

# A Survey on Hierarchical-Based Routing Protocols for Wireless Sensor Networks

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**Abstract** - A wireless sensor network is a network incorporate the largest number of sensor node which is positioned in an application environment to observe the physical entities in a target area, for example, temperature monitoring environment, water level monitoring, pressure, health care and various military application. Every sensor node collects information from the environment and forwards this sensed data to Base Station (BS) through a wireless link. This data collection and forwarding property of the sensor nodes, engross energy of a network. A number of protocols have been already proposed with the objective of maximizing the sensor network lifespan by acquire cluster-based network construction. This paper concentrate on reviewing some of the recently hierarchical based routing protocols that are created in WSNs and has oversee about Routing Techniques and basically about Hierarchical based routing with its protocols like LEACH, PEGASIS, HEED and PSO.

**Key Words:** Routing protocols, Energy efficiency, Wireless sensor networks, Cluster based routing.

## 1. INTRODUCTION

Recent technological advances in the area of wireless communications and micro-electro-mechanical systems have formed it suitable to expand small-sized and economical sensors. A sensor network is the group of sensors connect to transducers be determined to monitor the conditions at diverse locations. The Sensors are meant to evaluate the physical or environmental changes. A sensor network has a huge number of nodes, which are arranged in an open environment randomly [16].

Energy efficiency and energy balancing have been a very hot and challenging research issue for WSNs for many years [20].

Routing is one of an engaging research issue in WSNs. But it is a complex activity to develop a routing protocol which is efficient due to its inherent characteristics of WSNs like highly dynamic network, application specific, limited energy, storage, and processing capability etc. [18].

## 2. ROUTING TECHNIQUES IN WSNs

Routing is one of the best mechanisms that prolongs the lifetime of a network by decreasing energy consumption during this communication. The developed routing protocols can be grouped based on the routing structure into hierarchical-based, flat based, and location-based routing protocols. Hierarchical-based routing is the perfect solution for reducing energy consumption in WSNs due to the reduction of redundant data transmission.

Route Processing means how a node discover out its route from source to BS. These are classified into the following;

Location-based Protocols: MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF

Data-centric Protocols : SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent-Based Information Dissemination

Hierarchical Protocols: LEACH, PEGASIS, HEED, TEEN, APTEEN

Mobility-based Protocols : Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery

Heterogeneity-based Protocols: IDSQ, CADR, CHR QoS-based protocols: SAR, SPEED, Energy-aware routing [15].

### 3. HIERARCHICAL BASED ROUTING

Hierarchical based (also called cluster-based) routing is contemplated as one of the most eminent routing technique. A Clustering hierarchical method for the WSNs topology breaks the whole network of SNs into several areas called clusters and each cluster has a CH. The CH plays the operation of data aggregating and sending the aggregated and refined data to the BS. A data transfer always takes place from a lower clustered layer to a higher one [18].

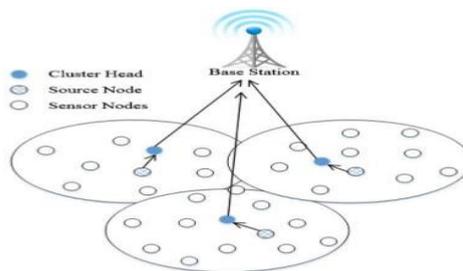
The major advantages of Hierarchical based routing are: [18]

- 1) Energy utilization of each SN and its transmission cost is economized.
- 2) Network scalability upgraded.
- 3) It reduces the routing table size which is stored at each SN.
- 4) Communication Bandwidth is conserved.
- 5) The chances of inter-cluster communications to CHs is lower and thus results in avoiding redundancy in message exchange among SNs.
- 6) The time frame of the network operation is increased by using various techniques of optimization.
- 7) The battery life of SN is enhanced by using numerous optimizing techniques.

Different common types of Hierarchical-based routing protocols are discussed below:

#### (1) LEACH:

LEACH is a hierarchical clustering protocol that contribute an elegant solution for such protocols. It uses the mechanism of cluster-head rotation, selects cluster-heads randomly, and each node has a balanced chance [9].



**Fig 1-**Schemetic Structure of LEACH protocol

The operation of LEACH protocol contains of several rounds with two phases in each: Set-up Phase and Steady Phase [7]. During the setup phase, each node creates a random number between 0 and 1. If the random number is lower than the threshold value, then the node becomes a CH for the present round. The threshold value is calculated based on the following equation [2]:

$$T(n) = \begin{cases} \frac{p}{1 - p^{(r \bmod \frac{1}{p})}} & , \text{ if } n \in G \\ 0 & , \text{ Other} \end{cases}$$

The drawbacks of this protocol are as follows:

- A sensor node is selected as the CH-using distributed probabilistic approach, whereas the non- cluster nodes evaluate which cluster to join based on the signal strength. This way assures lower message overhead, but can't assure that CHs are uniformly distributed over the network. The entire network is branched into clusters and load imbalance among the CHs may lead to minimum network lifetime.

- It is assumed that all nodes are isomorphic and all nodes have a identical amount of energy capacity in each election round. Such a supposition is impractical in most application circumstances. Hence, LEACH should be enhanced to report for node heterogeneity.

- LEACH involves source nodes to send data to CHs directly. However, if the CH is extremely far away from the source nodes, they might expend excessive energy in data transmission. Further, LEACH requires CHs to transfer their aggregated data to the sink node over a single-hop link. Nevertheless, a single-hop transmission may be quite costly when the sink appears far away from the CHs.

- LEACH also holds an assumption that all sensor nodes have sufficient power to reach the sink node if necessary, which might be resistant for energy-constrained sensor nodes.

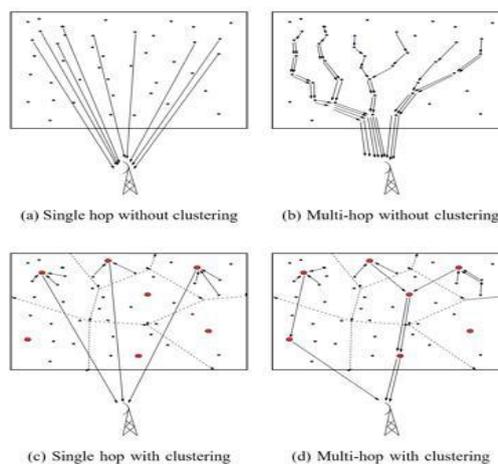
(1) PEGASIS:

PEGASIS (Power-Efficient Gathering in Sensor Information Systems) is a chain-based routing protocol for WSNs. In PEGASIS, each sensor node only needs to transmit data to its neighbor which is adjacent to the sink node. Several chains could be set up according to the greedy algorithm and the leader of each chain takes the responsibility to transfer the data to the sink node. Due to the excessive burden of the leaders of chains, each node takes turns to be the leader to equivalence the energy consumption. Because of multihop propagation, long-distance communication among the sensor node and sink node is avoided and much energy is saved. Meanwhile, due to multihop propagation, the delay of the network is very serious and it is not suitable for delay sensitive applications [20].

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is the most favored chain based hierarchical protocol. The nodes are arranged in the form of a chain for the transportation and aggregation of the data. The creation of the chain can be centralized based on the application. PEGASIS is based on the presumption that global knowledge of network is provided to all the nodes. The creation of the chain starts from the aftermost node from the sink and its nearest neighbor are selected as the next node in the chain and so on. The last node must be the sink and the node before sink acts as a leader of the node. Processes like data- processing and aggregation are accomplished by leader node. PEGASIS is not so relevant for the networks with dynamic or time-varying topology. As the size of the network will be larger, the delay in transmission will be as long, because of that PEGASIS undergoes with scalability issue. [16]

(2) HEED: [17] [19]

In [17], author presents a general distributed clustering approach that considers a hybrid of energy and communication cost.



HEED has four primary Objectives [15]:

- (i) Prolonging network lifetime by distributing energy consumption,
- (ii) Terminating the clustering process within a constant number of iterations,

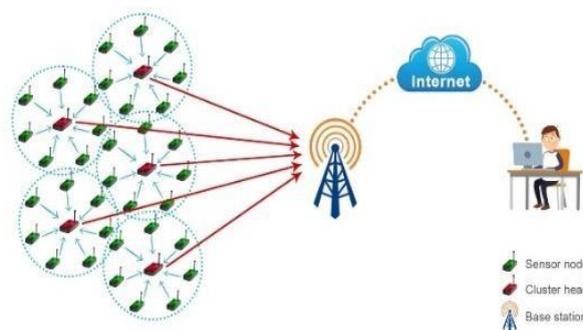
(iii) Minimizing control overhead (to be linear in the number of nodes), and

(iv) Producing well-distributed cluster heads.

In HEED, the proposed algorithm periodically selects CHs according to a combination of two clustering parameters. The first parameter is the intra-cluster communication cost as a function of cluster node degree (i.e. a number of neighbors). The second parameter is used to probabilistically select an initial set of CHs while the second parameter for breaking ties. The HEED clustering improves network lifetime over LEACH clustering because LEACH randomly selects CHs (and hence cluster size), which may cause some nodes to die. The final CHs selected in HEED are distributed beyond the network and the communication cost is diminished. However, HEED deals with only a subset of parameters, which can possibly impose constraints on the system. These network lifetime constraints are rather than for the entire needs of WSN [15].

(1) PSO:

PSO is an optimization technique in which natural species social behaviors are contemplated for the objective of computation, brought in by Kennedy and Eberhart in 1995. It is a swarm intelligence technique which is a population-based optimization scheme with the objective of optimizing a fitness function by updating the generations. The model of this algorithm is based on the social behavior of bird flocking. It is observed from the nature of birds which always travel in a group without colliding. The PSO technique uses certain particles, each represents a solution and finds the best particle position with respect to a given fitness function. In PSO, every individual solution is a particle (bird) in the search space. Each particle has fitness values that are evaluated by the fitness function to be optimized and stored as a record for all its coordinates which are related to obtaining a better solution by following the current best particles. The fitness value of the current optimum particle is called pBest. PSO optimizes the best population value that is obtained so far by any particle in the neighbors and its location is called lBest. When all the generated populations are considered as topological neighbors. By a particular particle, then the best value is chosen among the generated population and that particular best value is the best solution and it is known as Best. The PSO always tries to change the velocity of every particle towards its pBest and lBest. The velocity is determined by random terminologies, which are having randomly generated numbers for velocity towards pBest and lBest localities. From the large deposit of generated solutions, the best one is selected to resolve the problem. The PSO algorithm always stores and maintains a record of results for three global variables such as target value or condition, gBest and stopping value. Every obtained particle of PSO contains a data which can represent a global solution, value for velocity which will indicate the amount of data to be changed, lBest value. [2]



**Fig 2:** Schematic Structure of PSO protocol

PSO thrives to minimize (maximize) the cost (fitness) function. In the global-best version of PSO, the position where the particle  $i$  has its lowest cost is stored as  $pbestid$ . Besides,  $gbestid$ , the position of the best particle. The notation for representing the  $i^{th}$  particle  $P_i$  of the population is as follows:

$$P_i = [ X_{i,1} , X_{i,2}, X_{i,3}, \dots, X_{i,D} ] \quad (1)$$

In each iteration  $k$ , velocity  $V$  and position  $X$  are updated using (2) and (3). The update process is iteratively repeated until either an acceptable  $gbestid$  is achieved or a fixed number of iterations is reached.

$$Vid(k+1) = wVid(k) + c1r1(k)(pBestid-Xid) + c2r2(k)(gBestid-Xid) \quad (2)$$

$$Xid(k+1) = Xid(k) + Vid(k+1) \quad (3)$$

Where  $w$  = inertial weight  $c1$  and  $c2$  = acceleration factor (non-negative constants)  $r1$  and  $r2$  = distributed random numbers in the range of  $[0, 1]$

#### 4. CONCLUSIONS

Routing is one of an interesting research issue with rapidly growing set of research results. In this paper, different routing techniques are focused which are hierarchical based routing in WSNs have been studied in the literature. The main purpose of all of them is to prolong the lifetime of a sensor network.

In addition, a survey and comparative study of various hierarchical clustering routing protocols such as LEACH, HEED, PEGASIS, and PSO are described.

Routing Protocols	LEACH	PEGASIS	HEED	PSO
Classification	Hierarchical	Hierarchical	Hierarchical	Hierarchical
Position Awareness	No	No	No	No
Power Usage	Maximum	Maximum	Maximum	Maximum
Data aggregation	Yes	No	Yes	Yes
Scalability	Good	Good	Good	Good
Multipath	No	No	Yes	Yes
QoS	No	No	No	No

To select an appropriate hierarchical routing protocol, this survey can be helpful for researchers of WSNs in which mobile nodes are used.

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