# A Review on the Clustering Protocols of the Wireless Sensor Networks

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*Abstract*— Wireless Sensor Networks comprises a huge number of sensor nodes. Recent developments in WSN have led to many new methods designed for them where energy attention is important consideration. The lifetime of the WSNs rely upon the energy of the network. Clustering gives a powerful approach to prolong the life time of WSNs. Each cluster is presented by node as the head of the cluster to maintain the immediate interaction with the base station as well as with other cluster heads. Cluster head (CH) selection is an important issue in sensor network application and can drastically affect the network's communication energy dissipation. In this paper we discuss some power efficient routing protocols and also highlight the important characteristics and drawbacks of each protocol.

***Key words:*** Base station, Clustering, Cluster head, Energy efficiency, Wireless Sensor Networks

## I. Introduction

Wireless Sensor Network (WSN) has many applications like monitoring (health, building, habitat), target tracking, military surviving [6] etc. Some devices generally have batteries, which are non-rechargeable. A WSN consists of huge number of self-organised receptors (as caved in figure:1 [2]), spread in the area for specific application. Each sensor is capable of detecting data from the environment, performing simple calculations and transferring sensed data to the command centre, called gateway. Sensors nodes are battery powered and once deployed are unwatched and expected to work for a long time, from a few months to years. These sensor nodes are implemented in large numbers and form an ad hoc network having capacity of reporting to base station (BS). All nodes in the network are connected with each other or by means intermediate sensor nodes. A sensor node that produces data, depending upon the sensing mechanism observation and transfer the sensed data packet to the BS.

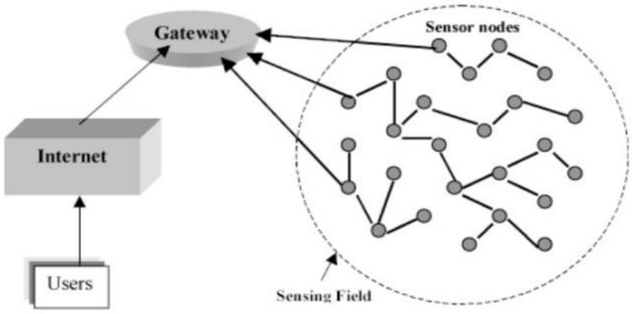


Fig. 1: Architecture of WSN

This technique generally direct transmission since the base station may situated very far away from sensor node needs. More energy is required to transmit the data over long distances, since energy is the limited resource of WSN hence its efficient use is crucial to extend the life time of the network. Sensing, computing and communication are the three main activities in which energy of the network is consumed. To increase the lifetime of the WSN, energy is the main issue.

## II. Clustering in Wireless Sensor Networks

Clustering is the process of grouping the sensor nodes in a densely deployed large network. It one of the ways to deal with the energy of sensor devices since just a few nodes called cluster-heads are permitted to communicate with the base station. The cluster-head gather the information sent by each node on that cluster, compress it and after that transmit the collected information to the base station [16].

### A. *Issues Of Clustering*

- How many sensor nodes should be taken to form a single cluster?
- What is the procedure for the selection of cluster head?
- Heterogeneity in network.

### B. *Sensor Network Model*

It is based on the model designed by Heinzelman et. al [15]. It comprises of base station (BS), through which the user access data from the network. All the nodes in the network have same initial energy. The BS have constant supply of power so, has no power constraint. The nodes cannot always reply to the BS straight due to their power restrictions, causes asymmetric communication.

This model uses hierarchical strategy. Consider the network as shown in figure.2 [8]. Each cluster has cluster head that gathers the information from its members, aggregates it and delivers it to the BS. The nodes 1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5 and 1.1 creates a cluster with 1.1 as a cluster head. Similarly the nodes 1.2, 1 etc. acts as cluster heads for other clusters. In turn, these cluster heads create a cluster with node 1 has their cluster head and the node 1 is second-level cluster head. This design is repeated to create a hierarchy of clusters with the topmost level cluster nodes reporting straight to the BS. The BS forms the root of this hierarchy and manages the network.

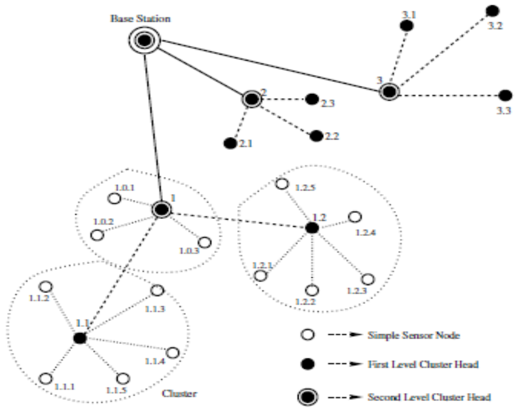


Fig. 2: Hierarchical Clustering

 

The main characteristics of this architecture are:

- All the nodes transfer only to their immediate cluster heads to preserve energy.
- None other than the cluster heads need to perform extra computation on data. Here energy is conserved again.
- CHs at increasing levels in the hierarchical clustering need to transfer information over larger distance. Combined with additional calculations they perform, they end up consuming power quicker than other nodes. In order to equally distribute this intake, all the nodes take turn to become cluster head for a time period T, known as the cluster period.

## III. Clustering Protocols

In past years, a few clustering procedures has been proposed.

### A. Low Energy Adaptive Clustering Hierarchy Protocol (LEACH) [1] [10]

LEACH is the first clustering strategy. It was the most famous protocol that proposed to delay the general lifetime of the system and to diminish the general energy consumed by the network. The operation in LEACH is partitioned into rounds. Each round contains a set-up stage, where each sensor node picks an irregular number somewhere around 0 and 1 to choose it will become cluster-head or not. If the number chosen by a specific node is less than the threshold value T(n), the node turns into cluster-head for the current round. We can find the value of T(n) using equation 1 [7].

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \frac{1}{p}\right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad \text{..... (1)}$$

#### 1) Features of LEACH

- It rotates the cluster head randomly to accomplish balanced power consumption.
- Sensors have synchronized clocks.
- Sensors do not need to know any details about location and distance.

#### 2) Drawbacks of LEACH

- 2-hop connection sinks.
- Dynamic clustering gives additional overhead which may limit the gain in power intake.
- LEACH depend upon probability model, hence there is possibility that all the CHs will be situated in same area.

LEACH is most suitable for continuous monitoring such as fault recognition.

LEACH-C (LEACH-Centralized) [15] uses centralized cluster development algorithm to create clusters. This protocol uses the same steady-state protocol as LEACH. During the set-up stage, the base station gets details from each node about their current location and energy level. Then the base station runs the algorithm to find out cluster head and clusters for that particular round. This protocol uses cluster head arbitrarily but the base station makes sure that only the nodes with sufficient energy are participating in cluster head selection process. Every node, except the node which is selected as cluster head, finds out its local TDMA slot, used for transmission of data, before it goes to sleep.

LEACH-F (LEACH with fixed clusters) [15] is the further development to LEACH. LEACH-F relies on clusters that are created once and then fixed. The position of the cluster head rotates among the nodes of the cluster. The benefit of this protocol is that, once the clusters are created, there is no set-up overhead at the starting of every round. LEACH-F also uses the centralized cluster formation protocol to create clusters. In the LEACH-F, the fixed clusters do not allow new nodes to be included somewhere in the network.

### B. Power Efficient Gathering In Sensor Information System (PEGASIS) [13]

PEGASIS makes progress on LEACH by building a node chain instead of cluster head. The essence of this method is that the nodes only need to communicate with their nearest neighbours they take turns in interacting with base station(BS) as shown in figure 3[12].

When the round of all nodes interacting with BS finishes, a new round begins, and so on.

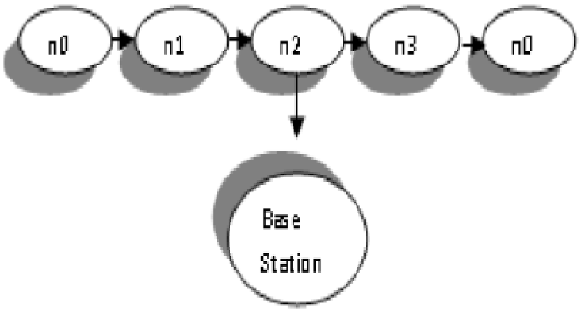


Fig. 3: Chaining in PEGASIS

The chain in PEGASIS involves those nodes that are nearest to each other and create a path to the BS. The aggregated type of data will sent to the BS by any node in the chain.

#### 1) The Important Characteristics Of PEGASIS Are:

- PEGASIS prevents cluster formation and uses only one node in the chain to transfer to the BS instead of several nodes.
- It boosts the lifetime of each node by using collaborative methods.
- It reduces the energy needed to transmit data as per round.

#### 2) There are some drawbacks of PEGASIS:

- It assumes that each sensor node is able to interact with the BS straight. In practical, the nodes use multi-hop interaction to reach the BS.
- It assumes that all sensor nodes have same degree of energy and are likely to die simultaneously.
- PEGASIS introduces extreme wait for distant nodes on the chain.

PEGASIS is most suitable for motion detection and other surveillance application.

H-PEGASIS (Hierarchical PEGASIS) allows further improvement to PEGASIS. It allows transmission even when the nodes are not adjacent. H-PEGASIS suggests a solution to the data gathering problem. In H-PEGASIS simultaneous transmission of data message are pursued to reduce the delay.

*3) Threshold-Sensitive Energy Efficient Sensor Network Protocol (TEEN) [5]*

The network structure in the TEEN is based upon a hierarchical grouping where closer nodes form clusters and this process goes on the second stage until the BS is achieved. In this method the nodes sense the medium consistently and the data transmitted is done less frequently. TEEN uses LEACH's process to form clusters. TEEN protocol separates the sensor nodes twice for grouping cluster in order to identify the sudden changes in the sensed attributes like temperature. After the clusters are established, TEEN divides the cluster head into second-level cluster head and uses Hard-threshold and Soft-threshold value to identify the changes. The time line for TEEN is depicted in fig 4 [5].

The important features of TEEN are:

- The user gets the time crucial data instantly

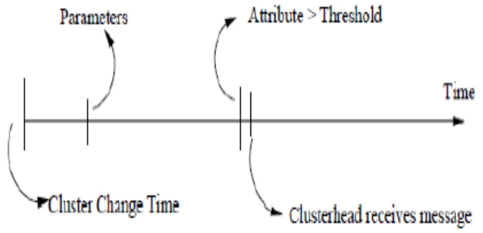


Fig. 4: Time Line for TEEN

- The soft threshold can be different based on sensed attribute.
- A smaller value of ST gives the better picture of network.

*4) Drawbacks Of TEEN Are*

- When the number of nodes in WSN is large, the delay of data transmission is obvious.
- A node may wait for their time slot for transmission of data.
- Complexness in the cluster formation takes place.

TEEN is well suited for time critical applications.

*C. Adaptive Threshold-Sensitive Energy Efficient Sensor Network Protocol (APTEEN) [2]*

APTEEN is an improvement to TEEN aiming to overcome its short comings and supporting periodic report for time critical events. APTEEN allows the sensor to deliver their sensed data regularly report to any change in the value of sensed feature. The time line of APTEEN is shown in fig 5

- Attribute (A): parameters about which the user has an interest in acquiring information.
- Thresholds: consists the HT and ST.
- Schedule: it is a TDMA scheme to assign a slot to each node.

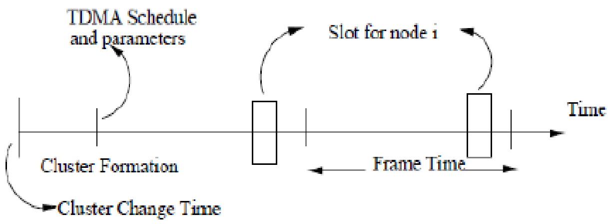


Fig. 5: Time Line of APTEEN

- Count time (CT): the maximum time interval between two successive reviews sent by the node.

*1) The Main Characteristics Of APTEEN Protocol Are:*

- It brings together both reactive and proactive policies.
- APTEEN provides flexibility.
- The power intake can be managed by changing the CT.

APTEEN is most suitable for periodic sensing and also for time critical applications.

*D. Hybrid Energy Efficient Distributed Clustering (Heed) [9] [12]*

HEED is an outstanding cluster-based protocol. It chooses CH based on residual energy and density of nodes. In HEED, the suggested criteria periodically select the CHs according to the combination of two clustering parameters. The main parameter is their residual energy of each node and the additional parameter is the inter-cluster interaction cost. HEED was proposed with four primary objectives:

- Extending the lifetime of network by distributing the consumption of energy.
- Ending the process of clustering with a constant number of iterations.
- Reducing management expense.
- Generating well-distributed CHs.

*1) The Important Characteristics Of HEED Are As Follows:*

- HEED distribution of energy expands the lifetime of nodes in the network.
- HEED does not need unique node capabilities.
- It functions properly even when nodes are synchronised.
- The nodes only need the neighbourhood information.

*2) Some Disadvantages Of HEED Are:*

- The random choice of cluster head may cause higher interaction overhead.
- The regular cluster head rotation needs extra power.

HEED is best suited to prolong the lifetime of the network.

*E. Energy- Aware Routing Protocol For Cluster-Based Sensor Networks (EARP) [11]*

EARP is mainly developed for cluster-based sensor networks. It is based on three-tier architecture. The algorithm consists of cluster head, namely gateways, which are less power restricted than sensors and believed to know the location of sensor nodes. The sensor is believed to be able to operate in an active mode or a less power stand –by mode.

*F. Position Based Aggregator Node Election Protocol (PANEL) [3] [4]*

The primary objective of the PANEL is to choose aggregators, i.e. CHs for efficient and persistent data storage applications. PANEL supposes that the nodes are implemented in bounded area, which is divided into clusters. The clustering is identified before the implementation of the network and the each node is pre-loaded with the regional of the cluster to which it belongs. Figure 6 [3] illustrates the geographical clustering in PANEL.

 

1) *Some Merits Of This Protocol Are:*
   - As the each node is elected aggregator, it insures load balancing.
   - It facilitates asynchronous applications

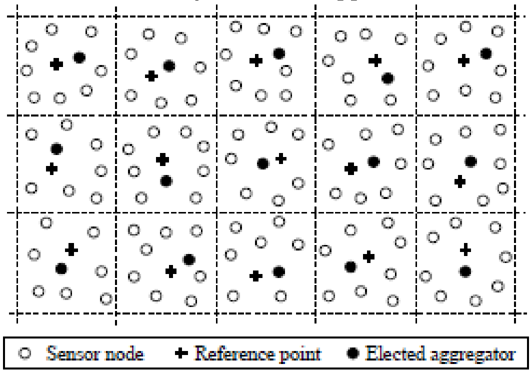


Fig. 6: Illustration of Geographical Clustering in PANEL

2) *The Following Are Some Drawbacks Of PANEL:*
   - The supposition that the clusters are determined before implementation and thus cannot be applied to WSN.
   - An important supposition of PANEL is that the nodes of the cluster create a sub-network, if this supposition is dissatisfied, then some nodes will not listen the statement of the node nearest to the reference point, and they will choose another node as aggregator.

## IV. Comparison between Clustering Protocols

Table 1 gives comparison of above mentioned energy efficient clustering protocols for wireless sensor networks. PEGASIS enhance the network lifetime two-fold as it is compared to the LEACH. The performance of APTEEN can be found between TEEN and LEACH with regard to energy intake and lifetime of the network. The HEED clustering prolongs the lifetime over LEACH because LEACH randomly selects CHs, which may result in quicker loss life of some nodes. The final CHs selected in HEED are well allocated across the WSN and the interaction cost is minimized as compared to other protocols. Simulation results show that both TEEN and APTEEN are more effective than LEACH in terms of power intake and response time.

| | **Type of routing** | **Mobility of node** | **Energy efficient** | **Cluster stability** | **Multi-hop** |
|---|---|---|---|---|---|
| **LEACH** | Clustered | BS fixed | No | Moderate | No |
| **PEGASIS** | Chain based | BS fixed | Yes | N\A | No |
| **TEEN** | Hybrid | BS fixed | Yes | High | Yes |
| **APTEEN** | Hybrid | BS fixed | Yes | High | Yes |
| **HEED** | Clustered | Stationary | Yes | High | Yes |
| **EARP** | Clustered | Stationary | Yes | High | Yes |
| **PANEL** | Clustered | N\A | Yes | Moderate | Yes |

Table 1: Comparison between Clustering Protocols

## V. Conclusion

In past years, routing protocols in WSN has become one of the most essential research places and there have been existed a large amount of research success. This paper provides some power efficient routing schemes designed for WSN. As our study reveals, it is impossible for a single routing protocol is suited for all scenarios and for all applications.

Although many routing protocols has been suggested in WSN, many problems like effectiveness, adaptability, scalability and security still exist and still many difficulties that need to be solved in WSN.

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