

Cluster Head Selection Algorithm for Mobile Wireless Sensor Networks

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Abstract—Cluster based routing protocols have significant impact on the energy dissipation and life time of wireless sensor networks (WSN). In this paper Basic Low Energy adaptive clustering hierarchy (LEACH) protocol has been modified with our proposed LEACH-MAE(LEACH-Mobile Average Energy based) protocol to overcome its shortcomings to support mobility along with the new average energy based Cluster Head selection technique. Our simulation in NS2 shows that proposed algorithm improves network life time up to 25 % as well as helps to maintain the equal distribution of energy resource among the sensor nodes.

Key words — *Wireless Sensor Network, NS2, LEACH, LEACH-M protocol, LEACH-MAE, RWP.*

I. INTRODUCTION

WSN is most emerging technology used in variety of applications such as Industrial areas, home networks, land and underwater disaster management, habitat monitoring, weather forecast, Medicare etc.[1]. In almost all these applications WSNs are deployed statically. In general WSNs, mobility factor of sensing entities, users and sensing environment is totally ignored. So the research has now turned in mobility of sensor nodes, observers and sink nodes in typical WSNs. Mobile-WSNs brought in many unique challenges to the researchers for data aggregation and diffusion, route management, security, coverage, packet loss and network lifetime.

Generally, WSNs consists of small sized, low-cost and low-weighted, sensor nodes with the limited processing power of sensing, communications and computation among them and to the base station (BS)[2]. Energy minimization and routing are two major constraints of mobile WSNs due to the moving sensor nodes. The node moving with certain velocity uses more energy than static sensor node hence suffers from severe energy dissipation. Cluster based and hierarchical routing has been accounted as one of the best routing techniques for WSNs by improving the network performance, energy minimization and efficient power usage among the sensor

nodes. To analyze the performance of conventional routing protocols different mobility matrices, CH selection algorithms and multiple mobility patterns are to be considered.

In this paper we proposed an improvement in LEACH protocol which is optimized for the mobile nodes. This proposed modification is made on the basis of CH selection algorithm to ensure that power resource is equally distributed among the sensor nodes and every sensor node has an ability to become cluster head. Random way point mobility (RWP) model is adapted by all the mobile sensor nodes.

The rest of the paper is organized as follows: section II describes the working for basic leach and Mobile WSNs, section III gives full understanding of LEACH-M protocol and the enhancement we proposed in our LEACH-MAE algorithm by using RWP mobility model. Section IV discusses the simulation of proposed algorithm and comparison of both routing algorithms defining some performance metrics and finally section V compares the performance and behavior of routing algorithms with various parameters.

II. RELATED WORK

In MWSN a routing protocol must be able to adapt the frequently changing topology and to consume less energy to prolong the network lifetime. Energy resource preservation has been focused in past. LEACH is one of the most adequate routing protocols for optimizing the energy resource. A greater work has been done in past to modify the LEACH protocols for better network performance described in [3]. Some of the modified LEACH algorithms are LEACH-C, F-LEACH, TL-LEACH, M-LEACH and V-LEACH which are specifically designed for static sensor networks and are not mobility adapted. They cannot directly apply to mobile-WSNs due to the movement and topological change in the network. Therefore LEACH-M and LEACH-ME [4] algorithms are proposed for mobile environment. Due to high energy consumption by the movement of nodes and transmission loss CH election mechanism still needed to modify so that most appropriate node can be elected to avoid more energy consumption and to ensure maximum data delivery. We

proposed a CH selection algorithm which guaranteed better data transmission and minimum energy dissipation for high mobility environment.

III. LEACH DESCRIPTION

A. Mobile Wireless Sensor Network

WSNs were originally assumed to have only static sensor nodes. MWSN is a new area of current research in which all the mobile sensor nodes [5] act same as the static sensor nodes with self-organization and self-configuration capabilities. It has been suggested that mobility feature of sensor nodes helps to improve the sensing coverage and data capacity as well as improves the network lifetime. Another major advantage of MWSN is data reliability. It has been already observed, increased number of hops that a data packet has to travel increases the probability of errors. So if the number of hops is reduced this error can be optimized. Further energy spent in data transmission also reduced.

B. LEACH Protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol is proposed by W. R. Heinzelman et.al [1] to minimize the energy dissipation in WSNs. This routing algorithm uses cluster formation based on the received signal strength and uses the CHs as the local sink while BS receives all the gathered data from cluster heads. Network topology of LEACH which uses single hop routing is shown below in Fig.1.

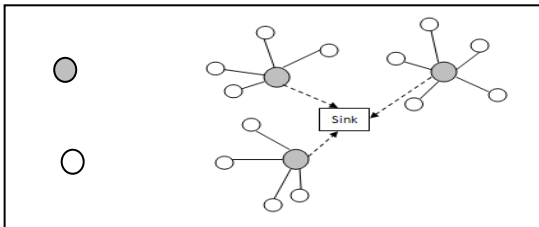


Fig.1. Cluster Architecture of LEACH

LEACH protocol doesn't involve the mobility of sensor nodes. In mobility based environments an agent based technique is used for data aggregation [4] where mobile agent saves the energy dissipation by effective data processing. The enhancement of basic LEACH to LEACH-M [6] supports the mobility and confirms that a sensor node is able to communicate with respective cluster head even with the mobility factor is involved.

IV. LEACH-M PROTOCOL ENHANCEMENT

We enhanced the LEACH protocol by modifying the cluster head selection algorithm for mobile sensor nodes. This section discusses CH selection in LEACH-M and in our proposed Energy-Based LEACH-MAE protocol.

C. Cluster Head Election in LEACH-M

LEACH-M protocol uses the same set up and steady state phases as in basic LEACH protocol. Initially sensor nodes organize themselves into clusters with one node acting as a CH or local sink. If the cluster heads are kept constant throughout the network lifetime as in conventional clustering algorithms, CHs will start to die out more quickly due to overloading and all the cluster nodes will fail to survive in the network. To prevent from the quick death of CH, LEACH rotates the cluster head position among all the cluster nodes and chooses CH in order not to drain all the power of a single sensor. LEACH also performs local data fusion to increase the network life time and to reduce energy dissipation.

The basic LEACH protocol uses distributed clustering technique and mainly divides the cluster formation into two phases:

Set-up Phase: Each round starts with the set-up phase. During which each node decides to be or not to be the CH based on the probability function. Each node in the cluster chooses a random number between 0 and 1. If the number is less than the threshold probability $T(n)$ as in (1), node is elected to be the cluster head for current round[1].

$$T(n) = \begin{cases} \frac{p}{1 - p \cdot (r \bmod \frac{1}{p})} & n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where p is the percentage of cluster heads, r is current round number and G is the group of nodes that have not been cluster head for past $1/p$ rounds.

Once a CH is elected, a status message is then broadcast to all sensors in the network. Each Sensor node then chooses its respective CH based on the RSS.

Steady-state Phase: Once clusters are formed steady-state phase is started. Each CH sets a TDMA schedule for all its cluster nodes which allow them to turnoff their radios except in their transmit time, thus reducing the energy dissipation in sensor nodes. All the cluster nodes transmit their data to the CH in their respective time frame. Sensor node goes to sleep mode after data transmission and only wakes up according to its TDMA schedule. However CHs must keep their radio on throughout the round to receive data. After getting all the data from cluster nodes, CH performs some local processing and aggregation on it and transmits it to the BS.

In LEACH-M, TDMA schedule is fixed for its entire cluster nodes and each cluster node keeps its allocated timeslot either if it has no data or has left the cluster.

On the basis of research studies we analyzed that LEACH-M has some drawbacks:

- There might be some isolated nodes moving far away from the CHs.
- Fixed number of clusters might not be able to facilitate all the other non cluster nodes.

- Random selection of CH nodes might cause quick failure of nodes hence result in minimum network lifetime.
- Packet loss rate increases when number of sensor nodes increases in the network.

D. LEACH-MAE Overview

In basic LEACH randomized rotation of CH election helps to prolong the network lifetime. In Mobile-WSN mobility can affect the election of CHs due to the random movement of sensor nodes over the sensing area. For mobile sensor nodes, CH election should be entirely based on residual energy of each individual cluster node. A fixed number of CHs is not enough to access all the mobile nodes. Clusters are not fixed as the nodes can move out of the clusters which can cause link breakage. This movement of sensor nodes can cause serious communication failure and maximum power depletion of the nodes. To prevent from the above mentioned problems an efficient CH selection algorithm is needed.

In this paper we proposed LEACH-MAE protocol in which we considered energy consumption of each individual sensor node for a particular round within Mobile-WSN.

In LEACH-MAE we considered:

- BS is fixed and located at far away from the sensor field.
- Mobile sensor nodes are Homogenous.
- Sensor nodes moving with certain speed following some mobility pattern with continuous movement.
- CH selection is purely energy based i.e. residual energy of nodes.
- All mobile nodes have enough power to communicate to the BS directly.

E. Cluster Head Selection in LEACH-MAE

In LEACH-MAE, we considered residual energy of each individual sensor node for a particular round. As in basic LEACH, our algorithm is based on multiple rounds. Initially each sensor node is eligible to be a cluster head with some probability P [1]. After successful completion of first round CH selection process is purely energy based.

In our proposed algorithm, just like LEACH each round consists two phases *Setup Phase* and *Steady-state Phase*

The method of CH selection and cluster formation in all rounds is explained as follows:

- In LEACH-MAE, cluster formation in first round is done by random selection of nodes as CHs.

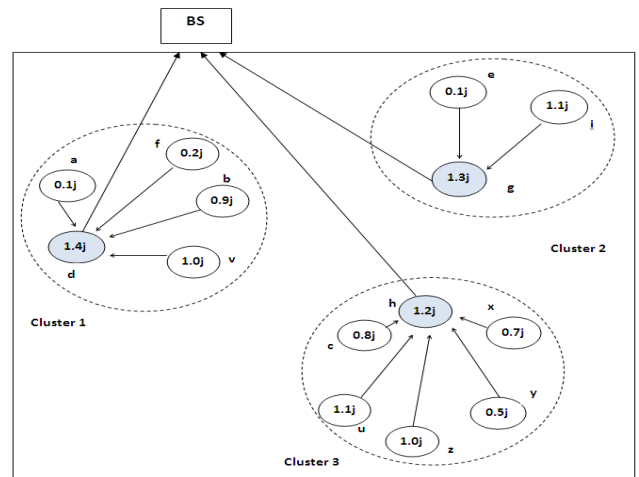


Fig2. Cluster formation of First round

- LEACH-MAE is based on average energy of previous cluster to ensure the CH selection of most suitable sensor nodes.
- In Mobile-WSN, sensor nodes can leave their clusters at any time due to the high mobility and join any other cluster described in Fig. 3

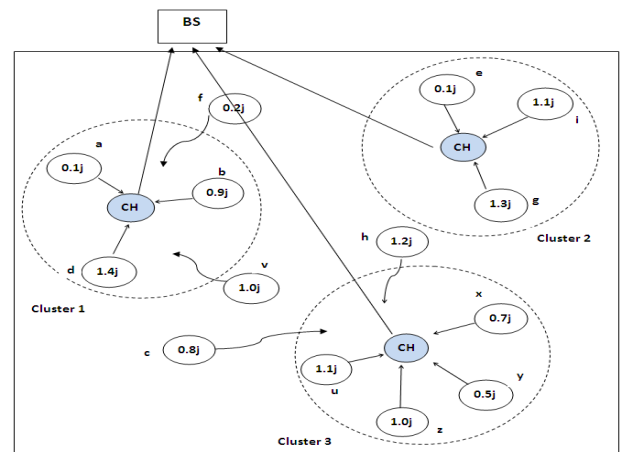


Fig. 3. Mobile nodes changing their location and joining other clusters

- After entering to the new clusters, neighbors of sensor nodes are checked to ensure if the nodes have moved out from previous cluster.
- Once all the nodes joined new clusters, nodes having maximum amount of residual energy meeting the eligibility criteria are elected as CHs for current round shown in Fig. 4.

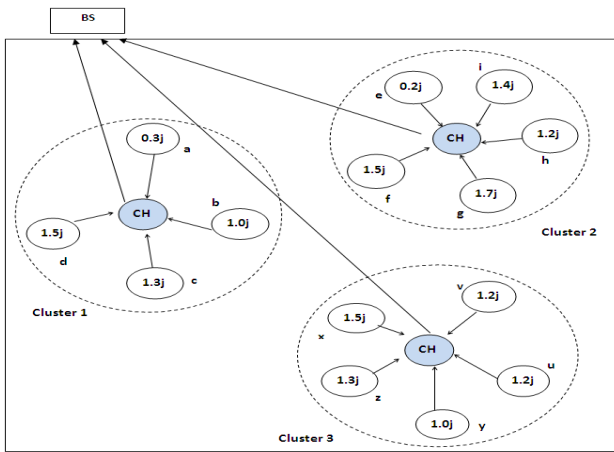


Fig. 4. High energy nodes are elected as CHs

- CHs then broadcast status message with unique code to the non-CH nodes.
- Sensor nodes then choose their CHs based on the strong RSS and sends join message to their respective CHs.
- These new CHs then create TDMA schedules to accommodate all the new sensor nodes and broadcast it to all the cluster nodes.
- In steady state phase mobile sensor nodes transmits data to their CHs by turning on their radios in respective timeslots.
- After getting the data from all cluster nodes, CHs transmits the gathered data to the BS.
- This procedure is repeated until all the nodes are dead.

We also proposed that all the sensor nodes are moving by following some mobility pattern which helps to improve the network performance.

F. Random Waypoint Mobility Model (RWP)

In MWSN a mobility model describes the pattern of mobile entities along with the location, velocity and acceleration change with time [7]. These mobility models have a great impact on the performance of routing protocols and on mobile networks therefore it is important to choose an underlying mobility model to evaluate any protocol. RWP is one of the simple and widely used mobility models in WSN, Johnson and Maltz[8] proposed it for Adhoc Networks.

In this model, mobile nodes move independently without restrictions. A mobile node chooses a random destination and moves towards the point with constant speed. Then it waits for a certain pause time, chooses new destination point and speed, and move towards this new point and so on.

V. SIMULATION AND PERFORMANCE ANALYSIS

In this section performance of LEACH-M and our proposed energy-based LEACH-MAE is implemented and compared in

different scenarios. The simulation is carried out in network simulator (NS-2) [9].

A. Performance Metrics

For wireless sensor network, lifetime is very important due to the limited power resources. Here, we used three performance metrics to state network energy consumption.

- Energy consumption of all nodes
- Number of alive nodes
- Throughput rate of all the sensor nodes.

B. Simulation Parameters

Here, we described all the parameters used to analyze the network performance for both routing algorithms. In our work we also kept the position of base station (BS) fixed.

Our proposed algorithm was tested for different number of nodes and different mobile speed of sensor nodes. For the results comparison analysis we used following parameters shown in table:

TABLE 1. SIMULATION PARAMETERS

Parameters	Description
Antenna Model	Omni Directional
Channel Type	Wireless Channel
Radio Propagation Model	Two ray ground
Interface Queue type	Drop tail / PriQueue
Link Layer Type	LL
Communication Model	Bidirectional
IFQ length	50 packets
Simulation time	200 Secs

The simulation is carried out with comparison of 10m/s, 20m/s, 30 m/s and 40m/s speed of sensor nodes. We have also chosen the 0sec pause time for the sensor nodes which allows sensor nodes to move continuously with maximum speed.

Following Table 2 describes the network topology which is used during our network performance analysis.

TABLE 2. NETWORK TOPOLOGY PARAMETERS

Field Size	No. of Nodes	BS position
100*100	100	(75m,150m)

VI. SIMULATION RESULT

The simulation of the sensor network is mainly focused on the speed with different performance metrics.

Performance metrics described in previous section are used to analyze the behavior and performance of our proposed algorithm with the basic LEACH-M protocol. For mobile-

WSN, life time is based on the number of alive nodes and energy consumption during each round.

For our simulation results we run our simulations 20 times and finally took average of them to show the network behavior for both of the routing algorithms.

G. Energy consumption Vs Time

In WSN, all nodes are battery power constrained but mobility causes to drain more power than in static WSN. Higher energy consumption leads to early death of sensor nodes. It can be observed that with higher mobility, efficient center selection algorithm results less energy consumption and more data transmission due to minimum link breakage.

Simulation results in Fig 5(a) and Fig 5(b) shows the energy consumption with time for different speeds of sensor nodes over the field of 100*100 m² when there is no pause time is set.

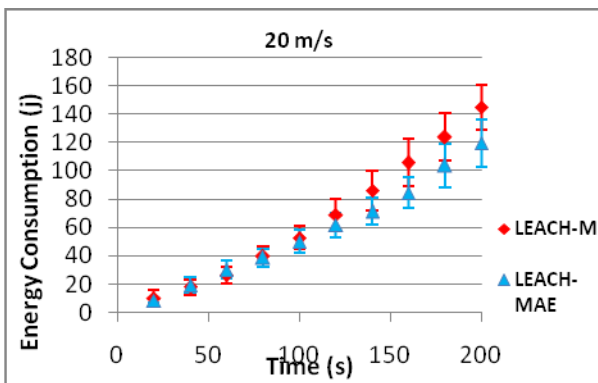


Fig 5(a). Energy consumption vs. Time at 20m/s speed

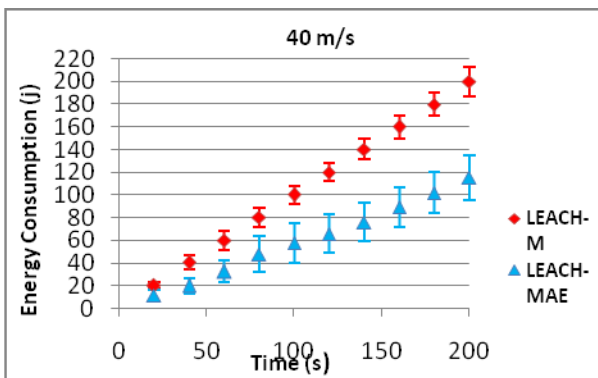


Fig 5(b). Energy consumption vs. Time at 40m/s speed

H. Throughput Rate Vs Time

In Mobile-WSN, link breakage is one of the major issues. Due to high mobility in sensor nodes links are hard to maintain with the CHs, which results greater data loss.

In following figures network performance in terms of throughput is observed for mobile nodes. LEACH-MAE ensures better data transmission.

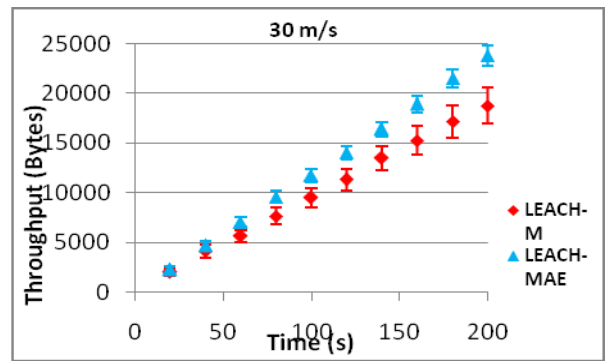


Fig 6(a). Throughput rate vs. Time at 10 m/s

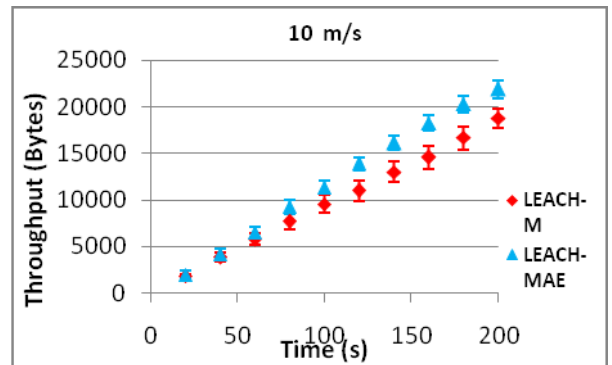


Fig 6(b). Throughput rate vs. Time at 30 m/s

I. No. of Alive nodes Vs Time

To optimize the performance of any WSN it is important to have maximum nodes alive during each round. Lifetime of WSN is based on the time of first dead node appear hence the network is considered for better performance if sensor nodes are not start to die quickly. Figures 7(a) and 7(b) shows total alive nodes at the end of simulation time.

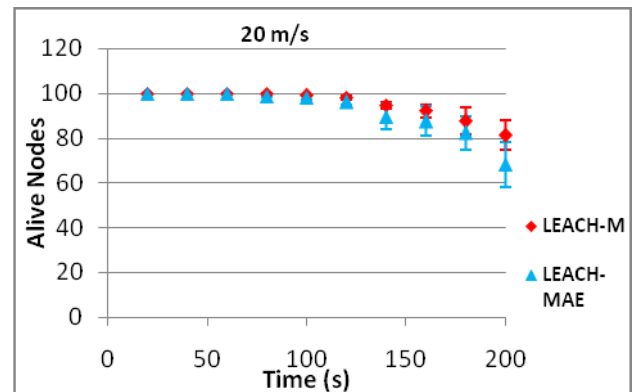


Fig 7(a). No. of Alive nodes vs. Time at 20 m/s

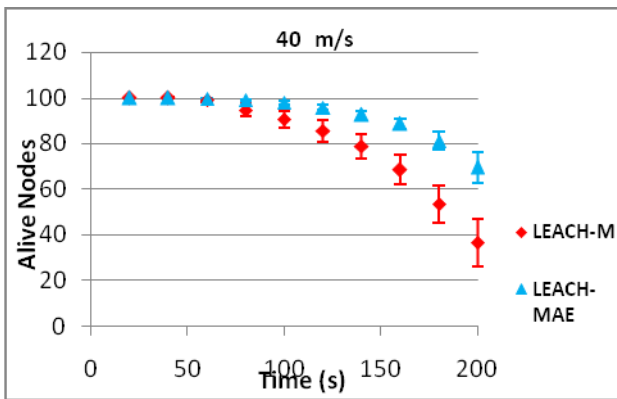


Fig. 7(b). No. of Alive nodes vs. Time at 40 m/s

VII. CONCLUSION

The Hierarchical routing protocol LEACH is observed as one of the best routing protocol for minimum energy consumption in wireless sensor network.

This paper presents the performance analysis of the modified LEACH algorithm i.e. LEACH-MAE for mobile wireless sensor network. Here energy resource and minimum link breakage have been focused. Comparison simulation result on the varying speed of sensor nodes proved that maximum link maintenance and less energy consumption improves the network lifetime and prevents data loss. Network lifetime would be degraded if there is random selection of CHs. Also as the speed of sensor nodes increases there are more chances of frequent link breakage which lead to quick power failure. Hence in our proposed algorithm it has been observed from the above results that even if the mobility is high there is minimum data loss as compared to LEACH-M as

well as the network life time is greater with less energy dissipation.

We also concluded that by using some mobility pattern for mWSNs, energy dissipation can be minimized and network lifetime can be optimized.

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