

# Energy Efficient Routing Protocols for Wireless Sensor Networks: A Survey

Honey A. Soni<sup>1</sup> and Ashish D. Patel<sup>2</sup>

<sup>1,2</sup>Department of Computer Engineering-IT Shri S'ad Vidya Mandal Institute of Technology Bharuch 392-001, Gujarat, India  
E-mail: <sup>1</sup>honey.a.soni@gmail.com, <sup>2</sup>ashishpatel.svmit@gmail.com

**Abstract**—Energy is the vital resource in the life of a wireless sensor node. So, its usage must be optimized to extend the network life. Routing protocols should also be concerned about the overhead energy which is wasted at each hop during data transfer. Main feature of routing protocol, in order to be efficient wireless sensor networks, is the energy consumption and the extension of the network's life. There are many routing protocols such as flat based, location based, multipath based, hierarchical based etc. Clustering is used to increase the lifetime of the wireless sensor networks. Clustering is the process where sensing region is divided in groups to balance the energy level of clusters. Energy is the main consideration when we analyze routing protocol of wireless sensor network. In this paper, a review on popular hierarchical based routing protocols such as LEACH, PEGASIS, TEEN etc considering the various aspects of Wireless Sensor Networks.

**Keywords:** Routing Protocols; Wireless Sensor Networks; Energy Efficient; Network lifetime

## 1. INTRODUCTION

Wireless sensor network consist of one or more sensor nodes connected via wireless network with sensing capabilities. Wireless sensor networks are used in a many applications for monitoring such as environmental, health, military, home automation, industry automation etc. In wireless sensor networks, main focus on low power consumption of protocols to increase the network lifetime. Mainly routing protocols are divided based on network structure and protocol operation. Based on network structure routing protocols classified in to 3 categories .they are Flat based, hierarchical based and location based. Depending on protocol operation we can divide routing protocol in to multipath based, query based, negotiation based, QoS based and coherent based. They describe as below:

- **Flat routing:** every node plays the same role and sensor nodes co-operate each other to perform the sensing task.
- **Hierarchical routing:** Nodes will play different roles and it's an efficient way to lower energy consumption within a cluster.
- **Location routing:** Nodes' positions are exploiting to route data. Sensor nodes are addressed by means of their locations.

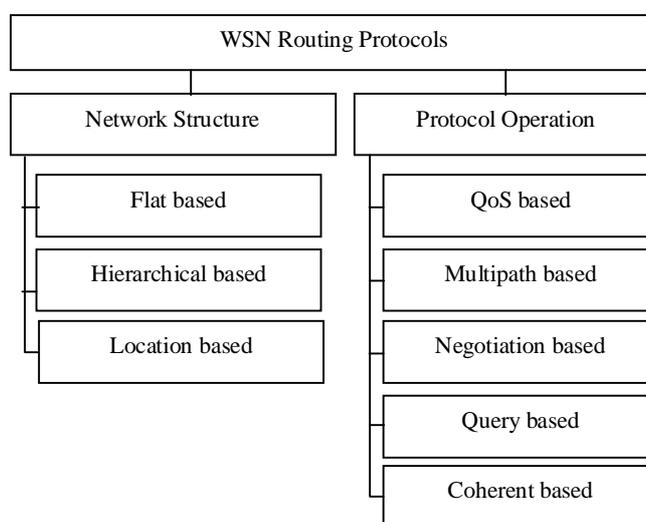


Fig. 1: Classification of WSN Routing Protocols

- **Multipath based routing:** Multipath routing protocols use multiple paths to enhance network performance. For instance the fault tolerance can be increased by maintaining multiple paths between sources to destination at the expense of increased energy consumption.
- **Qos-based routing:** When delivering data, the network balances between energy consumption and quality of service matrix such as delay, energy etc.
- **Query based routing:** Destination nodes generate a query for data. A node with this data sends matching data with the query back to initiate node.
- **Negotiation based routing:** Use negotiation in order to eliminate redundant data transmissions. Based on availability of resource they take a communication decisions.
- **Coherent based routing:** the entity of local data processing on the nodes divided in to coherent and non-coherent routing protocols.

This paper organized as follows: In section 2, Hierarchical routing protocols (such as LEACH, PEGASIS, TEEN etc.) for WSNs is presented. In section 3, the related work in the survey of energy efficient cluster based routing protocols for WSNs is presented. In section 4 we conclude the paper.

## 2. HIERARCHICAL PROTOCOLS

Network is break by hierarchical approach in to clustered layers. Cluster is a group of nodes with one cluster head (CH). Cluster head responsible for the routing from the cluster to different cluster heads or base station. The process of traveling data is lower clustered layer to higher one. Several techniques are used in current clustering algorithms to achieve longer life time [4]:

**CH rotation:** CH rotation between sensors is necessary because CHs consume more energy than the normal sensors due to their responsibilities of data gathering from sensors and data transmission to the Base Station.

**Energy aware CH election:** In cluster the node is elected as CH which has high residual energy to even the power usage.

**Cluster size:** Big cluster's CH consumes more energy than small cluster's CH. Cluster size is also mattered in energy management.

**Data fusion:** CHs assemble the received data and send the fused data to Base station. So, transmission cost became reduced.

**Transmission Power Control (TPC):** Using minimal transmission power level, sensor can communicate with its cluster head through transmission power control.

Most popular energy efficient hierarchical clustering protocols are LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient Gathering in Sensor Information System), HEED (Hybrid Energy Efficient Distributed Clustering) and TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol).

**LEACH (Low Energy Adaptive Clustering Hierarchy):** It's a routing protocol in which the data is delivered to the base station using cluster based approach. In LEACH, cluster heads selected randomly. This algorithm is simple but does not guarantee about even distribution of cluster heads over the network [6]. The advantage is that is it avoids data redundancy at the base station. But there is no peer to peer communication amongst the nodes of cluster [20]. Figure 2 shows the nodes connectivity in LEACH protocol. LEACH uses a single hop routing where each node can transmit directly to cluster head and the base station. Sensors must know the beginning of new cycle, for that, sensors have synchronized clocks. LEACH protocol has some deficiencies such as [6],

Some very big and small clusters may exist in the network at same time.

2) Unreasonable cluster head selection while the nodes have different energy.

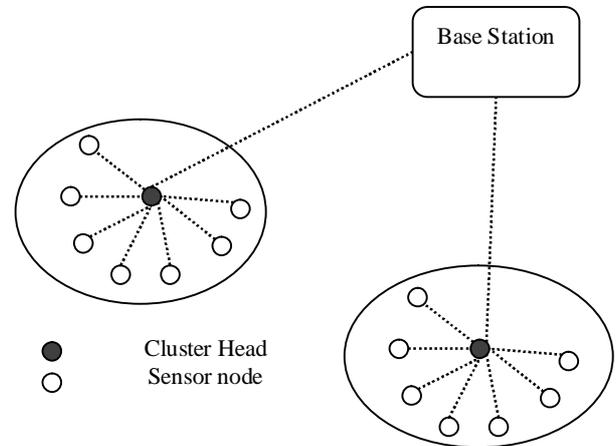


Fig. 2: Nodes connectivity in LEACH

**PEGASIS (Power-Efficient Gathering in Sensor Information System):** PEGASIS is a routing protocol which uses a chain based approach. This protocol follows a greedy algorithm at the starting from the farthest node and all sensor nodes of the chain. Each node will transmit and receive from its close neighbors and leader of chain responsible to transmit a combined data to base station. Fig. 3 shows the node connectivity in PEGASIS protocol.

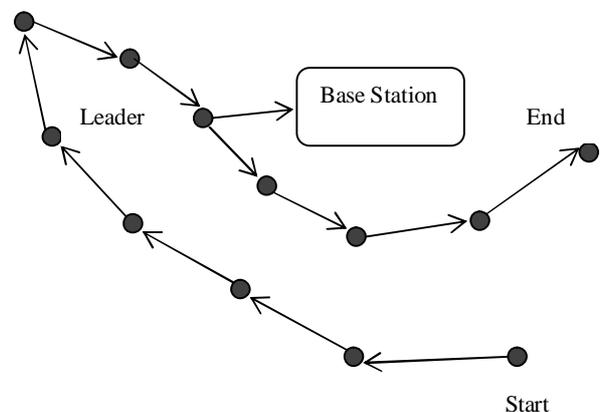


Fig. 3: Node connectivity in PEGASIS protocol

**HEED (Hybrid, Energy-Efficient Distributed Clustering):** HEED operate in multi-hop networks, using flexible power transmission in the inter-clustering communication [30]. Main goals of HEED:

1) Increasing network lifetime by distributing energy consumption.

2) Number of iterations to stable the terminating process of clustering.

3) Minimizing control overhead

4) To produce well distributed cluster-heads

HEED select CHs conforming to the mixture of two clustering parameters and LEACH randomly selects CHs which may result some nodes in rapid death so HEED clustering improves network lifetime over LEACH.

TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol): TEEN is a clustering protocol which bring together sensors in to cluster which is accompanied by CH. TEEN uses hierarchical approach with data centric method[30].

### 3. RELATED WORK

In this paper we survey different energy efficient Hierarchical based routing protocols which used in Wireless sensor network to increasing network lifetime.

Feng Sen et al. [1] improved energy efficient PEGASIS-based protocol (IEEPB) that overcomes the problem of uncertainty of threshold adopted when building chain. IEEPEB compared the distance between nodes and find the shortest path to link two nearest nodes. Authors present a new chain building method that is very effective to avoid the long link between adjacent nodes. It each round contains three stages: chain construction phase, leader selection phase and data transmission phase. In leader selection phase, using the weighting method, IEEPB select the leader considering the residual energy of nodes and distance of node to base station (BS). In data transmission phase, Using token passing approach, data transmission start to the end node of the chain. Data transmission chain end with the receive data to the base station (BS) from leader. Simulation result shows that IEEPB perform better performance than EEPB by increasing the life time of network and to achieve the high energy efficiency.

Wang Linping et al. [2] proposed a new algorithm PDCH based on PAGASIS to make each node lode balance and prolong the lifetime of the network. Author introduced a double cluster heads in one chain. This algorithm increased the efficiency of energy using by the cluster head of every round for receiving and sending messages of one chain. Author used the heretical chain topology overcome the problem of time delay. In this structure base station is placed at the center of the circle. To configure a level based configuration based on distance from the base station. Nodes have unique tag. This hierarchy always runs at start and ending of each round process will not change. Therefore this structure saves the energy in every round. According to double cluster head formation, author create a new method to solve the control token get to the branch chain node problem using a secondary cluster head out of the branch chain. Simulation result shows that PDCH performs better than PAGASIS and

EEPB to eliminating overhead of cluster formation and saving energy.

Wenjing Guo [3] performs a work on routing protocol based on PAGASIS protocol using an improved ant colony algorithm rather than the greedy algorithm to build the chain. PEG-ant achieved global optimization to compare of original PAGASIS. It forms a chain that makes the path more distributed and the total square of transmission, according to current energy of each node, a leader is selected to directly communicate with the base station. Simulation result shows that the proposed protocols prolong the network life.

Lina Xu et al. [4] introduced Balanced Energy Efficiency (BEE) clustering algorithm and its multi hop version (BEEM)

Exceeds HEED and LEACH from below perspective.

1. Longevity that means the system operating time: time from the system starts till the last node dies.

2. Balanced sensor distribution that means system operating quality.

It can guarantee the network coverage for a longer time, compare with HEED and LEACH. BEEM can be used in larger network to even the power usage through the network.

Wireless sensor network suffered from an energy loss and data delay problem. For these problem Wang hua-qian et al. [5] introduced a routing algorithm AIRP-PEGASIS (Improvement of Routing Protocol-Power Efficient Gathering in Sensor Information System) based on LEACH and PEGASIS theory that works on the concept of center of mass. The center of mass considered an imaginary point that can find a regional energy centers. This algorithm divided the whole sensor area in to five regions. Then according to distance from base station be a long chain in energy sub-domain. Simulation result shows that improved algorithm extend the network life and improved the efficiency of information transfer.

One major drawback of LEACH protocol is that cluster size. Cluster size is not limited; it can be very small or large. In large size of clusters, because of transmission distance, sensor nodes deplete energy faster. To solve this problem Vivek kaiyar et al. [6] introduced a new energy efficient clustering protocol FZ-LEACH (Far-Zone LEACH). Far zone is a group of sensors which are placed at location where their energies are less than a threshold. Simulation result shows that FZ-LEACH protocol saves around 30% energy of sensor network in comparison to LEACH.

B.Manzoor et al. [7] introduced Quadrature - LEACH (Q - LEACH) protocol for homogenous networks which enhances stability period, network lifetime and throughput. In this approach, Network divided in four quadrants to achieve a better coverage of the whole network. In Q-LEACH, because of network partition, clusters formed within sub factors are more deterministic in nature .so; nodes are well distributed

within a specific cluster and results in efficient energy drainage.

Rudranath mitra et al. [8] proposed a cluster based routing protocol. This protocol focused minimization of energy consumption based on load distribution. They used the 'Cluster head set' instead of one cluster head within a cluster. At a time one node selected as a cluster head from a cluster head set. Other nodes are off their radio transmitter that time to conserve energy. Each node within a cluster will become head set member for a just once. Result shows the less energy consumption in election of cluster heads phase compared to LEACH.

LI jian-qi et al. [9] focused on node characteristic of uneven distribution in the real environment. They introduced an improved algorithm combines the advantages of cluster heads under EUUC algorithm. Using multi objective particle swam optimization to optimized routing of cluster heads and also reduced the complexity of clustering significantly of real time problems. Improved algorithm is more suitable for large scale network and gave a more effective performance.

To maximize the energy efficiency of wireless sensor network, Geon yong park et al. [10] proposed an efficient cluster head selection method using K-means algorithm. This algorithm is totally based on Euclidean distance between cluster head and other nodes. Result of simulation shows this algorithm gives a better performance than LEACH and HEED. Time taken for clustering is the issue of this method.

Jianjun Yang [11] proposed a new routing protocol RPB. This protocol is combination of advantages of PEGASIS and GAF protocol. This protocol include three stages namely, the link establishment phase, the LEADER node selection and data transmission. With these three phases it provides a solution for realizing node's energy consumption farthest in the condition of guaranteeing coverage rate.

Sung ming jung et al. [12] introduced a centralized clustering algorithm, it's a multiple chain based clustering algorithm which based on PEGASIS. In this algorithm base station is a center of the cluster and each sensor assign itself a level number based on the received signal strength from base station. For each level, the sensors perform transmission and fusion in the same way as in PEGASIS. Cluster head elected by sensors will gather the data from other sensors on same level and transmit the fusion data to the cluster head in next level that is closer to base station. In this structure sensors change their level when base station changes their location. So, its suffer from a problem that the sensors near the base station die soon from routing packets. Only total power consumption of the network is used to evaluate the algorithm.

Deepika Sharma et al. [13] worked on improvement on LEACH protocol to enhance network life by reducing the transmission between cluster heads and base station. In this protocol, the strategy is choosing an optimum number of

master cluster head present in network. Improved clustering technique also minimized the load of the network.

Jn.Wang et al. [14] proposed an Energy Cost and Residual Energy Oriented (ECREO) routing algorithm based on Geographical and Energy Aware Routing (GEAR). ECREO algorithm considers a sufficient energy of base station and makes a good compatibility between energy cost and residual energy. This algorithm improved dijkstra algorithm to find

Best schema. ECRCO balance the energy consumption and life time among all nodes in network.

Mohammad Mehrani et al. [16] proposed a new method of clustering which increasing a network life time by using energy, density, centrality factors and other nodes distances. In this method every clusters have a supervise node. When cluster head replaced by cluster head failed, at that situation cluster head replaced by supervise node to prolong the network life time and also to be fault tolerant network. Simulation result shows this clustering method improves network lifetime in comparison with the LEACH and HEED methods.

N.javaid et al. [17] present a HEER protocol which is combination of TEEN and DEEC protocol. In this protocol cluster head selection is based on ratio of residual energy at node and average energy of network. HEER distributed load at the formation of high energy nodes to low nodes for minimizing energy consumption.

N. javaid et al. [18] proposed an Away Cluster Head (ACH) scheme which increases efficiency in terms of stability period and number of packet sent to base station of conventional clustering protocols. Author implement ACH scheme on LEACH, SEP, TEEN, DEEC and introduced a LEACH-ACH, SEP-ACH, TEEN-ACH and DEEC-ACH.

#### 4. CONCLUSION AND FUTURE SCOPE

In this paper, the energy efficient clustering protocols and some algorithms such as LEACH, PEGASIS, HEED, TEEN, PEGASIS-MH, Q-LEACH, EEPB, IEEPB, PEG-ant, BEE, BEEM, FZ-LEACH etc have been discussed. We show different clustering method s and their performance in terms of energy- efficiency and increasing network's life time. From this survey we found that many aspects should be taken in to consideration when designing energy efficient clustering protocols, such as the optimal selection of cluster head, Rotation of cluster heads, the cluster sizes, connectivity, coverage, placement of BS (Base Station) and duty life cycle.

Any protocol does not perfect to perform best in sensor network criteria under energy dissipation within the cluster head formation. Our future work is based on these criteria for sensor network long life time.

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**APPENDIX A: Comparative study of different clustering protocols.**

Title Name	Description	Protocol/Algorithm /scheme	Performance metrics	Methodology	Advantage
An Improved Energy Efficient PEGASIS-Based Protocol in Wireless Sensor Network[1]	Adopting new method for build chain , Selecting a leader node by weighting method , to balance energy consumption	EEPB,IEEPB	Residual energy of node, distance between node and base station	Assigning each node a weight so as to represent appropriate level, built a chain	Better performance than EEPB on balancing energy consumption and prolong network lifetime
Improved Algorithm of PEGASIS Protocol Introducing Double Cluster Head in WSN [2]	PDCH-a double cluster head choosing protocol that is near for data transmission, branch chain concept	PAGASIS,PDCH	Residual energy of node , main cluster head ,secondary cluster head	Hierarchical chain method to relief time delay ,bottom level cluster head and super level cluster head to balance energy consumption	Increasing the lifetime and quality of network, better performance than PEGASIS and EEPB
PEGASIS Protocol in WSN Based on an Improved Ant Colony Algorithm [3]	PEG-ant: global optimization, Leader selection based on current energy of nodes in each transition round	PEG-ant, PEGASIS, improved ant colony algorithm	energy consumption rate between nodes as energy factor, global sum of distance square least	Considered energy factor in both chain building and leader selection,	Prolong network life
Based on Center of Mass Concept Research and Improve of Routing Protocol for WSN [5]	Consider an imaginary point that can find a regional energy centers.	PEGASIS, AIRP-PEGASIS	Distance between node to BS , residual energy	Divide whole sensor are in five region, making a chain according to distance to BS	Overcome the problem of energy loss and data delay.
Improvement in LEACH Protocol for Large –Scale WSN [6]	Far zone –group of sensor placed at lowest energy than threshold	LEACH,FZ-LEACH	Residual energy, threshold value	Comparing energy with threshold for placing node	FZ-LEACH saves 30% energy than LEACH
Q-LEACH: A New Routing Protocol for WSNs [7]	Four quadrants, nodes distributed for specific clusters.	LEACH,Q-LEACH	Threshold , CH rate, coverage	Divide network n four quadrants ,deterministic node distribution	Suitable energy utilization, load balancing, increasing network life
Improving WSN Lifetime Through Power Aware Clustering Technique [8]	Energy consumption based on load distribution (cluster head set)	Power aware clustering algorithm	Energy factor, Signal to noise ratio value, CH rate,	Divided network n to predetermine clusters within cluster head set	To minimize the energy consumption
A Novel Cluster Head Selection Method Based on K-Means Algorithm for Energy Efficient WSN [10]	Based on totally Euclidean distance between CHs and nodes	K-algorithm, cluster head selection scheme	CHs threshold, Euclidean distance from CHS to other nodes	Using K-means algorithm, forms the cluster objects based on Euclidean distance	To maximize the energy efficiency of network
Rotation and Chain Based Energy Saving Routing Protocol of WSN [11]	RPB: routing protocol including three stages to energy consumption in certain coverage rate	Rotation and PEGASIS based protocol(RPB)	Residual energy of node, energy loss of sending and receiving data	Link establishment, selection of LEADER, data transition rate	Reduced Energy consumption
The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS [12]	BS is center of the cluster, node assigned level number based on signal strength from BS	CSS(Concentric Clustering Scheme), PEGASIS	Data aggregation rate, energy factor, data sending and receiving rate	Divide clusters by the shape of concentric circles	Avoid redundant transmission of data, saving 35% energy in comparison with PEGASIS
Improvement in LEACH Protocol by Electing Master Cluster Heads to Enhance the Network Lifetime in WSN [13]	To reduced the transmission between a CHs and sensor nodes.	LEACH, Master cluster head scheme	FND(first node dies), HND (half node die)	Selecting master cluster heads scheme from variation of clusters	Enhance the network life compare to LEACH