Cluster Based Routing Protocols in Wireless Sensor Network: an Energy Efficiency Based Comparison

Devika G[1], Nayana S[2]

[1,2]*Assistant Professor*

[1]*Government Engineering College, Mandya*

[2]*Siddaganaga Institute of Technology, Tumkur*

Abstract - A wireless sensor network (WSN) is a network with wireless transmission medium, where autonomous devices are spatially distributed using micro-sensors to monitor physical or environmental changes. From past few years WSN has been an area which has fascinated many researchers with their new ideas to increase the life-time of the sensor nodes. The battery power in these sensor nodes plays an important role in increasing the lifespan of the nodes. Hierarchical routing protocols are being proved to be best known protocols to minimize the energy consumption by many researchers. The optimization of hierarchical clustering can improve still better by applying evolutionary technique. In this paper we have surveyed the state-of art of different hierarchical routing protocols. In addition, improvement in Leach and PEGASIS hierarchical routing protocols in WSN using evolutionary techniques has been explored. This paper also highlights some of the drawbacks and issues related to basic hierarchical protocols and protocols based on evolutionary techniques.

Key terms: wireless sensor networks, hierarchical cluster, routing protocol, evolutionary techniques.

I INTRODUCTION

Wireless sensor networks have potential to monitor environments for both military and civil applications. The ability to add remote sensing points, without the cost of running wires, results in numerous benefits including energy and material savings, process improvements, labor savings, and increases productivity [1]. In recent years WSN has been identified as one of the emerging technologies in the field of wireless communication. In general, the WSNs consists of a large number of small and cheap sensor nodes that have very limited, processing power and storage deployed in the monitored area, constituting a network through the way of self organization. The nodes have ability to communicate either directly to the base station (BS) or among each other. Currently, sensors like this are considered for applications with limited power, reliability data transfer, and short range communication and reasonably low cost such sensing applications.

Opposed to traditional ad hoc networks, routing in WSNs is more challenging as a result of their inherent characteristics. Firstly, resources are greatly constrained in terms of power supply, processing capability and transmission bandwidth. Secondly, it is difficult to design a global addressing scheme as Internet Protocol (IP) [2]. Nowadays a cheap wireless sensor nodes having sufficient computation, transmission and receiving powers are available. By this improvement more than hundreds of nodes can be deployed in a network for any application. But the routing and collection of data from this deployed is a challenge as these nodes have limited power. Therefore, designing a WSN routing protocol, enhancing energy efficiency and extending the lifetime of the WSN are the most important challenges for researchers.

The existing WSNs routing protocols can be categorized based on path establishment, network structure and protocol operation. The path establishment are grouped on how network response to sensed data into proactive, reactive and hybrid. The network structure design consists of location based (geographic), hierarchal (clustering) and flat network (data centric). Protocol operation includes negotiation based, multi path based, query based, QOS based and coherent based routing protocol. In a flat topology as shown in Figure 2(a) and (b) shows single hop and multi hop respectively, all nodes perform the same tasks and have the same functionalities in the network (every node transmits data independently to the BS). But in hierarchical topology nodes perform different tasks in WSNs and normally they are organized into clusters according to specific requirements or metrics, only Cluster head (CH) nodes transmits data to BS using single or multihop. Hierarchical clustering protocols with single-hop communication done as in Figure 2(a) and multi-hop communication design as in Figure 2(b) based on data transmission.

In recent years, clustered routing protocol has gained increasing attention for researchers because of its potential of extending the lifetime of WSN. The clusters will formed

among nodes in the networks as shown in the Figure3. The basic idea of clustering routing is to use the information aggregation mechanism in the CH to minimize the number of data transmission from the nodes in the cluster, which reduces the energy dissipation in communication, which ultimately serves main objective of saving energy of the sensor nodes.

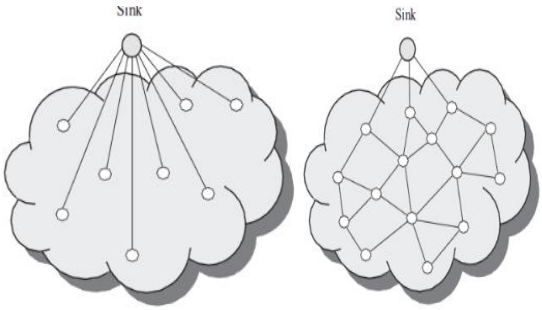

Figure 2.1 (a) Flat single hop (b) Flat multi hop

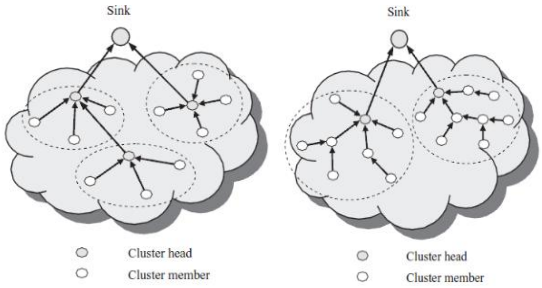

Figure 2.2(a) Hierarchical single hop (b) Hierarchical multi hop

The design factors that affect clustering are: fault tolerance, scalability, production costs, hardware constraints, sensor network topology, and environment of nodes deployment, transmission media and power consumption.

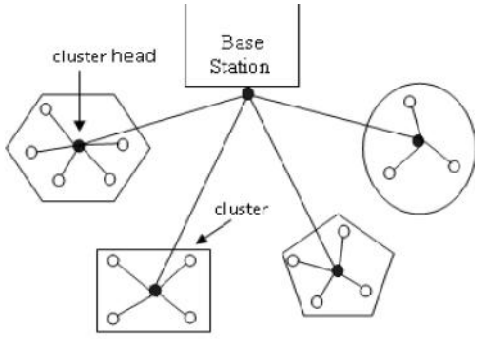

Figure 2.3 Typical cluster formations in WSN

Evolutionary Techniques [ET] often perform well approximating solutions to all types of problems as they based on generality. This generality as shown successes in many diverse fields like engineering, art, biology, economics, marketing, genetics, operations research, robotics, social sciences, physics, politics and chemistry. The routing algorithms uses evolutionary techniques such as optimization based, genetic based, swarm intelligence based to optimize the data transmission between nodes and CH and finally to BS. In the last few years, a relatively large number of routing protocols which are based on ET have been developed for WSNs.

These papers is a sincere attempt to include comprehensive review and critical discussions regarding most prominent hierarchal routing algorithms based on evolutionary techniques that have been developed for WSNs. Section II briefs about the basic hierarchical routing algorithm in terms of its working and problems associated with them. Section III discusses about the various improved protocols based on ET for LEACH and PEGASIS, followed by conclusions in Section IV.

BASIC HIERARCHICAL CLUSTERING PROTOCOLS

2.1 LEACH:

LEACH (Low Energy Adaptive Clustering Hierarchy), a clustering based protocol that exploits randomized rotation of local cluster based station (cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH is a hierarchical clustering–based protocol that utilizes randomized rotation of local CHs [CH] to evenly distribute the energy load among sensors in the network. It uses localized co ordination to enable scalability and robustness for dynamic networks and incorporate data fusion into the routing protocols to reduce the amount of information that must be transmitted to the base station [2].

LEACH Algorithm: The operation of LEACH is broken up into rounds, each round incorporates 2 phases: Set-up phase and steady phase. To minimize the overhead, the steady phase is longer than set-up phase.

In setup phase, nodes decide whether to become a CH or not for current round based on the suggested percentage of CH for the network. Nodes choose the number between 0 and 1. If selected number is less than T(n) as in equation 1, the node becomes CH.

$$T(n) = \frac{p}{1 - p * (r \bmod 1/p)} \quad if\ n \in G \tag{1}$$

where, p the desired percentage of CHs, r the current round, and G is the set of nodes hat have not been cluster-heads in

the last 1/p rounds. The node selected as a CH broadcast advertisement message to rest of the nodes. Non CH decides to join the cluster based on the signal strength received from the CH. Nodes inform the CH by transmitting the join request to the CH. CH receives all the messages from the nodes and schedules a TDMA for each of the nodes in its cluster.

In steady state the sensed information will be transmitted to the CH during its scheduled time. CH collects frames from all the nodes in the cluster and aggregates the data and transmits the data to the BS using CDMA code.

Some of the problems with the LEACH protocol are:

i. It assumes that nodes always have data to send and all the nodes including CH are have same initial energy.

ii. It requires the user to specify probability for use with the threshold function.

iii. Number of clusters is predefined.

iv. The CHS are randomly selected rotationally and residual energy of the node is not considered for cluster formation

v. CHs send aggregated data to BS in single hop manner.

vi. It does not guarantee good CH distribution and it involves the assumption of uniform energy consumption for the CHs

vii. The operations are carried out in rounds; all nodes in the network are considered while reconstructing new clusters, hence consumes lot of energy.

viii. It may be unstable during the setup phase which depends on the density of sensors.

ix. The CH used in the LEACH consumes a large amount of energy if they are located far away from sink.

x. LEACH uses dynamic clustering which results in extra overhead such as the CH changes, advertisement that reduces the energy consumption gain

Variants of LEACH have been proposed by many researchers. A survey on variants of LEACH algorithm is described in [3]. In addition authors have implemented a improvement LEACH, VLEACH and MODLEACH fro selection of cluster head [4].

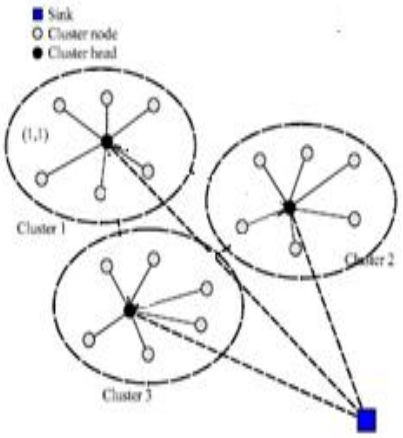

Figure 2.4 Cluster formations in Leach

2.2 HEED

Hybrid Energy-Efficient Distributed Clustering (HEED) is a multi-hop clustering algorithm for WSNs focuses on efficient clustering by proper selection of CHs based on the physical distance between nodes. CHs are determined based on two important parameters. The residual energy of each node is used to probabilistically choose the initial set of CHs and intra-cluster communication cost is used by nodes to determine the cluster to join. The power level used by a node for intra-cluster announcements and during clustering is referred to as cluster power level [5]. Low cluster power levels promote an increase in spatial reuse while high cluster power levels are required for inter cluster communication as they span two or more cluster areas. Therefore, when choosing a cluster, a node will communicate with the CH that yields the lowest intra-cluster communication cost. The intra-cluster communication cost is measured using the Average Minimum Reachability Power (AMRP) measurement. The AMRP is the average of all minimum power levels required for each node within a cluster range *I* to communicate effectively with the CH *i*. The drawback here is that,

i) A node can communicate with cluster head which yields lowest intra-communication cost.

ii) Like LEACH, HEED selects a percentage of cluster heads a priori that does not always lead to an optimal number of CHs. CH selection is probabilistic.

iii) The selection heavily relies on an a priori selected percentage of cluster heads allowed in the network and the a priori selected minimum ratio between the sensor residual and maximum energy.

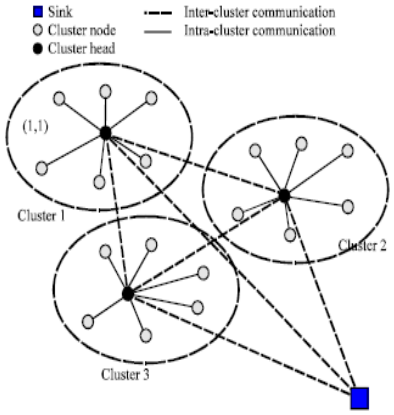

Figure 2.5Cluster formations in HEED

2.3 TEEN

Threshold Sensitive Energy Efficient Sensor Network (TEEN)[7]a routing protocol for enhanced energy efficiency for WSN is proposed. It is implemented for reactive network. In protocol the overall performance depends on a simple temperature sensing applications. Each node with in a cluster takes turns to be a CH for a time interval called cluster period. During cluster change period, the CH broadcasts two attributes hard and a soft threshold to its member nodes. Hard threshold is threshold value for the sensed attribute. Only cluster members within the range of interest will switch on transmitter to transmit the sensed value. Soft threshold is a small change in the value of the sensed attribute cluster members transmits data if sensed data varies from soft threshold. If for first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data. The sensed value is stored in an internal variable in the node, called the sensed value (SV). In further transmissions node transmit data only when following conditions are true:

i) Current value of the sensed attribute > the hard threshold value, and

ii) The current value of sensed attribute is different from sensed value that have sensed already by sensor node.

One of the drawbacks of TEEN is that it cannot be applied for sensor networks in which the nodes needs to send the data periodically to the sink. If sensed value does not exceed soft threshold, we cannot know about data changes after the default value is passed, especially if the data change is under the threshold value. Moreover, due to those thresholds it is hard to judge whether the nodes are alive or not. Another major drawback is that the CH only sends the data to the sink so if the CHs are not within the transmission range, the data will be lost.

2.4 APTEEN

This scheme is proposed to handle both proactive and reactive kind of application as an improvement over TEEN[8]. The cluster formation phase is same as in LEACH. The changes are made in steady phase.In APTEEN after deciding CH in each period the CH fist broadcasts parameters like attributes, threshold, Schedule, count time. Attributes are set of physical parameter which user is interested to collect, threshold includes hard and soft threshold value, schedule is TDMA schedule similar to LEACH to assign a slot for each node and count time is the maximum time period between two successive reports sent by a node. In APTEEN another change is made in TDMA schedule where in the midway if any of node has got critical data then it need to wait until its slot to come the nodes can change their role midway between cluster change time, so that sleeping node now go into idle and idle node go to sleep mode.It can handle 3 types of queries; historical, on-time and persistent queries. APTEEN has two schedule s TDMA and CDMA. TDMA is a uplink channel where nodes transmit to CH in its slot time. CDMA channel used by CH, aggregate the information and transmit to BS. Another modification in the TDMA slot Is BS can broadcast i.e it has downlink it can communicate to nodes. Nodes can also send query to BS which will be sent by the CH to BS at the end slot of TDMA as shown.

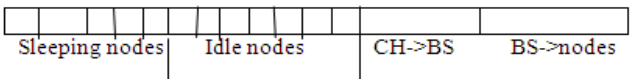

Figure 2.7 Slot of TDMA allotted to transmit from CH to BS

Literally, both TEEN and APTEEN have the same drawbacks of additional burdens and complexity of cluster construction and tracking at different levels using time control.

2.5 *EECS*

This is a clustering algorithm developed by extending LEACH known as Energy Efficient Clustering Scheme (EECS) [9] in which the candidates competes among themselves to be getting selected as a CH. If a given node does not find a node with more residual energy, then it becomes a cluster head. EECS extends LEACH algorithm by dynamic sizing of clusters based on cluster distance from the base station. Each node computes the approximate distance to the BS based on the received signal strength. This distance is used to balance the load among cluster heads. In cluster

formation phase, anovel weighted function is introduced to form load balanced clusters. This improves the resource utilization and extended lifetime of the network. The major disadvantage of EECS is based on controlling the control signals for selection of CH on negotiation based. Additionally, every node needs to know the global information of the network. Further, it is not suitable for long range applications.

III COMPARSION OF HIERARCHICAL PROTOCOLS

Comparison of different hierarchical routing protocols namely LEACH, PEGASIS, HEED, TEEN, APTEEN are provided in Table 1 in terms of parameters like power management, network lifetime, scalability, load balancing, cluster stability, algorithm complexity, design model.

From chart-1 shown below we can see that when first node dies the energy dissipation of LEACH is very much poor, so in terms of energy dissipation and network lifetime there is a lot more to do research work. Also researchers can futher make improvements in PEGASIA in terms of time delay. There are many open issues in WSN for improving the routing algorithms of LEACH, PEGASIS, TEEN/APTEEN, HEED.

TABLE 1 COMPARISON OF HIERARCHICAL ROUTING ALGORITHMS

Protocol	Power management	Network lifetime	classification	Scalability	Load balancing	Cluster stability	Algorithm complexity	Delivery delay	QOS	overhead	Data aggregation	Design model
LEACH	Very low	Good	Clustering	Very low	Moderate	Moderate	Low	Very low	No	High	Yes	Cluster based
HEED	Moderate	Very good	Clustering	Moderate	Moderate	High	Moderate	Moderate	No	High	Yes	Cluster model
PEGASIS	Very High	Very good	Reactive clustering	Low	Moderate	Low	High	Very high	No	Low	Yes	Chain based
TEEN	Moderate	Very good	Reactive clustering	Low	Good	Very low	High	Low	Yes	High	Yes	Active Threshold
APTEEN	Low	Very good	Hybrid	Low	Moderate	Low	Very high	Low	Yes	high	Yes	Active threshold

TABLE 2 NODES LIFE TIME

	Direct	LEACH	PEGASIS	TEEN	APTEEN	HEED
First node	54	402	788	500	500	415
Half node	76	523	1041	800	1200	968
last node	117	635	1096	1200	2100	1041

The above table II depicts first node, half and last nodes being dead in a network for 100 nodes. Network lifetime of LEACH is much longer than the other protocols. On the other hand the total network lifetime of APTEEN and PEGASIS is much higher compared to others.

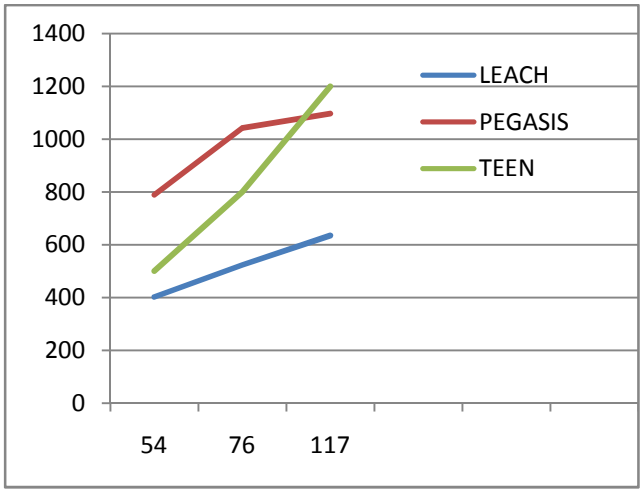

CHART 1 DEAD NODES VS LIFE TIME OF NODES

IV CONCLUSIONS

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to extend the network lifetime of sensors of WSN. This paper briefs about hierarchical protocol for wireless sensor networks. Most commonly LEACH, PEGASIS, ECS protocols can be used for proactive small scale networks. The TEEN is used for reactive networks. The APTEEN protocol is suitable for both proactive and reactive networks. HEED is suitable for large scale proactive networks. The survey reveals that we can still optimize the task of selection of CH and for formation of cluster in LEACH based; in PEGASIS optimizing the chain formation in the network can be done. It can be concluded from survey, that for an energy-efficient and prolonged WSNs, there is still a need for finding much more efficient, scalable and robust clustering scheme for better performance by applying evolutionary algorithm.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A Surveyon Sensor Networks," IEEE Communications Magazine, Vol. 40, No. 8,pp. 102–114, Aug 2002.

[2] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, Energy Efficient Communication Protocols for Wireless Sensor Networks In Proceedings of the 33rd Annual Hawaii International Conference on System Sciences (HICSS), pp. 3005-3014, Big Island, Hawaii, USA, January 2000

[3] Devika G, AshaGowda Karegowda, "A pragmatic study of LEACH and its descendant routing protocols in WSN", National conference on research issues in image analysis and mining intelligence, Erode Arts & Science college, Erode, Tamil Nadu, India, Feb 2015.(Accepted for publication in International Journal of Computation Intelligence and Informatics for upcoming issue(non paid Journal).

[4] Devika G, AshaGowda Karegowda," Performance enhancement of LEACH, V-LEACH and MOD-LEACH clustering routing protocols for wireless sensor networks", International Conference on Research in Business management & Information Technology(ICRBIT - 2015), April 29- 30, 2015, RNSIT, Bangalore.(Accepted for publication in International Journal of Computer Science Engineering and Information Technology Research)

[5] O. Younis and S. Fahmy, "HEED: A Hybrid Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks," IEEE Transactions on Mobile Computing, Vol. 3, No. 4, Oct-Dec 2004.

[6] Lindsey S., Raghavendra C. "PEGASIS: Power-Efficient Gathering in Sensor Information Systems", Aerospace Conference Proceedings, IEEE, LosAngeles, CA, USA, 2003; Vol. 3, No.3, pp.1125-1130.

[7] A. Manjeshwar and D. P. Agrawal, "TEEN: A Protocol for Enhanced Efficiency in Wireless Sensor Network", 1st international Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, 2001, pp.189.

[8] A. Manjeshwar and D. P. Agrawal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks", 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, 2002, pp.195-202.

[9] M.Ye,C.Li,G.Chen and J.Wu, ",EECS:An Energy Efficient Clustering Scheme in Wireless Sensor Networks", National Laboratory of Novel Softaware technology, ,Nanjing University,China.