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A Survey on Energy Efficient Hierarchical Routing Protocol in Wireless Sensor Network

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Abstract— As the wireless sensor network (WSN) is concerns, it is the huge network of low-cost micro sensors. The fundamental challenge in the design of WSN is to enhance the lifetime of the network. The power consumed due to various kind of data is transmitted from the node(s) to the sink i.e. BS which limits the network lifetime. The battery of the node is difficult to change, due to this problem the energy efficient routing is used to solve these problems. This paper outlines the advantages and objectives of Hierarchical clustering for WSNs. The comparison made between different hierarchical routing protocols and their behavior in the environment. Important factor to design protocols for WSN is the energy of nodes due to limited power availability. In this literature reviews we study hierarchical routing protocols which are used in wireless sensor networks.

Keywords— ***Wireless sensor network; Hierarchical routing protocols; clustering techniques;***

I. INTRODUCTION

Wireless sensor network is a network of low powered micro sensors that are deployed in the unattainable area such as forest, mountains, glaciers, desert and deep oceans. These Sensor nodes are generally consist of a transceiver, micro-controller, memory unit, and a set of transducers, using this component they can sense data and process it from the deployed regions. In spite of this, these sensor nodes are not as much powerful or accurate as their expensive macro-sensor counterparts. We have to build a high quality and fault-tolerant sensor network which uses thousands of sensor nodes work together [1][2].

WSN need accurate time synchronization, normally less than one microsecond, for many reasons, such as precise time stamping of messages in network signal processing and time based localization, TDMA-based medium access control, cooperative communication, coordinated actuation, and energy efficient duty cycling of sensor nodes[2][3].

The nodes can self organize; they form a multi-hop network and transmit the data to a sink node. In an energy constraint WSNs, each sensor node has limited battery energy for which enhancement of network lifetime becomes a major challenge. WSN has a wide range of potential applications like military

surveillance, disaster prediction, environment condition monitoring, etc. Thus it becomes one of the most important research fields and has aroused extensive research interest [1].

Energy consumption of a node is happened due to either "useful" or "wasteful" operations. The useful operations include transmission or reception of data, and processing the requests, and the wasteful consumption is due to the operation of constructing routing tree, retransmitting data because of unlikely environment, dealing with redundant broadcasting over headed messages, and idle listening to the media[10][11].

Routing protocol is one of the most important components of WSN. Routing protocol has to monitor the change of network's topological structure, exchange the routing information, locate the destination node, choose the route and transfer the information through route [11].

II. DESIGN PARAMETER FOR ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

The design of new routing protocols for WSNs is quite challenging because of number of network constraints are applied on network. WSNs may affect from the limitations of several network resources. For example:- Energy, bandwidth, storage, and CPU. Due to the computing, radio transmission and power constraints of sensors, routing protocols in WSN are required to fulfil the following requirements [10]:

Energy Efficiency: Routing protocols need to prolong network lifetime by limiting the energy consumption of the network.

Scalability: The Routing protocols specifically designed for wireless sensor networking environments must satisfy scalability.

Reliability: The Network protocols designed specifically for sensor networking environments could provide error control and correction mechanisms for delivering the data on erroneous noisy, and time-varying wireless channels.

QoS support: In the wireless sensor networking environments, different problems can have different QoS requirements related to packet delivery ratio, packet loss ratio and latency. Hence, the network protocol design must consider the QoS requirements for specific application.

III. CLASSIFICATION OF HIERARCHICAL ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

Generally, routing protocols on the basis of network structure are divided in to 3 main groups:-

1. Flat
2. Hierarchical
3. Location based

Specifically, hierarchical routing protocols proved to have sufficient reduction in energy consumption of the WSN. In hierarchical routing protocols, tree is created with numbers of clusters and a head node is assigned to each cluster. Head nodes are the leaders of their groups. They have some responsibilities like collection and aggregation the data from cluster node of their corresponding clusters heads and transmitting the aggregated data to the BS. This aggregated data in the head nodes which reduces energy consumption in the network by reducing the information to be sent to BS. This result in less energy consumption and more will be the network life time.

So here our prior focus on hierarchical routing protocol in the WSN. Here are some well known hierarchical routing protocols.

A. LAECH:

Low-Energy Adaptive Clustering Hierarchy is proposed by Heinzelman et al., is the first hierarchical clustering approach in WSN. In the LEACH protocol, sensor nodes of the network will be organizing themselves into local clusters, with one of the nodes of them acting as the cluster head (CH) [9].

The operation of LEACH is carried out into multiple rounds, where each round is categorize into two phases,

(1) Set-up phase and

(2) Steady-state phase.

In first phase each node considers itself as CH for the current round but it is decides based on the predefined percentage of CHs and how many times the node has been a CH in previous rounds. The decision is taken by the node choosing a random value from 0 and 1. The node will consider as a CH if the value is less than the given threshold value for current round:

$$T(n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \left(\frac{1}{P}\right)\right)}, & if\ n\ in\ G \\ 0, & Otherwise \end{cases}$$

Where, ‘r’ is the current round; ‘p’, the desired percentage for node becoming a CH; and ‘G’ is the collection of those nodes who are not elected as a CH in the last ‘1/p rounds’. Figure 1illustrate the topology of LEACH.

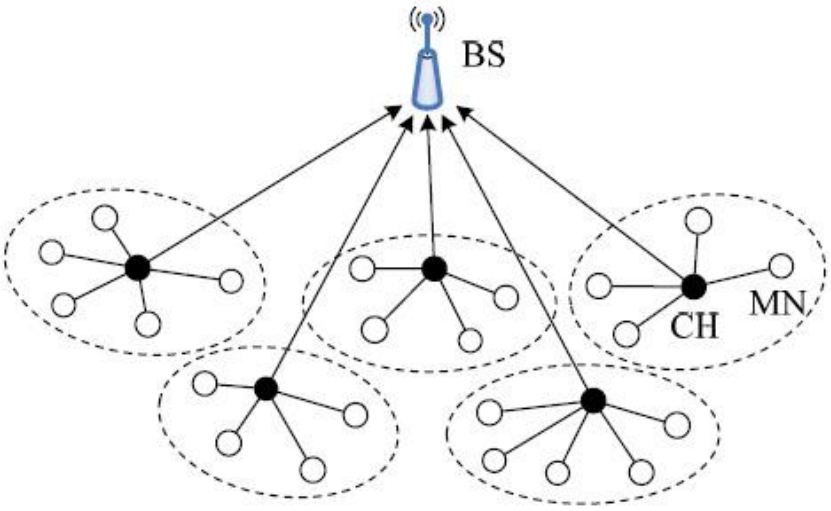

Figure 1. Topology of LEACH

Advantages:

- Node that select as a CH in particular round will not selected as the CH next round, so all node can equally share the load in the network.
- TDMA avoids unnecessary collision of CHs.

Disadvantages:

- It sends data directly from CHs to the BS without intermediate node which utilizes more energy for transmission.
- Because of probabilistic approach of CH selection, CH may select having low energy in it.

B. ***HEED****:*

Hybrid Energy Efficient Distributed clustering (HEED), proposed by Younis and Fahmy. It is a multi-hop clustering algorithm in WSN which uses an energy-efficient clustering by external energy consideration [4]. HEED extends the basic scheme of LEACH protocol by using residual energy and node density as a metric for cluster selection to achieve energy balancing. The main objectives of HEED are to:
(1) Distribute energy consumption to prolong network lifetime;
(2) Minimize energy during the cluster head selection phase;
(3) To minimize the control overhead in the network.

In HEED, CHs elected based on two important parameters that are Residual energy and intra-cluster data transmission cost of the nodes. The probability of a node becomes a CH is calculated using this formula:

$$CH_{prob} = C_{prob} * E_{residual} / E_{\max}$$

Where $E_{residual}$ is the residual current energy of the node, and E_{max} is a reference maximum energy assign to node, which is common for all nodes in the network.

Advantages:

- It is a completely distributed clustering method which uses important parameters for CH election such as Low energy levels of clusters participates in increasing reuse and clusters with high power levels are used for inter-cluster communication.
- Communications take place by finding a multi-hop route between CHs and the BS which improve energy conservation and scalability.

Disadvantages:

- Exactly same as LEACH, the performances of clustering in each round suffer from more routing overhead.
- Some CHs are near to the sink node, they may die sooner than other CHs.

C. ***TEEN****:*

Threshold Sensitive Energy-Efficient Sensor Network protocol [6], proposed by Anjeshwar and Agrawal. It is a hierarchical routing protocol whose aim to take immediate action on sudden changes detected by the sensor like heat, moisture etc. This protocol uses both hierarchical technique and data-centric approach. Each sensor nodes of network sense their environment continuously still it requires much less energy than the proactive network because data transmission is occur rarely. In TEEN, a CH informs all its members about the values of hard threshold and soft threshold.

Hard Threshold (HT): It is the absolute transmitting value of the attribute after this, the node sensing this value, it must switch on transmitter and it report to its cluster head.

Soft Threshold (ST): It is a small deviation in the value of the sensed data which inform the node to switch on its transmitter to transmit data to next node. Figure 2 illustrate the multi-hop Clustering in TEEN.

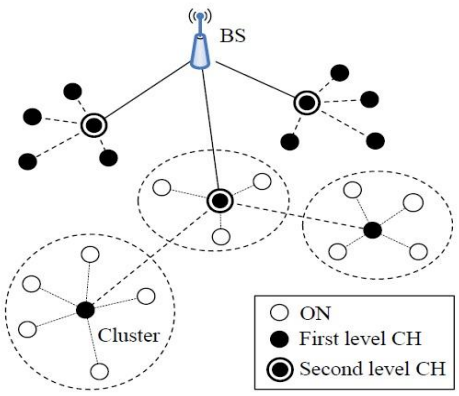

Figure 2. Illustration of the 2-tier clustering topology in TEEN protocol.

Advantages:

- Using the two thresholds values, data transmission and routing can be controlled more comfortably.

Disadvantages:

- It is not comfortable for periodic changes since all nodes will not get any data from the sensor while values of the attributes may not reach to threshold.
- If cluster heads are not in range of each other then the data may be lost.

D. ***APTEEN****:*

Adaptive Threshold sensitive Energy Efficient sensor Network protocol [7], is introduced by Manjeshwar and Agrawal. It is an extension to TEEN protocol and its aims to transmitting periodic data and adjustable to time critical applications. In APTEEN once the CHs are decided. In each cluster time slot, the cluster head first broadcasts message in which the following parameters to the cluster nodes are considered:
Attributes (A): Attribute is physical parameters to know the in which user has interest to deals with.

Thresholds: Threshold is the parameter consists of a hard threshold (HT) value and a soft threshold (ST) value. HT is predefined value of an attribute above this value a node can be transmit data packets. ST is a deviation in the attribute value which can forces a node to transmit data again.

Schedule: Schedule is a TDMA scheduling assign a slot to each node.

Count Time (TC): Count Time is the maximum time required to transmit the data from node to cluster head.

Advantages:

- APTEEN is a combination of both proactive policies as well as reactive policies, similar to LEACH and TEEN respectively.

Disadvantages:

- APTEEN exists additional time required to calculate the threshold value and the count time (TC).

E. ***PEGASIS****:*

Power Efficient Gathering in Sensor Information Systems, proposed by Lindsey et al. [8], which is an improvement of LEACH protocol. PEGASIS protocol requires formation of chain which is achieved in two steps:
•Chain construction
•Gathering data
(1) Chain Construction: This is a chain based protocol that forms chains of sensor nodes, which transmits and receives data from its neighbour and by randomly selecting one nod among them to transmit data to the base station (sink).The chain construction is performed in a greedy method, taking the farthest node from the sink. The nearest node to this node is selected as the next node in the chain of nodes. This process is carried out until all the nodes are included in the chain. A node can be placed in the chain only at single position and at every round a node acting as a leader is selected randomly.

(2) Gathering Data: The data is collected and send to next node, this gathered data which is in aggregated form sent to the BS in particular time interval. Unlike the LEACH, PEGASIS it avoids cluster formation and select only one node from the chain to transmit network information to the BS (sink). A sensor node transmits data to its nearest neighbours and next to neighbours neighbour which forms routing hierarchy to the CH. The method of data transmission and reception in PEGASIS is shown in Figure 3. In this figure, if node C2 is the leader, it passes the token along the chain to node C0 at left side. Then, node C0 will pass its data toward its right to node C2 through C1. After node C2 receives data from node C1 and it will pass the token to node C4 next it will pass its data towards node C2 through node C3. The data fusion takes place in this process.

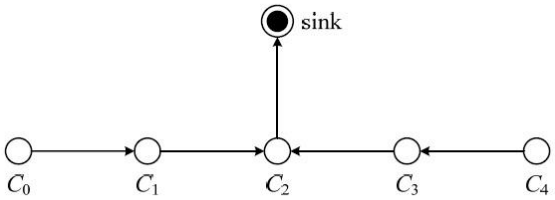

Figure 3. Data transmitting Scheme in PEGASIS.

Advantages:

- It reduce the overhead in the network because of chain formation
- The energy load is divided uniformly in the network.

Disadvantages:

- The communication may suffer from the delay in the network because of the single chain for multiple nodes and a high probability for any node to become a bottleneck and result in early die.
- It is quite complex task for all nodes to maintain a complete record about the position of all other nodes in the network it requires more processing power.

F. ***DWEHC****:*

Distributed Weight-Based Energy-Efficient Hierarchical Clustering protocol (DWEHC)[5], proposed by Ding et al., is a distributed hierarchical clustering protocol which is similar to HEED. The main task of DWEHC algorithm is to improve HEED by maintaining the balanced in cluster structure and optimizing the intra-cluster communication by applying location awareness in the sensor nodes. Apart from LEACH and HEED protocol, DWEHC protocol creates a multi-level routing structure within the cluster for communication between node inside the cluster i.e. multi op inside the cluster and limits number of children of parent node. Also the weight is assigned to each node for CH election in DWEHC. Nodes in network calculate its weight according to following formula:

$$T_{weight}(s) = \frac{E_{residual}\ (s)}{E_{initial}\ (s)} * \sum_{u} \frac{R-d}{6R}$$

Where $E_{residual}(s)$ and $E_{initial}(s)$ are residual energy and initial energy at node s respectively, R is the cluster and d is the distance between node s and its neighbouring node u. According to equation the largest weight node is elected as a CH and the other nodes become members. The structure of DWEHC protocol is illustrated in Figure 4. After running DWEHC algorithm, a node will becomes a CH or it will be becomes a child node in a cluster.

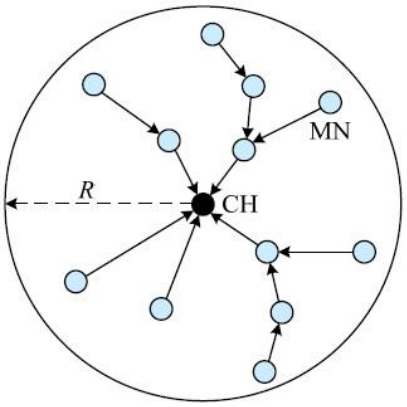

Figure 4. The Structure of Multi-hop Cluster in DWEHC.

Advantages:

- DWEHC results in balanced CHs selection and require comparatively lower energy in intra-cluster and inter-cluster communication than HEED protocol.
- The clustering process of DWEHC algorithm ends quicker probably in a few iterations it doesn't depend on network topology or size.

Disadvantages:

- As in LEACH, single-hop communication takes place between CHs to the BS in DWEHC which result in significant amount of energy consumption.

IV. COMPARISON OF DIFFERENT HEIRACHICAL CLUSTERING ROUTING PROTOCOLS IN WSNS

In this section, we summarize the different hierarchical routing protocols for WSN. Here we summarize differences of the routing protocols and compare the different routing approaches based on a few important parameters of WSN in Table 1.

Table 1. Comparison of Different Hierarchical Clustering Routing Protocols in WSNs.

Protocol Name	Energy Efficiency	Cluster Stability	Scalability	Delivery Delay	Load Balancing	Algorithm Complexity
LEACH	Very Low	Moderate	Very Low	Very Small	Moderate	Low
HEED	Moderate	High	Moderate	Moderate	Moderate	Moderate
TEEN	Very High	High	Low	Small	Good	High
APTEEN	Moderate	Very Low	Low	Small	Moderate	Very High
PEGASIS	Low	Low	Very Low	very large	Moderate	High
DWEHC	Very High	High	Moderate	Moderate	Very Good	Moderate

V. CONCLUSION

In this paper we have studied the current state of proposed hierarchical routing protocols, particularly with respect to their energy, stability and reliability. In wireless sensor networks, due to limited energy resources of sensor nodes, the main challenge in designing the routing protocols for WSNs is energy efficiency. The main objective of the routing protocol design is to keep the sensors in operating state as long as it's possible, so as to increase the life of a wireless sensor network. Energy consumption of the nodes is determined by data transmission and reception through it. In this paper the energy efficient routing protocols are described. Hierarchical protocols like LEACH, PEGASIS, TEEN, APTEEN, HEED, and DWEHC are described in this paper that is energy efficient because main aim of such protocols is to maintain the energy usage of sensor nodes by participating them in multi-hop communication within a particular cluster.

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