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CLUSTERING ALGORITHMS FOR WIRELESS SENSOR NETWORKS

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Abstract – A Wireless Sensor Network (WSN) Contains a large number of Small sensors can be an effective instrument for data collecting in diverse kinds of environments. The data gathering by each sensor is related to the sink, which unto the data to the end users. Clustering is presented to WSNs since it has proven to be an efficient method to prepare better data aggregation and scalability for great WSNs. Clustering also maintains the limited energy resources of the sensors. In This paper, we review the existing clustering algorithms in WSNs and compare them by different criteria; in addition, we describe the advantages and disadvantages of each algorithm.

Keywords *– Wireless Sensor Networks (WSNs), clustering, network lifetime, energy efficient.*

1 Introductıon

Wireless sensor networks contain a large number of low power multi functioning sensor nodes, operating in without care environment, with limited calculation and sensing abilities. Recent developments in low power wireless complex micro sensor technologies have made these sensor nodes available in large numbers, with a low cost, to be employed in a broad range of applications in martial and national security, environmental monitoring, and many other fields [1], [2].

Whereas wireless sensor nodes are power limited devices, long distance transfer should be maintained to minimum in order to prolong the network lifetime [3], [4], [5]. Therefore, straight connections among nodes and the sink are not persuasion. An efficient method for better efficiency is to order the network into some clusters, with each cluster selecting one

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node as its cluster head [6], [5]. Clustering algorithm in Wireless Sensor Network is known as a reliable method of self-organization [7].
The remainder of this paper is organized as follows. In section 2, we review clustering in WSNs and challenges in WSNs, also expressed some clustering parameters and process of clustering. In Section 3, we present most common classifications for WSNs clustering. In Section 4, we investigate several effective and popular clustering protocols for WSNs. Then, comparison discussed clustering protocols in Section 5. Finally, in Section 6 concludes the paper.

2 Clustering in WSNs and Challenges

Clustering can significantly effect on the overall scalability of the system, the lifetime and energy efficiency [8].

Clustering algorithms are used to reduce the number of nodes that transfer data to the sink or base station (BS). These algorithms, order the nodes based in the WSN into groups or clusters. One node in each cluster is identified as the leader of the cluster or the cluster head (CH). The nodes that are in a cluster though are not cluster head, become member nodes of that cluster. The member nodes will transmit their data to their CH, which is typically inside only a short distance, so consumed less energy [9].

Clustering in WSNs Is encountered some challenges, including confidence connectivity, electing the optimal frequency of CH circulation, calculation the optimal cluster sizes, and clustering the network in the attendance of a node duty cycle [11].

2.1 Clustering Parameters

Several important parameters with regard to the whole clustering method in WSNs are [10], [14]:

2.1.1 Number of Clusters (Cluster Count)

In most clustering algorithms the CH selection and cluster forming process, result in various numbers of clusters. However, in several spread method, the set of CHs are predefined and so the number of clusters are predetermined.

2.1.2 Intracluster Correlation

In certain basic clustering trends the relationship between a sensor and its CH is directly intended (one-hop communication). Whereas nowadays in most cases, multi-hop intracluster relationship is needed.

2.1.3 Mobility of Nodes and CH

If we suppose that the CHs and sensor nodes and are fixed; naturally encounter balanced and stable clusters with facilitated intracluster and intercluster network management. Against, if the nodes or the CHs themselves are supposed to be mobile, the cluster membership for each node should dynamically alteration, clusters that have recruited at any moment, and probably require permanent maintenance.

2.1.4 Nodes Types and Roles

In some provided network (i.e., heterogeneous environments) the CHs are supposed to be equipped with more calculation and communication resources than others. However, in many models of the usual network (i.e., homogeneous environments) all nodes have the same abilities and only a subset of the deployed nodes are selected as CHs.

2.1.5 Cluster-Head Selection

The leader nodes of the clusters (CHs) in some presented algorithms (mainly for heterogeneous environments) can be predetermined. However, in most cases (i.e., in homogeneous environments), the CHs are selected from the distributed set of nodes, in a probabilistic method or random methods or other specific criteria (Such as residual energy and connectivity, etc.).

2.2 Clustering Process

There are two basic stages in the clustering, which are CH selection and cluster establishment. But the evaluation degree of algorithms may differ in various steps. According to algorithm steps of all process of clustering algorithms, clustering routing protocols in WSNs can be classified into cluster formation based and data transition based ones [12], [13], [14].

3 Classification of Clustering Algorithms

There have been several different methods to classify the algorithms used for WSNs clustering, [10]. Four of the most common classifications are shown in Figure 1.

3.1 Clustering Algorithms Homogeneous or Heterogeneous Networks

This classification according to the characteristics and performance of sensor nodes in a cluster. In heterogeneous sensor networks, all nodes have the same specifications, hardware and processing capabilities. In these networks, which are common in nowadays applications, each node can be a CH. In addition to these networks, the CH role can be replaced between the nodes periodically (for the creation of better and more integrated load balancing energy). Against in *heterogeneous* sensor networks, generally, there are two types of sensor, the first type sensors with more processing abilities and complex hardware.

These sensors predetermined as a CH node. The other type conventional sensors, with lower abilities, which in fact, used to sense the environment properties.

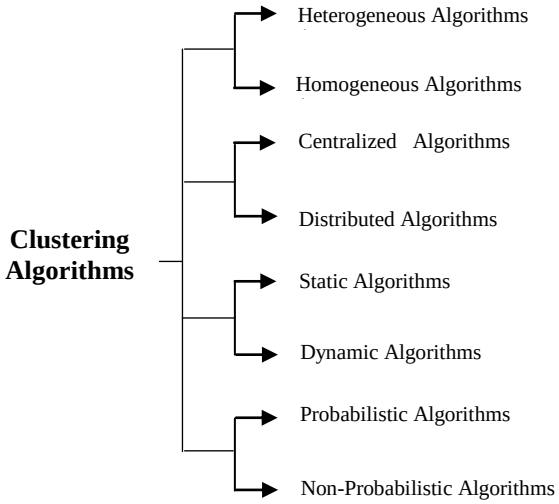

Figure 1. Common classification algorithms

3.2 Centralized or Distributed Clustering Algorithms

These clustering algorithms imply on the method utilized for shaping clusters. A distributed CH selection and shaping process are the most suitable way to obtain enhanced flexibility and faster convergence times independent of the number of nodes of the WSN. This approach is the most efficient method, particularly for large networks. Also, there are a few approaches using centralized or hybrid method, which one or more coordinate nodes or base stations (sink), responsible for the break up into detached and control of all network cluster members. These networks are not appropriate for overall objective large-scale practical application WSNs. They may be appropriate just for specific targets bounded-scale applications in which high-quality connectivity and network separation is needed.

3.3 Static and Dynamic Clustering Algorithms

Other conventional classification is static or dynamic clustering. Process shaping clusters is dynamic (otherwise as static) when it contains regular (periodic or event-oriented) CH re-election or includes cluster reorganization routine, these procedures may be effective in order to respond to changes in network topology and only accurately the cluster topology or proper movement with the purpose CH role between the nodes to obtain in energy saving. Dynamic cluster architectures make a better use of the sensors in a WSN and naturally result in improved energy consumption management and network lifetime.

3.4 Probabilistic and Non-Probabilistic Clustering Algorithms

This classification based on cluster shape parameters can be used to select the CH. These clustering algorithms are divided into two categories: probabilistic (random or hybrid) and non-probability (deterministic). Most clustering algorithms are known, they can be divided

into two main categories. In the probabilistic clustering algorithm for determining the initial CH, a probability assigned to each node. Probabilistic clustering algorithms, beyond the more energy-efficient, often running faster at the convergence and reduce the volume of messages they exchange. In the non-probabilistic clustering algorithms basically criteria (deterministic) more specific for CH selection and cluster formation, take into consideration. These criteria are essentially based on the proximity of adjacent nodes like (connectivity, degree, etc.) and information received from other closely located nodes.

4 Clustering Protocols

In this section, we analyses and classify several effective and popular clustering protocols for WSNs.

4.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

This protocol is one of the most popular protocols for WSNs. LEACH [15], [13] shapes clusters by distributed protocol. That nodes make independent decisions without any centralized control. Each round of the protocol is divided into two stages. The first stage, which is the startup phase, the phase is formed clusters. The second stage is related to the normal operation of the network is called the steady-state phase. The protocol prepares a balancing of energy utilization by random rotation of CHs. It shapes clusters based on the received signal power, and usage the CH nodes as routers to the base station.

4.2 Low-Energy Adaptive Clustering Hierarchy Centralized (LEACH-C)

LEACH-C [23] is a centralized prescription of LEACH, this mean that the responsibility of the cluster creation is transmitted to the base station. Each node in beginning obligated to make a direct connection to the base station in order that an overall view of the network is shaped. Therefore an improved cluster formed method is done and a little better overall performance of the network is obtained.

4.3 Two-Level Low-Energy Adaptive Clustering Hierarchy (TL-LEACH)

TL-LEACH [16], [17] is an offered extension to the LEACH protocol. It uses two levels (two stage) of cluster heads (primary and secondary). In this protocol, for every cluster, the primary cluster heads can communicate with a secondary cluster head and also communicates with other sub cluster. Associated data from source node to sink in two stages:

- Secondary nodes gather data from the cluster nodes will perform. Also on this level is data-fusion operations performed.
- Primary node collects data from secondary nodes are responsible. Data-fusion can also be performed at this level.

The two-level structure of TL-LEACH decrease the amount of nodes that require to transfer to the base station, effectively decreases the total energy usage.

4.4 Hybrid Energy-Efficient Distributed Clustering (HEED)

HEED [18] is another popular and improved energy-efficient protocol. HEED is a multi-hop clustering protocol for WSNs, which periodically selects CHs based on a hybrid of the node remaining energy and a secondary parameter, such as node adjacency to its neighbors or node degree. The main objectives of HEED are:

- Distribute energy consumption to prolong the network lifetime.
- Minimize energy during the cluster head selection phase.
- Minimize the control overhead of the network.

4.5 Energy Efficient Hierarchical Clustering (EEHC)

EEHC [19], [16] a distributed, randomized clustering protocol for WSNs with the purpose of maximizing the network lifetime. CHs gathered the nodes readings in their individual clusters and send an aggregated report to the base station. EEHC protocol is based on the assumption that the communication is free of errors. This Method is according to two steps; In the first stage called single-level clustering, each node introduces itself as a CH with probability p to the neighboring nodes within its communication range. Each node that receives this information becomes part of the cluster head near it. Then processed in the second stage clustering protocol is developed to make the creation of multi-level cluster hierarchy level h.

This protocol guarantees the connectivity between CHs and base station. This protocol ensures the wasted energy of CHs that are far from the base station is reduced, because the cluster heads to the base station can transmit.

4.6 Partition Low-Energy Adaptive Clustering Hierarchy (PEACH)

P-LEACH [20] is a LEACH protocol based on partition, it is the first partitioning the network into sectors and then a CH in each sector, using the centralized calculations is selected. A node that has the highest energy is selected as CH node. P-LEACH protocol is performed in two steps. In the first stage, the optimal number of CH by the sink node is calculated and is based on the partitioning of the network into sectors. If k is the optimal number of cluster heads, the network is divided into k sectors that each have approximately the same number of nodes. In the next stage nodes with the highest energy as CH in each division will be chosen by the sink node. Then data selected CH by a sink node, will be sent to the entire network.

4.7 DSBCA

A Balanced Clustering Protocol with Distributed Self-Organization for Wireless Sensor Networks (DSBCA) [21]. The basic idea DSBCA, the connection density and distance

from the base station to calculate k (cluster radius). DSBCA has three phases: cluster head selecting phase, clusters building phase and cycle phase. DSBCA objective is to balance the energy consumption of clusters as well as the connection density and location nodes, to create a balanced cluster.

4.8 Energy Efficient Clustering Scheme (EECS)

EECS [22], [12] is a clustering protocol, which better appropriate the periodical data collecting applications. EECS schema is like LEACH, where the network is divided into some clusters and single-hop connection among the CH and the base station is done. In EECS, CH candidates compete for the ability to raise to CH for a given round. This competition included candidates broadcasting their remaining energy to neighboring candidates. If a given node does not find a node with more remaining energy, it becomes a CH. Different from LEACH for cluster shaping, EECS deployments LEACH by the dynamic sizing of clusters according to cluster distance from the base station.

4.9 Energy Efficient Heterogeneous Clustered Scheme

EEHC [24] is an energy efficient clustered scheme for WSNs based on weighted election probabilities of each node to become the cluster head. It elects the cluster head in a distributed fashion in hierarchal WSN. This protocol is based on LEACH. This protocol works on the election processes of the cluster head in the presence of heterogeneity of nodes.

4.10 Fast Local Clustering Service

FLOC [25] is a distributed clustering protocol that produces approximately equal sized clusters with minimum overlap. A node can relationship reliably with the nodes that are in the inner band (i-band) range and unreliably with the nodes in its outer band (o-band) range. Therefore the i-band nodes suffer very little interference communicating with the CH, thereby it is a reliable communication. Messages from o-band nodes are unreliable during communication and hence it has the maximum probability of getting lost during communication. FLOC is fast and scalable, hence it achieves clustering in O(1) time, regardless of the size of the network. It also exhibits self-healing capabilities since o-band nodes can switch to i-band node in another cluster. It also achieves re-clustering within constant time and in a local manner. It also achieves locality, in that each node is only affected by the nodes within two units. These features stimulate FLOC protocol to be suitable for large scale WSNs.

5 Comparison of Discussed Clustering Protocols

Table 1 summaries the investigated clustering protocols in this paper.

6 Conclusion

Wireless sensor networks for military and civilian applications and deployment in remote and inaccessible areas, many researchers in the past few years has attracted. Due to lower power consumption in these networks, for reducing power consumption in these networks, clustering network seems inevitable.

Clustering protocols divide the network into several clusters, which each perform their work independently and each cluster has a head. This paper reviews some clustering methods have been investigated. It can be concluded that, different protocols based on power consumption, additional Information exchange rate, method clustering and determine the cluster head, is divided into several different groups.

Table 1. Comparison of the clustering protocols

Protocols / Criteria	**Methodology**	**CH Selection**	**Cluster count**	**Node Mobility**	**Multi-Level**	**Residual Energy CH**	**Cluster Size**	**Distance from CH to BS**	**Hops**
LEACH [15]	Distributed	Prob/random	Variable	Limited	No	No	No	No	1
LEACHC [23]	Centralized	Prob/random	Variable	Limited	Yes	Yes	Yes	Yes	1
TLLEACH [17]	Distributed	Prob/random	Variable	Limited	No	No	No	No	2
HEED [18]	Distributed	Prob/energy	Variable	Limited	No	Yes	Yes	No	1
EEHC [19]	Distributed	Prob/random	Variable	No	Yes	No	No	Yes	K
PLEACH [20]	Centralized	Prob/energy	Variable	Limited	No	Yes	No	No	1
DSBCA [21]	Distributed	Prob/ Connectivity	Variable	No	Yes	No	Yes	Yes	1
EECS [22]	Distributed	Prob/energy	Constant	No	No	Yes	Yes	Yes	1
EEHC [24]	Distributed	Prob/ Density	Variable	No	No	Yes	No	No	K
FLOC [25]	Distributed	Random	Variable	Possible	No	No	No	No	1

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