Energy Efficient Hierarchical Routing Protocols for Enhancing the Lifetime of Wireless Sensor Networks-A Survey

Shivani Rana, Shelza Thakur, Anamika Rangra

***Abstract*— The recent advances in the low power and highly integrated digital electronics have led to the integration of wireless sensor networks to the vast application areas. The limited power of sensor nodes is the major constraint with wireless sensor networks. The routing of data gathered in the network from the nodes to base station is the main activity of these data centric networks. The energy of the nodes gets drained out due to constant transmissions of nodes. So our aim is to present the survey of hierarchical routing protocols which are energy efficient and minimize the energy consumption and hence result in achieving the extended lifetime of the sensor networks.**

***Index Terms*—Wireless Sensor Networks (WSN), LEACH, PEGASIS, Multi-Chain, Sink Mobility.**

I. INTRODUCTION

Advances in the wireless communication and miniature electronics have enabled the development of the small, low-cost, low power devices with sensing, computation and communication all capabilities in a single unit. This single unit can be termed as sensor node (SN). The network created by the SNs is a Wireless Sensor Network (WSN). Thus, WSN is an infrastructure-less network created by the dense deployment of SNs.

Wireless sensor network (WSN) is an emerging technology that shows great promise for various applications both for mass public and military. The sensing technology combined with processing power and wireless communication makes it lucrative for being exploited in abundance in future.[1] Depending upon the requirement and characteristics of system, wide variety of applications are there which require constant monitoring and detection of specific event. The applications areas can be categorised into military, environmental, health, home, and other commercial areas.

The four main units of the sensor node are sensing unit, communication unit, processing unit and power unit. These sensor nodes observe an event or gather some physical data from its area of interest and then processes the gathered data by the processing unit embedded in it and sends processed data via a short range radio transmitter i.e. the communication unit to a central data collector called the base station (BS) [2]. Thus the main task is to route data to the BS for further manipulation of the information from the data. Fig 1 presents the basic WSN concept.

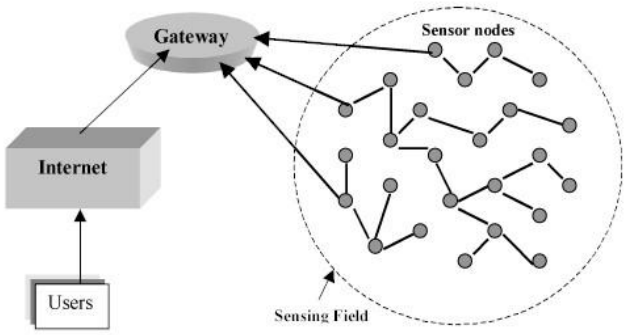

Fig.1 Wireless Sensor Network

While designing wireless sensor networks one has to pay attention on various issues of WSNs, such as limited power and energy consumption, working in extreme conditions, speed and accuracy, size, cost of installation and maintenance. But the main concern is to save the available energy of the sensors as recharging of these standalone batteries again and again is impossible. Due to these factors many efforts have been made for making the WSNs energy efficient. In this survey paper we are going to study some of the hierarchical routing protocols for their contribution in enhancing the network lifetime of the WSNs.

In the first section we will have the short introduction of routing in WSNs. In the second section the survey of the studied Hierarchical routing protocols is presented. The third section concludes the study.

II. ROUTING IN WSNS

Routing techniques are required for sending the data from the sensor nodes to the BS. The design of routing protocols for WSNs is challenging because of several network constraints. The WSNs suffers from the limitations of several resources, for example, energy, bandwidth, limited processing and small storage. The routing in WSN s can be categorized in many different ways. The protocols can be classified according to the network structure as the flat, hierarchical and direct routing. In this paper we will focus on Hierarchical routing protocols as they are used to perform energy efficient routing.

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III. HIERARCHICAL ROUTING PROTOCOLS

The single tire network is not scalable for a large set of sensors in large areas and there is a problem of service degradation. As the node density increases the single tier architecture is overload thus causing unnecessary energy dissipation of nodes and reduce network lifetime. To overcome these problems the Hierarchical routing approach is used in WSNs to maintain the energy consumption of nodes using multi-hop communication by forming clusters or chain formation for routing of data from nodes to BS. In this paper we will discuss the LEACH, PEGASIS, Multi-Chain PEGASIS and TEEN.

3.1 LEACH

Low-energy adaptive clustering hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes [3].

In LEACH the operation is divided into rounds, during each round a different set of nodes are cluster-heads (CH). Nodes that have been cluster heads cannot become cluster heads again for P rounds. 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 to transmit data. The cluster heads aggregate and compress the data and forward it to the base station, thus it extends the lifetime of major nodes [4]. The cluster formation in LEACH is shown in fig.2

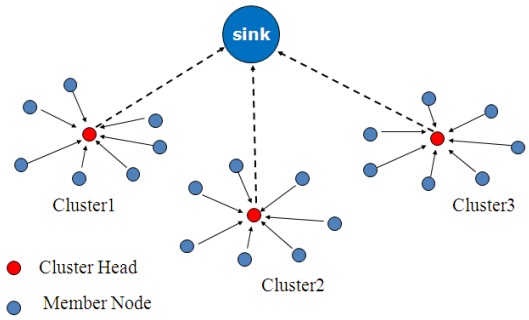

Fig.2 Cluster Formation in LEACH

Each round completes in two phases: set up phase and steady phase. In setup phase the cluster and cluster heads are formed. In steady phase the sensor nodes begin sensing and transmitting to the BS. The rotating cluster heads evenly distribute the energy load among sensors. The LEACH achieves considerable amount of reduction in energy dissipation compared to direct communication. But an extra energy dissipation, because in each round nodes acting as CH will consume a lot of energy to transmit data to far distance base station.

3.2 PEGASIS

PEGASIS stands for Power efficient gathering in Sensor Information Systems. It is considered to be an extension of LEACH protocol. In this protocol the concept of chaining comes into picture. The sensor nodes which are closest to each other will be considered to form the chain and this chain is responsible for communicating with the base station [2]. The process of PEGASIS can be divided into two steps:

i) Chain Construction

The chain is formed using the greedy approach starting from the node farthest to the sink node. The procedure continued until all the nodes are included in the chain. It will distribute the energy load evenly among the sensor nodes in the network. The node nearest to the sink becomes the leader of the chain and passes data to the sink.

ii) Gathering Data

After the chain is constructed only the leader node is allowed to transmit to the base station. Each node fuse its own information with the information of the neighbouring node and form a single packet.

The signal strength is considered to measure the distance of all the neighbouring nodes.

A new chain is constructed using the same process when a sensor node in the chain dies due to limited battery power. The overhead of new chain construction every time a node dies in the network is the major drawback of the PEGASIS.

3.3 Multi-Chain PEGASIS

In [8] the multi-chain PEGASIS protocol for reduction of energy consumption in WSNs is proposed. The proposed method is the modified version of the PEGASIS. It is found to be 20% better at performance then PEGASIS and 72% than LEACH.

In multi-chain PEGASIS the chain formation is done same as the PEGASIS except in multi-chain PEGASIS the nodes are distributed in four regions and each region contains its own different chain. The 100 nodes area is divided in each 25-25 nodes. The chain formation is as:

- ☐ Sink find the far node by comparing the distances of all nodes from itself in first region.
- ☐ The chain construction is start from end node which is far from the sink.
- ☐ The end node finds the most near neighbor and makes the chain between end node and nearer node.
- ☐ Each node finds the distance between itself and the nearest node not connected in chain and connect it with the same method which mention above.
- ☐ The same procedure of chain formation is applied in all four regions.

The different chains constructed in multi-chain PEGASIS is shown in fig 3.

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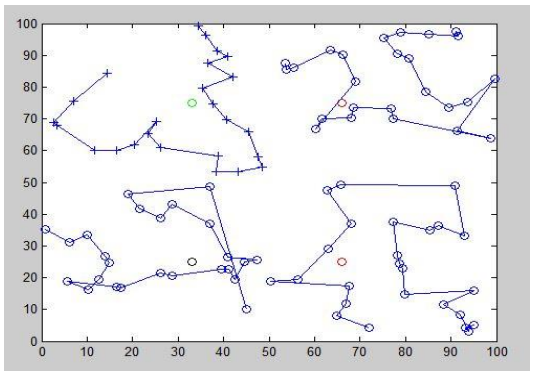

Fig. 3 Multi-Chain PEGASIS

3.4 TEEN

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is first protocol for reactive networks. The reactive networks are event driven networks the nodes are sensitive to the environmental changes like temperature, weather etc. TEEN uses hierarchical network architecture with data centric mechanism. The fig. 4 shows the mechanism of cluster formation in TEEN. At every cluster change time the cluster head broadcast two attributes to its members – hard threshold and soft threshold. The nodes sense their environment continuously. The first time the hard threshold value is

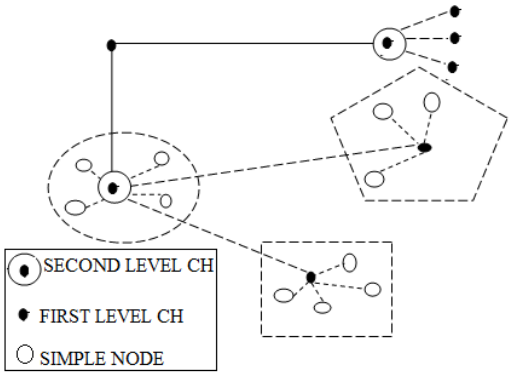

Fig 4. TEEN protocol Architecture [6]

reached the node switches on its transmitter. So, transmission occurs only when the node's sensed attribute in turn lower the number of transmissions. Once, the node had sensed a value beyond hard threshold, it only transmits a data when value of sensed attribute changes by an amount equal or greater than the soft threshold. So, soft threshold will also decreases the number of transmissions [6].

The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate; the user will not get any data from the network at all and will not come to know even if all the nodes die [7]. The message transmission consumes more energy than data sensing. The energy consumption in this protocol is less than in proactive protocol as data transmissions are very less frequent.

The Table 1 shows the summary of studied Hierarchical routing protocols.

Table 1. Summary of Hierarchical Routing Protocols

Protocols	Advantages	Drawbacks	Scalability	Mobility	Network Lifetime	Power Usage
LEACH	Low energy consumption than direct communication	Not suitable for large area networks as clustering brings extra overhead	Good	Fixed BS	Good	High
PEGASIS	Reduced transmission distance between nodes	Extra overhead of new chain construction if one node die	Good	Fixed BS	Better Than LEACH	Max.
Multi-Chain PEGASIS	Small chains reduces energy consumption	Multiple chain formation	Very Good	Fixed but Multiple BS	Excellent	Min.
TEEN	Best suited for reactive networks	More energy consumption and delays in large networks	Good	Fixed BS	Very Good	High

IV. CONCLUSION

In this survey paper different hierarchical routing protocols are studied in order to analyze their efficiency in enhancement of network lifetime of sensor networks. The multi-chain PEGASIS works best for the energy efficiency of sensor nodes and enhancing the network lifetime of WSNS.

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