Clustering Routing Protocol for Energy Efficiency of Wireless Sensor Network using Genetic Algorithm

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Abstract - *Wireless Sensor Network has been used in various fields of work. Wireless Sensor Network(WSN) consist of large number of wireless nodes called as sensor nodes and one or more base stations called as sink. The main function of sensor nodes in every wireless sensor network is sensing the target area and sending the gathered data to the sink node for further use. Sensor nodes in the big wireless sensor networks are generally powered by small and low energy batteries, which are not sure for surviving a long period [2]. Thus the main constraint in designing a clustering routing protocol in WSNs is less power of the sensor nodes, which directs the design of energy efficient clustering routing protocol. In the proposed system, a clustering routing protocol is designed for energy efficiency and load balancing of the wireless sensor network. The proposed system uses genetic algorithm for energy efficient clustering of sensor nodes and selection of optimal path for routing with better network lifetime and lesser energy consumption. It also shows how energy efficiency can be increased if we make the sink mobile.*

Key Words: **Wireless Sensor Network (WSN), Low Energy Adaptive Clustering Hierarchy (LEACH), Low Energy Adaptive Clustering Hierarchy- Simulated Annealing and Genetic Algorithm (LEACH-SAGA), Mobile Sink Load Balancing- Low Energy Adaptive Clustering Hierarchy (ML-LEACH)**

1. INTRODUCTION

The sensor nodes used in wireless sensor network collect information from the environment based on their sensing mechanism. The nodes are arranged in large numbers in the area. All the nodes together form an ad hoc network which can send data to the sink (base station). A sample Wireless Sensor Network is shown in figure-1. Wireless sensor network have many applications in Agriculture, health care systems, military surveillance, Anti fire systems, etc.

The sensor node must have capability to collect the data and send that data to other nodes or directly to an external sink which may be fixed or mobile [2].

Resource constraint of the sensor nodes and weak low-power wireless links, along with various performance requirements of different applications generates many challenges in designing energy efficient communication protocols for wireless sensor network. So, designing suitable energy efficient clustering routing protocol to increase the lifetime of the wireless sensor network is considered as an important issue in wireless sensor networking.
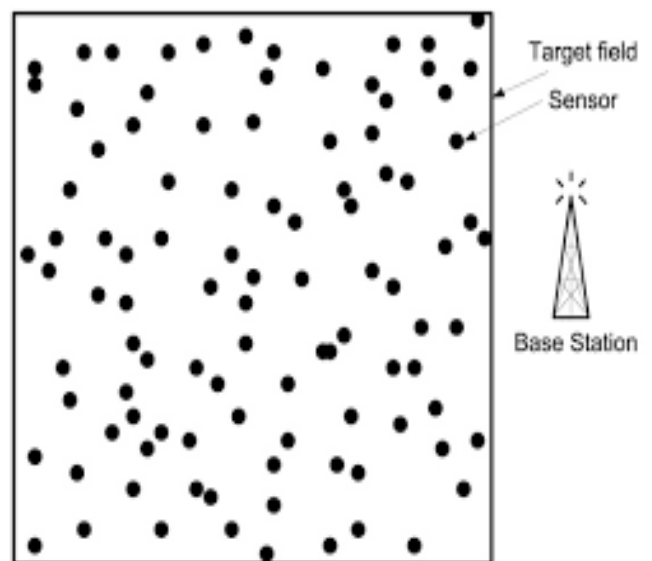

Figure -1: A sample Wireless Sensor Network

 Many protocols have been proposed for mobile or ad-hoc networks. However, there are many limitations in using these protocols directly for wireless sensor network. Compared to flat and multi hop communication, the architecture which makes use of clustering gives long life time, hence these are preferred [3]. The clustering is energy efficient as compared to single and multi hop routing. In clustering, one sensor node in the cluster will be selected as the Cluster Head (CH) for that cluster, which will collect the sensed data from each ordinary sensor node and send that data to the remote sink. In clustering if few CH nodes are heavily loaded, then energy depletion may occur. To get uniform energy consumption, load balancing is introduced

over the clusters.

As size of the sensor network increases, distribution of the networking load effectively will be an important concern. By spreading the workload across the cluster in sensor network that is by load balancing we can average the energy consumption. Load balancing is also useful for reducing energy-hole problem, and thus increasing the reliability of the data and network.

Therefore, the proposed system tries to address the challenge of balancing energy consumption and maximizing the network lifetime for WSNs by developing the energy efficient clustering routing protocol using genetic algorithm and mobile sink.

2. RELATED WORK

Wireless sensor networks have been more extensively considered for research and use in different fields. Many clustering algorithms in different contexts have been proposed in the past by [4, 5, and 6]. Many of these algorithms aim at minimizing the energy spent in the homogeneous system.

Mhatre and Rosenberg (2004) [7] give guidelines about the modes of propagation, clustering and battery energy of normal and CH nodes. Cheng and Shi (2009) [8] analyzed the heterogeneity with new clustering algorithm, which decides the cluster head according to the node energy.

Hur and Kim (2008) [9] explains about adaptive clustering and power control for homogeneous sensor networks. A survey on energy saving mechanisms for WSN is given by [10] (Wang and Xiao, 2005).

As there is no centralized cluster formation mechanism in 'Power Efficient Gathering in Sensor Information Systems (PEGASIS)' [11], thus each node has to spend additional energy for performing data aggregation to achieve hierarchical distribution of energy. In [12], Chan *et al.* proposed An Emergent Algorithm for Highly Uniform Cluster Formation. In [13], Chen *et al.* proposed Energy Efficient Clustering Scheme in Wireless Sensor Networks. In [14], Hong-Yen *et al.* proposed an Axis-based virtual coordinate assignment protocol and delivery-guaranteed routing protocol in wireless sensor networks.

In [15], Mohamed *et al.* proposed a uniform energy balancing routing protocol for wireless sensor networks. Lu *et al.* in [16] proposed an Energy-Efficient Multi-path Routing Protocol (EEMRP); it has the capability of searching multiple node-disjoint paths and utilizes a load balancing method to assign the traffic over each selected path. Both the residual energy level of nodes and the number of hops are considered to be incorporated into the link cost function. It uses a

fairness index to evaluate the level of load balancing over different multi-paths. Furthermore, since EEMRP only takes care of data transfer delay, sometimes reliability of the successful paths is limited.

3. MOBILE SINK LOAD BALANCING- LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY PROTOCOL (ML-LEACH)

3.1 Low Energy Adaptive Clustering Hierarchy Protocol (LEACH)

LEACH protocol is a routing protocol in wireless sensor networks. It selects some nodes as cluster heads (CH). Other ordinary sensor nodes send data to the cluster head. Cluster head fuses the data sent by the ordinary nodes and then send it to the sink, thus it reduces the cost of redundant data transmission. The LEACH protocol consists of two stages namely setup phase and ready phase. A round means the total time of setup phase and ready phase. In the setup phase, clusters are formed and cluster heads are selected. In the ready phase, ordinary nodes send the sensed data to the cluster head; further cluster head sends integrated data to the sink. Cluster head uses TDMA to allocate time slots to each node to send data. Cluster heads also use CDMA encoding mode for communication to avoid conflicting with other cluster nodes.

3.1.1 The disadvantages of LEACH protocol

LEACH protocol considers the cost of communication between the ordinary node and cluster head; it does not consider the remaining energy of cluster head and its current location information. Probability of a node to become a cluster head is roughly same in each round regardless of the remaining energy of the node. If node with lower residual energy is selected as a cluster head, it may get dead in short time resulting in some area in monitoring region appearing blind, thus reducing the robustness of the network.

LEACH protocol selects the cluster head randomly, resulting in uneven distribution of cluster head nodes. LEACH protocol can not guarantee the number and best location of cluster heads, it may be case that no cluster heads present around some normal nodes, so the transmission distance will be too far and consuming more energy. In other case if the nodes in a region are too crowded, members may be redundant to other cluster members, the rate of the energy consumption of the cluster head will be faster, thus leading to unbalanced energy dissipation of cluster head, thus affecting the life cycle of the network.

3.2 Low Energy Adaptive Clustering Hierarchy-Simulated Annealing and Genetic Algorithm (LEACH-SAGA)

LEACH-SAGA protocol selects the cluster heads using simulated annealing and genetic algorithm. Sink has continuous supply of the energy. The clustering is done in two phases: setup phase and ready phase. In the setup phase, clustering of randomly deployed sensor nodes is done using simulated annealing and genetic algorithm. At the time of selection of cluster heads, residual energy of the sensor node and the average energy of the cluster are considered, the sensor node having residual energy greater than the average energy of the network and which is near to the cluster center is selected as cluster head. In the ready phase, the ordinary sensor nodes send the sensed data to the cluster head and further cluster head sends the integrated data to the sink through one hop or multi-hop mode of communication.

The simulated annealing algorithm depends on the physical process of metallurgical annealing [17]. Initial solution is evaluated, and then new candidate solution with small modification is evaluated. If the new solution is better than the previous solution, it is accepted and assumed as current solution, in other case if new solution is not better than the last solution, it can accept the new worst solution with certain probability.

3.2.1 The disadvantages of LEACH-SAGA protocol

Sink in the LEACH-SAGA is static. Sink is generally positioned at the geographical center of the wireless sensor network area. If density of cluster heads is more at some corner of the target area and less in the rest of the target area, in this case communication cost increases due to large distance between sink and those cluster heads in the area of more density. This increased communication cost can be reduced by moving the sink to the area where density of cluster heads is more and thereby reducing the cost of communication between cluster heads and the sink. So, new clustering routing protocol with this concept is designed in proposed system.

3.3 Mobile Sink Load Balancing - Low Energy Adaptive Clustering Hierarchy Protocol (ML-LEACH)

ML-LEACH protocol uses genetic algorithm in combination with simulated annealing for cluster formation and selection of cluster heads. The clustering is done in two phases: setup phase and ready phase. In the setup phase, clustering of randomly deployed sensor nodes is done using genetic algorithm in combination with simulated annealing. By considering residual energy of the sensor node, the average energy of the network and distance of the node from center of the cluster, cluster heads are selected. The sensor node having residual energy greater than the average energy of the network and which is nearer to the cluster center is selected as cluster head. Sink is moved to area where density of cluster heads is more so as to reduce the communication cost between a cluster head and sink, thereby increasing the energy efficiency of the network, which in turn increases the life time of the network. In the ready phase, the ordinary sensor nodes send the sensed data to the cluster head and further cluster head sends the integrated data to the sink.

3.3.1 Cluster formation process

The genetic algorithm is an effective search algorithm that can simulate the adaptive evolution process of natural systems; it can be applied to many similar problems in the field of wireless sensor network. Each individual in the population of genetic algorithm represents a possible solution to the problem.

Finding best individual to the problem is the ultimate aim of the genetic algorithm. Different elements of Genetic Algorithm are:

3.3.1.1 Selection

Individuals are selected according to some fitness standards also called as fitness value.

3.3.1.2 Crossover

It is one way of breeding. Here best individuals are combined to form a new individual. It is an important stage of evolution process.

3.3.1.3 Mutation

In Mutation, new genetic patterns can be introduced in the new chromosomes. Mutation inserts new patterns of genes into a chromosome. But it is not guaranteed that there will be desirable features in the new chromosome after the mutation.

By applying the above operations repeatedly, population will evolve into best individuals.

Flowchart shown in the figure-3.1 shows the flow of operations for clustering process.

3.3.2 Cluster Head selection

After forming the clusters, cluster head for each cluster is selected. First average energy of the network is calculated, the nodes having energy more than average energy of network are added to a set of candidate cluster heads. Distance between each candidate cluster head and center is calculated. Candidate cluster head having lowest distance from the center is selected as cluster head for this cluster and remaining nodes from the candidate cluster head set becomes normal nodes. After the first complete round,

where cluster head collects data from the normal nodes and send this integrated data to the sink, energy of the cluster head is significantly reduced. In the second round again the new cluster head will be selected using the above process. Thus, cluster head role will be circulated among the eligible members of cluster and thus increasing the first dead node time, resulting in maximizing the life time of the network.
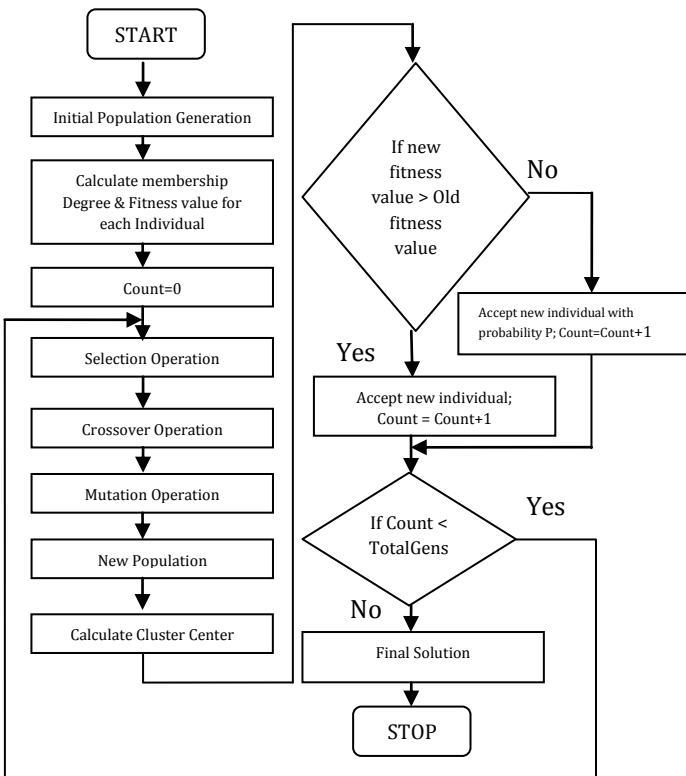
Flowchart shown in the figure-3.2 shows the cluster head selection process.

Figure-3.1: Cluster formation process using genetic algorithm and simulated annealing [18]

3.3.3 Sink Positioning

The main objective of the proposed protocol is the minimization of overall energy required in the wireless sensor network. Sink location is one of the important factors in wireless sensor network. Generally sink is positioned at the geographical center of the wireless sensor network area. As cluster head role is rotating among the cluster members, cluster head location gets changed. If density of cluster heads is more at some corner of the total area, then geographical center as location for sink is not good, as when each cluster head communicates with sink, energy consumption is increased due to large distance between cluster heads and sink. If we move the sink near to the area, where density of cluster heads is more, communication cost can be reduced. So in the proposed protocol, we place the sink at centroid of the distributed cluster heads and we can see communication

cost gets reduced. When location of cluster heads gets changed, centroid also gets changed, thus changing the location of the sink, resulting in reducing the communication cost. Coordinates of the sink location C(X, Y) can be found using following equations:

$$X = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (3.3.3.1)$$

$$Y = \frac{\sum_{i=1}^{n} y_i}{n} \qquad (3.3.3.2)$$

In the above equations, n is total number of cluster heads. Flow chart in the Figure-3.3 shows process for deciding location of mobile sink.
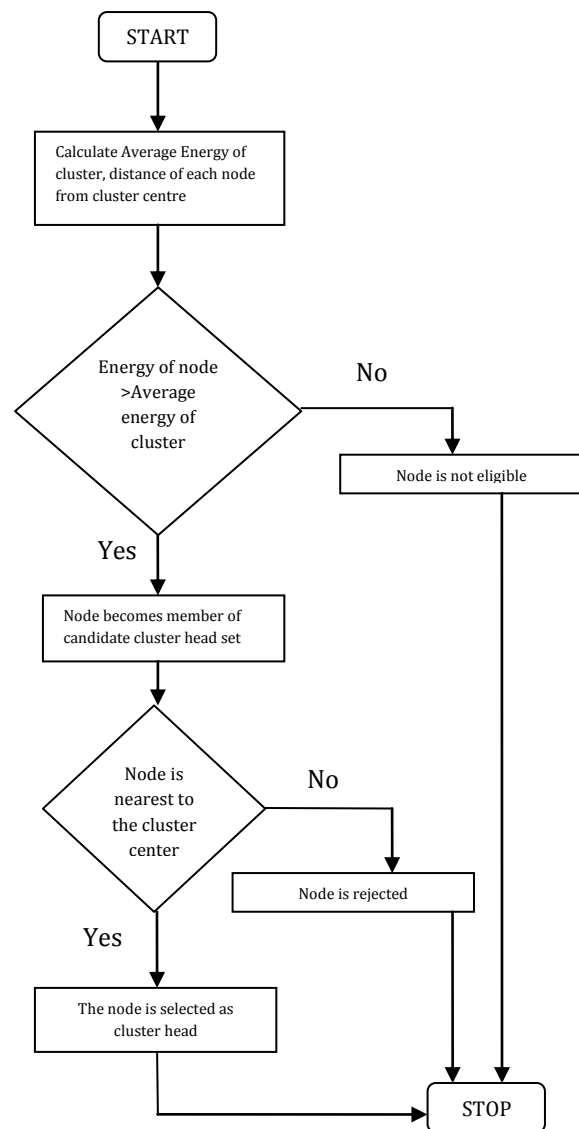

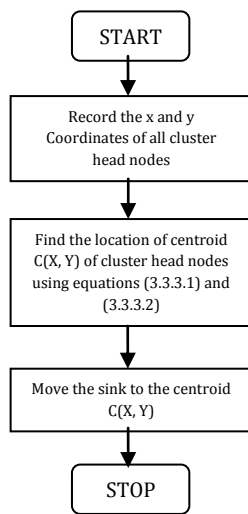**Figure-3.2:** Cluster head selection process

Figure-3.3: Process of finding the location of sink

In case of large number of cluster heads and large wireless sensor network area, we can assign weights to cluster heads according to their distance from the centroid, and use those weights for finding the more optimized location for sink.

4. RESULT ANALYSIS

4.1 Experiment Setting

We compare the LEACH protocol, LEACH-SAGA protocol and the proposed ML-LEACH protocol in MATLAB.

Experiment settings required are:

(1) All the sensor nodes are randomly deployed in the area. In this experiment we are using 300 sensor nodes.

(2)Sink is located at centroid of cluster head locations. The sink location is dynamic as centroid gets changed   with changing location of cluster heads.

(3) Energy of all the nodes is same initially.

(4) ID and location of each node is known to the base station.

The number of clusters formed is 9. Here we have used packet size as 5000bits.Total numbers of generations in the genetic algorithm are 50. Population size is 10. We have considered crossover probability and mutation probability as 0.7 and 0.01 respectively.

4.2 Experimental Result Analysis

We compare LEACH protocol, LEACH-SAGA protocol and the proposed ML-LEACH protocol for three features like Life cycle, data packets received by sink(bits) and energy consumption(J).

Figure-4.1 is graph of dead nodes Vs number of rounds(time steps), we can see that rounds or time required for the first node to become dead and Last node to become dead is more for ML-LEACH than LEACH-SAGA and LEACH. Thus it can be seen that life cycle of ML-LEACH is longer than LEACH-SAGA and LEACH.
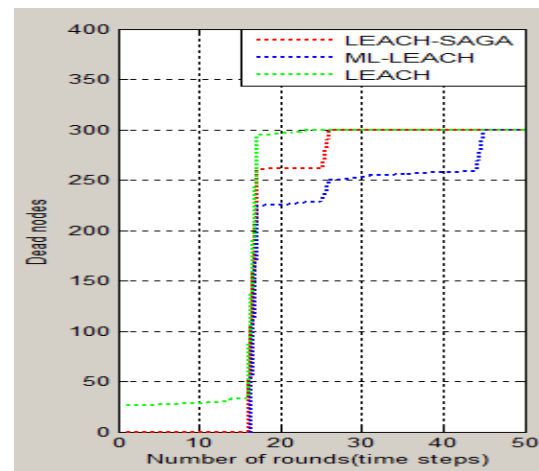

Figure-4.1: Number of Dead nodes with increasing rounds

Figure-4.2 is graph of Data packets received (bits) by sink Vs number of rounds (time steps), It can be seen that total data packets received (bits) by ML-LEACH is more than LEACH-SAGA and LEACH. So we can say that ML-LEACH can receive more data at the cost of same energy. So ML-LEACH is doing better load balancing than LEACH-SAGA and LEACH.
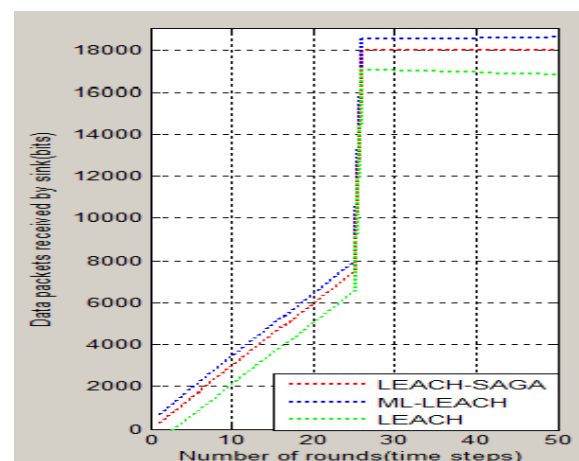

Figure-4.2: Data packets received by the sink (bits)

Figure-4.3 is graph of Energy consumption (J) Vs number of rounds (time steps), we can see that after completion of all the rounds, Total energy consumed by ML-LEACH is less than LEACH-SAGA and LEACH. Thus we can say ML-LEACH is more energy efficient than LEACH-SAGA and LEACH. Thus ML-LEACH does better energy balancing.
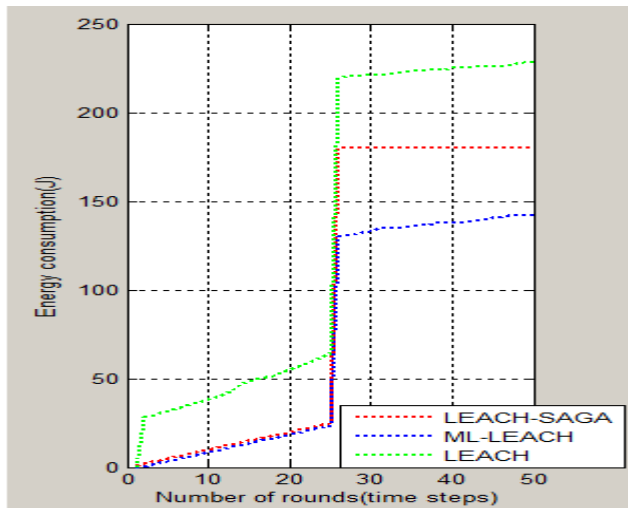

Figure-4.3: Energy Consumption

4. CONCLUSION

In this paper, we have explained ML-LEACH protocol. First we deeply studied LEACH and LEACH-SAGA protocols, and found shortcomings of them. Then we developed the ML-LEACH protocol to overcome those shortcomings. ML-LEACH uses genetic algorithm for clustering, here sink location is dynamic, which gets changed with new cluster head locations, resulting in reducing the communication cost, thereby increasing the energy efficiency of the network. Thus ML-LEACH protocol maximizes energy efficiency, do the better energy and load balancing and thus increasing the life time of the wireless sensor network.

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