will join a particular head. After joining of members CH determine the TDMA schedule broadcast it to the member nodes. Steady state operation begins here. All the member nodes send the sensed information to the head in their slot in a round. CH aggregates this information to send it to the base station. At end the CH checks its remaining energy.

If it is greater than Emin that is 1J then next round starts. If the energy reaches Emin then this node sets its priority to 3 and hands over the charge of CH to the node with priority 2 resumes the operation of the network. The operation continues till the energy of this node also reaches Emin. When this node's energy also depletes all the other clusters might also have reached the similar condition therefore the operation of the network is shifted to Extended Leach Protocol.

Steps in the algorithm are as follows:

#### **Start with Priority mode operation:**

1. Nodes with priority 1 broadcast the message to collect the members.
2. Nodes join the heads according to the signal strength detected.
3. The heads design the TDMA schedule for the member nodes.
4. Heads broadcast the schedule to member nodes.
5. Loop for each CH for data collection / transmission rounds.
6. All the member nodes send the sensed and preprocessed information to the heads.
7. CHs aggregate them and send it to base station in single hop.
8. CH checks for its remaining energy
  - If it is greater than Emin then continue the loop
  - Else
  - Check for the priorities of the nodes
9. If some node has priority 2 then
  - i. Set own priority to 3
  - ii. Select the new node as CH
  - iii. Go back to loop in step 5Else switch to Leach mode.
10. **Leach mode operation.**

Implementations and comparison with other schemes can be done with NS2.

## **5. CONCLUSION**

The sensor nodes are very much sensitive to the energy consumption. For large networks hierarchical protocols will be more suitable. Traditional LEACH like protocols use setup and steady state phase for network operation. The energy consumption during setup phase is not considered in these protocols but it is needed. This method of heterogeneous nodes uses high energy, high priority nodes to become cluster heads so that energy consumed during cluster head selection can be reduced. At fixed time interval cluster head's residual energy will be checked which should be greater than a predefined minimum Emin. If this energy goes below Emin then only next cluster head selection round will take place.

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