# Energy Efficient Routing Protocols for Wireless Sensor Networks (WSNs) based on Clustering

Aditya Kumar
M.Tech (CSE) Research Scholar
Punjab Technical University (PTU), Jalandhar
aditya279138@gmail.com


Anand Nayyar
Assistant Professor
Department of Computer Applications & IT
KCL Institute of Management and Technology, Jalandhar, Punjab
anand_nayyar@yahoo.co.in

**Abstract**— In recent years, development of micro sensors for the purpose of tracking and monitoring has opened the door of numerous fields of sensor applications. A WSN is a collection of nodes which are organized into a network. Sensor nodes can gather the information from an unattended location and transmit to a particular user. In wireless sensor network, sensor nodes are operated with low power and small size batteries. Energy efficiency is one of the critical concerns for wireless sensor networks .There are a number of energy conservation algorithms like power scheduling algorithms, clustering algorithms and on-demand routing algorithms. Significant overhead energy consumption takes place due to tasks like processing, aggregation, message broadcasting, acknowledgement messages etc. Hence the sole purpose to design the energy conservation algorithms is that maximum energy should be consumed in transmission of sensed data to the base station and the overhead energy consumed should be minimized. Clustering is one of the robust approaches to energy-efficient sensor networking. Performance estimation of the clustering technique is the calculation of deviation from integrated optimization of different tasks like deployment, cluster formation, cluster-head selection, cluster-head rotation and data communication. The main objective of this paper is to highlight all the routing protocols which are energy efficient based on Clustering for WSN.

**Index Terms**— Wireless Sensor Networks (WSNs), Routing Protocols, Clustering, LEACH, PEGASIS, TEEN, APTEEN, SEP, DEEC, HEED, Energy Efficiency

——————————  ◆  ——————————

## 1 INTRODUCTION

A wireless sensor network (WSN) can be defined as network consists of tiny, cheap, and small sensors deployed in area of interest. A wireless sensor network system usually comprised of sensor nodes, sink node and management node. A large number of sensor nodes are deployed in the monitored area, constituting a network through the way of self-organization. The data sensed by sensor nodes is transmitted to other nodes one by one, that will reach the sink node after a multi-hop routing and finally reach the management node through the wired and (or) wireless Internet. A sensor node is a device embedded with a sensor (e.g. temperature, acoustic, image ) can sense some environment's attributes, a digital processor for processing of data received from sensor and implementing functions of network protocols, a radio trans-receiver module for communication and a battery to energize all hardware modules. Every sensor attains a certain view of its

sensing environment. This view is constrained both in range and in accuracy; it can deliver only information about limited sensing field. The attained view or information or data accuracy depends on quality of the hardware; lacking which noisy data may be produced. Aggregation or Combination of the data from individual nodes delivers the accurate and reliable information about the monitored environment [1]. The energy, the ability of signal process, storage capacity and communication capability of sensor nodes are very limited. The important design goal for wireless sensor networks is to use the energy efficiently. The Cluster-based routing algorithm has a better energy utilization rate as compared with the non-cluster routing algorithm.
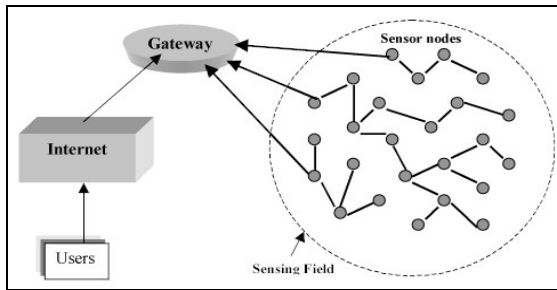
Figure 1. Wireless Sensor Network Architecture

Figure1 represent the snapshot of sensor network. Sensor nodes are the network components that will be sensing and delivering the data. Sensor nodes will initiate transmission according to a query originated from the Task Manager/User depending on the routing algorithms used. Sensor nodes may do some computation and pass its data to its neighboring nodes. The sensor node can act as a source or sink/actuator in the sensor network field. The main purpose of a source node is to sense and deliver the desired information to the sink. Gateways allow the system managers to interface motes to personal computers, personal digital assistants, Internet, existing and protocols. In a nutshell, gateways behave as a proxy for the sensor network on the Internet. Gateways can be categorized as active, passive, and hybrid. The Active gateway allows the sensor nodes to send its data to the gateway server whereas the passive gateway operates by sending a route request to sensor nodes. Hybrid gateway is the combination of the active and passive gateways. The user will connect to the gateways through some media like satellite link or internet. The Task Managers consists of data service, client data browsing and processing. These Task Managers can be considered as the information retrieval and processing platform. All data coming from sensor nodes is stored in the task managers for analysis purpose. Users can use any display interface (i.e. PDA, computers) to retrieve or analyze these information locally or remotely. Different components can be added into sensor nodes depending upon application criteria. In our paper, Sec-tion I deals with the introduction of wireless sensor network. Section II highlights the design goals and issues of wireless sensor networks. Section III deals with clustering and routing in WSN respectively. The Section IV gives details description about the various energy efficient routing protocols based on clustering and Section V describes the overall conclusion of the paper.

## 2 DESIGN ISSUES IN WIRELESS SENSOR NETWORKS

Design and implementation of good protocols are primary concerns in wireless sensor networks for the purpose to utilize the resources as the WSN is resource constrained mainly in power and bandwidth. Hence, there are following metrics that should be considered while designing the protocols for WSNs.

- Ease of Deployment: A hundreds or thousands of nodes can be used to deploy a sensor network in remote or dangerous environment. Therefore sensor nodes should be small and cheap enough so that it is economical to throwing hundreds or thousands nodes over a remote or dangerous area from a plane to retrieve the information in ways that may not possible otherwise [3].

- System Lifetime: Wireless sensor networks should be designed in such way that they can function for long duration. System lifetime is measured in terms of time to node failure or node die or time until network does not provide acceptable quality results.

- Latency: Data extracted from sensor networks is typically time sensitive. So data must be received in a timely manner. Processing or communication can cause long delays that may be unacceptable.

- Quality: This parameter measures the accuracy of extracted data that to what extent it matches to actually occurring in the environment. It is a data dependent

and application-specific parameter but amount of data is directly proportional to the accuracy. The more data to the base station is transmitted, base station or end user extracts more accurate view of environment.

- Self-configurability and fault tolerance: In sensor networks, sensor nodes are deployed without caring and engineering. Once deployed, sensor nodes should be able to autonomously organize and reconfigure themselves in the event of topology changes. Sensor nodes should be fault tolerant and ability of self repairing and self testing in harsh deployment environments.

- Node Heterogeneity: All sensor nodes are assumed to be homogeneous on wireless sensor field. This term refers to that all sensor nodes having equal capacity in terms of computation, processing, aggregating and battery power. The diverse nature of sensor nodes creates technical issues which are related to routing. So different/special sensors are deployed in order to observe the diverse quality of service constrains [14]. This burden can be handled by certain cluster heads which are more powerful than other sensor nodes.

- Data reporting model: Data sensing depends upon application specific task and time criticality. Reporting of data can be divided into different approaches such as time driven, event driven, query driven and hybrid. These all types of reporting model highly affect the route stability and energy consumption when dealing with routing protocols.

## 3 CLUSTERING IN WIRELESS SENSOR NETWORKS

Energy consumption is the prominent issue in wireless sensor networks where the sensor nodes are operated with low pow-

er, small size batteries and the life of the network depends upon the rate of drainage of the energy of that batteries. Clustering is one of the robust approaches to energy efficient sensor networking. The major benefits of clustering in wireless sensor networks are listed below [2]:

- Clustering provides the spatial reuse of resources to increase system capacity. For example, if the clusters aren't neighbors, they'll use identical frequency for wireless communication.
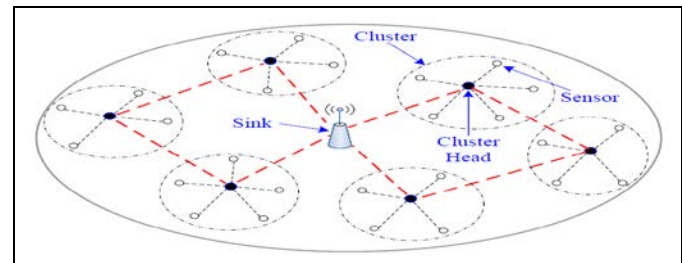


Figure2. Clustering among sensor nodes

- Routing info of a cluster is shared with solely different cluster-heads or cluster gateways. This restriction reduces the amount of transmissions performed for distributing routing info. By making use of these advantages of cluster, additional energy efficient routing protocols are implemented.

- Once cluster structure is formed during a WSN, the native changes needn't be mirrored to entire network. This reduces the data processed by sensor device nodes and data kept in sensing device nodes.

- Clustering can conserve communication bandwidth and avoid redundant exchange of messages among the sensor networks.Commnication gap among sensor nodes is also minimized with the help of clustering.

- A CH can perform data fusion over sensed data and decrease the number of redundant exchange of pack-

ets [16]. A CH can reduce the rate of energy consumption by scheduling activities in the cluster.

# 4 CLUSTERING BASED ENERGY EFFICIENT ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORKS

Multiple routes can communicate a node and the sink. The objective of energy-aware algorithms is to choose those paths that are expected to maximize the lifetime of network. In order to do this, the paths composed of nodes with maximum energy resources are preferred. The energy efficiency is most significant for wireless sensor networks than any other networks. In general, information transmission in wireless communication takes additional power than data processing. Whenever the nodes are transmitting large number of data proportionately their battery power also get decreased. In order to reduce the data size, data fusion or aggregation techniques can be used. Data fusion is that technique in which the data sensed by sensor node from different nodes are fused together at certain point suitable for the transmission in its reduced size. There are two types of data fusion, the first type of data aggregation fuses the information collected from different sources nodes and sends the final fused data in reduced size. However the problem behind this technique is that it lacks in accuracy and precision of data from many sensor nodes. The second techniques combine the data from various sources node under the single header and forward it to the base station.

## A. LEACH: Low Energy Adaptive Clustering Hierarchical protocol

Leach is self –organizing, adaptive clustering protocol. In leach nodes organize themselves into local clusters, with one node act as cluster head. Leach utilizes the randomized rotation of cluster heads to evenly distribute the energy load

among the sensors in the network [4]. This randomized approach is done in order to not drain the battery of a single node. Here, not only the cluster heads have the responsibility of collecting data from their clusters, but also to combine the gathered data for reducing the amount of messages to be sent to the base station, which results in minimum dissipation of energy to enhance the lifetime of sensor network.
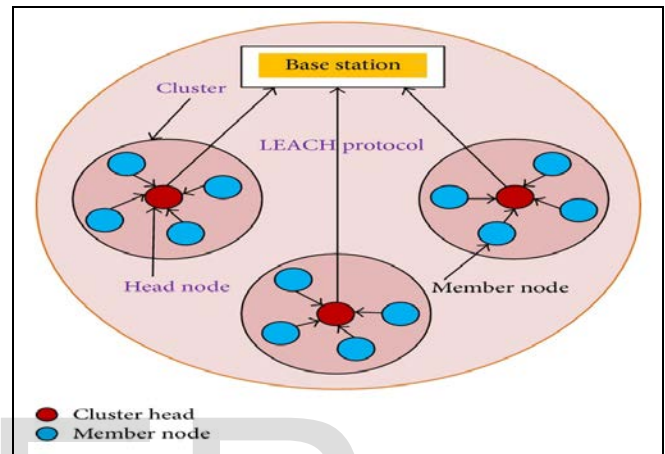


Figure 3.LEACH protocol

In LEACH protocol, the sensor nodes choose themselves to be CHs at any given time with a given probability. The decision of whether or not to become a cluster head for current round is based on suggested percentage of cluster heads for network and number of times the node has been cluster-head so for. There are n number of nodes which choose a random number between 0 and1.if the value of random number is less than a threshold t(n),then node becomes cluster head for current round. The Threshold function is defined as-

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod \frac{1}{P})} & : n \in G \\ 0 & : otherwise \end{cases}$$

Where n is the given node, P is the a priori probability of a node being elected as a cluster head, r is the current round number and G is the set of nodes that have not been elected as

cluster heads in the last 1/P rounds [4]

## B. PEGASIS: Power-Efficient Gathering in Sensor Information Systems

PEGASIS which stands for Power-Efficient Gathering in Sensor Information Systems [8] is a data-gathering and near-optimal chain-based algorithm that establishes the concept that energy conservation can result from nodes not directly forming clusters. The nodes are organized to form a chain. To construct a chain, we start with the furthest node from BS, which can be accomplished using a greedy algorithm. Each node receives data from one neighbor, combines with its own data, and sends to other neighbor on the chain.
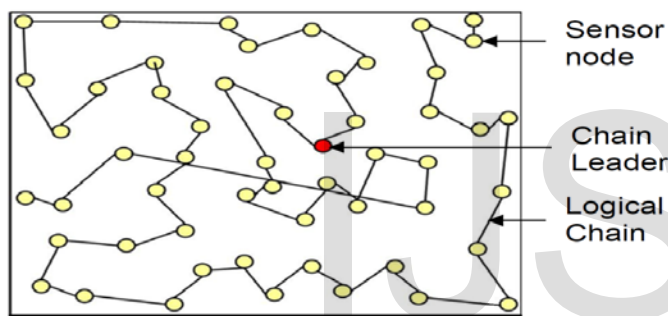


Figure 4. Chain Oriented topology in PEGASIS protocol

PEGASIS routing protocol performs data fusion at every node except the end nodes in chain. When a node dies, the chain is formed by using the same greedy approach by bypassing the dead nodes. PEGASIS routing protocol avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes [5].

## C. TEEN: Threshold Sensitive Energy Efficient Sensor Network Protocol

TEEN is reactive protocol which is suitable for time critical applications. It is also called as responsive protocol due to sudden changes of some of the attributes observed in the WSN (e.g. temperature) [6].In this protocol, cluster head broadcast two thresholds for sensed attributes. Hard Threshold (HT),

which is the minimum of data transmission and specify the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head. Soft Threshold (ST) specifies that there is a small variation in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. It stimulates the node to switch on its transmitter and report the sensed data. If the sensed data is exceeding the hard threshold the first time, nodes can send data to the CH, and set the data as current hard threshold and save sensed data [7]. The nodes can send data only if the monitoring data is greater than the hard threshold and the absolute difference with the sensed data is not less than the soft threshold, and then the new data can be set as the current hard threshold
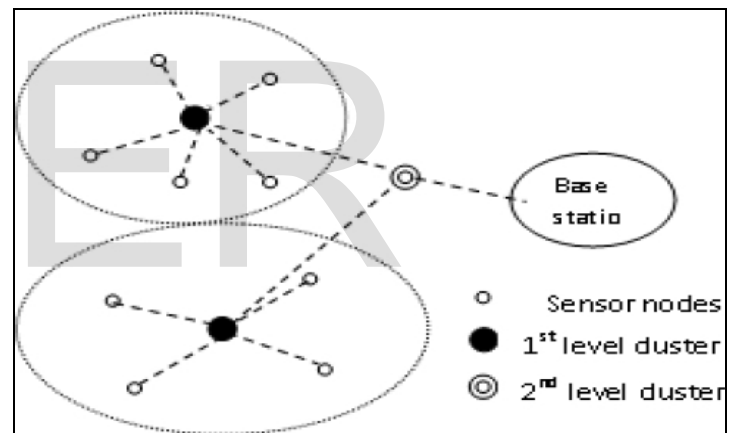


Figure 5 .Hierarchical Clustering in TEEN

The protocol reduces the amount of data transfer by this method. In teen protocol, sensing consumes less energy than transmission. Teen is not suitable for those applications where data is needed at regularly basis. To ensure collision among different clusters is also the main issue in it.

## D. APTEEN: Adaptive Threshold Sensitive Energy Efficient sensor network protocol

This protocol combines the features of both TEEN and LEACH. This allows the sensors to send their sensed data periodically and react to any sudden change in the value of

sensed attribute. Here clustering approach is same as TEEN followed by query routing. In APTEEN [8] , cluster head broadcasts different parameters in their cluster period i.e. attributes, threshold, schedule count-time. It deals with three types of queries. It can convey historical queries by extracting data associated with past actions. It can also respond to one time queries that give a snapshot view of network. Moreover, persistent queries handles the future aspects and monitoring the object within a time interval. APTEEN is best suited for both periodic sensing & reacting to time critical events such as habitat monitoring for example animal monitoring in the forest etc.

### E.    SEP: Stable Election Protocol

Sep is a heterogeneous protocol which improves the stable region of the clustering hierarchy process. Stability period is defined as the time interval before the death of first node. It only operates under two level heterogeneous networks. Sep is based on weighted probability of each node to become the cluster head.sep involves two types of nodes: i.e. advanced nodes and normal nodes. Advance nodes have $\alpha$ amount of more energy than normal nodes. Due to this parameter, advanced nodes have to become cluster heads more often than the normal nodes, which is nearly equal to a fairness constraint on energy consumption. Suppose that the initial energy of each normal sensor is $Eo$ and energy of each advanced node is $Eo \cdot (1 + \alpha)$. Then total energy of the new heterogeneous network is equal to:

$$n \cdot (1 - m) \cdot Eo + n \cdot m \cdot Eo \cdot (1 + \alpha) = n \cdot Eo \cdot (1 + \alpha \cdot m)$$

So, the total energy of the system is increased by $1+\alpha \cdot m$ times [9]. In Sep, worse scenario is created when a normal node becomes the cluster heads within first round of election. In order to maintain this situation, well distributed energy constrains is taken into account. For this purpose, a weight is assigned for individual probabilities for election of CHs for advance and normal nodes.

### F.    DEEC: Design of Distributed Energy Efficient Clustering protocol

DEEC is a distributed energy-efficient clustering algorithm for the multilevel heterogeneous wireless sensor networks which is based on clustering, when the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The level of hierarchy is directly proportional to energy of the nodes. In DEEC, the nodes equipped with high initial and residual energy will have more chances to be a cluster head than the low energy nodes. Therefore, cluster head formation in DEEC, based on residual energy on node and average residual energy of network. DEEC does not require the global knowledge of energy at every election round. Average energy of network is taken as reference energy and on the basis of this, base station estimate the lifetime of all nodes [10].

### G.    HEED: Hybrid Energy Efficient Distributed Clustering protocol

HEED (Hybrid, Energy-Efficient Distributed Clustering) [11] is a multi-hop cluster-based protocol in which the nodes  elect themselves as  CHs based on residual energy and node degree as a metric for cluster selection to achieve power balancing. The efficient clustering in HEED protocol is also based on physical distance between nodes during cluster head selection. Every cluster is assigned a cluster range to sensor nodes within its coverage area [17]. In HEED, the main important parameter is their residual energy of each sensor node and the secondary parameter is the intra-cluster communication cost as a function of cluster density. HEED protocol objective is related with prolonging network lifetime by distributing energy consumption, minimize energy during the process of cluster head selection and minimizing control overhead.In HEED, each

sensor node sets the probability *CHprob* of becoming a CH in each round.



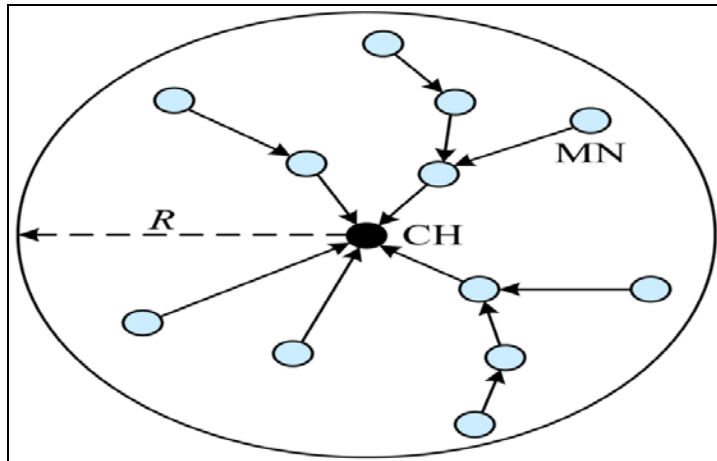Figure 6. HEED protocol

Where *Eresidual* is the estimated current residual energy in this sensor node and *Emax* is the maximum energy corresponding to a fully charged battery. The *CHprob* value must be greater than a minimum threshold *pmin*. A CH is either a temporary CH, if its *CHprob* is <1, or a final CH, if its *CHprob* has reached 1. Every sensor node that never heard from a CH chooses itself to become a CH with probability *CHprob* during each round of HEED. If a sensor node is chosed to become a CH, it broadcasts a message as a temporary CH or a final CH. A sensor node hearing the CH list chooses the CH with the lowest cost from this set of CHs. Then every node doubles its *CHprob* and moves to the next step. If a node completes the execution without choosing itself to become a CH or joining a cluster, it announces itself as a final CH. A temporary CH node can become a regular node at a later iteration if it hears from a lower cost CH. Here, a node can be chosen as a CH at consecutive clustering intervals if it has maximum residual energy with lower cost. HEED is free from location-awareness problems and nodes update their neighbor's status periodically. The nodes require neighborhood data to form the clusters and operate correctly even when nodes are not timely synchronized. Communication overhead arises due to random

selection of cluster head and extra energy is wasted due to regular cluster head election.

## Conclusion

In this paper, various energy efficient routing protocols of wireless sensor networks have been discussed. The energy efficiency is main issue in routing protocols of WSN due to resource constraint of sensor node. There is need to have energy efficient protocol in WSN for maximizing the lifetime of network. A comparison of various energy efficient protocols has been discussed. Future works is possible to improve the performance of network by proposing new energy efficient routing protocols based on clustering.

### REFERENCES

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

[2] W. R. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communications*, vol. 1, no. 4, pp. 660–670, October 2002.

[3] K. Akkaya and M. Younis, "A Survey of Routing Protocols in Wireless Sensor Networks, " in the Elsevier Ad Hoc Network Journal, Vol. 3/3 pp. 325-349, 2005.

[4] 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), 3005±3014, Big Island, Hawaii, USA, January 2000.

[5] S. Lindsey and C.S. Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Information Systems", *Proceedings of the IEEE Aerospace Conference*, Big Sky, Montana, March 2002, vol. 3.

[6] N. Saini , A. Singla , "A Wireless Sensor Networks Routing Protocols Survey for Energy        Efficiency Techniques , International Journal of Advanced Research in Computer Science and Software Engineering, Vol 4 , Issue 4 , 2014

[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, p.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]   G. Smaragdakis and I. Matta , "SEP: A Stable Election Protocol For Clustered Heterogeneous Wireless Sensor Network ", 2004.

[10]   L. Qing , Q. Zhu and M. Wang , " Design of distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks.

[11]  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.

[12]   M. Younis, M. Youssef and K. Arisha, ―Energy- Aware Routing in Cluster-Based Sensor Networks‖, in the Proceedings of the 10th IEEE/ACM Inter- national Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS2002), Fort Worth, TX, October 2002.

[13]   S. Lindsey, C. S. Raghavendra and K. Sivalingam, "Data Gathering in Sensor Networks using the Energy *Delay Metric", in the Proceedings of the IPDPS Workshop on Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[14]   J. Al-Karaki, and A. Kamal, *Routing Techniques in Wireless Sensor Networks: A Survey*, IEEE Communications Magazine, vol. 11, no. 6, Dec. 2004,pp. 6-28.

[15]   N. Saini  , A. Singla , "A Wireless Sensor Networks Routing Protocols Survey for Energy        Efficiency Techniques , International Journal of Advanced Research in Computer Science and Software Engineering, Vol 4 , Issue 4 , 2014

[16]   Nayyar, Anand, and Agam Gupta. "A Comprehensive Review of Cluster-Based Energy Efficient Routing Protocols in Wireless Sensor Networks." *IJRCCT* 3.1 (2014): 104-110.

[17]   Sharma, Naveen, and Anand Nayyar. "A Comprehensive Review of Cluster Based Energy Efficient Routing Protocols for Wireless Sensor Networks."*Volume* 3 (2014): 441-453.

| PROTOCOL | ENERGY EFFICIENCY | CLUSTER STABILTY | LOAD BALANCING | CLASSIFICATION | ALGORITHM COMPLEXITY | DELIVERY DELAY | SCALABITY |
|---|---|---|---|---|---|---|---|
| **LEACH** | Very poor | Medium | Medium | Proactive/ Clustering | Low | Very small | Very poor |
| **PEGASIS** | Poor | Low | Medium | Reactive/ clustering | High | Very large | Very low |
| **TEEN** | Very high | High | Good | Reactive Clustering | High | Small | Poor |
| **APTEEN** | Medium | Very low | Medium | Hybrid | Very high | Small | Low |
| **SEP** | Medium | Medium | Good | Reactive/ Clustering | Very low | Very small | Medium |
| **DEEC** | High | High | Good | Proactive/ Clustering | Very low | Very small | High |
| **HEED** | Medium | High | Medium | Hybrid | Medium | Medium | Medium |

Table: Comparitive Analysis of various Clustering
Based Energy Efficient Routing Protocols for Wireless
Sensor Networks