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A Survey on Cluster Head Election Techniques in Wireless Sensor Networks

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ABSTRACT

Recent technological advances in communications and computation have enabled the development of low-cost, limited power, small in size, and multifunctional sensor nodes in a wireless sensor network. Wireless sensor networks consist of small battery powered devices which have limited energy resources. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus replacement of the energy source is not possible. Energy efficiency is one of major design issue that must needs to be enhanced in order to improve the life span of the network. Much research has been done in last few years, developing different features like, low power protocols, network establishments, routing protocol, cluster head selection and coverage problems of wireless sensor networks. In this paper, we present a recent survey of cluster head election techniques in various clustering approach. To reduce the power consumption various facets are considered such as rotation of cluster head, deterministic cluster head selection, Non-deterministic cluster head selection, residual energy basis, distance from the BS etc. The study concludes with comparison of various CH election algorithms in WSNs based on various parameters.

Keywords:- Wireless Sensor Networks, Cluster Head, Energy Efficiency, Routing.

I. INTRODUCTION

With the development in the technology of micro electro mechanical system (MEMS) and developments in wireless communications, wireless sensor networks have emerged. Wireless Sensor Networks (WSNs) have been becoming the most important technologies for the twenty –first century. In the recent years, have seen an increased interest in the potential use of Wireless Sensor Networks(WSNs) in various fields [13] like disaster management, battle field surveillance, and border security, monitor manufacturing processes, intelligent guiding ,hazard monitoring, medical field but now it mainly focused in civilian applications etc. A WSN consists of a collection of spatially distributed sensor nodes which are interconnected without wires. Each of the individual sensor nodes typically consist of one or more sensing elements, a data processing unit, communication components and a power source which is usually a battery. The sensed data is collected, processed and then routed to the desired end user through a designated sink point, referred as base station [1], [4], [12].

II. CLUSTERING IN WSN

Clustering [2], [3], [4] is a generally a cross cutting technique which can be used in almost all layers of protocol stack. A sensor network can be made scalable by assembling the sensor nodes into groups i.e. clusters. Every cluster has a leader, often referred to as the cluster head (CH).The key idea is to group sensor nodes around a cluster head which is responsible for inter cluster connectivity, data sensing, data transmission, aggregation and state maintenance [5], [6], [7], [9] etc .The clustering Algorithm, routing techniques, efficiently data gathering techniques and many other protocols [10], [11], [1], [14] are the primary technique used to reduce energy consumption. It can increase the scalability and lifetime of the network.

A. Clustering Advantages

Clustering has a number of advantages. Some of following are given below.

1. Clustering minimize the size of the routing table stored at the individual nodes by localizing the route set up within the cluster (Akkaya, 2005).
2. The CH can prolong the battery life of the sensor also the network lifetime by implementing various optimized management strategies (Younis, 2003).
3. Clustering reduces on the topology maintenance overhead. All the individual sensor would care only for connecting with their CHs (Hou, 2005).

4. Clustering can conserve communication bandwidth as it limits the scope of inter cluster connectivity to CHs and minimize redundant transmission of the data among sensor nodes.
5. A CH can also perform aggregation in its cluster and decreases the number of redundant packets within the networks (Dasgupta, 2003).
6. A CH can minimize the rate of energy consumption by scheduling activities in the cluster.

A CH may be elected by the sensors in a cluster or pre assigned by the network designer. The cluster membership may be fixed or variable. In clusters without any selection of cluster head, there will be a heavy traffic overhead occur within the network, as the network size increases. Therefore, usually a node is selected as a cluster head or leader within the cluster and it acts as a local coordinator for transmission within the cluster. Simply, the cluster head does not have any particular hardware and is in fact can be selected dynamically among the collection of nodes in a cluster. Cluster head performs various additional functions likes as connectivity to the nodes, aggregation, inter cluster connectivity, central administration point and a cluster head failure would decrease the stability period and performance of the entire network and may cause the bottleneck. As a Cluster head needs to perform more functions as compare to normal nodes, it may consume energy more as compare to other nodes. So, a randomly changing Cluster head mechanism has to be used to evenly distribute energy consumption within the network. So as to increase network life time, a number of cluster head selection algorithms have been specifically designed for WSNs for scalability and efficient communication.

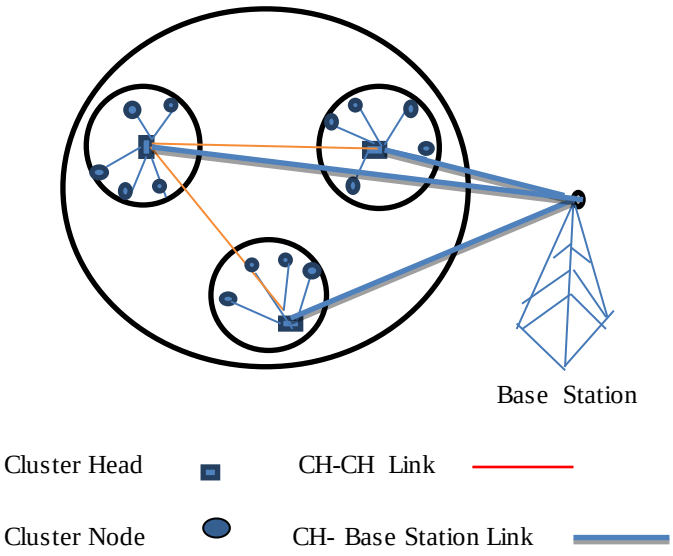

Fig. 1 Schematic diagram of clustering mechanism [8]

B. Clustering Parameters

1) Number of Clusters: It may be varied according to the CH selection algorithms. In some cases this count will be the predetermined.

2) Intra-cluster Communication: Communication between the normal node and CH may be one-hop communication or multi-hop communication.

3) Nodes and CH Mobility: Cluster formation is dynamically changed in the case of sensor nodes are in mobility i.e. they keep on changing their position.

4) Node Type: Nodes may be classified in homogeneous or heterogeneous nature. In homogeneous, all sensor nodes have same capabilities such as same energy level, configurations. In heterogeneous, nodes are different in configurations.

5) Cluster Head Selection: Cluster Head are elected from the deployed nodes based on the parameters such as residual energy, connectivity, communication cost and mobility.CH selection may be in deterministic or probabilistic manner.

6) Multiple Levels: In very large networks, multi level clustering approach is used to achieve better energy distribution.

III. CLUSTER HEAD ELECTION IN VARIOUS CLUSTERING PROTOCOLS IN WSN

Distributed clustering algorithm play the vital role for WSN. It is that mechanism in which there is no fixed CH and the Cluster head usually change from node to node based on some pre-determined parameters. Cluster Head Election technique was usually based on various factors such as remaining energy and relative position of the node, random waiting, on the basis of threshold value T, energy level and also using Analytical Hierarchy in the cluster i.e. CH is elected on basis of three factors i.e., energy, mobility and distance etc. In this section, we have discussed various clustering algorithm for WSN's based on various factors of cluster head election.

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [15] is a clustering mechanism that is mainly used for equal energy consumption by all sensor nodes in the network to enhance stability period and life time of the network. It is a dynamic protocol because the CH keeps on changing at each round. In this, the whole network is divided into clusters and a Cluster Head is elected which acts as a local coordinator for that round. Each node uses a probability based approach at each round to determine whether the node become a cluster head in this round or not. Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired percentage of cluster heads. Thereafter, each node has a $1/P$ probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data.CH collects the data from all other nodes which are coming under its cluster. LEACH performs its task in two phases: firstly setup phase in which CHs are chosen and in second steady phase CHs has been maintained and data is transmitted.

Set Up Phase	Steady Phase

Cluster Head can be chosen stochastically (randomly) based on the following algorithm

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

Where n is random number between 0 and 1
P is the cluster head probability
G is a collection of nodes that are not cluster head at previous round
If n<T(n), then that node becomes the cluster head for that round

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

HEED protocol [16] is basically used to reduce random selection of the CHs. In this election of the CHs is based on both communication cost and residual energy basis. HEED protocol perform its task in three sub phases.

Initialization phase	Repetition phase	Finalization phase

In the initialization phase, the initial CH probability percentage is given to the nodes, which is represented by CProb. Each node calculates it probability to become CH using equation

$$CHprob= CProb*(Eresidual/Emax)$$

Where, Eresidual is residual energy of particular node. Emax is maximum battery energy, while in repetition phase, CH node calculates least transmission cost and this phase is repeated. If node cannot find the suitable CH, then node declare itself as a CH. At last, in finalization phase the selected node is declared as the CH.

C. *Energy Efficient Clustering Scheme (EECS)*

In this [17] several cluster heads are elected. Various nodes become participated nodes with a probability T and broadcast an advertisement message to all other nodes within its transmission range. If its finds a node with more residual energy with its range. The node will leave the participation without listening to all other nodes. Otherwise, it will be elected as a HEAD in the last.

D. *Threshold Sensitive Energy Efficient Sensor Network (TEEN)*

This protocol [18] is used in time critical applications. In this approach node continuously sense their medium, but the transmission rate is lower as compare to sensing. The network consists of the ordinary nodes, first level cluster heads and second level CHs.

In TEEN, CH selection criteria are same in both TEEN and LEACH protocol. It is based on the probability based approach. The decision is made by a random number selection between 0 and 1.
In this, first level CHs are obtained away from the Base Station where is second level are obtained near to the Base Station. A Cluster Head transmits two types of sensed data to neighbors- one is the hard threshold (HT) and other is soft threshold (ST). In the HT, the nodes send data if the data sensed by it is in the range of interest. The hard threshold decreases the number of transmissions. But in case of the soft threshold, any small change in the value of the sensed attribute is transmitted.

E. *LEACH-C Algorithm*

It stands for LEACH Centralized [19]. In this, the election of the CH depends upon two parameters first is on the current location of the node and secondly on the residual energy. As in LEACH, there is two phases. In Set Up phase, each node in the network sends its current location and residual energy to the BS. Base Station calculates the average energy from the all collected energy information from the sensor nodes. If any node's energy level is more than its average energy level, then those nodes will be elected as a Cluster Head. After the election of CHs, BS broadcasts the Cluster Head's ID to all sensor nodes. Node whose ID is get matched with the ID broadcasts by the Base Station becomes Cluster Head. The main advantage of using this approach is that CHs are spread all over the network because they are elected on location and residual energy basis. Here, the main problem is that if due to any failure such as far away from the BS, node fails to connect to the BS and then optimal selection cannot take place because it depends upon the residual energy of all nodes to calculate average residual energy.

F. Distributed Weight Based Hierarchical Clustering (DWEHC)

This mechanism [20] is mainly used to have balanced cluster size and enhance intra cluster topology. In this location information and energy level are predefined. The cluster head distances from it member nodes is fixed. Firstly, individually seven iterations are performed on each node, after that DWEHC creates a multi-hop intra cluster structure in which cluster head is at the root position and cluster member are in a breath first order. A node which has the most weight among all sensor nodes will elects as a temporary cluster head . It will chosen as a real cluster head only if a given percentage of its neighbour select it as their Cluster Head.

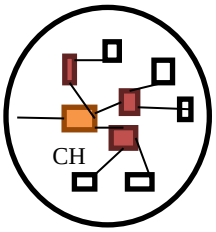

Fig. 2 An example of one cluster in multi-hop intra-cluster topology

G. Concentric Circle Based Power Efficient Gathering in Sensor Information System (PEGASIS)

In PEGASIS [7] sensors are organized in a way to form a chain, which can be performed either by the sensors themselves using a greedy algorithm or by the sink, which has to broadcast the chain to all sensors in the network. The chain has two end sensors and in each data fusion phase only one leader (i.e., a sensor responsible for transmitting the fused data to the sink) will transmit the fused data to the sink. The main idea of the concentric clustering scheme [11] is to consider the location of the base station to enhance its performance and to prolong the lifetime of the wireless sensor networks. The concentric circle approach is used for increase network performance by dividing the entire sensing region into different circular levels. At each round there is randomly election of cluster head at each level to aggregate data and send to upper level CH and on next one.

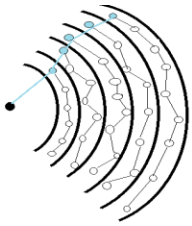

Fig. 3 Concentric circle based PEGASIS [11]

H. Eenergy Efficient Hierarchical Clustering (EEHC)

In this approach [12] all the sensor network is organised into clusters with a hierarchy of cluster heads. The CH collects the data from the nodes within the cluster and sends the aggregated data to the BS through cluster head hierarchy. There are two approaches used for clustering.

1. Single Level Clustering.
2. Multilevel Clustering.

In single level Hierarchy, for the election of cluster head a predefined probability P is used and declares itself as a volunteer cluster head to its surrounding nodes that are within k hops range. Any node that receives this information becomes member of nearest cluster if it is not a cluster head. The nodes that are not member of any cluster and also not a cluster head, will become forced cluster head. In the multilevel clustering, the cluster head at each level collects the information from its cluster head, aggregates the information and forward to upper level cluster head. The upper level cluster head aggregate the data and send to other cluster head at higher level and it continues until it reaches to BS.

I. Stable Election Protocol (SEP)

This protocol [8] is based on weighted parameter of each node to become Cluster Head according to their respective energy. It deals with heterogeneous network. The nodes are of various energy level, the high energy nodes are referred to as advance nodes and probability of the advance nodes to be selected as cluster head is more as compared to other nodes .This protocol ensures that the CHs is randomly selected and spread based on the fraction of energy of each node for equal use of nodes energy. At each round, new cluster heads get elected and a result load is uniformly distributed. In this, an optimal percentage of nodes 'P' is used to become cluster head in each round. To decide whether the node is CH or not a threshold T(s) is addressed as follows.

$$T(s) = \begin{cases} \frac{p}{1 - p * (r \bmod \frac{1}{p})} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases}$$

IV. COMPARISON OF DIFFERENT PROTOCOLS IN WSN

TABLE 1: COMPARATIVE STUDY OF VARIOUS PROTOCOLS ON THE BASIS OF CLUSTER HEAD ELECTION APPROACH.

Protocol	**Approach**	**Intra Cluster Topology**	**Network**
LEACH	Fixed Probability	Single Hop	Homogenous
HEED	Weight Based ,Communication Cost	Single Hop	Heterogeneous
EECS	Residual Energy	Single Hop	Heterogeneous
TEEN	Fixed Probability	Single Hop	Homogenous
LEACH-C	Current Location, Residual Energy	Single Hop	Heterogeneous
EEHC	Fixed Probability	Multi Hop	Homogenous
DWEHC	Location Information and Energy Level	Multi Hop	Heterogeneous
CONCENTRIC CIRCLE BASED (PEGASIS)	Randomly	Multi Hop	Homogenous
SEP	Probability Based	Single Hop	Heterogeneous

Table 2: Comparative Study of Various Protocols on the Basis of Cluster Head Election Approach.

Protocol	**Node Type**	**Cluster Count**	**Uniform Distributed Cluster Head**	**Connectivity of CH to BS**
LEACH	Sensor	Variable	No	Single Hop
HEED	Resource Rich	Variable	Yes	Multi Hop
EECS	Resource Rich	Variable	Yes	Single Hop
TEEN	Sensor	Variable	No	Multi Hop
LEACH-C	Resource Rich	Variable	Yes	Single Hop
EEHC	Sensor	Variable	Yes	Multi-Hop
DWEHC	Resource Rich	Variable	Yes	Single Hop
Concentric Circle Based (PEGASIS)	Sensor	Variable	Yes	Single Hop
SEP	Sensor	Variable	Yes	Single Hop

V. CONCLUSION

Cluster Head Election is one of the main issue in the clustering approach in wireless sensor networks. Many CH selection mechanisms have been proposed in the past for effective selection of the CH. The main objective of the CH selection issue is energy efficient and routing. Almost all of the given protocols involve more than one CH selection in each election process. Each CH selection is generally based

on various parameters such as the probability based, residual energy, transmission cost, location based etc. Generally, all the data sense by cluster members is sent through CH to Base Station. So, an optimal solution is required for efficient Cluster Head selection so that it can handle all the traffic being sent to BS. Finally, it is concluded from the survey that yet it is required to find more energy efficient, scalable, efficient cluster head selection strategies for wireless sensor networks.

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