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# Energy Efficient Clustering Techniques for Wireless Sensor Networks – A Review

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**Abstract**

A Wireless Sensor Network (WSN) is a collection of sensor nodes for monitoring the physical conditions of the environment and send it to the sink. The sensor nodes equipped with limited power sources. Therefore, efficiently utilizing sensor node energy can maintain a prolonged network lifetime. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption. Compressive sensing (CS) can reduce the number of data transmissions and balance the traffic load throughout networks. This paper surveys different energy efficient clustering techniques for wireless sensor network.

***Keywords:*** *Wireless Sensor Networks, clustering, compressive sensing, data collection.*

## 1. Introduction

Wireless Sensor Networks (WSN) is group of heterogeneous sensor nodes which are small, low cost, placed randomly and connected by wireless media to form a sensor field. The sensors are spatially distributed to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to the Base Station (BS). WSN has the ability to dynamically adapt to changing environments.

Each sensor node in the network is capable in sensing, processing and transmitting the data to the sink via wireless channel. Sensor nodes are equipped with small powered battery, transceiver, and processing and communication unit. Node has limited energy and it cannot be recharged easily so special attention has to be made to low power consumption. Many researches show that clustering/ hierarchal network increase network performance than a flat network.

In hierarchal network, sensor nodes are group together to form clusters and a node from each clusters which satisfying evaluation criteria such as high received signal strength and high energy level is selected as a cluster head(CH). CH not only aggregate the data send by the nodes in the cluster but also act as a controller to make various routing and scheduling criteria [2].

Hierarchical clustered sensor networks can be divided into two categories: homogeneous and heterogeneous.

The clustering technique applied in homogeneous sensor networks is called homogeneous clustering schemes, and the clustering technique applied in the heterogeneous sensor networks is referred to as heterogeneous clustering schemes.

There are many advantages of clustering are [4]:

1. It saves a lot of energy of the node that send the data by reducing the distances travelled by the data.

2. In clustering cluster head perform data aggregation process and reduce the amount of redundant data.

3. It reduces channel contention.

4. It reduces packet collision.

5. Clustering result in better throughput of the network under high load.

6. The main advantage of a clustered solution is automatic recovery from failure

Performance Measures :

Network lifetime:
It is the time interval from the start of operation (of the sensor network) until the death of the first alive node.

Number of cluster heads per round:
Instantaneous measure reflects the number of nodes which would send directly to the base station, information aggregated from their cluster members.

Number of alive nodes per round:
This instantaneous measure reflects the total number of nodes and that of each type that has not yet expended all of their energy.

Throughput:
This includes the total rate of data sent over the network, the rate of data sent from cluster heads to the base station as well as the rate of data sent from the nodes to their cluster heads.

The rest of the paper is organized as follows. Section II provides minimum transmission clustering algorithm. Section III presents hybrid energy efficient distributed protocol. Section IV provides MEMAC protocol. Section V presents LEACH protocol. Section VI demonstrates performance analysis of all clustering techniques. Finally, conclusions are presented in Section VII.

## 2. Minimum Transmission Clustering Algorithm

This algorithm assumes that

1) Every sensor node knows its geographic location. This location information can be obtained via attached GPS or some other sensor localization techniques.

2) The sink knows the area of the whole sensor field, but does not need to know the location information of all sensor nodes.

In this distributed algorithm, the sink divides the field into C cluster-areas, calculates the geographic central point of each cluster-area, and broadcasts the information to all sensor nodes to elect CHs. The sensor node that is the closest to the center of a cluster-area is selected to be the CH. The CHs then broadcast *advertisement* messages to sensor nodes to invite sensor nodes to join their respective clusters.

### 2.1 Calculating Central Points of Cluster-Areas

Given a sensor field and the number of cluster C to be divided to, the sink needs to find out the central points of C cluster-areas. First divides the whole sensor field into small grids, as shown in Fig. 1. Then, place a virtual node at the center of each grid to represent the grid. C nodes in the grids will be chosen as the approximate central Points of the cluster-areas.

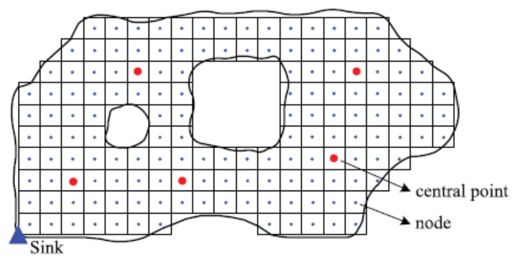


Fig. 1 An example of calculating the central points of cluster-areas: an irregular sensor field is roughly divided into small grids, and a virtual node is placed at the center of each grid. Five nodes are chosen as the approximate central points

Using an auxiliary graph $G_A=(V_A,E_A)$ to help finding the central points, where $V_A$ is the set of nodes in the grids, and each node $v_i$ in $V_A$ has an edge to each of the nodes in its neighboring grids. Each grid, except those on the border of the sensor field, has eight neighboring grids (as shown in Fig. 1). The distance of all edges in EA is set to 1. Then , compute a subset of nodes, such that the total distance from all nodes in $V_A$ to their nearest nodes in $V_C$ is minimized.

The nodes in $V_C$ are the approximate central points of the C cluster-areas in the sensor field. After computing $V_C$, the sink can calculate the geo-graphic locations of the nodes in $V_C$, which are the approximate locations of C central points of the cluster- areas. The sink then broadcasts the locations information of central points to all sensor nodes for CHs election. The size of the grids that the sink divides the sensor field to depends on the accuracy of locating the central points. The smaller the size is, the more accurate the locations information will be, but it incurs more computation cost in this case.

## 2.2 Cluster Head Election

Given the geographic location of the central point of a cluster-area, the sensor node that is the closest to the central point will become the CH. let all nodes within the range of Hr from the center be the CH candidates of the cluster, where r is the transmission range of sensors. The value of H is determined such that there is at least one node within H hops from the central point of a cluster.

To elect the CH, each candidate broadcasts a CH election message that contains its identifier, its location and the identifier of its cluster. The CH election message is propagated not more than 2H hops. After a timeout, the candidate that has the smallest distance to the center of the cluster among the other candidates becomes the CH of the cluster. In the extreme case that no sensor node falls within H hops from the central point so that there is no CH for this cluster-area, the nodes in this cluster-area accept the invitation from neighboring CHs and become members of other clusters. Thus, no node will be left out of the network.

## 2.3 Sensor Node Clustering

After a CH is elected, the CH broadcasts an advertisement message to other sensor nodes in the sensor field, to invite the sensor nodes to join its cluster.

An advertisement message carries the information: the identifier and location of the CH, and the number of hop that the message has traveled. The hop count is initialized to be 0. When a sensor node receives an advertisement message, if the hop count of message is smaller than that recorded from the same CH, it updates the information in its record including the node of previous hop and the number of hop to the CH, and further broadcasts the message to its neighbor nodes; otherwise, the message is discarded.

## 2.4 Backbone Tree Construction and Network Maintenance

A backbone tree is constructed in a distributed fashion to connect all CHs and the sink. Through the Broadcasting of the advertisement messages from CHs, each CH receives the advertisement messages from the other CHs that are close to it. Thus, it has the knowledge about the locations of its nearby CHs and the number of hops to them. Since the sink needs to broadcast the central points information to all sensor nodes, all sensor nodes know the location of the sink and the hop distance to it.

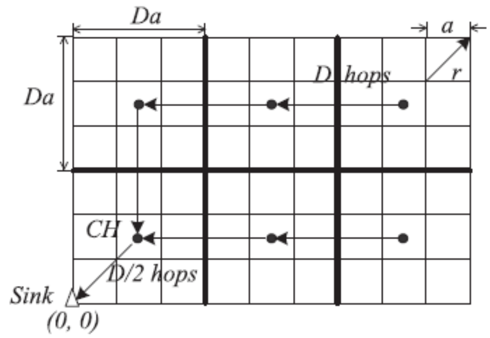


Fig. 2 The sensor field is partitioned into small grids with size axa. All nodes in a cluster-square of the size Da X Da form a cluster, where the cluster head (CH) is located at the center.

For each CH, we define its upstream CHs as the set of CHs (including the sink) that are closer to the sink than itself in terms of Euclidean distance. An approximate MST algorithm used to construct the backbone tree. For each CH, it chooses the CH that has the minimum number of hops to it from the set of its upstream CHs as its parent CH in the backbone tree.

After constructing the backbone tree, each CH has the knowledge about its children CHs in the backbone tree. When M projections are generated at the CH, they are transmitted to the parent CH along the backbone tree in M rounds. When a CH fails or runs out of energy, the neighboring nodes of the CH will detect the failure of the CH. These nodes will broadcast a message to all the nodes in this cluster to start the new CH election.

# 3.Hybrid Energy Efficient Distributed Protocol (HEED)

The main requirement of sensor network is to increase network lifetime. Data aggregation method helps a lot in improving network life. HEED uses residual energy level as primary parameter for selecting cluster head (CH). In case of tie where two or modes have same residual energy and are capable of being a cluster head (CH), network topology features e.g. node ID, node degree, distances to neighbor are considered as a secondary parameters. Sensor nodes are of two types: homogeneous nodes and heterogeneous nodes. Homogeneous nodes are those which have same initial energy level and heterogeneous nodes are those which have different initial energy level. In this all nodes in the network are assumed to be homogeneous having same energy level [4]. HEED (Hybrid Energy Efficient Distributed) protocol uses the concept of clustering.

Clustering can be extremely effective in one-to-many, many-to-one, one-to-any, or one-to-all (broadcast) communication.

HEED has four primary objectives:

1. Prolonging network lifetime by distributing energy consumption.
2.Terminating the clustering process within a constant number of iterations.
3. Minimizing control.
4. Producing well-distributed cluster heads.

## 4. Mobile Energy Aware Medium Acces Control( MEMAC) Protocol

In the Wireless sensor network, there may be possibility of failure of nodes because of the power drained or addition of new nodes or may be change in location of nodes due to physical movement. So to accommodate these types of dynamic changes in sensor nodes MEMAC protocol presents hybrid scheme of contention based and scheduled based scheme of previous MAC protocol having the purpose of overcome the drawbacks. For the mobility handling of sensor nodes MEMAC differs from previous SEHM protocol by acquiring frame length according to mobility conditions.

The issues related to designing of MAC protocols are frame errors in mobility network, probability of collision increases in contention based MAC protocol and requires retransmission, schedule inconsistency, lack of mobility information and unable to choose mobility model. So it is necessity to cope with frame errors and adjusting frame time. To avoid collision and energy consumption it must uses mobility information and acquires schedule according to mobility conditions and it also needs proper designing of mobility model for real life setting. Now let us see what the actual difference between both systems. In sensor networks, nodes may fail (e.g., power drained) or new nodes may be added (e.g., additional sensors deployed), or sensor nodes may physically move from their locations, either because of the motion of the medium (e.g. water, air) or by means of a special motion hardware in the mobile sensor nodes.

To accommodate these topology dynamics, our MEMAC protocol uses a hybrid approach of contention-based and scheduled-based schemes as in our previous MAC protocol (SEHM protocol) presented in [3]. MEMAC differs from SEHM protocol in terms of mobility handling of sensor nodes. MEMAC adapts the frame length according to mobility conditions by incorporating a mobility prediction model As MEMAC is a hybrid protocol, it overcomes some of the disadvantages of MMAC through providing contention slots for short control messages and scheduled slots for data messages. Furthermore, MEMAC allows only nodes that have data to send to be included in the schedule which increases the energy efficiency of the protocol. MEMAC is combination of contention based and scheduled based protocols to achieve significant amount of energy saving. MEMAC adjusts dynamically frame size according to mobility information of sensor nodes and number of nodes that have data to send; this avoids wasting slots by excluding the nodes which are expected to leave or join the cluster and those nodes which have no data to transmit from the TDMA schedule and to switch nodes to sleep mode when they are not included in the communication process. Through simulation experiments, we studied the performance of MEMAC protocol against MMAC protocol. Simulation results shoes that MEMAC protocol is better than MMAC in terms of energy consumption, packet delivery ratio and average packet delay

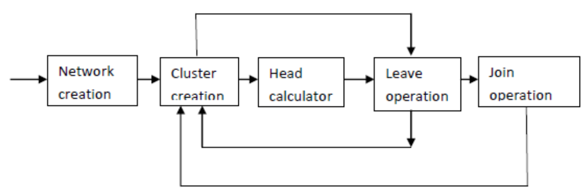


Fig 3.Architecture of MEMAC Protocol

Above Fig 3 shows the basic architecture of MEMAC protocol.

### 4.1 Network Creation

Creating network for connectivity. Basically in general Wi-Fi network if there are n numbers of nodes in network which are actively participated in message transfer or communication. Then if any node say node no 1 want to communicate with node no 16 then for this communication or message transfer; firstly node must connect with its neighbor nodes and so on; up to the destination node 16. Out of that it will choose shortest path to reach up to destination and then it will send message packets. This process is happen in various wireless networks. But due to some disadvantages this system is fail to acquire reliability and\proper flow control in energy efficient way. So all this disadvantages are overcome in MEMAC system

### 4.2 Cluster Creation

Clusters which are dynamically formed contain all nodes in sensor network. In MEMAC system, for eg. when node no. 1 want to communicate with node no. 16, then node 1 firstly communicate with its own cluster head (here ch1). After that ch1 communicate with ch2 which is cluster head of node no. 16 and then finally ch2 transfer message which is come from node no 1 to destination node (i.e. node no 16). In this way in MEMAC system three way communications is happen. So it is faster and energy efficient system.

### 4.3 Head Calculator

Clusters Head created with respect to cluster quantity. phase-In this phase CH broadcast the calculated schedule to the other node within cluster. The schedule contains those nodes which have data to send only. The current schedule does not consider nodes that want to leave or join the cluster. If the number of request message is greater than number of join or leave messages, then frame length is increased otherwise decreased.

### 4.4 Leave/Join Operation

In case of request or leave phase the contention period should be long enough to enable all Sensor node. In MEMAC protocol handles the channel access through the following four phases: request\leave\join phase, schedule calculation and distribution phase and data transfer phase. In case of request or leave phase the contention period should be long enough to enable all sensor nodes that have data to transmit contain for the channel in order to acquire the access to send its request to CH as well as those nodes which are expected to leave or join the cluster should the CH by sending message of leave or join

## 5. LEACH Protocol

In low-energy adaptive clustering hierarchy (LEACH), the nodes organize themselves into local clusters, with one node acting as the cluster head. All non-cluster head nodes transmit their data to the cluster head, while the cluster head node receives data from all the cluster members, performs signal processing functions on the data (e.g., data aggregation), and transmits data to the remote BS. Therefore, being a cluster head node is much more energy intensive than being a non- cluster head node.

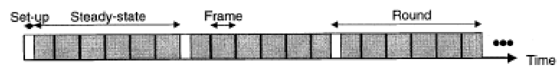


Fig. 4 Time line showing LEACH operation. Adaptive clusters are formed during the set-up phase and data transfers occur during the steady-state phase.

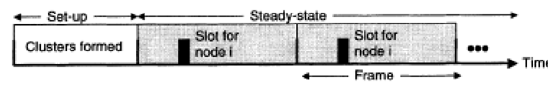


Fig. 5 Time line showing LEACH operation. Data transmissions are explicitly scheduled to avoid collisions and increase the amount of time each non-cluster head node can remain in the sleep state.

If the cluster heads were chosen a priori and fixed throughout the system lifetime, these nodes would quickly use up their limited energy. Once the cluster head runs out of energy, it is no longer operational, and all the nodes that belong to the cluster lose communication ability. Thus, LEACH incorporates randomized rotation of the high-energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way, the energy load of being a cluster head is evenly distributed among the nodes. The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster head and on to the BS, as shown in Fig.4.

## 6. Performance Analysis

Table 1: Comparison of clustering techniques

| Algorithm/ protocol | Objective |
|---|---|
| Minimum transmission clustering algorithm | Reduces the number of data transmissions and balance the traffic load throughout network |
| MEMAC | Used for removing network congestion and improve the energy efficiency of sensor nodes |
| HEED | Prolonging network lifetime by distributing energy consumption |
| LEACH | Improve system lifetime and provides the high performance needed under the tight constraints of the wireless channel |

## 7. Conclusions

Wireless sensor network uses huge number of sensor nodes to collect data and sent it to the sink. Sensor nodes have limited sensing, processing and communication capabilities. Clustering is used to increase the lifetime of a network. Sensor nodes are organized into clusters .Within a cluster ,data are forwarded to the cluster heads by shortest path routing; at the cluster head, data are compressed to the projections using the CS techniques. In this paper, various approaches or protocols has been proposed for increasing the lifetime of the Wireless sensor network.

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