Clustering in Wireless Sensor Networks: Performance Comparison of EAMMH and LEACH Protocols using MATLAB

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Abstract

One of the main design issues for a sensor network is conservation of the energy available in each sensor node. Increasing network lifetime is important in wireless sensor networks. Many routing algorithms have been developed in this regard. Out of all these, clustering algorithms have gained a lot of importance in increasing the network lifetime thereby the efficiency of the nodes in it. Clustering provides an effective way for prolonging the lifetime of a wireless sensor network. This paper elaborately compares two renowned routing protocols namely, LEACH and EAMMH for several general scenarios, and brief analysis of the simulation results against known metrics with energy and network lifetime being major among them. In this paper will the results and observations made from the analyses of results about these protocols are presented.

Keywords

Wireless Networks, Comparison, LEACH, EAMMH, Energy Efficient, Multi Path, Multi Hop

Introduction

Recent advances in the field of communication technologies and the manufacture of cheap wireless devices have led to the deployment of minimum power wireless sensor networks. Due to their ease of deployment and multi-natured functionality of the sensor nodes, wireless sensor networks have been utilized for a range of applications such as ocean waves monitoring, temperature monitoring, etc [1,2]. Key issue in wireless sensor networks is maximizing the network lifetime and the amount of data transferred successfully during the network lifetime. In sensor networks, the data transport model is such that a base station, typically is located at the boundary of or beyond the field from where the sensors sense/measure data [3]. Researchers have proposed numerous routing protocols to improve performance of different application in a wireless sensor network. Most of the protocols in Wireless Sensor Networks are designed based on single path-routing strategy without considering the various effects of various load traffic intensities. A hop by hop basis data transfer increases the overhead on routing table management and quickly brings down the lifetime of those nodes which are near to the base station as these nodes will be used extensively as relay nodes. Such a network will be nonexistent as the energy of the nodes near the base station drains quickly. Many routing protocols have been suggested to overcome such issues [4,5]. Out of these, clustering algorithms have been of much interest as they well balance several key factors of Wireless Sensor Networks operation simultaneously [1]. Choosing one arbitrary node to act as servicing node for several sensor nodes than each trying to reach Gateway node can extend network lifetime and bring down energy utilization considerably. This process of choosing one node to act as servicing node for several neighbor nodes is known as 'clustering'.

In the rest of this paper , section 2 gives the brief working and analysis of LEACH protocol , section 3 gives the analysis and working of EAMMH protocol section 4 presents details about simulation using MATLAB tool and the analysis of results is presented. Paper is concluded in section 6 by mentioning the effectiveness of both LEACH and EAMMH.

Low-Energy Adaptive Clustering Hierarchy (LEACH)

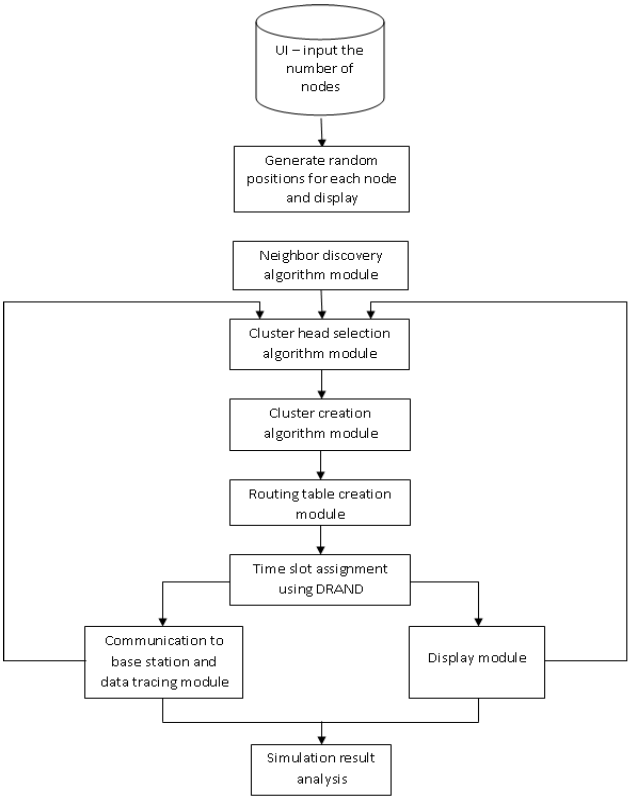
LEACH is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption [7,8]. In LEACH, the clustering task is rotated among the nodes, based on duration. Direct communication is used by each cluster head (CH) to forward the data to the base station (BS). It uses clusters to prolong the life of the wireless sensor network. LEACH is based on an aggregation (or fusion) technique that combines or aggregates the original data into a smaller size of data that carry only meaningful information to all individual sensors [9]. LEACH divides the a network into several cluster of sensors, which are constructed by using localized coordination and control not only to reduce the amount of data that are transmitted to the sink, but also to make routing and data dissemination more scalable and robust. LEACH uses a randomize rotation of high-energy CH position rather than selecting in static manner, to give a chance to all sensors to act as CHs and avoid the battery depletion of an individual sensor and dying quickly. The operation of LEACH is divided into rounds having two phases each namely (i) a setup phase to organize the network into clusters, CH advertisement, and transmission schedule creation and (ii) a steady-state phase for data aggregation, compression, and transmission to the sink. LEACH is completely distributed and requires no global knowledge of network. It reduces energy consumption by (a) minimizing the communication cost between sensors and their cluster heads and (b) turning off non-head nodes as much as possible. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption. While LEACH helps the sensors within their cluster dissipate their energy slowly, the CHs consume a larger amount of energy when they are located farther away from the sink. Also, LEACH clustering terminates in a finite number of iterations, but does not guarantee good CH distribution and assumes uniform energy consumption for CHs.

Energy Aware Multi-hop Multi-path Hierarchical (EAMMH) Routing Protocol

EAMMH routing protocol was developed by inducing the features of energy aware routing and multi-hop intra cluster routing [10]. The operation of the EAMMH protocol is broken up into rounds where each round begins with a set-up phase, when the clusters are organized, followed by a steady- state phase, when data transfers to the base station occur. The below flow chart describes the overview of the protocol initially the user has to give the input which is in the form of number of nodes.

For the nodes generated, their positions are randomly assigned and displayed. Once the nodes are deployed, every node uses the neighbor discovery algorithm to discover its neighbor nodes. Using the cluster head selection algorithm cluster heads are selected among the nodes. These cluster heads broadcasts the advertisement message to all its neighboring nodes and thus clusters are formed with a fixed bound size. Each node in the cluster maintains routing table in which routing information of the nodes are updated. DRAND (distributed randomized time slot assignment algorithm) method is used, it allows several nodes to share the same frequency channel by dividing the signal into different time slots. The cluster head aggregates the data from all the nodes in the cluster and this aggregated data is transmitted to the base station.

Figure 1: Flowchart of EAMMH



Setup Phase

Initially, after the node deployment the neighbor discovery takes place. This can be done using many methods like: k-of-n approach, ping, beacon messaging.
After the neighbor discovery [11], when cluster are being created, each node decides whether or not to become a cluster-head for the current round. This decision method is similar to the one used in LEACH. The setup phase operates in the following sequence:
1. CH (Cluster Head) Selection
2. Cluster Formation

Data Transmission Phase

Once the clusters are created, the sensor nodes are allotted timeslots to send the data. Assuming nodes always have data to send, they transmit it at their allotted time interval.

When a node receives data from one its neighbors, it aggregates it with its own data. While forwarding the aggregated data, it has to choose an optimal path from its routing table entries. It uses a heuristic function to make this decision and the heuristic function is given by,

$$h = K (E_{avg} / h_{min} * t) \qquad (1)$$

where K is a constant, E_{avg} is average energy of the current path, h_{min} is minimum hop count in current path, t = traffic in the current path.

The path with highest heuristic value is chosen. If this path's E_{min}> threshold, it is chosen. Else the path with the next highest heuristic value is chosen, where

$$E_{min} = E_{avg} / const \qquad (2)$$

The constant may be any integer value like 10.
If no node in the routing table has E_{min} greater than threshold energy, it picks the node with highest minimum energy.

Periodic Updates

The information about the paths and routing table entries at each node becomes stale after a little while. The heuristic values calculated based on the stale information often leads to wrong decisions. Hence the nodes are to be supplied with fresh information periodically. This will increase the accuracy and timeliness of the heuristic function. During the operation of each round, the necessary information is exchanged at regular intervals. The interval of periodic updates is chosen wisely such that the node does not base its decisions on the stale information and at the same time, the periodic update does not overload the network operation.

Simulation and Analysis of Results

Both LEACH and EAMMH are simulated using MATLAB. The parameters taken into consideration while evaluating EAMMH and LEACH are as follows.

- Round Number vs Number of Dead Nodes (with variation of probability)
- Round Number vs Average Energy of Each node (with variation of probability)
- Round Number vs Number of Dead Nodes (with variation of number of nodes)
- Round Number vs Average Energy of Each node (With variation of number of nodes)

To simplify the simulation of these protocols few assumptions are made. They are as follows:

- Initial energy of nodes is same.
- Nodes are static
- Nodes are assumed to have a limited transmission range after which a another equation for energy dissipation is used
- Homogeneous distribution of nodes.
- Nodes always have to send the data.

Details of the simulation environment are mentioned in Table 1, given below:

Table 1: Simulation Details

Simulation Area	100*100
Base Station Location	(150,50)
Channel Type	Wireless Channel
Energy Model	Battery
Transmission Amplifier Efs Emp	 10*0.000000000001 0.0013*0.000000000001
Data Aggregation Energy	5*0.000000001
Transmission Energy,ETx Receiving Energy,ERX	50*0.000000001 50*0.000000001

Simulation of protocols at 0.05 probability

The below set of results represent the simulation of both LEACH and EAMMH protocols at 0.05 probability that is the percentage of total nodes which can become cluster head is 5% of the total number of nodes

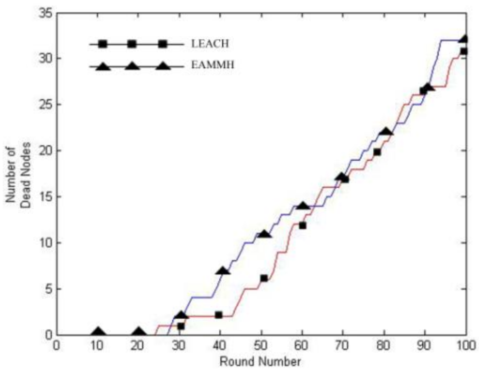


Figure 2: 50 nodes

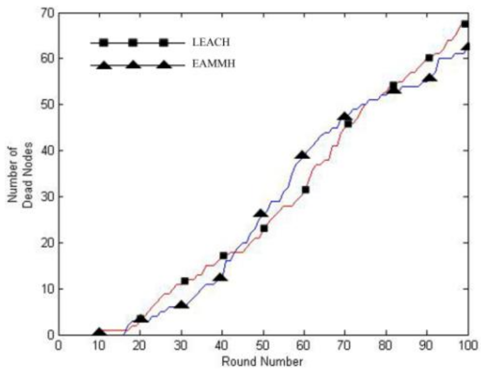


Figure 3: 100 nodes

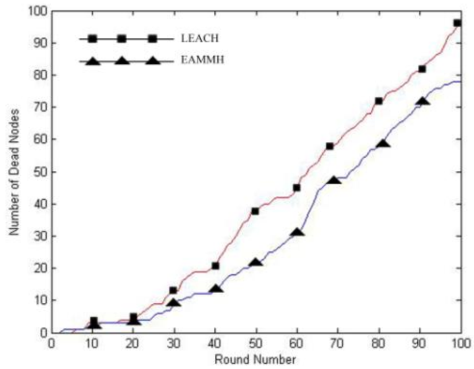


Figure 4: 150 nodes

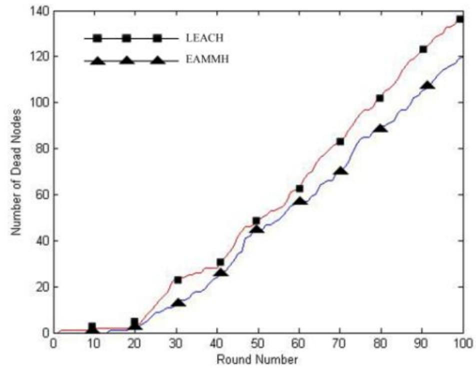


Figure 5: 200 nodes

Figures 2, 3, 4 and 5 represent the comparison of LEACH and EAMMH protocols for the number of dead nodes against the round number elapsed for 50,100,150 and 200 nodes respectively. From Figure 2 we observe that, the number of dead nodes with the simulation of LEACH protocol is almost as comparable to number of dead nodes in EAMMH protocol. However as the number of nodes increase, we observe from Figure 3,4 and 5 that EAMMH results in lesser number of dead nodes after the completion of 100 rounds when compared to LEACH. .

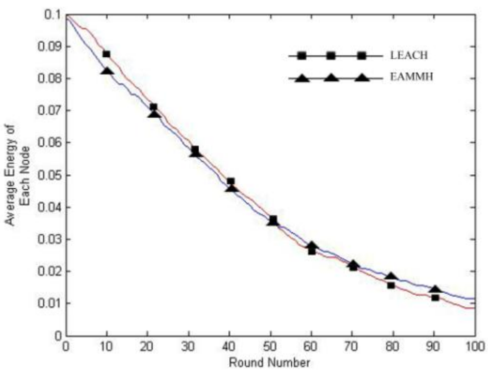


Figure 6: 50 nodes

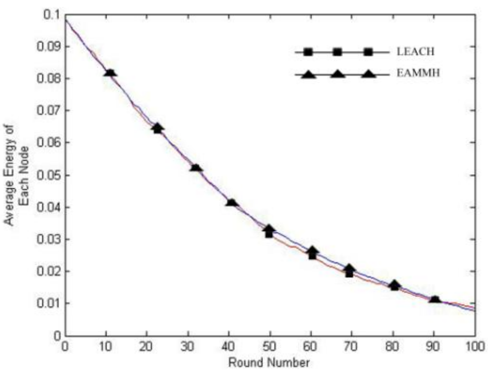
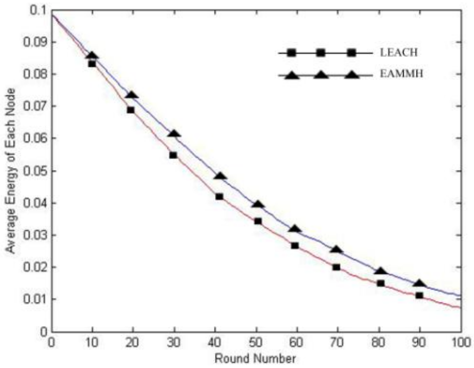


Figure 7: 100 nodes



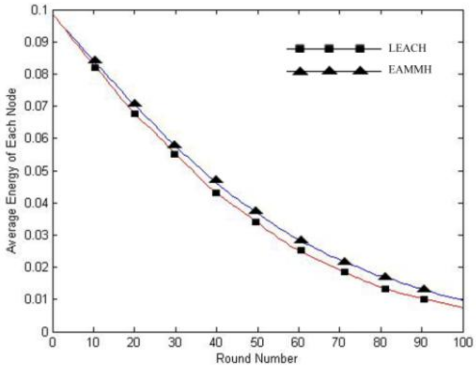


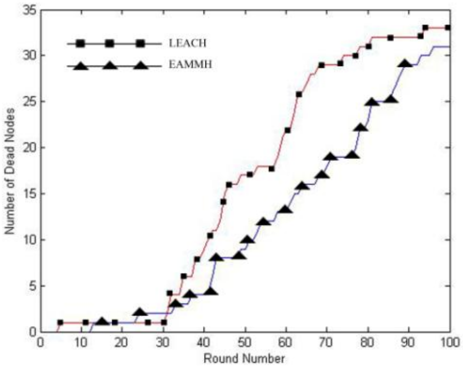
Figure 8: 150 nodes

Figure 9: 200 nodes

Figures 6,7,8 and 9 represents the average energy of each node as the round progresses for LEACH and EAMMH protocols. In Figure 6 and Figure 7, the average energy of each node after 100 rounds is almost equal for both EAMMH and LEACH whereas EAMMH performs slightly better in Figure 8 and Figure 9.

Simulation of Protocols at 0.1 probability

The above set of results represent the simulation of both LEACH and EAMMH protocols at 0.1 probability that is the percentage of total nodes which can become cluster head is 10% of the total number of nodes.



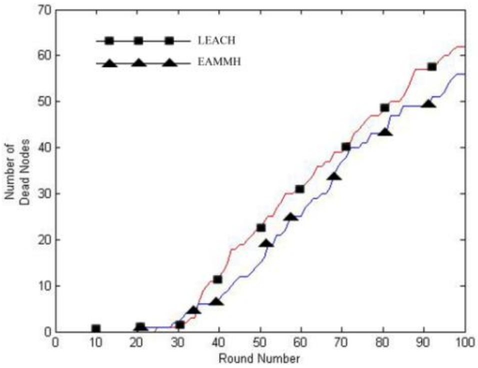
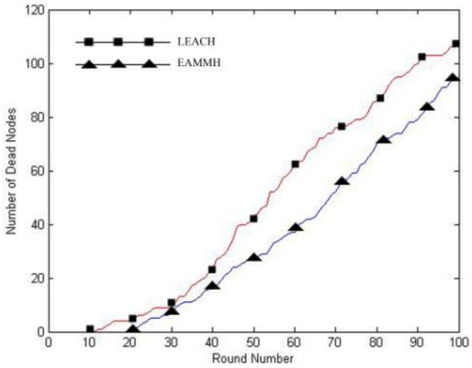


Figure 10: 50 nodes

Figure 11: 100 nodes



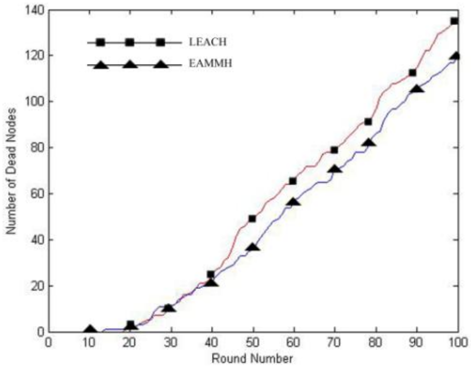


Figure 12: 150 nodes

Figure 13: 200 nodes

Figures 10,11,12 and 13 represents the comparison of LEACH and EAMMH protocols for the number of dead nodes against the round number elapsed for 50,100,150 and 200 nodes respectively for a cluster head probability of 0.1. In all the figures we can observe that after a total of 100 rounds the number of dead nodes resulting from EAMMH protocol is less than the number of dead nodes resulting from LEACH protocol.

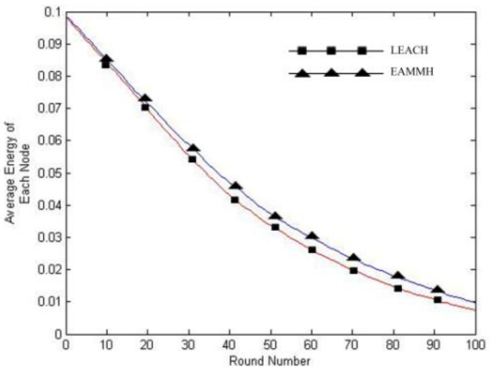


Figure 14: 50 nodes

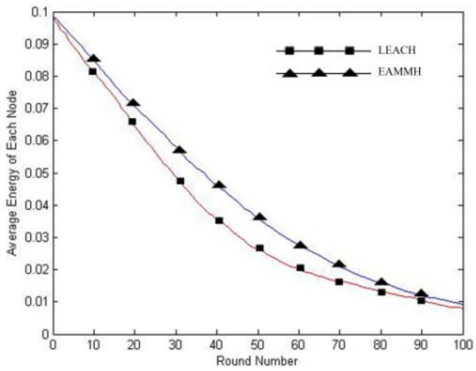


Figure 15: 100 nodes

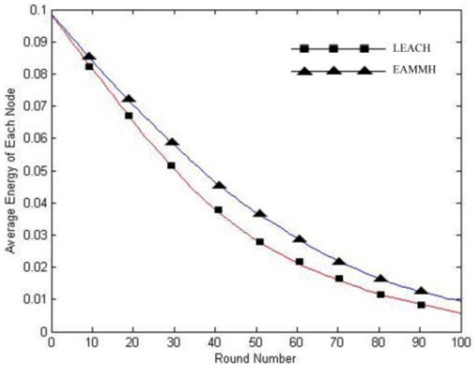


Figure 16: 150 nodes

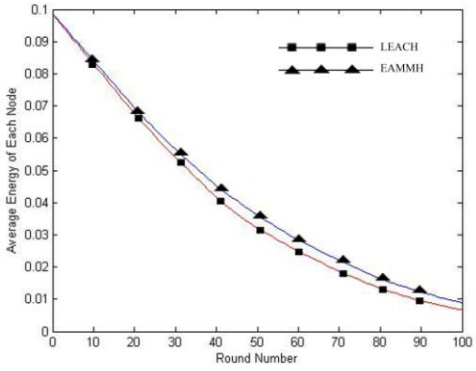


Figure 17: 200 nodes

Figures 14,15,16 and 17 represents the average energy of each node as the round progresses for LEACH and EAMMH protocols for the cluster head selection probability of 10% or 0.1. We observe from the figures that the average energy of each node using EAMMH protocol after 100 rounds is better in all scenarios of different nodes when compared to LEACH.

Simulation of Protocols at 0.2 probability

The above set of results represent the simulation of both LEACH and EAMMH protocols at 0.2 probability that is the percentage of total nodes which can become cluster head is 20% of the total number of nodes.

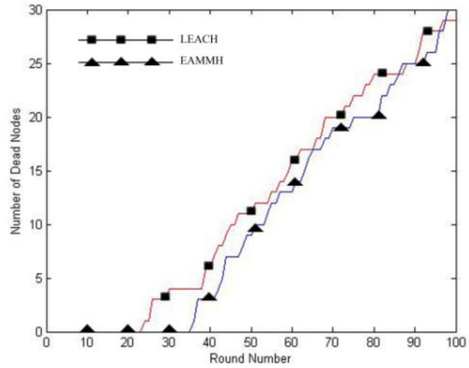


Figure 18: 50 nodes

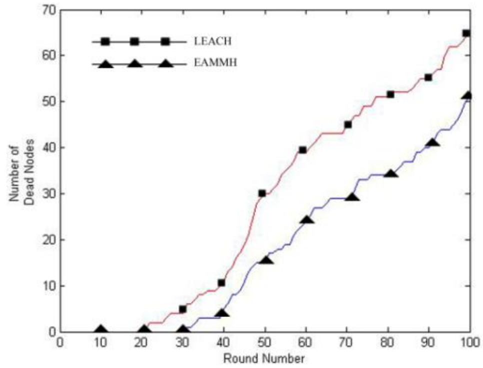


Figure 19: 100 nodes

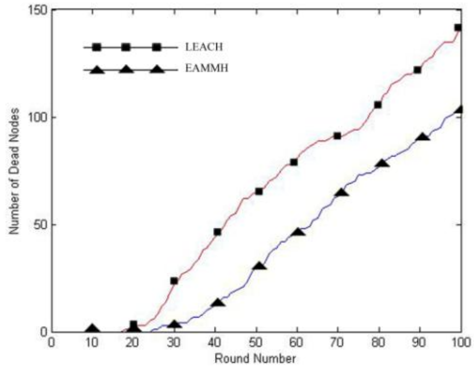


Figure 20: 150 nodes

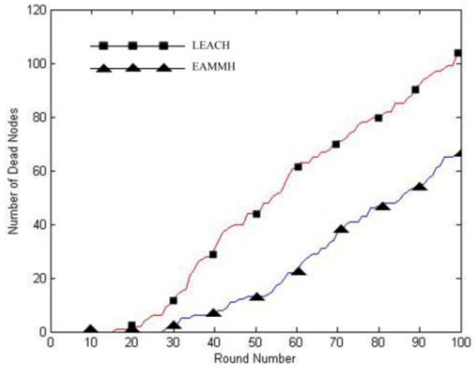


Figure 21: 200 nodes

Figures 18,19,20 and 21 represents the comparison of LEACH and EAMMH protocols for the number of dead nodes against the round number elapsed for 50,100,150 and 200 nodes respectively for a cluster head probability of 0.2. We observe in Figure 18 , with a simulation of a total of 50 nodes that the number of dead nodes after 100 rounds is 29 and 30 respectively for LEACH and EAMMH protocols. LEACH protocol performs slightly better than EAMMH when the number of nodes is 5 , whereas as the number of nodes increases, we observe from Figures 19,20 and 21 that EAMMH outperforms LEACH in all the scenarios.

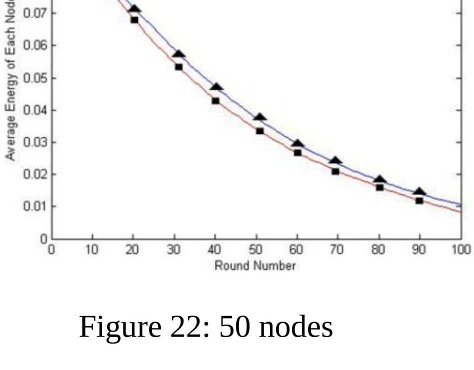


Figure 22: 50 nodes

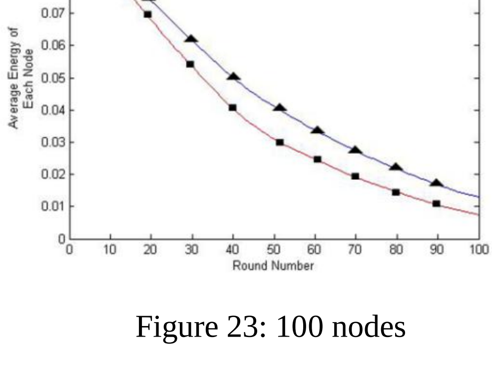
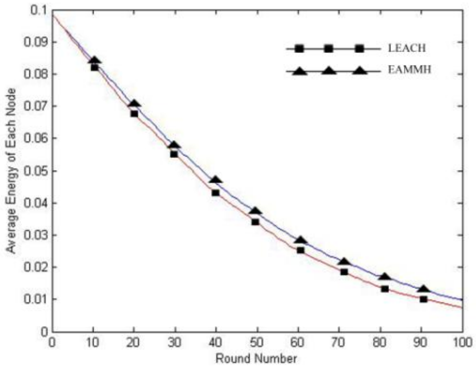


Figure 23: 100 nodes



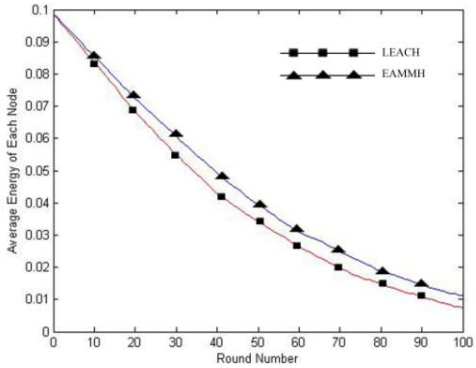


Figure 24: 150 nodes

Figure 25: 200 nodes

Figures 20,21,22 and 23 represents the average energy of each node as the round progresses for LEACH and EAMMH protocols for the cluster head selection probability of 20% or 0.2. From Figure 22, we observe that the average energy of each node curve for both EAMMH and LEACH is very close after 100 rounds, where in EAMMH energy is slightly better than LEACH. From Figures 23,24 and 25 we observe that the energy gap of the curves of EAMMH and LEACH vary significantly with EAMMH outperforming LEACH protocol.

Analyses of Results

It is observed from the figures 2 to 25 ,that as time progress LEACH and EAMMH both lose energy as the number of round increases. It is also observed that once a node reaches the value of zero it is no longer functional and is deemed as a dead node. From Figures 3-9 we observe that as the number of nodes increase EAMMH curve for average energy of each node is slightly better. The numbers of dead nodes also get lesser as the number of total nodes increase when compared to LEACH. Therefore for a probability of 0.05 as the number of nodes increases, the better is EAMMH when compared to LEACH. From the Figures 10-25, it is be evident that for each probability level as the number of nodes increase EAMMH is seen to perform better in terms of average energy of each node and the total number of dead nodes. However for a lesser number of total number of nodes, LEACH is found to perform better. From the Figures we observe from most cases that even though EAMMH performs better, the first dead node in most of the operations is by EAMMH. LEACH on the other hand has a delayed time in getting the first dead node but a larger number of nodes run out of energy in a short period of time subsequently. From the Figures, it can also be observed that for a fixed set of nodes, if the probability of election of Cluster Head is increased, then the average energy of each node gap between the curves increases favoring EAMMH. From Figure 5,13 and 21 we observe that LEACH at 0.05 probability is better than EAMMH, while at a probability of 0.1, EAMMH outperforms LEACH by a factor of 25% and at 0.2 probability by a factor of around 45%/. The number of dead nodes from Figure 5 for EAMMH and LEACH is at 62 and 68 , from Figure 13 , 57 and 62 , from Figure 21, 51 and 62 respectively. From the simulations we observe that the nodes which are far away from the base station are the ones which run out of energy more quickly than the rest which are nearer to the Base Station. This is due to the fact that the nodes or the Cluster Head which are farther from the Base Station have to dissipate large amounts of energy to send the information as they will have to travel longer distances when compared to the ones which are nearer. The reason why EAMMH performs better than LEACH in majority of the scenarios is for the reason that EAMMH consists of a inter cluster routing mechanism which will help make the network survive for a longer time. LEACH on the other hand has a direct hop communication with the Cluster Head and then to the Base Station. Even though LEACH employs Multi-hop mechanisms, EAMMH with the usage of Multi-path and hierarchical routing parameters and techniques with the inclusion of Multi-hop can perform with much better energy efficiency than LEACH in cases where more number of nodes are involved. In cases when there are a few nodes as an intra-cluster routing mechanism can add to the overhead of the node, LEACH in its simple mode of operation proves to be more energy efficient.

Conclusion

Wireless Sensor Networks are usually spread over large areas are recently finding applications in many fields. In this regard, there is a requirement of methods which can manage the WSN's in a better way. Wireless Sensor Networks are powered by the limited capacity of batteries. The main challenge in the design of protocols for Wireless Sensor Network is energy efficiency due to the limited amount of energy in the sensor nodes. The ultimate motive behind any routing protocol is to be as energy efficient as possible to keep the network running for a longer period of time. In this paper we have presented clustering as a means to overcome this difficulty of energy efficiency. Detailed description about the working of two protocols, namely LEACH and EAMMH are presented. We have also presented the details about the simulation and the results of it. From the brief analyses of the simulation we have come to a conclusion that LEACH can be preferred in cases of smaller networks where the total number of nodes is less than fifty where it performs slightly better than EAMMH and EAMMH can be chosen in larger networks and also when the heuristic probability of Cluster Head selection is more.

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