# Clustering Algorithms for Wireless Sensor Networks: A Review

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***Abstract – Wireless sensor networks (WSNs) have many applications in military services, health centers, industries as well as home surveillances. In such networks energy efficiency of nodes and life time of network are main concerns. Different clustering approaches are used to efficiently optimize the energy of sensor nodes. Clustering also improves the scalability of sensor nodes. We reviewed different approaches of clustering which are centralized, distributed and hybrid used in Sensor Networks. Recently there have been many researches on developing algorithms using equal and unequal clustering techniques. These techniques use residual energy of nodes and distance to base station as parameters for selecting cluster heads. This paper aims to examine various distributed and hybrid clustering algorithm as on date reported by different authors actively working in this area. We also briefly discuss the operations of these algorithms, as well as compare on the basis of various clustering attributes.***

***Keywords – Clustering algorithms, energy efficient routing, equal clustering, unequal clustering, wireless sensor networks.***

## NOMENCLATURE

BS- Base Station, CH- Cluster Head and WSNs – Wireless Sensor Networks.

## I. INTRODUCTION

A wireless sensor network may contain large no. sensor nodes. Each sensor node has a sensing capability along with limited energy source; computation capability, and communication ability. The communication medium of nodes is wireless and are self organize when deployed in adhoc fashion. As sensor nodes have limited and non-rechargeable energy resources, a very important issue in designing the protocol is energy efficiency, which affects the life of sensor networks big times. In order to increase the energy efficiency and decrease transmission delay, nodes are combined into many small groups called clusters. This methodology of combining sensor nodes is known as clustering.

For every cluster a selected node is called cluster head (CH). CH is responsible for gathering the aggregated data sent by others sensornode in cluster and transmit it to base station or sink. A cluster node is a node which has higher energy and capability than other sensor nodes. CH provides the scalability for large counts of nodes and reduces the energy consumption. Selection of cluster head is an important issue in designing clustering protocols. Most clustering protocols uses these techniques which are:

- CH with greater residual energy [5-8]
- Rotation of cluster head periodically so that energy consumption of network would be balanced [ 3]
- Cluster head selected on the basis of residual energy and base station communication distance.

Optimized management strategies can be introduced to CHs to further enhance the network operation and save energy of individual sensors and prolong network life [1]. We can classify the clustering algorithm in three categories: centralized clustering, distributed clustering and hybrid clustering. In Centralized clustering, cluster head is fixed. Other than cluster head node, remaining nodes are member nodes. In Distributed clustering, cluster head is not dynamically moving. The CH location changes form node to node based on some parameters. Hybrid clustering is the one which is formed choosing features of both centralized and distributed clustering.

In this paper we review some distributed clustering algorithms which can be divided into Equal and Unequal clustering algorithms. Some popular Equal clustering algorithms are LEACH [3], HEED [4], PEGASIS(Lindseyet.al.,2002), These algorithms works well in equal sized clustered homogenous networks. In unequal clustering algorithms, the network is partitioned into different size clusters. The clusters near to the BS are smaller than the clusters that are away from the base station [12]. These algorithms uses location of base station [BS] along with residual energy as a parameter for selecting the CH. Using unequal clusters decreases the intra-cluster

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work of the sensor nodes which are closer to the base station or have lower battery level. Some recent unequal clustering algorithms are proposed by researchers [5-8, 12].Unequal clustering can lead to more uniform energy dissipation among the cluster head nodes, effectively increasing network lifetime,
The rest of this paper is organized as follows: Section II presents taxonomy of clustering algorithms and classification of different clustering parameters used later to compare different clustering techniques. Section III briefly describes different clustering algorithms. This section also contains tabular comparison of described algorithms. Finally paper is concluded in section IV with future directions.

## II. TAXONOMY OF CLUSTERING ALGORITHMS

Different clustering techniques proposed can be classified as given in fig. 1 on the basis of network architecture, CH selection type and clustering objectives.

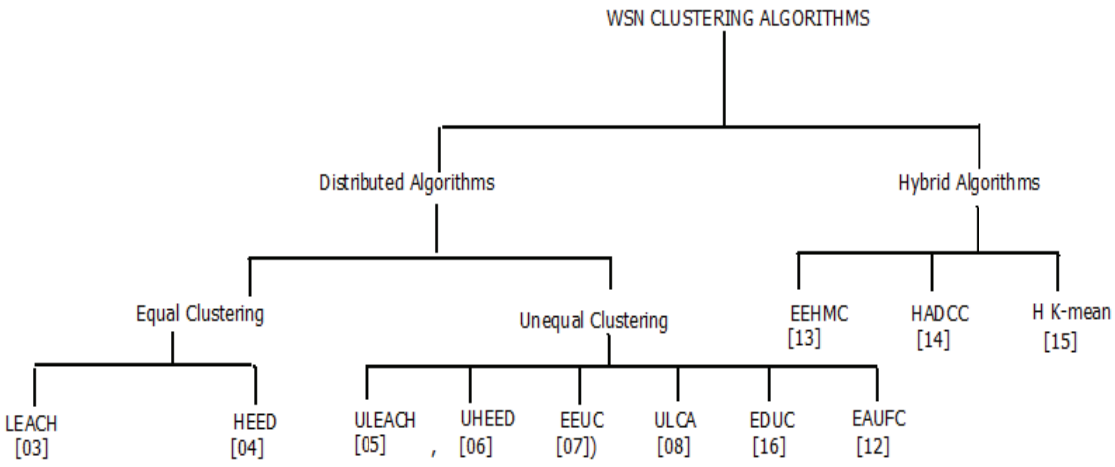


Fig.1. Taxonomy of Clustering Algorithms

### *A. Classification of clustering parameters*

- *Network Model:* For various WSN applications different architectures and models are considered. Some important architecture parameters purposed by [4] are enlisted below.
  - *Network dynamics:* A WSN basically contains sensor nodes, base station and monitored events. Other than few setups that utilize mobile sensors, most of the network architectures assume that sensor nodes are stationary [4]. Sometimes mobility of sensor nodes or CHs is required by WSN which make clustering very challenging since the node membership will dynamically change, and forces clusters to advance overtime.
  - *Node deployment and capabilities:* during the topological deployment of the sensor nodes we follow two procedures deterministic or self-organizing. Sensors are placed manually in deterministic manner so clustering is unnecessary.

But when sensors are placed randomly in self-organizing deployment in ad hoc manner, position of BS and CH are crucial issues in terms of energy efficiency and network life time.

- *Clustering objectives*
  In a WSN, objective of clustering may vary according the need of networks. Recently the main objective of clustering is improving energy efficiency and network life time but other than that load balancing, fault-tolerance [2] is also the reasons for clustering. Increasing the connectivity by using multi-hoping to communicate with BS in inter-cluster communication is also an important issue.

- *Clustering attributes*
  Attributes used to categorize and compare different clustering algorithms are enlisted below.
  - *Clustering type:* Size of clusters in network could be equal or unequal. LEACH [3], HEED [4] are algorithms with equal clustering i.e. size of clusters in same in network. In unequal clustering clusters near to base station are smaller.
  - *Inter-cluster connectivity:* According to the BS distance from CH communication could be single-hop or multi-hop.
  - *Cluster count:* For some algorithms CHs are

predetermined and thus the number of clusters. Lots of unequal algorithms prefer random cluster sizes.

- *Cluster head selection parameter:* initial energy of nodes, distances to BS and residual energy are some parameters based on which we select the cluster head.

Some attributes mentioned above are mutually exclusive like cluster count and clustering type. Other than these there are some attributes like mobility, node type and complexity which we will use to compare our algorithms in last section of this paper.

## III. CLUSTERING ALGORITHMS FOR WSNS

Clustering algorithms surveyed here are classified on the basis of methodology of clusters i.e. centralized, distributed and hybrid clustering. But here we will discuss some distributed and hybrid clustering algorithms respectively.

***3.1 distributed clustering algorithms:*** Algorithms in which cluster head keeps on moving from node to node are called distributed clustering algorithms. Here we introduce some distributed clustering algorithms on the basis of their cluster size.

***3.1.1 Equal clustering based algorithms:*** In large scale WSN energy efficiency and prolonging network life time were main issues. Clustering of network made data aggregation and communication between node and BS more efficient, thus saving node energy and prolonging network lifetime. In this section we discuss some equal clustering distributed algorithms.

### *A. Low-Energy Adaptive Clustering Hierarchy (LEACH)*

Heinzelman et al.[3] proposed a clustering-based protocol that usedlocal coordination and control mechanism for cluster set-up and operation. Randomized rotation of cluster-heads and the corresponding clusters is used to evenly distribute the energy load among the sensors in the network. LEACH forms clusters by using a distributed algorithm, where self-ruling decisions are made by nodes without any centralized control. The decision of working as a CH is made by the node *n* choosing a random number between 0 and 1 with a probability *p*. If number is less than threshold T(n), the node becomes a cluster-head for the current round. The threshold is determined by equation 1 given below:

$$T(n) = \begin{cases} \frac{P}{1-P*(r mod \frac{1}{P})} & \text{if n} \in \text{G} \\ 0 & \text{otherwise} \end{cases} \quad \text{.....(1)}$$

Where P is the desired percentage of cluster heads and G is the set of node that are not CH in 1/p rounds and r is current round number. At r=0 each node has probability p of being CH. As r increase probability that the remaining nodes are cluster-heads must be increased, since there is less no. of nodes that are eligible to become CH. In LEACH first order radio model was used to calculate energy dissipation on sending and receiving the message.

### *B. Hybrid Energy Efficient Distributed Clustering (HEED)*

Younis et al. [4]proposed HEED where CH selection is done according to a hybrid of the node residual energy and a secondary parameter, intra-cluster communication cost. HEED requireO(1) iterations to terminate,. CH is selected in probabilistic manner by residual energy parameter. By using intra-communication cost node joins the cluster head with minimum degree or with maximum degree to distribute cluster head load or to create dense clusters simultaneously. Probability of a node for becoming a CH can be define in equation 2 as:

$$CHprob = Cprob * \frac{Eres}{E\max} \quad \text{.....(2)}$$

Where C*prob*=initial percentage of cluster heads among all n nodes, E*res* is initial residual energy of node. CHs are well distributed in HEED and probability that two nodes within each other's cluster range are both cluster heads is small.

***3.1.2 Unequal clustering based algorithms:*** With the equal clustering there exists the hot spot problem which causes Unbalanced energy consumption in equally formed clusters. Clusters which are away from base station are dead than near clusters because of the more communication cost. To overcome this problem unequal clustering was proposed. Here we discuss some unequal clustering algorithms.

### *A . Unequal Clustering Scheme based LEACH*

Ren et al. [5] proposed an improved model for LEACH [hien.,2000] which has more different set-up stage. In the CH selection stage, they used the round robin and send "HELLO" message to get competition distance from BS for cluster head selection. To decrease energy consumption a distance matrix was used by each node to get information about neighbor nodes and energy ratio of current to primary energy and competition distance were used for generating a network structure with unequal clusters. Single hop communication method was used to interact with BS.Base station creates matrices of the distance and the residual energy, and then broadcasts it to all sensor nodes in the network. CH is defined by generating a random number, $a \in (0,1)$ by each node and by comparing *a* with threshold value of T(i) judgment of becoming a cluster head is made.

### *B. Energy Efficient Unequal Clustering (EEUC)*

During data transmission from nodes to base station the CHs closer to the base station are suffered with large relay traffic so due to more energy uses these nodes die early, generating hot spot problem. To address this problem *Li*et al. [7] presented an Unequal Clustering (EEUC) mechanism for periodical data gathering. As CHs closer to the base station act as routers of cluster heads away from the base station during delivering information to BS, clusters near to BS are smaller than clusters

away from BS given as in Fig.2 and uses multi hop data forwarding method.

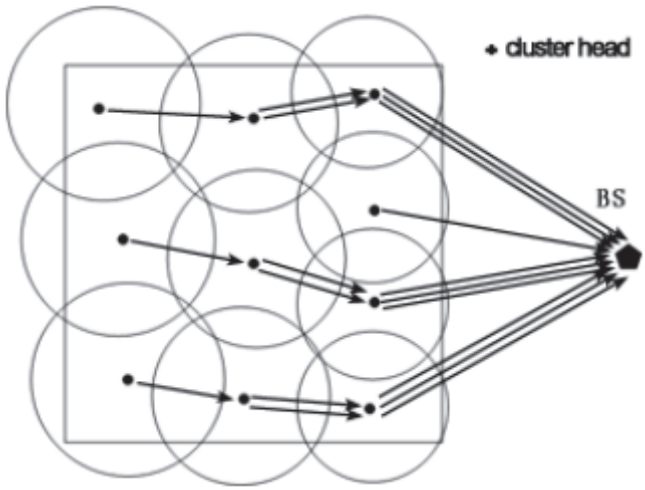


Fig.2. Cluster Mechanism of EEUC

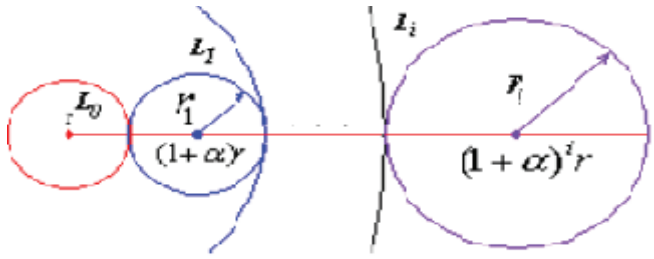


Fig.3. cluster formation in layers

First several CHs are selected with predefined threshold value *T*, each having its competition range *Rcomp.* After that If a node becomes a cluster head at the end of the competition, there will not be another cluster head within that node's competition diameter.

*C. UHEED- An Unequal Clustering Algorithm*

Ever et al. [6] proposed this algorithm which uses unequal clustering and leads to a more uniform residual energy in the network and improves network lifetime. The network mechanism of UHEED is same as EEUC[7]. UHEED uses the competition radius formula from EEUC which creates smaller clusters as the BS is neared. The simulation parameters used are same as HEED [4]. All nodes are homogeneous means energy, communication and processing capabilities of nodes are equal. For creating cluster in network competition radius is used. Fig (6) in UHEED shows that after the first node is dead, the overall residual energy level for all the cases is much higher than LEACH or Unequal LEACH. Also, it is observed that when half of the nodes are alive, the residual energy level in case of UHEED is comparatively higher than LEACH and Unequal LEACH.

*D. ULCA: Unequal Layered Clustering Approach*

Zaho et al.[8]proposed an unequal layered clustering protocol to mitigate the hot-spots problem in large scale wireless sensor network. Size of cluster increases as the distance from BS to nodes increases. In ULCA the entire network divided into layers of different size, which results in unequal size of clusters. Algorithms runs in 3 phases: initial phase, cluster setup phase and data transfer phase.
Fig-3 shows the cluster radius of clusters. The width of layer 0 (r0) and the expanding factor αo flayer are basic parameters for cluster formation. ULCA uses Inter-cluster Multi-hop Routing for data transmission from node to base station [8].

*E. EDUC: Energy-Driven Unequal Clustering*

Jiguo et al. [16] proposed an energy-driven unequal clustering protocol (EDUC) for heterogeneous wireless sensor networks. EDUC uses energy-driven adaptive cluster head rotation method to achieve balanced energy depletion in different clusters. To transmit an l-bit message to a distanced same energy model is used as EEUC [7]. During CH competition stage waiting time Tw of all nodes is calculated based on their residual energy, which can be calculated by equation 3:

$$Twi = \left(1 - \frac{Ecuri}{E\max}\right) * T1 * Vr, \quad \text{.....(3)}$$

Where E*curi* is the residual energy of node i, and E*max*isthe max residual energy of network.

*F. EAUFC: Energy Aware Unequal Fuzzy Clustering*

Bagci et al. [13], proposed an unequal clustering algorithm which uses fuzzy logic approach for handling the quandary in cluster-head radius evaluation. In order to assign competitive radius to clusters it utilizes the residual energy and the distance to the base station parameters of the sensor nodes [6]. Tentative cluster-heads are elected by using probabilistic model used in LEACH [3]. Tentative CH exchange *candidate CH* message with each other locally and CH having greater residual energy becomes Cluster Head. EAUFC performs better than LEACH [3], And EEUC [7] when compared according to FND (first node die) and energy efficiency matrices.

***3.2 Hybrid Clustering Algorithms:*** Recently researchers have shown lots of interest in developing clustering algorithms using Hybrid Clustering techniques i.e. combining the features of more than one algorithm into one. Here we present some hybrid clustering techniques proposed recently for WSN.

*A. EEHMC: Energy Efficient Hybrid Multi hop Clustering*

Ananya et al.[13] proposed EEHMC to prolong network life

using hybrid multi hop communication between CH and BS. In this scheme CH set-up decisions are executed at the BS (centralized) and cluster formation, relay node selection and data transmission decisions are taken by sensors (distributed). To select CH, base station uses remaining energy of nodes, no. of neighbor in transmitter range and min separation distance between CHs as deciding parameters. Algorithm 1[13] present the Ch election, distribution and multi hop transmission scenario. EEHMC increases network lifetime upto 27.63% over LEACH-C.

*B. HADCC: Hybrid Advanced Distributed and Centralized Clustering*

Aslam et al.[14] proposed this algorithm in which BS is positioned at center of network and algorithm works in 2 levels. In 1st level cluster formation of network is done and in 2nd level distributed CH selection is performed. For CH selection parameters used are position of node and residual energy. In order to select CH, suitability of each nodes m is calculated in equation 4:

$$Suitability(m) = \frac{Er}{ECR * Dbs} \text{ .....(4)}$$

Where ECR= energy consumption ratio, *Er= residual energy* HADCC add flexibility in cluster formation.

*C. H k-mean: Hybrid Clustering Algorithm for Optimal Clusters*

Kumar et. al. [15] proposed this new hybrid self decisive clustering technique based on Hierarchical Agglomerative Clustering and k-means algorithm presented by Kanungo. They used new clustering algorithm which merges hierarchical and k-mean algorithm. In hierarchical approach two closest clusters are grouped recursively until single cluster arrives. K- Mean clustering present specific number of disjoint and non-hierarchical clusters. Cluster configuration along with their centroid is gained and node nearest to centroid is select as CH. optimal number clusters are obtained by this hybrid technique.

TABLE I.COMPARATIVE STUDY OF VARIOUS CLUSTERING ALGORITHMS ON THE BASIS OF PARAMETERS

| **Clustering algorithm** | *Network model* | | ***Clustering Objective*** | *Clustering attributes* | | |
|---|---|---|---|---|---|---|
| | ***Node Deployment*** | ***Node capability*** | | ***Clustering Type*** | ***Intra-cluster Connectivity*** | ***CH selection Parameter*** |
| LEACH | Random | Homogenous | Energy saving | Equal | Single hop | Initial energy/ random approach |
| HEED | Random | Homogenous | Energy saving | Equal | Single hop/ Multi hop | Residual energy |
| ULEACH | Random | Homogenous | Energy saving | Unequal | Single hop | Energy ratio and competition distance |
| UHEED | Random | Homogenous | Energy saving | Unequal | Multi hop | Residual energy and distance to BS |
| EEUC | Uniform | Homogenous | Energy saving | Unequal | Multi hop | Localized competition distance |
| ULCA | Uniform | Homogenous | prolong Network life | Unequal | Multi hop | Residual energy /Distance to BS |
| EDUC | Random | Heterogeneous | Energy saving | Unequal | Single hop | Residual energy/ distance to BS |
| EAUFC | Random | Homogenous | Save energy | Unequal | Multi hop | Residual energy / distance to BS |
| EEHMC | Random | Homogenous | Improve energy efficiency | ---- | Multi hop | Residual energy / no. of neighbors and distance to BS |
| HADCC | Random | Homogenous/Heterogeneous | Energy saving | Equal | Single hop | Residual energy/ distance to BS |
| H k-Mean | Random | Heterogeneous | Optimal cluster/ Energy saving | ---- | ----- | Weighted residual energy |

Table I shows the brief summery and comparative study of various clustering algorithms on the basis of parameters like network model, clustering objective and different clustering attributes.

## IV.CONLUSION AND FUTURE SCOPE

Wireless sensor networks have broad area of applications. In large scale WSNs, due to limited energy of sensor nodes, clustering of nodes is required to provide scalability, energy efficiency and network life. Many researchers developed different clustering techniques like unequal clustering, hybrid clustering to get optimal clusters and prolonging network life. As the conclusion of this survey we found that by using unequal clustering, lifetime of CHs close to BS can be improved and so the network life. Unequal clustering variants of different clustering algorithms like LEACH and HEED perform better than these algorithms.

We have seen different unequal clustering algorithms for distributed environment. As future work we can use unequal clustering technique in hybrid environment for better energy utilization.

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