

# PERFORMANCE COMPARISON OF VARIOUS CLUSTERING TECHNIQUES IN WIRELESS SENSORS NETWORKS

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## ABSTRACT

*The study in preceding years shows that the clustering techniques have enhanced the use of WSNs in diversified fields. This makes it useful in many areas where other networking infrastructures are impossible to implement. Flat and hierarchical routings are two kinds of routing protocols in wireless sensor networks (WSNs) those are commonly used. In this paper, various clustering protocols with their advantages and disadvantages have been studied. Taxonomy of clustering in WSN is also studied. Relatively, extension using fuzzy with some prominent schemes has also been proposed.*

**Keywords:** *Wireless sensor networks (WSNs), Clustering, Cluster head (CH), Base Station (BS).*

## 1. INTRODUCTION

In the past few years, technological progress in the field of microcontroller architectures, sensors and low power wireless transceivers have enhanced the deployment of large wireless sensor networks (WSNs). Thousands of wireless sensor nodes are expected to operate for extended periods of time (days or months, possibly years) without physical human interposition. As replacing the batteries in many applications could be expensive or impossible, for such WSNs applications the power management technique helps in extending the lifetime of the network. [1]

A sensor network consists of a large number of tiny sensing devices which are small, lightweight and portable. These sensing networks are equipped with wireless interface, with which, they can communicate with one another to form a network. Sensor nodes sense the environment and then the sensed data is being transmitted to other nodes over wireless channels and to a pre-determined sink point, which is known as the Base Station (BS). The BS does collection of data from various CHs in the network. Due to deployment flexibility and maintenance simplicity, WSNs have been seen in many areas like object tracking, traffic control, fire detection, telecommunication, medical, defense etc. [2] The Mobile Nodes do sensing and information collection from their surroundings and send this to Cluster Heads (CHs). The CHs are responsible for data aggregation, information dissemination and network management [3]. This strategy improves energy efficiency of the network.

## 2. GOALS OF CLUSTERING

Less energy consumption, localization, maximum network lifetime and load balancing are some of the features to be considered in clustering routing protocols which are discussed as follows:-

### 2.1 Energy conservation

In scheme of routing of clustering, data aggregation is the process which reduces the transmission of data and preserve energy consumption .sensor nodes in clustering which performs long distance transmission/receiving in inter-clustering or intra-clustering can be reduced. Thus efficient amount of energy is consumed. Data transmission is done from CH to BS in clustering routing process and directs saving of energy consumption.

### 2.2 Scalability

Clustering in WSNs is a very effective technique for increasing survivability and scalability of nodes b dividing the whole network into a set of limited and individual nodes that could be controlled easily. Routing table size, repetition of messages and energy consumption can be reduced by applying clustering. Through which nodes sends their data in most efficient way and taking shortest path to communicate.

### 2.3 Network lifetime maximization

Maximizing the network lifetime is a very important goal in WSNs because sensor nodes are resource constrained and the clustering process increases the network lifetime as only cluster heads are taking care of the communication between network and the base station instead of all involving all the nodes.

### 2.4 Guarantee of Connectivity

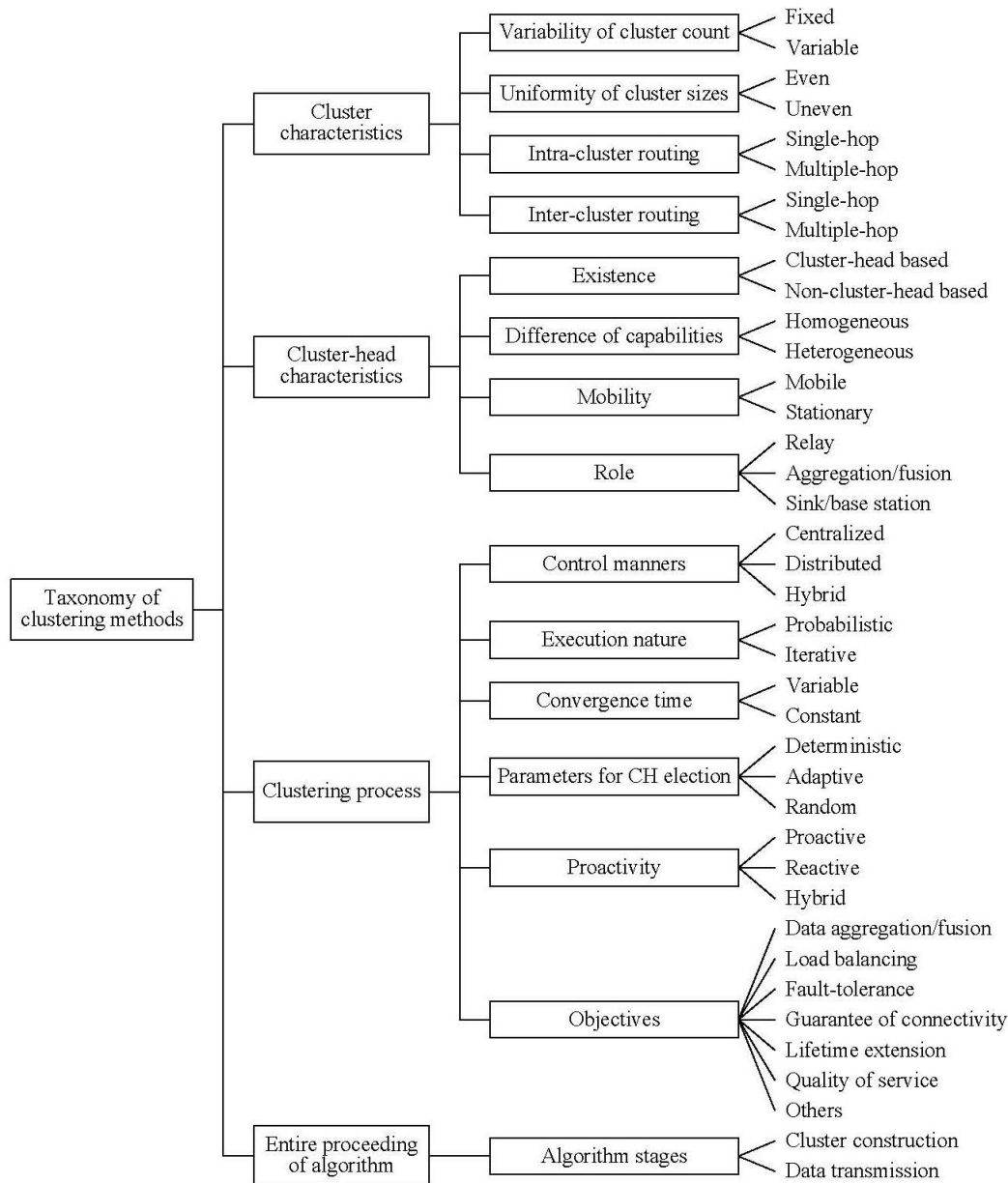
In WSNs, transmission of data is done to the base stations through the single or multi-hop routing. Checking whether a data is delivered successfully to BS or not is determined by the connectivity of node with its next neighboring node. If the nodes cannot communicate with each other, then the data cannot be transferred to the BS.

### 2.5 Load Balancing

Load balancing is helpful in extending the lifetime of network in WSNs. Sensor nodes are also deployed into the clusters for cluster construction where processing of data and intra-cluster management performed by the CHs. Even size of clusters extends the lifetime of networks and prevents exhaustion of energy of CHs.

Taxonomy of clustering in WSNs based on some features of is as given in figure 2.1

Figure 2.1 Taxonomy of Clustering in WSN[4]



### 3. RELATED WORK

Extensive surveys on clustering routing protocols in WSNs have been proposed by Xuxun Liu et al. [4]. Based on some matrices and taxonomy, some WSN clustering routing protocol have been in

analyzed in the present work. Some of the important clustered based routing protocols those have been studied are as follows:

### 3.1 LEACH

Heinzelman et al. [5] proposed the protocol named Low Energy Adaptive Clustering Hierarchy (LEACH). This protocol selects the sensor nodes as CHs randomly. This is the main objective of the LEACH. Randomly, the high energy usage in the communication to the BS is distributed in whole network due to selection of CHs. The operation of LEACH is divided into lots of rounds and each round is separated into two phases:

**Set-up phase:** In this phase, all the nodes in cluster take decision of becoming a CH or not for that round. The decision of CHs is done by percentage of CHs in the network and number of times a node has become a CH. If the value of that node is less than a threshold value then the node becomes a CH. The threshold is determined by following formula:

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

$$T(n) = 0 \quad \text{otherwise}$$

Where,

$P$  is the desired percentage of CH nodes in the sensor network.

$r$  is the current round number.

$G$  is the set of nodes that have not been CHs in the last  $1/P$  rounds.

**Steady-state phase:** In this phase, the data is transferred to the base station. The duration of steady-state phase is long as compared to the set-up phase in order to minimize overheads. LEACH is a completely disseminated approach. It does not require global information of network.

#### 3.1.1 Advantages of LEACH:

- 1) Node that have become CH in some round then that node cannot be CH again for next rounds.
- 2) Using TDMA schedule, gratuitous collisions for CHs are removed.
- 3) Prevention of extreme energy dissipation takes place.

#### 3.1.2 Disadvantages of LEACH:

- 1) It is not worthy for long distance communication network.
- 2) This clustering process brings extra overhead.

LEACH-C [6] was an extension of LEACH that uses centralized algorithm to select the CHs under the BS using fuzzy logic. In this work three parameters have been considered which the node remaining energy, the concentration is and the centrality of sensor nodes, the fuzzy logic selects suitable CHs among all sensor nodes. Depending on location and the remaining energy of sensor nodes, cluster head selection mechanism is done. The inputs of fuzzy inference system (FIS) are the energy and the distance between particular node and the BS. Based on the rule base, computation and decision of the output is taken by FIS which takes best node to become a CH. BS will select  $p \times$  total number of nodes

to become CHs based on their fitness. A list of Sensor nodes will be maintained from highest to lowest according to their fitness. Each round is restored in the table that keeps the information up-to-date. In short, the selected CH should be the best leader in every round.

### 3.2 HEED

Hybrid Energy-Efficient Distributed clustering (HEED) [7] as being introduced by Younis and Fahmy . It is a multi-hop clustering algorithm. Energy efficient clustering routing protocol is obtained with concern of energy. HEED is different from LEACH because it does not select CH randomly. The way of construction of cluster is achieved by combination of two factors: residual energy and cost of communication within the cluster. In HEED, chosen CH have comparatively high average residual energy related to MNs. Probability that a node becomes a CH is:

$$CHprob = Cprob \left( \frac{E_{residual}}{E_{max}} \right) \quad (2)$$

Where  $E_{residual}$  is the estimated current energy of the node.

$E_{max}$  is a reference maximum energy, which is typically identical for all nodes in the network.

$Cprob$  is a percentage of CHs among all nodes.

#### 3.2.1 Advantages of HEED:

- 1) It contains fully distributed clustering method that considers two factors for the election of CH.
- 2) Provides CH distribution and load balancing through the network.
- 3) It supplies multi-hop communication between CHs and BS to support more energy conservation and scalability.

#### 3.2.2 Disadvantages of HEED:

- 1) HEED undergoes a consequent overhead as it considers some loops to form cluster.
- 2) The CHs close to the sink node dies earlier because of it has extra work load.
- 3) HEED causes comparative energy dissipation which causes decreasing the network lifetime.

HEED-NPF protocol, an improvement on HEED protocol uses fuzzy logic and a nonprobabilistic approach for CH election. In [8], the authors showed that HEED-NPF acts better than HEED protocols in terms of network lifetime. In this, Non probabilistic CH election is done by studying delay which has inverse relation with residual energy of each node. The delay time is less of a node that has higher energy than that of nodes with a lower amount of energy. As a result, because its delay time has expired sooner, the node will be having high probability of becoming a tentative CH. Simulation results in [8] demonstrate that performance of HEED-NPF approach is better than HEED and LEACH protocols in terms of network lifetime and cluster formation.

### 3.3 DWEHC

Ding et al. [9] introduced a Distributed Weight-based Energy-Efficient Hierarchical Clustering protocol (DWEHC). This protocol is extension of HEED. It improves construction of cluster size and intra-cluster topology with awareness of the nodes. Both DWEHC and HEED while electing CHs has similarities like no supposition about size of network and density. Residual energy is another factor for CH election. Each node implements DWEHC separately and algorithm terminates after some iterations. Weight factor for CH election is defined in this process. Weight of the each node is calculated by:

$$W_{weight} = \frac{E_{residual}}{E_{initial}} \times \sum_u \frac{R-d}{6R} \quad (3)$$

Where  $E_{residual}$  and  $E_{initial}$  are residual and initial energy of nodes respectively.  $R$  is the cluster range that is the distance between a CH and a node inside a cluster.  $d$  is the distance between Node  $s$  and the neighboring node  $u$ .

According to Equation (3), Node having highest weight is elected as a CH and remaining node becomes a MNs. Initially MNs are very first node in a cluster (first level) that communicate with CH directly. On the basis of distance knowledge from its neighbors, it decides if a node will stay in first level or goes in h-level. Where, h-level gives the number of hops from CH to itself. If MN conserves energy while reaching destination then MN became h-level member. In DWEHC, these levels have been created for intra-cluster communication and a cluster range  $R$  is for the range of number of levels.

#### 3.3.1 Advantages of DWEHC

- 1) DWEHC is completely distributed clustering technique founded on the nodes energy reservation and distance to its neighbors for CH election.
- 2) Less energy consumption in intra-cluster and inter-cluster routing due to stability in CHs distribution.
- 3) Clustering process in DWEHC ends in few repetitions.

#### 3.3.2 Disadvantages of DWEHC:

- 1) Single-hop inter-communication takes place in DWEHC. Therefore it is not appropriate to networks of large-region.
- 2) Much control message overhead has been produced as compared to other protocols.

### 3.4 PANEL

Position-based Aggregator Node Election Protocol (PANEL) was introduced by Buttyan and Schaffer [4]. The main objective of PANEL is to select aggregators. It means that CHs for regular and tenacious data storage applications. The nodes are arranged in a limited area and it is separated into geographical cluster. The clustering is determined before the positioning of network and each node having the geographical information of the cluster within same cluster. At starting of each era, a reference point

$R_j$  is calculated in each cluster  $j$  by the nodes in dispersed manner in terms of the epoch number by using:

$$R_j = Q_j + Q$$

(4)

Where  $Q_j$  is the position of the lower-left corner of cluster  $j$ .

Further, every node knows the current epoch number  $e$  and in computation, a pseudo-random function  $H(e)$  is generated that maps  $e$  to a relative position inside the cluster, *i.e.*:

$$H(e) = Q$$

(5)

Where  $Q \in (-\delta d, d + \delta d) \times (-\delta d, d + \delta d)$ ,  $d$  is the size of the cluster and  $\delta < 1$  is a parameter which conveys the value of this re-sizing process in percent of the original cluster size  $d$ .

This CH election procedure in PANEL ensures load balancing since each node of the cluster can become CH with almost the same probability.

### 3.4.1 Advantages of PANEL

- 1) This protocol is an energy-efficient protocol and ensures load balancing by selecting aggregator.
- 2) Supports both synchronous and asynchronous applications.

### 3.4.2 Disadvantages of PANEL

- 1) PANEL needs geographical position which is not always available such as GPS.
- 2) Assumption which is determined by cluster before positioning is not useful of WSN dynamics.

## 3.5 EECS

Energy Efficient Hierarchical Clustering [10] is a probabilistic clustering algorithm. Algorithm was an extended version of LEACH with multiple hop architecture.

At first each node decides whether it can become cluster head or not based on its residual energy. If a given node does not find a node with more residual energy, it becomes a CH and advertises its presence to all its neighbor nodes. The cluster head is now called volunteer cluster head. All nodes that are farther away from cluster head receive all messages from cluster head if a member node receives this advertisement message, it will become a member of cluster head from which it has received its advertisement.

### 3.5.1 Advantages of EECS:

- 1) Low message overheads and uniform distribution of CHs.
- 2) Maintains balance between inter-cluster communication load and intra-cluster energy consumption.



### 3.5.2 Disadvantages of EECS:

- 1) Produces much more control overhead complexity since all nodes compete for becoming CHs.
- 2) Long-range transmissions from CHs to the BS produce much energy consumption.
- 3) Requires more global knowledge about the distances between the CHs.

GFCM protocol in Energy Efficient Clustering Scheme in Wireless Sensor Networks [11] has improved FCM protocol. It uses genetic algorithm and fuzzy methods for network clustering. In this protocol, distance between cluster head nodes and base station is main feature on which, fitness function calculation depends and the motive of implementing genetic algorithms is to select the most accurate cluster heads. It is a centralized method in which cluster members and transmission time are decided. All cluster heads directly sends information to base station. This method balance energy consumption in the network, which increases the network lifetime and reduces the energy consumption. This method is compared with the LEACH show better results, although the total residual energy of nodes and lifetime are not considered.

### 3.6 PEGASIS

PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [4] an enhanced version of the LEACH protocol follows the chain topology. It constructs the chain from sensor nodes in such a way that all the sensor nodes can communicate with neighbor node. One sensor node is elected as chain leader from that chain to collect the data from neighbors, and that broadcasts to the sink. The chain is being constructed from the most distant node of the sink o base station. The closest node from this furthest node will be the next node for the chain. When a node in the chain dies, reconstructed of the chain will be done in same manner to bypass the dead node.

#### 3.6.1 Advantages of PEGASIS:

- 1) Dissimilar network sizes and topologies can decreases the upstairs of dynamic cluster creation in LEACH and decrease the data transmission.
- 2) The energy load is isolated equally in network.

#### 3.6.2 Disadvantages of PEGASIS:

- 1) Long-term transportations straight from the node to the sink consume lots of energy.
- 2) A single chain causes communication that experience from extreme delays for distant nodes and possibility for a node having blockage.
- 3) All nodes have to preserve a whole database about the location of each node in the network.

## 4. CONCLUSION

The main objective of clustering routing techniques is to deploy sensors in such a way that network lifetime increases. The WSN is a wide area the paper has covered only few clustered based routing



protocols and the main characteristics of discussed protocol with their major advantages and disadvantages have been discussed here. By studying different clustering routing protocol, we conclude that use of fuzzy system in these protocol is relatively more efficient compared to other routing protocols. Fuzzy logic has potential for dealing with contradictory situations and requires low precision in data using heuristic human reasoning without needing complex mathematical modeling.

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