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# Comparative Analysis of Clustering Algorithms for Homogeneous Wireless Sensor Networks

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**Abstract**

Wireless sensor network is makeup of a large number of sensor nodes. The sensor nodes accurately monitor the system by collecting the information from their surrounding environment and sending their sensed data to Base Station or sink node. In Wireless sensor network the sensor nodes have limited energy so conserving the energy of each node is an imperative goal that must be considered when developing a routing protocol for wireless sensor networks. Hierarchical Routing is most energy efficient technique. Routing protocols are classified into two types: Homogeneous approach and heterogeneous approach. In Homogeneous approach, all nodes are identical in terms of size, shape, hardware configuration and the mode of energy supply. In Heterogeneous approach nodes are of different types in the terms of size, shape, hardware configuration, processing capability and the mode of energy supply. Mostly in the fields of wireless sensor network homogeneous nodes are used. In this paper some clustering techniques for homogeneous wireless sensor network are described. This paper also compares all these techniques based on some parameters.

**Keywords**: Network, Base Station, Sensor Nodes, hierarchical, Wireless Sensor Network, LEACH.

## 1. Introduction

Wireless sensor network is an arrangement makeup of a large number of inexpensive, low power sensor nodes which are highly disseminated either within the system or very near to it. These nodes are randomly placed so protocols and algorithms of sensor networks must have ability of self organizing in inaccessible areas. However nodes have limited energy supply and bandwidth. One of the most important challenges for sensor nodes is the requirement of low power consumption.

Routing is a method by which a path between source and destination is found for the data transmission. In WSNs the network layer is used for implementing the routing of the incoming data and Routing protocol is imperative factor in design of a communication stack. According to types of nodes routing protocols are classified as: Homogeneous and Heterogeneous approach. [1, 12]

In *Homogeneous approach* all nodes are identical in terms of size, shape, hardware configuration and the mode of energy supply. All nodes have the same transmission power (range), transmission data rate and processing capability, the same reliability and security.

In *Heterogeneous approach* nodes are of different types in the terms of size, shape, hardware configuration, processing capability and the mode of energy supply.

In Clustered protocols different nodes are grouped together to form clusters and data from nodes belonging to a single cluster are combined and send to base station by the cluster head of that cluster. The clustering protocols have several advantages like scalability, energy efficiency in finding routes and easy to manage. In the non–clustered approach, there is no need to form a cluster of nodes. Each and every node is free to send data to the Base station on its own. [12]

## 2. Description of Various Clustering Algorithms for Homogenous Network

### 2.1. LEACH (Low-Energy Adaptive Clustering Hierarchy)

LEACH is a self-organizing and adaptive clustering protocol. To uniformly distribute the energy load among the sensor nodes of the network, LEACH utilizes rotation between the cluster head positions. In LEACH protocol the nodes arrange themselves into local clusters and from each cluster one node acts as the cluster head. The operation of LEACH protocol is split divided into rounds. Each round has two phases: a set-up phase and steady-state phase. In the set-up phase the clusters are organized. In the steady-state phase data is transferred from the nodes to the cluster head and on to the BS.

3.1.1. Set –up Phase: Set up phase is further consists of three phases: Advertisement Phase, Cluster Set-Up Phase, and Schedule Creation.

**3.1.1.1. Advertisement Phase:** In LEACH clusters are formed by using a distributed algorithm. Nodes make autonomous decisions without any centralized control. In this phase each node decides whether to become a cluster-head or not for the current round. This decision is made based on the desired percentage of cluster heads for the network and the number of times the node has acted as a cluster-head so far. For making a decision node n chooses a random number between 1 and 0. If the chosen number is lower than the threshold value T(n) of the node then node becomes a cluster-head for the current round. The threshold value T(n) is calculated by using following formula:

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

Where P denotes the desired percentage of cluster heads, r denotes the current round, and G denotes the set of nodes that have not been cluster-heads in the last 1/P

rounds.This threshold ensures that each node will be a cluster-head at some point within 1/P rounds. During round 0 each node has a probability P for becoming a cluster-head. The sensor nodes which had acted as cluster-heads in round 0 cannot act as cluster-heads for the next 1/P rounds. This increases the probability of the remaining nodes to act as cluster-heads because there are fewer nodes that are eligible to become cluster-heads. After (1/P)-1 rounds, T = 1 for all the remaining nodes that have not been act as cluster-heads yet. After 1/P rounds, all nodes are once again eligible to become cluster-heads. Each node that has selected itself a cluster-head for the current round broadcasts an advertisement message "cluster-head-advertisement" to the rest of the nodes using a CSMA MAC protocol.

**2.1.1.2. Cluster Set-Up Phase:** When each node has decided the cluster to which it belongs, it should inform the cluster-head node of that cluster. Each node transmits a join-request message (Join-REQ) to the chosen cluster head using a non persistent CSMA to inform that it will be a member of that cluster.

**2.1.1.3. Schedule Creation:** The cluster-head node receives the messages from nodes which have joined that cluster. The cluster head node creates a TDMA schedule and broadcasts this schedule to all the cluster members to inform when it can transmit.

**2.1.2. Steady-State Phase:** Once the clusters are created and the TDMA schedule is fixed, data transmission begins. The steady-state operation is broken into frames. The nodes send their data to the cluster head at most once per frame during their allocated transmission slot. The time required to send a frame of data depends on the number of nodes in that cluster. [4, 5]

**2.2 TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol)**

This protocol is for reactive networks. In this protocol a hierarchical clustering scheme of LEACH is used. In this a hierarchy of clusters is formed, so the sensor nodes send their sensed data to their corresponding cluster head and the cluster heads nodes in turn forms a hierarchy. The lower level cluster heads send their data to their higher level cluster head and only the topmost level cluster head nodes transmits directly to the *BS*. Thus the root of the hierarchy is the *BS.* According to this protocol at every cluster change time, along with the attributes two more parameters (hard threshold and soft threshold) are also broadcasted by cluster-heads to their members.

***Hard Threshold (HT):*** Hard threshold is a threshold value. If any sensing node found value of the sensed attribute greater than or equal to this hard threshold, it turns on its transmitter and conveys this to its cluster head.

*Soft Threshold (ST):* This threshold indicates the small variation in the value of the sensed attribute that causes the node for switching on its transmitter and starting transmission.

The nodes continuously sense the environment. When the first time the value of any parameter of the attribute set is found equal to hard threshold value of that parameter, the node turn on its transmitter and transmits the sensed data. In the internal variable (SV) in the node this sensed value of the parameter is stored. Next time the nodes will transmit their data when currently sensed value of the sensed attribute becomes greater than the hard threshold and also differs from SV by an amount equal to or greater than the soft threshold. The hard threshold decrease the number of

transmissions by letting the nodes to transmit only when the sensed attribute is in the range of interest and the soft threshold further lessen the number of transmissions by removing all that transmissions that may occur even when there is small or no variation in the sensed attribute. Both hard and soft threshold values can be adjusted for controlling the number of packet transmissions. The values of both soft and thresholds have an effect over TEEN. [12, 2]

### 2.3. APTEEN (Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol)

APTEEN is an improvement to TEEN. This protocol is for Hybrid networks, it means the sensor nodes transmits data periodically (as in LEACH), and also reacts when abrupt changes occur in the values of the attributes (as in TEEN). APTEEN also uses the hierarchal clustering as TEEN. When selection of cluster head is completed, the cluster heads broadcasts some parameters such as the attributes, value of the hard and soft thresholds, and TDMA schedule for transmission to all sensor nodes, and it also broadcasts maximum time gap between two successive reports which are to be sent called count time (TC). Cluster Heads perform aggregation of the data for energy saving. APTEEN is capable of handling three different types of queries such as: Historical query (for analyzing past data values), One-time query (for taking a snapshot view of the network), and Persistent queries (for monitoring an event for certain time period). The difference between LEACH and APTEEN is that in LEACH sensing nodes send their sensed data continuously, but in APTEEN sensing nodes send their sensed data on the basis of values of the thresholds. [12, 6]

### 2.4. LEACH-CENTRALIZED (LEACH-C)

LEACH is a distributed cluster formation algorithm and LEACH does not offer guarantee about the placement and number of cluster head nodes. In LEACH-C protocol centralized clustering algorithm is used to produce better clusters. It produces better clusters by dispersing the cluster head nodes along the whole network. LEACH-C protocol also has two phases: setup phase and steady state phase. During the setup phase of LEACH-C protocol BS selects CHs by using information of node location and energy level and determines the near-optimal clusters. The BS ensures that the energy load is evenly distributed among all the nodes. The steady state phase of LEACH-C protocol is same as LEACH protocol. [5]

### 2.5. Three-layered LEACH (TL-LEACH)

The disadvantage of LEACH protocol is that all cluster head nodes directly communicate with BS. TL-LEACH protocol has three phases: cluster-heads choosing, cluster set-up and data transmission. Cluster-heads choosing phase of TL-LEACH protocol has two steps. In first step N*P cluster heads are chosen according to LEACH. These are called first level cluster heads. In second step by taking into consideration residual energy of nodes top N'*p level2 cluster heads from N*p level1 cluster heads are selected. In Cluster set-up phase clusters are formed. According to number of level2 cluster-heads, number of level1 cluster-heads belonging to corresponding level2 cluster-heads and number of leaf nodes belonging to

corresponding level1 cluster-heads, the level1 cluster-head creates a TDMA schedule informing each node when it can transmit and broadcasts the schedule to all nodes. In data transmission phase Level1 cluster heads collect information from their cluster members, aggregate it and transmit it to level2 cluster-heads, then level2 cluster heads aggregate this information again and send it finally to the base station. [12]

### 2.6. Energy-LEACH And Multihop-LEACH

In LEACH during cluster head selection residual energy of cluster head nodes is not considered. Energy-LEACH protocol improves the cluster head selection procedure of LEACH by taking into consideration residual energy of nodes. In first round N nodes randomly selected to become cluster head, after first round every node has different amount of energy. In next rounds n nodes having more residual energy are selected as cluster heads and this procedure is repeated until all the nodes in the network are dead. Steady state phase of Energy-LEACH is same as LEACH. In LEACH all the cluster head transmits directly to base station which may lead to more energy consumption. Multihop-LEACH improves the data transmission between cluster heads and BS. In Multihop-LEACH protocol communication between cluster head and sink is multihop instead of single hop communication as in LEACH. Setup phase of Multihop-LEACH is same as LEACH. [9]

### 2.7. TB-LEACH

In LEACH cluster heads are selected on the basis of random number and number of cluster heads is not constant. In TB-LEACH constant 4% cluster heads are chosen in each round. In TB-LEACH cluster heads are selected on the basis of random timer and number of cluster heads is constant (4%). To select the constant number of cluster heads a counter is used. Each node in the network generates a random timer at starting of a round. When the timer of a node expires it checks the number of CH's advertisement messages it has received so far, if it has received less than four CH's advertisement messages then it declares its cluster Head status. Otherwise it cannot become cluster head in this round. Remaining process after the cluster heads selection is same as LEACH protocol. [10]

### 2.8. CTPEDCA *(*A cluster-based and tree-based power efficient data collection and aggregation protocol for wireless sensor networks)

In LEACH all the cluster heads transmit data to BS directly so consumes more energy. In CTPEDCA set up phase is same as LEACH but in steady phase minimum spanning tree routing strategy is used for cluster heads to transmit data to base station. By using minimum spanning tree mechanism for transmission only one cluster node have to transmit data to the base station. [8]

### 2.9. LEACH-Based Clustering Algorithm for Optimizing Energy Consumption in Wireless Sensor Networks

This proposed algorithm solves the extra transmissions problem that may arise in LEACH algorithm. They have proposed a change in the set-up phase of the LEACH algorithm. In the setup phase of proposed algorithm, once the cluster heads are

selected, the other sensor nodes select cluster head among the cluster heads which are closer to BS in comparison to themselves and when node have chosen closest cluster head, it informs that cluster head that it will become a member of that cluster. If such a cluster head does not exist, it will not be the member of any clusters and will send its data directly to the BS. [7]

### 2.10. C-LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol randomly chooses some nodes as cluster heads on the basis of a probability model. In LEACH, due to probabilistic approach clusters of unequal size are created which leads to imbalance in consumption of energy and reduction in the efficiency and lifetime of the network. In C-LEACH protocol equally sized clusters are maintained which are situated uniformly within the network. In this protocol to create clusters two thresholds are used one for minimum (*thresh1*) and other for maximum (*thresh2*) number of children allowed for a cluster-head, thresholds are used so that clusters have approximately same number of child nodes. [11]

**Table 1**: Comparative Analysis of Clustering Algorithms for Homogeneous Wireless Sensor Networks [13]

| **Clustering Approach** | **Clustering Properties** | | | **CH Selection based On** | | **Type of protocol** | | |
|---|---|---|---|---|---|---|---|---|
| | **Cluster - Count** | **Intracluster Topology** | **Type of communication between CH And BS** | **Initial Energy** | **Residual Energy** | **Pro - active** | **Re-active** | **Hybrid** |
| **LEACH** | variable | Single hop | Single hop | No | No | Yes | No | No |
| **TEEN** | variable | Single hop | Multihop | No | No | No | Yes | No |
| **APTEEN** | variable | Single hop | Multihop | No | No | No | No | Yes |
| **LEACH-C** | variable | Single hop | Single hop | No | No | Yes | No | No |
| **TL-LEACH** | variable | Single hop | Multihop | No | Yes | Yes | No | No |
| **A. Energy-LEACH** | variable | Single hop | Single hop | No | Yes | Yes | No | No |
| **Multihop-LEACH** | variable | Single hop | Multihop | No | No | Yes | No | No |
| **B.TB-LEACH** | constant | Single hop | Single hop | No | No | Yes | No | No |
| **CTPEDCA** | variable | Single hop | Multihop | No | No | Yes | No | No |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **C-LEACH** | variable | Single hop | Single hop | No | No | Yes | No | No |
| **C. LEACH-Based Clustering Algorithm** | variable | Single hop | Single hop | No | No | Yes | No | No |

## 3. Conclusion

Homogeneous wireless sensor networks are those in which all nodes are identical in the terms of size, shape, hardware configuration and the mode of energy supply. In this paper some clustering techniques such as LEACH, TEEN, APTEEN and some descendants of LEACH for homogeneous wireless sensor networks are presented. These techniques are compared on the basis of their clustering properties, strategy used for selection of cluster heads and type of network in which these are used.

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