CLUSTERING PROTOCOLS FOR WIRELESS SENSOR NETWORKS: A REVIEW

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ABSTARCT

Over the years there has growing demand for wireless sensor networks (WSN) due to their use in wide variety of applications like military surveillance, environmental monitoring, disaster management, medical and health but their utilization is hindered owing to limited energy resources of sensor nodes, due to this that large part of research is focused on the need for energy efficient protocols with a aim to increase the life time of sensor nodes and hence sensor network. Clustering protocols are compelling due to their competence regarding energy conservation, data aggregation etc. In this paper we present a review of some of widely used clustering protocols in WSNs.

Keywords: WSN, Sensor nodes, Data aggregation, clustering

1. INTRODUCTION

Recent years has seen a growing demand for WSN due their use in application like military surveillance, environmental monitoring, disaster management medical and health etc. WSN consists of large number of autonomous small and low power tiny sensor nodes distributed in large area with one or more base station (BS). Each node has capability to collect data and route data to the sink (base station).

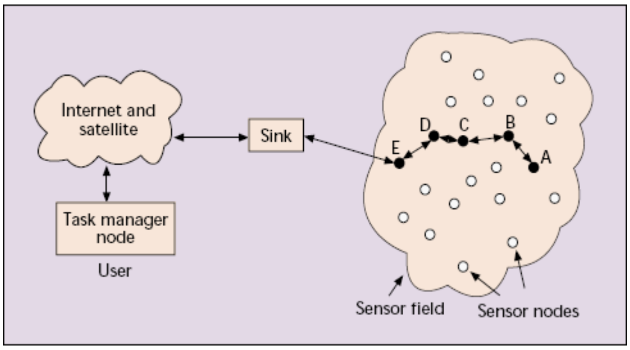

Fig 1: Typical WSN [12]

Sensor networks are classified as:

- **proactive networks**

Here sensor nodes regularly switch on sensors and transmitters to sense the environment and transmit the data.

- **Reactive Networks**

Here the sensor nodes react promptly to sudden changes in the sensed attribute's values.

Unlike ad hoc networks routing is more challenging in WSNs due to their inherent properties like constrained resources like bandwidth, processing power and battery life. Clustering protocols have turned out efficient and so large number of cluster based routing protocols has been designed for use in WSNs. On the basis of network structure routing protocols are classified into three main types:-

1. Flat
2. Location based
3. Hierarchical

Categorically, hierarchical protocols provide considerable amount of savings in energy consumption by sensor nodes. In hierarchical protocols sensor nodes are organized into clusters. Each cluster has a leader called cluster head (CH) and others as member nodes (MNs) [16] .Nodes with higher energy level become CH and perform data aggregation ,data processing and data transmission, while nodes with low energy level become MNs sense data and transmit it to the cluster head. Data aggregation at the cluster head enormously minimize energy consumption by reducing the messages sent to the BS and in turn increasing network's life time [16].

Commonly used clustering protocols are LEACH (Low Energy Adaptive Clustering Hierarchy protocol), HEED (Hybrid Energy Efficient Distributed clustering protocol), TEEN (Threshold sensitive Energy Efficient sensor Network protocol), APTEEN (Adaptive Threshold sensitive Energy Efficient sensor Network protocol), PEGASIS (Power-Efficient Gathering in Sensor Information System) and EECS (Energy Efficient Clustering Scheme).

Challenges of clustering:

Clustering present various challenges which should be addressed before its use, some of them are:

- Clustering cost
- Cluster head selection
- Quality of service (QOS)
- Data aggregation
- Repair mechanism

2. CLUSTERING PROTOCOLS

2.1 LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular protocols for sensor networks. In LEACH sensor nodes organize themselves into local clusters and select CH by rotation.

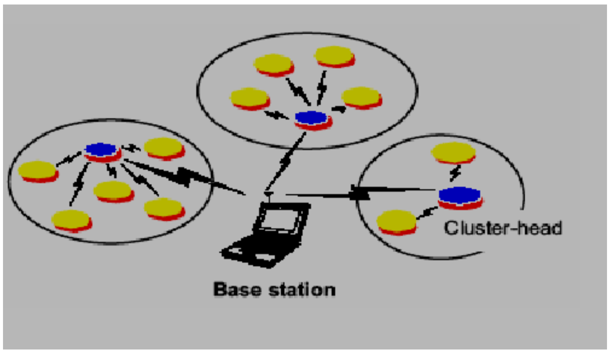

Fig 2: LEACH architecture [12]

The randomized selection of CH is done not to drain the battery of any single node [18][16].So energy load associated with being a cluster head is equally distributed among sensor nodes. Cluster head employ a TDMA schedule to inform each node when to transmit its data. The operation of LEACH consists of rounds where each round consists of set- up phase and steady-state phase. In the set-up phase sensor nodes are organized into clusters and CHs are chosen .Each node takes its own decision whether to become a Cluster head for current round based on number of time it has become CH and percentage of CHs. CHs are chosen randomly based on following algorithm:

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

If n< T (n) then node become cluster head and each node become cluster head at least one. In the steady-state phase CH is maintained when data is transmitted to the BS. LEACH operation is shown in fig 2:

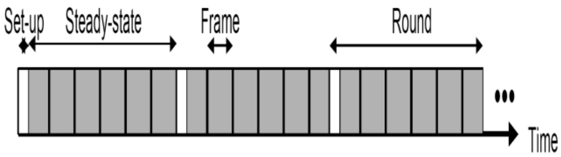

Fig 3: TimeLine for LEACH operation [5]

LEACH is a distributed approach and which does not requires any global information of network [16]. Various modifications have been made to the LEACH protocol, such as E-LEACH [4], M-LEACH [11], TL-LEACH, LEACH-C [5], V-LEACH [16], LEACH-FL [13][9], *etc*. LEACH has various benefits which are: 1) Better energy utilization and network life time; 2) Low latency; 3) Utilization of TDMA prevents CH from unnecessary collisions. However there are certain limitations of LEACH as follows: 1) Cluster heads are selected randomly which does not ensure optimal number and distribution of CHs; 2) LEACH is a single-hop protocol so not suitable for large WSNs; 3) The low energy nodes as well as high energy nodes have equal probability to be selected as CH.

2.2 HEED

Hybrid Energy Efficient Distributed clustering protocol (HEED) is a multi-hop protocol with explicit energy consideration in order to reduce energy consumption. HEED does not select Cluster head randomly as in LEACH but CH selection is done based on the amount of energy that is distributed relative to a neighboring node. The main goals of HEED are:

- Distribution of energy consumption extends nodes life time
- Minimizing control over head
- Terminating clustering process within fixed number of iterations

In HEED selection of cluster head based on two parameters [18]

1. Average residual energy of nodes. The average residual energy of CH is more as compare with member nodes.

The probability that node will become a CH is [16]:

$$CH_{prob} = C_{prob} \times \frac{E_{residual}}{E_{max}},$$

e.g., 5%

Here E (residual) is current predicted energy of node; E (max) is a reference maximum energy which is same for all nodes. Clusters are elected in iterations: A sensor advertise its willingness to become a CH, along with a cost estimation of communication cost if it were elected a CH. A non-Cluster head sensor select a candidate with the minimum cost and A non-CH sensor not selected as CH doubles its CH_{prob} in each iterations until CH_{prob} becomes 1, in which case the sensor node become a CH.

2. Intra-cluster communication cost in case nodes fall within range of more than one cluster head.

The intra-cluster communication cost is defined as Average Minimum Reach ability Power (AMRP) measurement [18]. The AMRP is the average of all minimum power levels required by all the nodes within a cluster range to reach the Cluster head. The advantages of HEED are follows: 1) Nodes should not have location aware capabilities; 2) reduces network load and increases network life. However HEED has certain limitations as follows: 1) Extra energy required to rebuild clusters to have rotation of Cluster heads; 2) Significant overhead due to various iterations to form cluster; 3) Cluster heads near the sink may die soon due to more load [13].

2.3 TEEN

Threshold-sensitive **E**nergy **E**fficient sensor network and is first protocol designed for such network .It combine hierarchical clustering and data centric approach. The sensor network architecture is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until base station (sink) is reached.

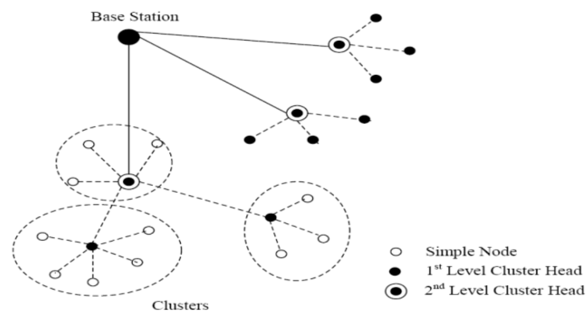

Fig 4: Hierarchical clustering in TEEN [1]

TEEN is responsive to sudden changes in sensed attributes of WSN for example temperature. In this scheme at cluster change time, the CH broadcast two threshold called hard threshold (HT) and soft threshold (ST). Hard threshold is threshold value for sensed attribute and soft threshold is small change in sensed value which triggers the node to switch on its transmitter and transmit. Nodes continuously sense their environment and store the sense value is an internal variable called sensed value (SV), when the sense value first time reaches the hard threshold, node sends the sensed data.

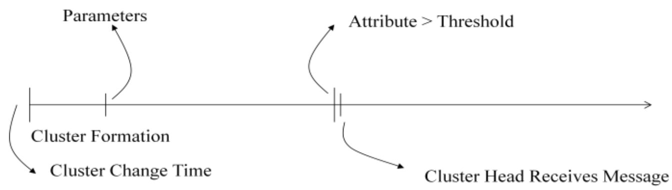

Fig 5: TEEN timeline

TEEN is based on 2-tier clustering topology; Cluster head transmit a hard threshold and a soft threshold to its members. Thus the hard threshold attempts to reduce data communications by permitting the MNs to transmit if the sensed attribute is within the range of interest. The soft threshold minimizes data communications might have occurred when there is small or no change in the value of sensed attribute. A smaller value of the soft threshold generates more accurate information of the network at the cost of increased energy consumption. So users can control the trade-off between data accuracy and energy efficiency [16] .The advantages of TEEN are as follows: 1) Data transmission can controlled efficiently based on two thresholds;2) Responsive to large change in sensed attribute so suitable for time critical applications. However TEEN has certain limitations as follows: 1) When CHs are not in the communication range of each other there can be loss of data [6]; 2) nodes will never communicate if threshold is not reached; 3) Not suitable for areas where regular reports are required.

2.4 APTEEN

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [10] is an improved version of TEEN.APTEEN was designed for hybrid networks. It is responsive to time critical events and capture periodic data. APTEEN changes the threshold values utilize in case of TEEN in accordance with the requirements of users and variety of applications. It supports three types of queries as follows [3].

- Analysis of past data values
- Persistent monitoring of an event over a time period
- One time snapshot of the current network view

In each round once CH is selected, CH broadcast threshold values, attributes and transmission schedule to all the sensor nodes and count time .CH also perform the task of data aggregation in order to save energy. The advantages of APTEEN are followss:1) It can emulate reactive or proactive network using count time and threshold values; 2)Sensor node is forced to sense and retransmit the data in case it does not send data for a time equal to count time in order to maintain consumption of energy . However APTEEN has certain limitations as follows: 1) More complex due additional features of count time and threshold; 2) Additional overhead in cluster formation at multiple levels [16].

2.5 PEGASIS

Power Efficient Gathering in Sensor Information Systems (PEGASIS) is data gathering and near-optimal chain based protocol [14].Unlike LEACH, PEGASIS does not forms multiple clusters, instead forms chains from sensor nodes so that every sensor node sends and receives from a neighboring node and only one node is selected from that chain to transmit to sink instead of using multiple nodes. Nodes are organized to form a chain, using a greedy algorithm starting from some node.

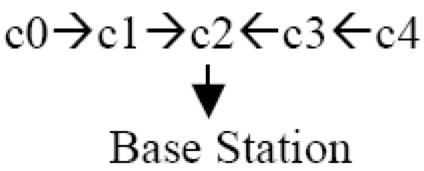

Fig 6: Chain formation in PEGASIS

PEGASIS uses simple token passing scheme. Consider a network having five nodes. In the above figure. 6, node c2 is the Cluster head, it sends the token to node c0, node c0 will sends data to node c2. After node c2 receives data from c1, it sends the token to node c4 and node c4 will pass its data to node c2.The leader selected in a particular cycle receives the fused data packets of the nodes in the network from its two neighboring nodes , fuses it with its own data packet and ultimately this single data packet is transmitted to the sink [15][7].The benefits of PEGASIS are as under: 1) It out perform LEACH by avoiding overhead of dynamic cluster formation ; 2) Uniform distribution of load in the network; 3) Enhance life time of network as nodes communicate with their nearest neighboring nodes. However PEGASIS has certain limitations as follows: 1) Use of greedy algorithm to form chain results in distance between a pair of nodes too long and this pair of nodes will utilizes more energy than other nodes and hence their chances of dying earlier become more [3]; 2) Each node should be able to communicate directly with the BS; 3) Single leader can cause bottleneck; 4) Based on assumption that all the nodes have same energy and hence will drop off at the same time.

2.6 EESC

Energy Efficient Clustering Scheme (EECS) resembles LEACH in which network is divided into clusters with one Cluster head in each cluster and there is single –hop communication between CH and sink. Cluster formation in LEACH and EECS is different. In LEACH cluster formation is based on minimum distance between nodes and CHs. EECS broaden this algorithm by resizing of clusters based on cluster distance from the sink. Nodes interested to become CH broadcast their residual energy and if there is no other node with higher residual energy then it can become a CH. In the network formation phase, the sink broadcasts a hello message to all the nodes at a certain energy level so that each node can calculate the distance to the sink based on the received signal strength [12][9] . The advantages of EECS are as follows: 1) Construct more balanced network in term of communication load and energy consumption; 2) Dynamic sizing of clusters improve distribution of energy throughout the network. However the EECS has certain limitations as follows ; 1) Additional overhead due to the use of global information for communication;2)Single hop communication between cluster head and base station lot of energy is used;3) As all the nodes compete to become CHs so more control overhead complexity is achieved .

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