Clustering Approaches & Hierarchy in Wireless Sensor Network

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ABSTRACT: The arrival of wireless technology has reduced the human efforts for accessing data at various locations by replacing wired infrastructure with wireless infrastructure and also providing access to devices having mobility. The evolution of Wireless Sensor networks (WSNs)is a demandable, efficient and emerging area of Computer Science Engineering which has been currently employed in various field of engineering particularly in communication system to make it effective and reliable. The main challenge in wireless sensor network (WSN) operation is efficient use of energy to increase the life time of network. One of the techniques that can be used is 'clustering'. The sensor nodes are grouped into small clusters and a cluster head (CH) is elected for each cluster. The sensor nodes are grouped into small clusters and a cluster head (CH) is elected for each cluster. Sensor node transmits the data to the respective CH. In this paper a survey of different clustering algorithms and their comparisons is briefed.

Keywords: *Base station , Cluster, Cluster Head, Sink, Quality of Service (QoS)*

INTRODUCTION :

Wireless communication continues to enjoy exponential growth in the cellular telephony, wireless internet and wireless home networking arenas. With advent of Wireless LAN (WLAN) technology, computer networks could achieve connectivity with a useable amount of bandwidth without being networked via a wall socket. New generations of handheld devices allowed users access to stored data even when they travel. Wireless sensor networks composed of spatially distributed autonomous self organized system consisting of a large number of small, low cost battery operated sensor nodes. Sensor nodes are small with limited, power, processing and computational resources. The sensor network is mainly used to monitor physical and environmental conditions, gather data such as temperature, pressure, humidity and so on. To administer massive distributed sensors, the main challenges like scalability, fault tolerance, robustness and need for energy efficient solutions have to be met. Clustering is one of the techniques that can be used to meet the challenges in WSN[1]. In clustering, sensor nodes are portioned into smaller groups called clusters. In each cluster a cluster head (CH) is elected. The data from the sensor node is passed to the CH in each cluster; the CH forwards it to the base station or sink.

The cluster based organization of the sensor nodes leads to a two level hierarchy, where CH is the higher level and the sensor node the low level[2]. As mentioned the sensor nodes transmit the data to the CH. The CH aggregates the data directly or through communicating with neighboring CHs and forwards it to sink/base station. The base station is the data processing centre where the end user access data. Clustering provides overall system scalability, increase network lifetime and energy efficiency. In this paper different clustering algorithms in the WSN are discussed.

CLUSTERING PARAMETERS :

Before discussing the different algorithms, some important parameters are discussed. The different algorithms are compared based on these parameters.

A. Clustering Parameters

Cluster count: May be preset or variable depending on algorithm.

Communication between sensor and CH: The communication between a sensor and its CH (intra cluster) is assumed to be direct (one-hop communication) or multi-hop.

Mobility of Nodes and CH: The sensor nodes and CHs may be stationery which leads to stable clusters. On the other hand, if the CHs or the sensor nodes are assumed to be mobile, the cluster membership for each node changes dynamically so that cluster changes with time.

Type of Nodes: In heterogeneous environments the CHs have significantly more computation and communication resources than others. In homogeneous environments all nodes have the same computation and communication resources.

Method of Cluster formation: May be distributed or centralized. Selection of CH: The CH may be selected based on residual energy, connectivity etc., Complexity of algorithm: The time complexity and convergence rate of clustering algorithm may be constant or depends on total number of CHs or number of hops.

Overlapping: Sensor node overlapping within different clusters may or may not be supported depending different protocols.

*B. **Classification of Clustering Protocols***

There have been number of ways to classify clustering algorithms. Some of the common classification is:

1. Depending on the sensor capabilities: Clustering algorithms for Homogeneous or Heterogeneous networks.
2. Depending on formation of cluster: Centralized or Distributed clustering algorithms and *Static* and Dynamic clustering.
3. Depending on cluster formation and parameters for CH election: Probabilistic and Non-probabilistic clustering algorithms

In the following section the different clustering algorithms are briefed:

Linked Clustering Algorithm (LCA): is one of the initial clustering algorithms based on uniformly assigned unique identifiers as the key parameters for selecting cluster heads. It is a one-hop, static clustering algorithm. The main limitation of LCA is that, it leads to large number of clusters in the network and also LCA and its improved version LCA2 do not consider energy limitation of wireless sensor networks. It's a hierarchical, probabilistic, distributed, One-hop protocol. Other improved clustering protocols for WSNs are based on LEACH.

Probabilistic Clustering Algorithms: The most widely used probabilistic clustering algorithms are LEACH, EEHC and HEED and their extensions. The main objective of these algorithms is to reduce the energy consumption and increase the network lifetime.

Low Energy Adaptive Clustering Hierarchy (LEACH):

It is one of the first and most popular clustering protocols proposed for WSNs by Heinzelman. It is a dynamic protocol, using randomly deployed homogeneous stationary sensor nodes.

In this protocol clusters are formed based on the received signal strength and also CH nodes are used as routers to the BS. LEACH performs local data processing such as data fusion and aggregation. Clusters are formed by using a distributed algorithm, where nodes make autonomous decisions. CH is elected by sensor nodes with certain probability at any given time. To balance the load the role of CH is rotated periodically among the sensor nodes of the cluster.

The cluster formation of LEACH is divided into rounds. There are two phases in a round: 1) setup phase: during this phase, clusters are organized; 2) steady-state phase: during this phase, data is transmitted.

There are several modifications of the LEACH algorithm such as Two-Level hierarchy LEACH(TL-LEACH) ,Energy-LEACH (E-LEACH) , Multihop-LEACH (M-LEACH), LEACH with Centralized clustering algorithm (LEACH-C) , LEACH with Vice-cluster head (V-LEACH) , LEACH implementation using Fuzzy Logic (LEACH-FL) , Weighted-LEACH (W-LEACH) , Threshold based LEACH (T-LEACH) .

Advantages of LEACH

(1) Load is shared between nodes. (2)Prevents cluster heads from unnecessary collisions. (3) Avoid a lot of energy dissipation.

Limitations of LEACH

(1) LEACH cannot be used in networks spread over large distances. (2)Uniform distribution of cluster heads cannot be ensured (3) Dynamic clustering increases overhead.

Energy Efficient Hierarchical Clustering (EEHC)

This algorithm overcomes the shortcoming of one-hop communication of LEACH by extending the cluster design to multi-hops. It is a distributed hierarchical algorithm which aims at increasing network life time. Initially, each sensor is elected as cluster head (volunteer) with probability 'p' and broadcast this to the neighboring nodes within the communication range. Any node that receives this message and if it is not a cluster head, becomes cluster member .If any node that does not receive the message with in a preset time't', it becomes a 'forced' cluster head. This initial process is recursively repeated at all the levels of the clusters.

Advantages of EEHC

(1)Suitable for large networks (2) Energy consumption is minimum.

Hybrid Energy-Efficient Distributed Clustering (HEED)

It is an improved and very popular protocol introduced by Younis and Fahmy. HEED is a hierarchical, distributed, clustering algorithm.

Within each cluster a single-hop communication is used and among CHs and the BS multi-hop communication is allowed. Based on residual energy and intra cluster communication cost the CH nodes are chosen. To choose initial set of CHs, residual energy of each node is used. Intra cluster communication cost is used by the nodes in deciding to join a cluster or not. Thus in HEED the CH nodes are not selected randomly and CH nodes are well distributed in the network[5].

The clustering algorithm is divided into three phases:1) In the beginning, the algorithm sets an initial percentage of CHs among all sensors.2) Every sensor goes through number of iterations until it finds the CH that it can communicate to with the least cost.3) At the end, each sensor either picks the least cost CH or announces itself as CH.

Advantages of HEED

(1) It is a uniformly distributed cluster-based algorithm. (2) There is load balancing in the cluster. (3) High energy efficiency and scalability.

Limitations of HEED

(1) Energy consumption is not balanced.

(2) Overhead is more.

Nonprobabilistic Clustering Algorithms

These algorithms adopt more specific criteria for cluster head election and formation of clusters such as nodes connectivity, residual energy transmission power, mobility etc., Some of the Non-probabilistic clustering algorithms are given in the following section.

Hierarchical Control Clustering (HCC)

It is a distributed multi-hop hierarchical algorithm. Any node in the network can initiate the formation of cluster. There two phases: (1) Tree Discovery – basically a distributed formation of BSF tree. (2) Cluster formation.

Advantages of HCC

(1)Balanced clustering (2) Handle dynamic environments

Limitations of HCC

(1)Time complexity of O(n)

Distributed Weight-Based Energy-Efficient Hierarchical Clustering Algorithm (DWEHC)

DWEHC is an improvement over HEED was proposed by Ding *et al*.. Every node in the cluster runs the DWEHC algorithm on its own iteratively (seven times) resulting in a distributed network structure. Each cluster has a CH and child nodes which are divided into levels (level 1, level 2, etc.) depending on the clusters' range and the minimum energy of the CH. TDMA is used for intra-cluster communication. The sensor transmits the data to its CH which forwards it to the next CH and in turn to the base station.

Advantages of DWEHC

(1) Similar to HEED, DWEHC is a fully distributed clustering algorithm. (2) It significantly reduces energy consumption and results in balanced cluster head distribution. (3) The clustering process doesn't depend on size of network size.

Limitations of DWEHC

(1) Has low energy efficiency (single-hop inter-communication). (2) Has a large control message overhead.

Threshold-Sensitive Energy Efficient Sensor Network (TEEN)

Hierarchical scheme for reactive networks, was proposed by Anjeshwar *et al*.. It is used mainly in time-critical applications. TEEN is a combination hierarchical and data-centric, two-tier clustering topology. It uses two thresholds: hard threshold (HT) used for the sensed attribute and soft threshold (ST) used to show small changes in the value of the sensed attribute. A CH sends its members its HT and ST values try to reduce data communications.

Advantages of TEEN

(1) Data transmission can be controlled. (2) It is mainly suited to time-critical applications.

Limitations of TEEN

(1) If the node dies, the network will not be able to sense it. (2) Data may be lost in communication.

Some of the other clustering algorithms are:

MWBCA

The Multi-Weight Based Clustering Algorithm (MWBCA) introduced by Fan *et al*. is a reactive clustering algorithm based on LEACH. In MWBCA cluster is selected based on the evaluation of a score function called combined weight. The score function is a weighted combination of the residual energy of the sensor and the transmission power. The cluster head is selected by broadcasting the combined weight of every sensor to its neighbors. The sensor with the lowest weight is elected cluster head. All nodes alternately take turns to become CH.

Advantages of MWBCA

(1)The energy consumption of a cluster head is lower than LEACH.(2) The consumption of energy is balanced.

Power-Efficient Gathering In Sensor Information Systems (PEGASIS)

Proposed by Lindsey *et al*. is an improved version of LEACH. The basic idea of this algorithm is that each node communicates only with its close neighbors and one by one becomes the leader for data transmission to the sink. The location of the nodes is random. The nodes are organized into a chain by using a greedy algorithm. Each sensor node can perform data detection, communication, data fusion, and positioning. Energy is evenly distributed in the network.

Advantages of PEGASIS

(1) Due to chain of data aggregation number of data transmission is decreased. (2) The energy is distributed uniformly in the network.

Limitations of PEGASIS

(1) It is not suitable for networks with time-varying topologies. (2) Due to very long communication delays, a node can become a bottleneck. (3) The network is not scalable.

CONCLUSION

In this paper we had given the survey of different clustering algorithms used in WSNs. The need of clustering in WSNs and method of approach of different algorithms are discussed with their merits and short comings. It is proved from literature that clustering is useful in WSNs.

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