Hierarchical Routing Protocols in Wireless Sensor Networks: A Survey and its Comparison

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Abstract— In Wireless Sensor Networks (WSN), profound research articles are presented to address the hierarchical routing protocols which reduce the energy consumption of sensor nodes and also prolong the life of the network. The state of art of this research article focus on the survey of different hierarchical routing protocols which is utilized to efficiently deliver the sensed data from source to sink node. This article presents a detailed survey on major clustering techniques LEACH, SEP, PEGASIS, and TEEN. Also, this article strongly examines about the advantages and limitations of each hierarchical routing protocol with its recent research issues. Finally, the paper concludes with some of the research issues in hierarchical routing protocols of wireless sensor networks.

Keywords *- Routing protocol; Wireless sensor network; Clustering; Energy consumption; Network lifetime*

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I. INTRODUCTION

WSN consists of numerous battery powered Sensor node which normally operates in unattended mode. Since sensor nodes are limited with energy and, computational power, a lot of research is ongoing to design various routing algorithms that enhance the performance by considering single or multiple metrics. Designing a new routing protocol for wireless sensor networks are analyzed and presented the surveys [1-3], in various literature. This article presents the overview of hierarchical routing protocols with respect to the performance factors considered for selecting the cluster head and mobility support. Normally clustering techniques fall into two categories: Based on communication range and partitioning method to form clusters. Intra clustering and inter clustering falls in the first category. Based on method of Partitioning, it is classified as

- Hierarchical
- Density-based
- Grid-based
- Model-based

Protocol operation and network structure are the two types of routing protocols. Hierarchical based routing protocols are examined in this paper. It is used to lower retransmission of data, strong scalability and high robustness [4]. To improve the system lifetime, hierarchical routing protocols support data collection, network scalability and also decreases data delay. In wireless sensor networks, several clusters are formed due to network partition. Each cluster has several nodes and that nodes send its information to the cluster head. Cluster head used to gather and aggregate the data from nodes and forward that data to sink node in clustering routing protocols [5]. The various hierarchical routing protocols based on clustering methods are LEACH, SEP, PEGASIS, and TEEN.

II. RELATED WORKS

A.LEACH [LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY] PROTOCOL

The LEACH algorithm is the most widely used clustering algorithm in wireless sensor networks. In order to reduce energy consumption of sensor nodes, the algorithm uses the random rotation method for cluster head selection in LEACH protocol. A number of variants for LEACH protocol have been proposed in the wireless sensor networks. The phases of LEACH protocol operation are the set-up phase and the steady-state phase. In set-up phase, the selection of cluster head and formation of cluster and also assignment of TDMA schedule are performed. The cluster formation is done based on centralized, distributed and hybrid. The cluster head selection is performed based on deterministic, random and probabilistic schemes. In steady-state phase, data transmission made based on inter or intra cluster communications. The cluster head transmits data to the sink using TDMA schedule [6]. The routing protocol in wireless sensor network for energy efficiency is multipath LEACH, which is used to reduce energy consumption and control overheads. The whole network is divided into clusters and each cluster will have a cluster head, which receives data from each nodes in the clusters and transmit that data to the sink. Multipath LEACH uses a number of paths to efficiently deliver data from source to destination [7].

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, which has been proposed in wireless

sensor networks is a dynamic clustering method. The protocol LEACH-I (Improved LEACH algorithm) has aided facility that it reduces the consumption of the network resource as compared to LEACH algorithm in each round. The proposed protocol simulation and the result shows a significant reduction in energy consumption as compared to LEACH. Our major focus is based on maximizing node-degree that is defined as the number of alive nodes that lie within the transmission range of a given node is more as compare to LEACH algorithm [8].

Q-LEACH (Quadrant Cluster based LEACH) used to enhance the network lifetime by partitioning the network into four quadrants and then the cluster head selection is done [9]. Sec-LEACH is used to protect the network from different types of attacks also it provides better energy consumption in wireless sensor network [10].

LEACH-Mobile (LEACH-M), is one of the variants in LEACH, that supports node mobility and uses TDMA schedule. In clustering, the non-CH nodes, the CH node, and the sink can be mobile. High control overheads may lead to increase in energy consumption in LEACH-M. While clustering the reliability of member nodes are not considered. Framing the clusters continuously at each time will offer maximum overhead in the cluster setup [11].

In sensor networks, cluster node sends its information to the cluster head and the cluster head directly sends data to the base station as shown in Figure 1. The node which is selected as a cluster head in each cluster sends its information and location to other nodes that it has been elected as a cluster head. From which all nodes forward its data to cluster head directly.

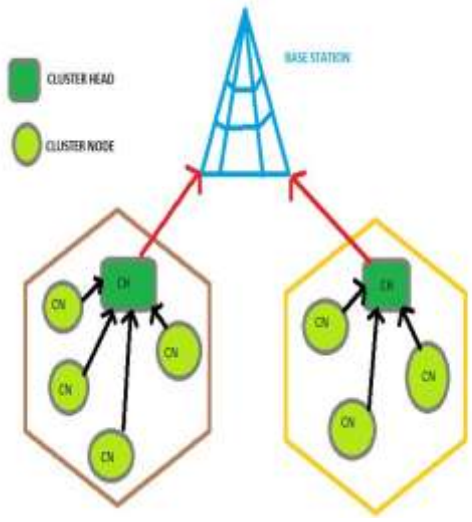

Figure 1. LEACH CLUSTER MODE

ADVANTAGES

The main advantages of LEACH protocol are

- Clustering concept is used to increase the lifetime of the network. It makes very less communication between the member nodes and the sink.
- Single hop communication and multi-hop communication is used in LEACH protocol to efficiently deliver data from cluster head and sink.
- It is one of the most widely used efficient hierarchical routing protocols in wireless sensor networks.

DISADVANTAGES

- More energy is required to transmit data from cluster head to sink. When the cluster head is far away from the sink node in steady-state phase.
- Single hop communication will lead to energy dissipation and the lifetime of the networks are degraded.
- The network robustness will be affected while choosing the cluster head randomly. Based on high and low energy, CH election is done. The nodes will die when cluster head is chosen based on low energy.

B.SEP (STABLE ELECTION PROTOCOL)

SEP is used to select Cluster Head based on weighted election probabilities. In sensor networks, it captures the energy imbalance. It has normal and advanced nodes. The advanced node makes SEP yield longer stability region than other hierarchical routing protocols. Stable Election Protocol is a heterogeneous protocol [12]. SEP works based on three levels of heterogeneity. They are normal nodes, advanced nodes, and intermediate nodes. The cluster head is selected based on probabilistic method. The energy imbalance is captured in the network [13].

In order to balance the network load and also to prolong the network lifetime, SEP-E has been proposed. To choose reasonable cluster head, the scheme initially selects an initial cluster head and redundant cluster head are in every cluster at each round. The node which has higher remaining energy and least mean distance is chosen as cluster head of current round [14].

In Z-SEP (Zonal SEP), the clustering technique is used to send data from nodes to sink node. It improves the stability period and throughput than other hierarchical protocols such as LEACH, SEP and extended SEP. To transmit the data received from nodes to sink two techniques are used. They are

• Direct communication
• Transmission through Cluster Head

System lifetime is short, in the field of the weighted probability for normal and advance nodes [15].

ADVANTAGES

- The cluster formation is best in SEP with three level of heterogeneity also more stable than other protocols.

- The network topology is efficiently organized in heterogeneous wireless sensor networks.
- It does not require any global knowledge of energy at each selection round.

DISADVANTAGES

- SEP performs very poor in multilevel heterogeneous wireless sensor networks.
- When the election of cluster head is not dynamic, the nodes that are far away from powerful nodes will die.
- Maximization of sensor node life makes network stable.

C.TEEN (THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK PROTOCOL)

TEEN is a homogeneous wireless sensor network and also designed for time-critical applications. The two threshold values broadcasted by cluster head, in forming the clusters are

- Soft threshold
- Hard threshold

The information is transmitted in both the hard mode and soft mode threshold values. In the system, it does not have the capacity to recognize the number of nodes is alive or dead. It is based on information-driven method. To develop the cluster head, the TEEN protocol depends on LEACH protocol. The performance metric is based on delay, throughput, and packet delivery ratio [16].

APTEEN (Adaptive Threshold Sensitive Energy Efficient Sensor Network protocol) is an extension to TEEN. It not only reacts to time-critical events but also to the capturing of the network at periodic intervals. When the clusters are formed by the sink, the cluster heads broadcast the threshold values, the attributes and the schedule of transmission to all nodes. In order to reduce energy consumption, cluster head performs data aggregation.

The user requests the data from the network in the form of historical, to view past data values, one-time, to take the snapshot view of the network and persisted to monitor an event for a period of time and employed in the hybrid network. The cluster collects and aggregates data received from nodes and transmit that data to sink. It periodically changes not only cluster members but also the cluster head for saving more energy. The reclustering is done periodically to enable another active node for cluster head selection [17].

EX-APTEEN (EXTENDED APTEEN) is same as APTEEN. It has some features like backup node detection and improved TDMA schedule. Compare to TEEN, it yields better performance and also have security policies [18].

ADVANTAGES

- The soft threshold in APTEEN prevents from the redundant data.
- Like TEEN, proactive policies and reactive policies are merged by APTEEN.
- For reactive policies, more changes are done in the sensed attributes.

DISADVANTAGES

- It is more complex when it is needed to implement threshold functions and the count time.
- In multiple levels, cluster formation yields more complexity and overhead.
- The data transmission is done only by cluster head if the communication range does not seem, and then the data vanish.

D.PEGASIS (POWER-EFFICIENT GATHERING IN SENSOR INFORMATION SYSTEMS) PROTOCOL

In the network, it is based on chain formation of sensor nodes. Each node in clusters communicates with its nearest neighbor node to create a chain structure. To reduce energy consumption, each node transmits its information to the sink. PEGASIS uses multi-hop transmission and outperforms better than LEACH [19].

The two objectives are:

- The network lifetime is increased and energy consumption is reduced.
- In the network, the data that are passed to the neighboring node make to reduce bandwidth consumption.

IEEPB (Improved Energy Efficient PEGASIS Based routing protocol) is an improved version of EEPB. It has mainly three stages to actualize the round operation such as

- Chain arrangement
- Selection of the head node
- Communication stage

PEGASIS is an optimal chain based protocol for extending network lifetime. There is no need of cluster head, node directly communicates with its nearest neighbors and the data are forwarded to the sink [20].

ADVANTAGES

- In the network, uniformly energy load distribution is done.
- It is a homogeneous network and not need cluster head for data aggregation.
- The information aggregation is done in chain structure to reduce the number of data transmission.

DISADVANTAGES

- Power consumption is maximum and network lifetime is also high in PEGASIS.
- It uses multi-hop communication between the node and the sink. But, far range communication; it will need more energy consumption.
- It performs better than LEACH, but is not scalable and uses a greedy algorithm.

III. RECENT RESEARCH ISSUES

Wireless sensor networks are the most developing area in the sensing technology field. Also, an issue arises in the node communication, when the energy becomes low. If the node generation is done there is no way of replacement of batteries. The research issues mainly focus on reducing energy consumption and increase in network lifetime. The research domains in LEACH protocol is based on harvesting techniques [21], round length [22], 3D scenarios [23], Mobility [24], scalability [25], Heuristic and metaheuristic optimization techniques [26], Fault tolerance management [27] , security. SPINs [28], SLEACH [29], SecLEACH [30] are based on security LEACH. The numerous improved algorithms based on PEGASIS are PEG-ant [31], EEPB [32], and IEEPB [33]. Mobility in wireless sensor networks is an important research issue. Compared to static sensor networks, mobility in wireless sensor networks are more adaptable to fast topology changes. Exploitation is not possible in LEACH variants. The new ideas in mobility WSN is identified to be mobile base station and cluster heads [34 -35].

TABLE I. COMPARISON TABLE FOR DIFFERENT HIERARCHICAL PROTOCOLS

	LEACH	SEP	TEEN	PEGASIS
Classification	Hierarchical	Hierarchical	Hierarchical	Hierarchical
Data aggregation	Yes	Yes	Yes	No
Power consumption	High	Maximum	High	Maximum
Mobility	Stationary	Stationary	Stationary	Stationary
Location based	No	No	No	Yes
Network lifetime	High	High	Less	Very high
Security	No	No	No	No
Application type	Health monitoring	Re-energization of sensor networks	Home/office	Health monitoring
Homogeneous/Heterogeneous	Homogeneous	Heterogeneous	Homogeneous	Homogeneous

IV CONCLUSION

In this paper, different hierarchical routing protocol techniques are discussed. The LEACH, SEP, PEGASIS, and TEEN are used to load balance and uniform energy dissipation in sensor networks. The different hierarchical routing protocol comparison is shown in Table I. In this survey, routing protocol has been discussed with its advantages and drawbacks and also with its recent research issues. Also, the mobility concept is discussed in this survey.

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