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Energy-efficient clustering for Wireless Sensor Networks-A Survey

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Abstract: Research in clustering has been very active in the last two decades. Clustering schemes decreases the communication overheads, intern reducing the power consumptions and interferences among nodes. Clustering is one of the best known methods used to face this type of challenges. In this paper, we study and compare various objectives, features & characteristics of some of the popularly explored clustering algorithms & published clustering schemes in Wireless Sensor Networks like advantages and disadvantages of respective clustering schemes. This paper also presents future research topics and highlights the challenges in clustering in Wireless sensor networks.

***Keywords*:** Wireless Sensor Networks, Cluster Head, Cluster-based routing, Hierarchical clustering, Base Station

I. INTRODUCTION

Over the recent years, researchers witnessed tremendous popularity and growth in the potential useof Wireless Sensor Network (WSNs) in various applications which includes Security surveillance, large-scale environment monitoring, Medical Applications and Disaster Management etc. They also observed the most important & critical operation for Wireless Sensor Network is Data Collection (collecting the sensed data from the nodes and routing the sensed data) to develop a routing protocol that has maximum energy efficiency. The good and effective clustering of a WSN saves energy and improves coverage efficiency.

Clustering in WSNs is the process of splitting the sensor nodes of the network into groups, where each set of nodes agrees on a central node, called the Cluster Head (CH), which is responsible for collecting the raw local data obtained (sensed data) of each and every team member sensor nodes, aggregating it and sending it to the Base Station (BS). The Main goal of clustering is to reduce, not increase, energy consumption. Essentially, a clustering algorithm decides a set of sensor nodes that can acts as a backbone to connect the network to the base station (BS). Routing, Data Aggregation and clustering schemes are the well appreciated and authenticated techniques to reduce power usage in WSNs. These research avenues have attracted a lot of interest lately; still there is no general holistic approach to meet the needs and challenges of many various applications and network types, like different network sizes and topologies or node failures.

Most of the researchers care mostly about nodereachability and route stability, without much concernabout critical design goals ofWireless Sensor Networks such as energy efficient networks and coverage. Recently, a number of clustering algorithms (Schemes) have been specifically designed for WSNs [01-05].

a. It reduces the size of the routing table stored at the individual sensing node. [06].
b. Clustering can also conserve communication bandwidth since it limits the scope of inter-cluster interactions to CHs.[07].
c. Clustering algorithmsdecreases the communication overheads, intern reducing the energy consumptions and interferences among sensor nodes.

Section I will introduce the main design goals of clustering.Section II will bring out the objectives of clustering;Section III will draw comparisons on these schemes interms of power and quality. We will conclude this paper withSection IV, in which we will examine some future researchproblems and draw conclusions on the current state of sensornetwork clustering.

II. CLUSTERING OBJECTIVES

Clustering algorithms in the literature survey changes in theirobjectives and it's the applications requirements.The following parameter highlights popular objectives for sensor network clustering:

a. ***Load balancing***: Uniform distribution of sensors nodes among the clusters is usually an important objective where Cluster Heads perform informationprocessing. It is very important when CHs perform data aggregation; it should have same sized nodes in the cluster for further smoothen processing in the next tier. [08].

b. ***Fault-tolerance***: In most of the real-time application, Wireless Sensor Networks will beoperational in harsh situation and thus sensor nodes are normallyexposed to high risk of malfunction and physicalenvironment.

c. ***Minimum delay with good connectivity:*** In WSNs, the efficient energy usage can be achieved only when there is good connectivity between inter-CHs and Intra-cluster topologynodes. It is very important prerequisite in many applications.

d. Minimal cluster count: The wireless sensor network designer normally looks out to use the minimalnumber of sensor nodes since they are more expensive and vulnerable than sensors.

III. CLUSTERING ALGORITHMS FOR WSNS

a. Clustering Algorithms:

There are many methods and algorithms for clustering. Some of them will be presented later on, but this section is far from being a complete review of the clustering algorithms available. In this section, we classify and analyze some of the most popular, prominent andeffective clustering algorithms (schemes) for Wireless Sensor Networks

A. LEACH: Low-Energy Adaptive Clustering **Hierarchy**.

LEACH [9]is designed forsensor networks where an end-user wants to remotely monitor theenvironment. It is a clustering-based protocol, self-organizing that uses randomization to distribute the energy load uniformlyamong the sensor devices in the network.

Thus LEACH utilizes randomized rotation of the cluster-head (CH) position to distribute the energy to all nodes pertaining to its group evenly.It uses localized coordination to robustness for dynamicnetworks and incorporates information*aggregation* (or *fusion)* into the routing protocol to decrease the size of data that needs to be transmitted to the base station (BS) intern reducing energy dissipation to prolong the nodes lifetime.

CHs normally lose more energycompared to regular nodes. Hence, it is necessary to carryoutre-clustering at regular intervals in order to choose nodes with higher energy to serve as CHs, thus distributing the energy uniformlyon all the sensor nodes. LEACH is completely distributed andrequires no global knowledge of network.

B. LEACH-C: LEACH-Centralized:

W. Heinzelman. [10] Proposed a cluster scheme out of LEACH and developed LEACH-C is to use a Centrally Controlled algorithm to establish clusters.

The Base Station (BS) receives data from each and every node about their local information andenergy status. According to author the sensor nodes may get their present location information by using aglobal positioning system (GPS) receiver, which must be activated at the beginning of each and every round. The cluster with sufficient node will involve in CHs selection.Soon after the selection of CHs, the message will be broadcasted to all belonging sensor nodes.

Each ofthe member nodes, excluding the CHs, determines its TDMA slot for the data transmission.Then, the sensor node will go to rest (sleep)till other team members transmit data to its clusterhead.

C. LEACH-F: LEACH with Fixed clusters:

Again the same authors [10] improvised this algorithm as LEACH-F (LEACH with Fixed clusters). LEACH-Fis depending on clusters that are derived once - and then fixed. To decide clusters,LEACH-F employs the same centrally controlled cluster formation algorithm as LEACH-C.The CHs position rotates among the member nodes within the cluster.

D. EECS: Energy Efficient Clustering Scheme:

In [11], the authors proposed Energy Efficient Clustering Scheme which has a cluster head election. In this a definite number of nodes participates and elect their CH purely based on nodes residual energy status. That is candidate nodes sends its candidature to all member nodes which are in its radio range and checks for most powerful node with more energy and if it find some node ,it withdraw its candidature from the competitions. If node it will become the cluster head.

In this cluster formation stage each and every CHs sends out a broadcast messageacross the sensor network and let the sensor nodes decide which CHs to join. The decision of these nodes purely depends on distance cost from the sensor node to the CH and distance cost from the CHs to the Base Station (BS).

E. HEED: Hybrid Energy-Efficient Distributed Clustering:

HEED [12] is a multi-hop clustering algorithm for WSNs, which employs a distributed algorithm that can converge quickly with low overhead, is called HEED. HEED uses an iterative cluster formation algorithm, where sensors assign themselves a “cluster head probability” that is a function of their residual energy and a “communication cost” that is a function of neighbor proximity. The Clustering Head (CH) formation is purely determined on residual energy of the node and intra cluster communication cost of the node that it want to join the respective cluster. The advantages of HEED are that sensor nodes only require neighborhood data to form the clusters, the algorithm terminates in O(1) iterations, the scheme ensures that every sensor nodes is part of just one single cluster, and the cluster heads (CH) are well-distributed.

HEED has advantage over generalized LEACH, i.e., LEACH randomly selects cluster heads (CHs), which results in a quicker death of some sensor nodes [12]. HEED avoids quicker death with better distributing cluster heads throughout the network.

F. DWEHC: Distributed Weight-Based Energy-Efficient Hierarchical Clustering:

Ding et al. [13] have proposed DWEHC an improved version of Hybrid Energy-Efficient Distributed Clustering protocol to generate distributed, balanced sized cluster and optimized intra-cluster links. In this protocol each and every node device calculates its weight after placing the neighboring sensor nodes in that segment. The node with highest weight in that group would be elected as Cluster Head (CH) and all other remaining nodes become the member nodes or Base Stations (BS).This first level noes will have direct contact with the Cluster Head. All member nodes try to adjust to reach CH using minimum amount of energy. Normally, a sensor node checks with its non- CH neighbor member to checkout their minimal cost to reach aCH. Based on the information and node’s knowledge of the distance to its neighbors, it decideswill it be good to stay a first-tier memberor to become a second-tier one; reaching the Cluster Head over atwo-hop path. The process progresses until sensor nodes occupies on the best energy efficientintra-cluster topology. To restrict the number of tiers, each and everycluster is allocated a range within which member sensor nodesshould occupy.

Both DWEHC and HEED are resembles in many ways. All the nodes, participates in cluster formation activity without any particular assumptions. But there are many differences between them.eg. Firstly, the clusters generated by HEED are more balance compared to DWEHC. Secondly, the DWEHC attracts significantly lowerenergy usage in intra-cluster and as well as in inter-cluster communicationthan HEED.

G. LCA: Linked Cluster Algorithm:

In the Linked Cluster Algorithm [14], each sensor node is assigned a unique identification ID number. In this scheme, there were two ways of selecting the Cluster Head, in first way is if the sensor node has the highest ID number in the given cluster including the node itself and other neighboring group members. In second type, sensor node it checks its neighbors (within one hop); if none of them are CHs.Then it becomes a Cluster Head.

H. CHC: Collective Hierarchical Clustering:

In [15], the authors present a scheme, Collective Hierarchical Clustering algorithm which works on information that is heterogeneously distributed, with each& every site having only a subset ofall features. Initially, local hierarchical clustering is performed on the respective site. Then onwards, the resulted prototypes are forwarded to a facilitator which processes the global model, using statistical bounds. The aggregated results are very similar to centralized clustering results, doing CollectiveHierarchical Clustering an exact algorithm. An implementation of this CollectiveHierarchical Clusteringalgorithm forsingle hop clustering is also presented in the paper.

I. PEGASIS: Power-Efficient Gathering in Sensor Information Systems

In [16], authors presented a paper which is an extension of the LEACH protocol; it is a grid type of Protocol. In this multiple chains of sensor nodes are formed so that each node transmits and collects the data from the neighboring nodes and only a single sensor node is selected from that chain to deliver the aggregated data to base station (BS) which is called as sink node. The chain formation is performed in a greedy way. In PEGASIS protocol, the formation phase presumes that all the sensor nodes will have global knowledge about the network, especially, the location of the sensor nodes, and it employs a greedy approach. In this, when a sensor nodes fails /dies due to energy problems, the link is established using greedy approach by skipping that dead node. Hence PEGASIS is one of the optima chain based protocol. To identify the nearest node in PEGASIS, each and every node checks the signal strength to measure the distance to nearby nodes and adjusts the signal strength, in such an only single node to receive the information or heard. When the round of all sensors transmitting with the respective base station ends, a fresh round will begins and continues.

The main objectives of this PEGASIS algorithm are (a). To prolong life of the sensor node by collaborative method. (b).To consumes lesser communication bandwidth.

The main disadvantage of PEGASIS is excessive delay for the distant sensor node. Secondly single leadership may become a critical issue. Lastly, if the nodes are mobile, then it affects the functionality of the protocols since the authors are assumed that the nodes are fixed.

J. H-PEGASIS: Hierarchical PEGASIS

In [17], authors presented a paper which is an extension of the Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol with main objective of decreasing the delay incurred for packets duringtransmission to the distant sensor node (BS). Now, H-PEGASIS presents a scheme to information collecting issues by considering energy × delay matrices

In order to minimize the delay in PEGASIS, parallel transmissions of data are pursued.

In order to eliminate the collisions and possible signal interference in between the sensors, two schemes are proposed (a).Firstly, CDMA technique is proposedand secondly,only spatially separated sensor nodes are permitted to forward at the same time

K. EB-PEGASIS: Energy Balancing Power-Efficient Gathering in Sensor Information Systems

In [18], authors presented a paper which is an extension of the Hierarchical Power-Efficient Gathering in Sensor Information Systems (H-PEGASIS) protocolinwhich a sensor node will consider average distance of formedchain. If the distance from nearestsensor node to its other ends (farthest) sensor node is greater than the threshold distance, the closest sensor node is treated as “far node” .in case closest node joins the chain link, it will emerge as long chain.

In this situation, the "far node" will search a close by node on established chain. With this scheme, the new proposed algorithm EB-PEGASIS can avoid "long chain" effectively

Table 1.Difference types of Cluster Algorithms

	Convergence time	**Node Mobility**	**Cluster Overlapping**	**Cluster Count**	**Inter Cluster Connectivity**	**Location Awareness**	**Balanced Clustering**	**Cluster Stability**
Heuristic Algorithm								
Linked Cluster Algorithm (LCA)[14]	Variable 0(n)	Possible	No	Variable	Direct Link Multihop	Required	OK	Moderate
Hierarchical Algorithms								
Low-Energy Adaptive Clustering Hierarchy (LEACH)[09]	Constant 0(1)	Fixed Base Station	No	Variable	Direct Link	Not Required	OK	Moderate
Low-Energy Adaptive Clustering Hierarchy Centralized	Constant 0(1)	Fixed Base Station	No	Variable	Direct Link	Not Required	OK	Moderate

(LEACH-C)[10]								
LEACH with Fixed Cluster (LEACH-C)[10]	Constant 0(1)	Fixed Base Station	No	Variable	Direct Link	Not Required	OK	Moderate
Energy Efficient Clustering Scheme (EECS)[11]	Constant 0(1)	Fixed Base Station	No	Variable	Direct Link Multihop	Not Required	OK	Moderate
Hybrid Energy Efficient Distributed Clustering (HEED)[12]	Constant 0(1)	Stationary	No	Variable	Direct Link Multihop	Not Required	Good	High
Distributed Weight Based Energy Efficient Hierarchical Clustering (DWBEEC)[13]	Constant 0(1)	Stationary	No	Variable	Direct Link Multihop	Not Required	Very Good	High
Grid Algorithms								
Power-Efficient GA thering in Sensor Information Systems (PEGASIS)[16]	Constant 0(1)	Stationary	N/A	Variable	Direct Link Multihop	Not Required	Very Good	High
Hierarchical PEGASIS (H-PEGASIS)[17]	Constant 0(1)	Stationary	N/A	Variable	Direct Link Multihop	Not Required	Very Good	High

IV. CONCLUSION AND FUTURE WORK

At present, there is a good numberof excellent clustering routing algorithms and we could only survey very few of them in this paper. Most of theresearchers concentrated on clustering in Wireless Sensor Networks mainly on network lifetime, data latency, nonfunctionalgoals and energy saving methods. These protocols areheuristic in nature and their main target is to create less number of clusters to deliver that any sensor node in anycluster is just at most minimum hops distant from the CHs. Maximum of them have a convergence time of O(n), where n is the totalnumber of nodes.

New clustering algorithms need to be developed for the communication environments of today: especially in a large scale wireless sensor network containing more number of nodes, location-un-aware nodes, distributed, dynamic energy adaptive clustering approaches with minimum iterations along with multihop communications, very good balance are expected.

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