Performance Evaluation of a Multi-hop Balanced Clustering Routing Protocol for WSN

J. Martin Sahayaraj[1], Dr. J. M. Gnanasekar[2], N. Dhasarathan[3]
[1]Assistant professor, Dept of ECE, Kurinji College of Engg and Tech, Trichy
[2]Professor & Head, Dept of CSE, Karpaga Vinayaga College of Engg & Tech, Kanchipuram
[3]Assistant professor, Dept of ECE, Cauvery College of Engg and Tech, Trichy

Abstract* – Our research article is proposed for two purposes. First one is to improve energy consumption. And second one is for distance transmission in wireless sensor network. While comparing to single hop clustering our proposed design has better performance in the field of energy consumption as well as increased lifetime. LEACH and multi-hop LEACH are the most popular clustering protocols. This protocol is based on k-means clustering and uses genetic algorithm for multi-hop communication among cluster heads. The used methods in our paper affect balanced and uniform energy dissipation. Simulation is done by NS2 and mat lab simulator. Mat lab simulator output graph indicates that lifetime of our design and NS2 simulator output graph indicates that energy consumption.

***Keywords* – Balanced Clustering, Genetic Algorithm, K Means Clustering, Gateway Node, Cluster head.**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are formed by hundreds or thousands of nodes that gather information and forward it to a sink node. Distinguished from traditional wireless networks, sensor networks are characterized of severe power computation, and memory constraints [1]. As the wireless nodes in a WSN are usually driven by power sources (e.g. batteries) which are irreplaceable, energy resource of sensor networks should be managed wisely to extend the lifetime of sensors. Routing protocol is one of the core technologies in the WSN. Due to its inherent characteristics, routing is full of challenge in WSN [2]. Clustering is a well-know and widely used exploratory data analysis technique, and it is particularly useful for applications that require scalability to hundreds or thousands of nodes [3]. For large-scale networks, node clustering has been proposed for efficient organization of the sensor network topology, and prolonging the network lifetime.

We consider a network of energy-constrained sensors that are deployed over a geographic area for monitoring the environment. Among the sources of energy consumption in a sensor node, wireless data transmission is the most critical. Hybrid Energy-Efficient Distributed (HEED) clustering approach is one of the most recognized energy-efficient clustering protocols [4]. It extends the basic scheme of LEACH by using residual energy and node degree or density. In HEED, the initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the intra-cluster communication cost. The clustering process is divided into a number of iterations, and terminates within a constant number of iterations. HEED achieves fairly uniform distribution of cluster heads across the network consumption. In the data transmission stage, each cluster head sends an aggregated packet to the base station by single hop. Hybrid Energy-Efficient Distributed (HEED) clustering approach is one of the most recognized energy-efficient clustering protocols. It extends the basic scheme of LEACH by using residual energy and node degree or density. In HEED, the initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the intra-cluster communication cost. The clustering process is divided into a number of iterations, and terminates within a constant number of iterations [5]. In this paper, we propose and evaluate a Multi-hop Clustering Routing Protocol (MCR) for mitigating the existent problem. MCR consists of two parts, one is with respect to cluster management in sensor area, and the other is about the data transmission between base station and the sensor area.

A routing protocol main task is finding and maintaining path from sensor nodes to BS. Frequent dynamic topology changes in WSNs due to node failure and mobility requires flexible and adaptive routing protocols [6] which reduce energy consumptions. Many routing protocols have been proposed for WSNs. A classification of routing protocols, based on network organization is as follows:

- Flat routing protocols
- Hierarchical routing protocols
- Location based routing protocols[6, 7]

Hierarchical routing protocols are the most energy efficient routing protocols [7], in which nodes divide into groups named clusters. In each cluster one node, called Cluster Head (CH), act as a controller. CHs aggregate data sensed by member nodes and transmit them to BS. They can transmit data in a directed or multi-hop manner. In this paper a balanced multi-hop clustering (MBC) protocol is proposed which aims to reduce energy consumption from several aspects by using machine learning methods. The rest of the paper is organized as follows:

In section 2 the proposed protocol is described. Simulation results and performance evaluation is presented at section 3. Finally section 4 concludes the paper.

II. MULTI HOP CLUSTERING ROUTING PROTOCOL

To increases the network lifetime and well balances the energy consumption, we adopt an energy driven method to rotate cluster-head, and propose a Multi-hop Clustering Routing Protocol (MCR) for long range transmission in the wireless sensor networks.

2.1 System Model

This protocol mainly includes three stages: Build up the network topology, Data collection and transmission and Cluster-head rotation and network topology rebuild. We make some assumptions about the sensor nodes and the underlying network model:

2.1.1 There is a base station (i.e. data sink) located far away from the sensing field. Sensors and the base station are all stationary after deployment.

2.1.2 Sensors are homogeneous and have the same capabilities. Each node is assigned a unique Identifier (ID).

2.1.3 Every node is assumed to use the same, fixed power level for intra-cluster communication (e.g. broadcasting and communicate with CH). For the outside cluster communication, CHs are capable of increasing its transmission power level to reach its gateway node. And the gateway nodes can also use power control to vary the amount of transmission power according to the distance to the desired recipient [8].

2.1.4 Links are symmetric. A node can compute the approximate distance to another node based on the received signal strength, if the transmitting power is known.

2.1.5 Energy Model

The same energy model in [7, 9, 10 and 11] is used to evaluate the performance of the protocol. It is based on the radio model shown in Fig. 2.1.

Both free space (ε_{fs}) and multipath (ε_{mp}) fading channel models are considered for energy consumption of nodes during transmitting and receiving packets.

The energy dissipation of transmitting L bit packet over distance d is:

$$E_{TX} = E_{elec} * L + \varepsilon_{fs} * L * d^2 \qquad d < d_o$$

$$E_{elec} * L + \varepsilon_{mp} * L * d^2 \qquad d \geq d_o \qquad (1)$$

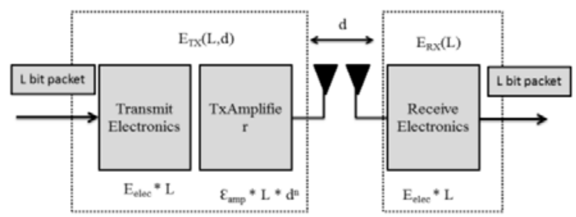

Fig.2.1. Radio model

E_{elec} is the energy required for processing 1 bit data with the electronic circuits. The threshold distance, *do* is calculated as follows:

$$d_o = \text{root of } (\quad / \varepsilon\ ) \qquad (2)$$

The energy taken to receive a packet is shown in (3):

$$E_{RX} = E_{elec} * L \qquad (3)$$

BS also consumes energy for data aggregation as follows:

$$E_{agg} = E_{DA} * L \qquad (4)$$

2.2. MCR Algorithm

The concrete steps of MCR protocol are as below:

2.2.1 Build up the network topology:

This stage is comprised of three sub-stages:

2.2.1.1 Gateway nodes selection:

Firstly, the sink node adjusts its transmission power and broadcasts *SinkMesg* message to the sensor area. A node which receives this broadcast sends *Child* Re *q* message to the sink node applying for being gateway node. Then the node processes in wait state. A node receiving the reply message from Sink node indicates that it has been a gateway node then goes to sleep.

2.2.1.2 Clustering process:

In this stage, the rest of the nodes except the gateways execute HEED to construct the clusters. That is to say, we use HEED cluster as the underlying clustering approach for MCR because of its generality and energy efficiency. After completion, all the normal nodes go to sleep whereas the CH nodes and gateway nodes go into the third phase.

2.2.1.3 Each CH node connects its gateway node:

In order to balance the energy consumption well and avoid the gateway nodes being failure too quickly. This protocol limits that a gateway node can connect with only one CH node. Initially, each gateway node adjusts its transmission power and broadcasts its initial message.

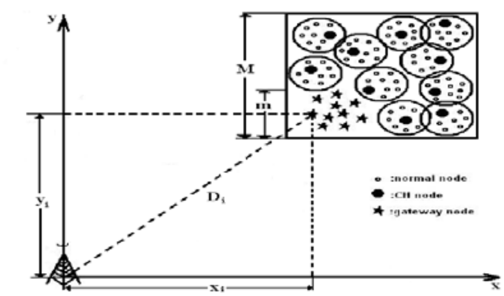

Fig.2.2. Network topology of Multi-hop Clustering

A node which receives this broadcast, sets up a temporary father-nodes form *Temp Father node Form* first, records the values of the gateway node's ID, LEVEL and RSSI. If the number of the temporary father-nodes in a node's *Temp Father node Form* is more than one, it sorts the form according to the value of RSSI and picks up the maximal one as its final father node, then sends apply message to it. After receiving reply message, a node indicates that it has been in net. So far, the network topology has been built up, and the network topology is shown in Fig.2.2. All nodes move into the Data collection and transmission stage.

2.2.1.4 Data collection and transmission:

In this stage, cluster member nodes collect data and transmit to their cluster-head nodes. Each cluster-head fuse the data receiving from all its cluster members and then send to its gateway node. The task for the gateway node is to send data to the sink node. Each node will check it's remain energy after accomplish its transmission assignment.

Genetic Algorithm (GA) is used in this paper to determine the most energy efficient multi-hop route among CHs based on (12). The GA algorithm using in this paper is described below.

Population: A population consists of several Chromosomes which itself made up of genes. First population is generated randomly. A chromosome represents a multi-hop tree among CHs as shown in Fig.2.3.

Selection: Parents for generating next generation are determined in selection process. There are several selection methods such as “Roulette Wheel”, “Rank selection” and “Tournament selection” which is used in this paper.

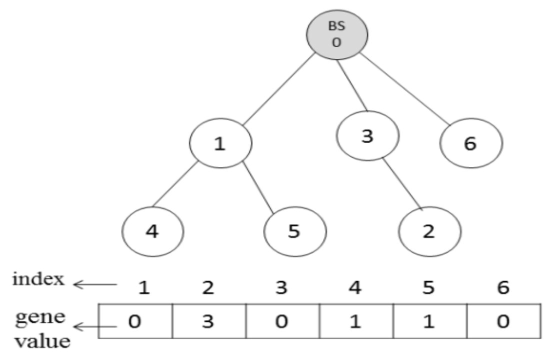

Fig.2.3. A chromosome which represents a multi-hop tree

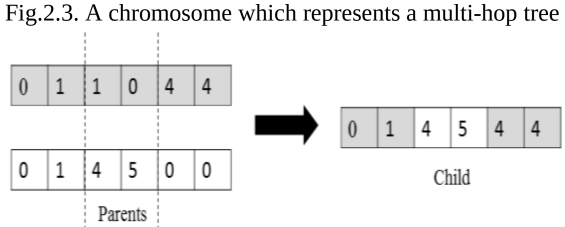

Fig.2.4. Crossover operation

Crossover: This operation combines the parents to birth children. In this paper a two point crossover is used. Two random points are selected on parents. The child gets the middle gene(s) from one parent and the rest from the other as shown in Fig.2.4.

Mutation: Mutation operation adds variation to new population. In mutation the value of a randomly selected gene is changed.

III. SIMULATION RESULTS

All simulations have been implemented using NS2 simulator.

3.1 Sources Vs Energy

The above graph shows that the MCR Energy consumption is very low compared to HEED by varying load.

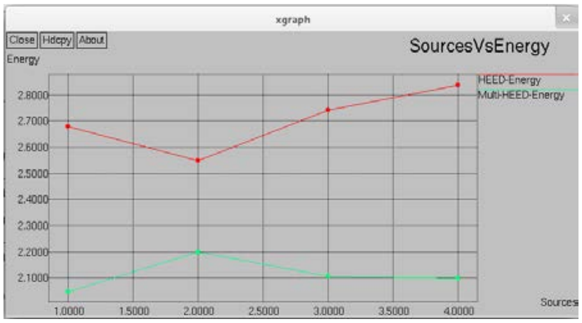

Fig. 3.1 Snapshot of Sources VS Energy

3.2 Sources vs Del-Ratio:

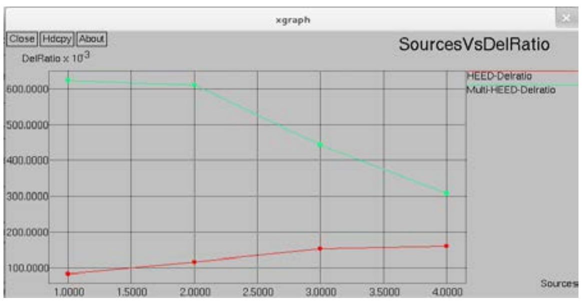

Fig. 3.2 Snapshot of Sources VS Del-Ratio

The above graph shows that the MCR throughput is very high compare to HEED with respect to the number of sources.

3.3 Sources Vs Packet Drop

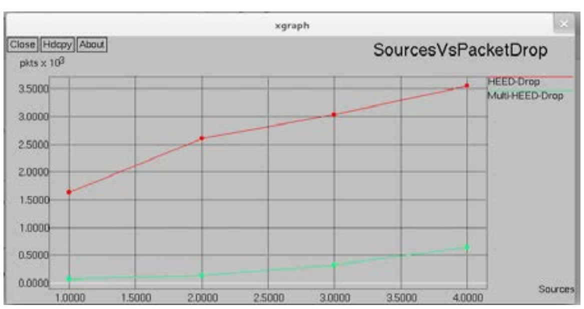

Fig. 3.3 Snapshot of Sources VS Packet Drop

The above graph shows that the MCR Packet drop is very low compare to HEED with respect to the number of sources.

3.4 Rate Vs Energy

The below graph shows that the MCR Energy consumption is very low compare to HEED with respect to the rate.

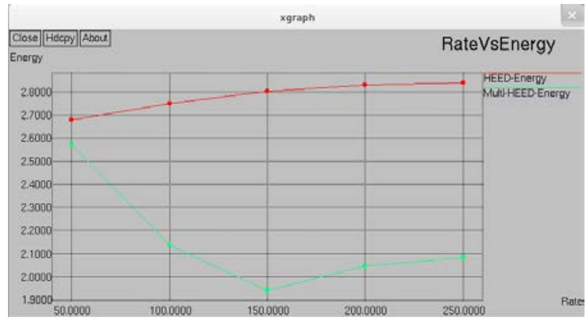

Fig. 3.4 Snapshot of Rate Vs Energy

3.5 Rate Vs Packet Drop

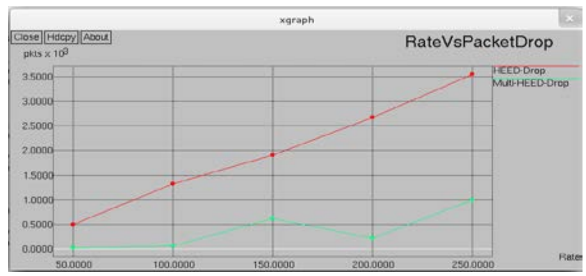

Fig 3.5 Snapshot of Rate Vs Packet Drop

The above graph shows that the MCR Packet drop is very low compare to HEED with respect to Rate.

To evaluate the MBC protocol it is simulated using Matlab. We ran the simulations 10 times. The results are compared with LEACH.

Multi-hop Communication

We put a single hop chromosome in the first population of genetic algorithm process to make sure that the result of GA is better than single hop communication. The variation between best fitness and average fitness is shown in Fig.3.6. The sudden decrease is because of inserting the single hop chromosome. After this decreasing there are small variations in the value of best fitness function which means that GA was successful in finding the optimum path for most cases. Fig.3.7 shows the number of live nodes during Simulation. As seen in this figure LEACH has a pseudo linear manner in decreasing number of live nodes and about 50% of nodes are dead when 50% of network lifetime passed. Fig.3.7 also shows that the most of MBC nodes are alive in most of the network lifetime.

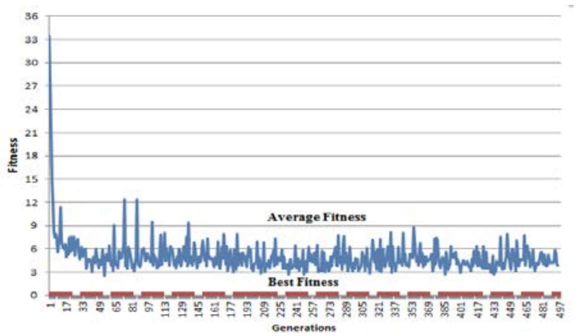

Fig.3.6. Fitness variations with respect to generations

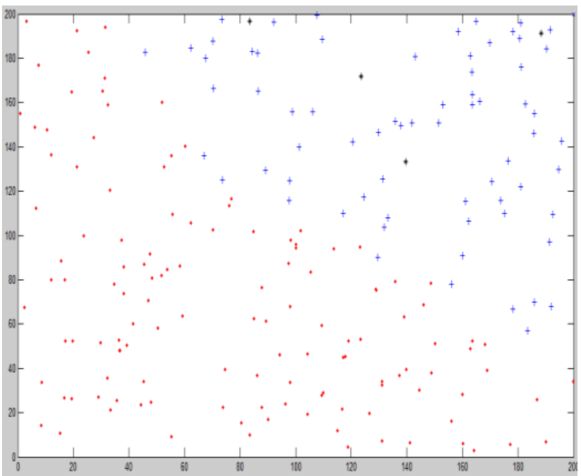

Fig.3.7. Nodes' status in half of the network lifetime in LEACH. Red dots show the dead nodes and blue "+"s show the live nodes.

IV. CONCLUSION

In this paper, a Multi-hop Clustering Routing Protocol (MCR) for long range transmission in wireless sensor network is proposed. We proposed Multi-hop Balanced Clustering routing protocol in this paper. We tried to improve energy efficiency of the network in several aspects. MBC consists of several steps. Clustering is done at first step by using K means algorithm based on their Euclidian distance. This can reduce energy consumption of each cluster. Then the CHs are selected by means of a weighted function based on SD of nodes distances, means of nodes distances and residual energy of each node. This helps to uniform and balance the energy consumption among nodes in each cluster. The last step is finding the optimum multi-hop path to BS from CHs and optimizing inter-cluster energy consumption. The simulations results show that the proposed protocol outperforms LEACH protocol in terms of network lifetime, energy dissipation. It also outperforms LEACH and multi-hop LEACH in terms of number of nodes live during performing in the network. It has balanced energy consumption during network lifetime so that there are live nodes all over the network in 97% of network lifetime. Another advantage of MBC is that the number of clusters can be chosen based on network application and nodes ability, without effecting on overall network performance or changing its behavior. Gateway nodes is used to forward from the CHs to the base station, so that the CHs can preserve some energy in data transmission and the gateway nodes can lighten their burden by not participating in clustering. Furthermore, an energy-driven method to rotate cluster-head instead of time-driven cluster-head rotation is also adopted to balance the energy consumption. Simulation results show that MCR obviously increases the network lifetime and well balances the energy consumption among the sensor nodes using NS2.

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