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Extended version of Leach and its comparison with Energy aware multi-hop multi-path Hierarchy Protocol

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ABSTRACT:
Wireless sensor networks are generally battery limited deployed in remote and crucial areas where continuous monitoring is essential. One of the main design issues for such a network is conservation of the energy available in each sensor node. Increasing network lifetime is important in wireless sensor networks. The proposed scheme describes a new way to select the Cluster head. Analysis shows that the extended version or enhanced LEACH protocol balances the energy expense, saves the node energy and hence prolongs the lifetime of the sensor network. Also a comparison between LEACH, proposed scheme (extended version) and Energy aware multi-hop multi-path hierarchy protocol (EAMMH) is presented.

KEYWORDS: *Cluster head(CH) , Energy conservation, Energy level, Optimum distance, Comparison, LEACH, EAMMH, Energy Efficient, Multi Path, Multi Hop, Lifetime.*

I. INTRODUCTION

LEACH is a clustering-based protocol. LEACH is one of the first hierarchical routing approaches for sensors networks. It randomly selects a few sensor nodes as cluster heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station(negotiation). WSN is considered to be a dynamic clustering method.

Section 1-**Study of LEACH protocol**

Operation of Leach

It has 2 phases :

1. Set up State Phase

2. Steady State Phase

- In the setup phase, the clusters are organized an.
CHs are selected.

- In the steady state phase, the actual data transfer to the base station takes place.
- The duration of the steady state phase is longer than the duration of the setup phase.
- During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs.

A sensor node chooses a random number, r, between 0 and 1. Let a threshold value be T(n). If this random number is less than a threshold value, T(n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G.

$$T(n) = \frac{p}{1-p*(r*mod\frac{1}{p})} \quad \forall \text{ n } \epsilon \text{ G}$$

$$T(n) = 0 \quad \forall \text{ n not } \epsilon \text{ G}$$

where G is the set of nodes that are involved in the CH election.

Each elected CH broadcasts an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong. This decision is based on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate cluster-heads that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster.

During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster-head node, after receiving all the data, aggregates it before sending it to the base-station. The energy spend by any transmitter to send a L-bit message over a distance d is,

$$S(i).E = E_{Tx}(l,d) = \begin{cases} \{L.Eelec + \epsilon_{fs}.d^2 \quad if \ \ d \le d_o\} \\ \{L.Eelec + \epsilon_{mp}.d^4 \quad if \ \ d > d_o\} \end{cases}$$

Where $d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$

This is the energy dissipated in sending the data packets to the base station. This gives also gives the estimate of the remaining energy with the node. After a certain time, the network goes back into the setup phase again and enters another round of selecting new CH.

II. RELATED WORK

The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed[1] . Taxonomy of the different architectural attributes of sensor networks is developed [2] . Further improvements on LEACH protocol for wireless sensor networks has been developed where both security & efficiency features have been dealt with [3]. Here the sensing area has been divided into a number of equilateral areas, called as clusters. Each cluster consists of six equilateral triangles called cells. The protocol consists of a number of rounds but after forming the clusters they do not change in each round. Both each equilateral triangle & each equilateral hexagon has same number of nodes. In each cell one cell head is selected & one CH is selected is chosen from six cell heads. The data are sent to the base station by using the multi-hop manner through a secure path consisting of cluster heads. The analysis shows that the improved protocol saves nodes energy, prolongs WSN lifetime, balances energy expenses and enhances security for WSNs.

To allow a single-tier network to cope with additional load & to be able to cover a large area of interest without degrading the service, networking clustering has been pursued in some routing approaches[4] . The hierarchical routing protocols involve nodes in multi-hop communication within a particular cluster to efficiently maintain the energy consumption of sensor nodes as well as perform data aggregation fusion to decrease the number of transmitted messages in the sink. Cluster formation is typically based on the energy reserve of sensors and sensor’s proximity to the cluster head[5][6] . LEACH is one of the first hierarchical routing approaches for sensors networks.

<u>Section 2</u>-**Proposed Scheme**

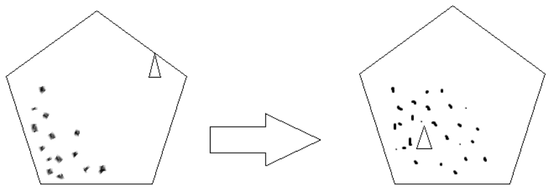
The aim of LEACH protocol is to minimize energy consumption or in other words, to maximize the network lifetime. To make this happen several ideas are proposed for CH selection but they were based on mainly the node’s (to be selected as CH) energy level. The node having greater energy level will be selected as CH most of the times. But here in the new proposed scheme not only the node’s energy level is considered but also it’s location or position both within the CH & from outside the cluster(neighbour clusters) are considered.

We know that there may a number of nodes in a cluster & there is always a CH. Suppose for example, if the CH lies at a distant position from the majority of nodes. So to communicate between CH & sensor nodes, since the distance between them is high, energy consumption for the communication is also high. That means, the higher the distance between CH & sensor nodes the greater the energy consumption.
Here a new idea to select the CH is given below :

1. Select the CH in the dense node zone.

   To illustrate this say for example, you are announcing something. If the persons, for whom your announcement is, are very far from you, you have to shout more to make them listen to it but if those persons are near to you, you won't have to shout that much.

That means, if nodes are near to the CH, energy consumption is less.



2. Suppose a cluster is surrounded by 6 clusters. So 6 CH can communicate with the central CH. This central CH should be at an optimum distance from those CH. That means the distance between them should be balanced or on average.

   Say, C0,C1,C2,C3,C4,C5,C6 are the CH of cluster 0(central cluster),cluster 1, cluster 2, cluster 3, cluster 4, cluster 5, cluster 6 respectively. There should not be a huge difference among distances between C0-C1,C0-C2,C0-C3,C0-C4,C0-C5,C0-C6.

   Hence, energy consumption will be in control.

$$T(n) = \frac{p}{1-p*\left(r*\mathrm{mod}\frac{1}{p}\right)}\left(\frac{S(i).E}{E_{max}}\right)\left(\frac{D_{avg}}{\sum D_{inter_{node}}}\right) \quad \forall\, n \in G$$

$$T(n) = 0 \quad \forall\, n \text{ not } \in G$$

Where S(i).E is the current energy of each node and E_{max} is the initial energy of each node.

D_{avg} is the average distance from all other nodes in the cluster.
D_{inter_node} is the distance between any two nodes in the cluster.

<u>Here with the original formula two factors are multiplied.</u>

- Average distance from other nodes in same cluster/∑ inter-node distance

This factor checks whether the node, to be selected as CH, belongs to a density popular area as well as the distance from the node to the other nodes within the cluster is on average.

- Current energy of the node/Initial energy of each node

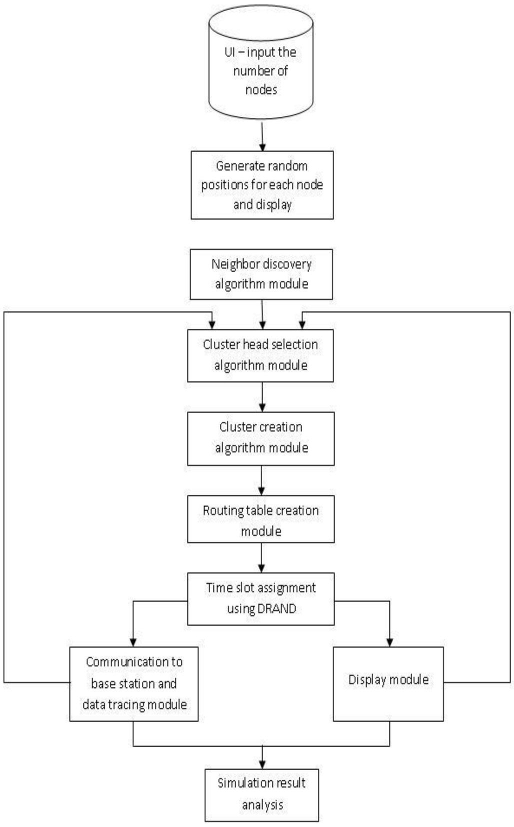
This factor suggests that each node computes the quotient of its own energy level and the aggregate energy remaining in the network. With this value each node decides if it becomes cluster-head for this round or not. High-energy nodes will more likely to become cluster-heads than low-energy nodes.

<u>Section 3-</u>**Energy-aware multi-hop, multi-path hierarchy (EAMMH)**

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.

EAMMH routing protocol was developed by inducing the features of energy aware routing and multi-hop intra cluster routing [7]. 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.

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) [8] 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.



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, 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,

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

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

$$E_{min} = E_{avg} /const$$

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.

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.

III. SIMULATION

(A).LEACH and proposed scheme are compared using MATLAB.
(B). Both LEACH and EAMMH are simulated using MATLAB.
(C). Finally the three protocols are compared for energy consumption and lifetime.

The parameters taken into consideration while evaluating EAMMH and LEACH are as follows.

1.Round Number vs Number of Dead Nodes

2.Round Number vs Average Energy of Each node.

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

1. Initial energy of nodes is same.
2. Nodes are static
3. Nodes are assumed to have a limited transmission range after which a another equation for energy dissipation is used.
4. Homogeneous distribution of nodes.
5. 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	200*200
Base Station Location	(150,100)
Channel Type	Wireless Channel
Energy Model	Battery
Transmission Amplifier Efs Emp	 10pJ/bit/m2 0.0013pJ/bit/m4
Data Aggregation Energy	5nJ/bit
Transmission Energy,E_{Tx} Receiving Energy,E_{RX}	50nJ/bit 50nJ/bit
Packet size	4000bits
CH proportion	P=0.2
Number of nodes	200
Initial energy	1 J

Results:

(A). LEACH and proposed scheme are compared using MATLAB.

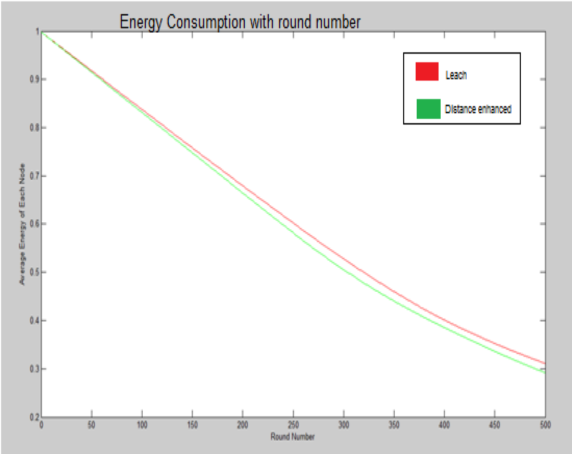


Fig. 2. Dissipation of energy in each node.

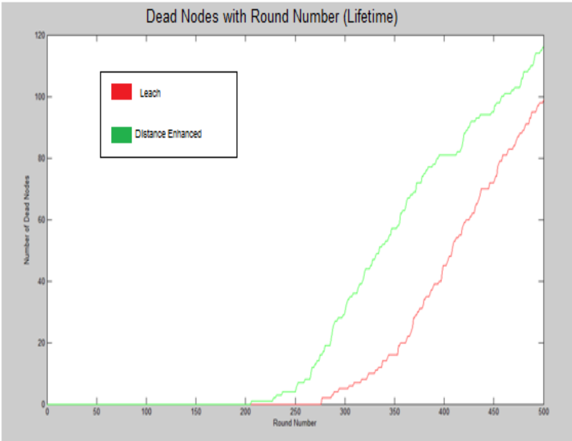


Fig. 3. Number of nodes dying with time

Since the goal is to maximize the lifetime of the network or to minimize the energy consumption, according to the new proposed formula the lifetime of the network will be greater than the Leach, as seen by the above graphs.(Fig.2,3)

The new proposed scheme obviously has future scope for betterment of increasing network lifetime. There will be more advancement in placing CH over the cluster to minimize energy conservation. The two new factors need further studies and practical implementation to understand their exact importance and efficiency.

(B). Both LEACH and EAMMH are simulated using MATLAB

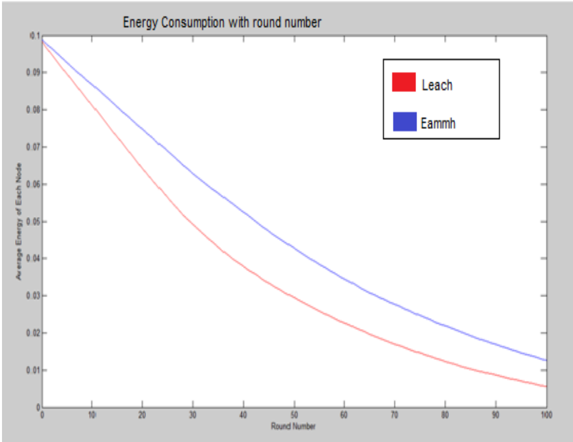


Fig. 4. Dissipation of energy in each node.

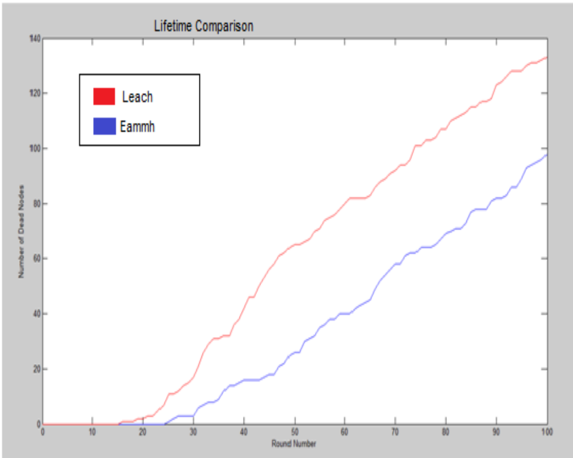


Fig. 5. Number of nodes dying with time

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(Fig.4) and the total number of dead nodes(Fig.5). However for a lesser number of total number of nodes, LEACH is found to perform better. 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. 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 23% and at 0.2 probability by a factor of around 46%.

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.

(C). Comparison of all three protocols using MATLAB

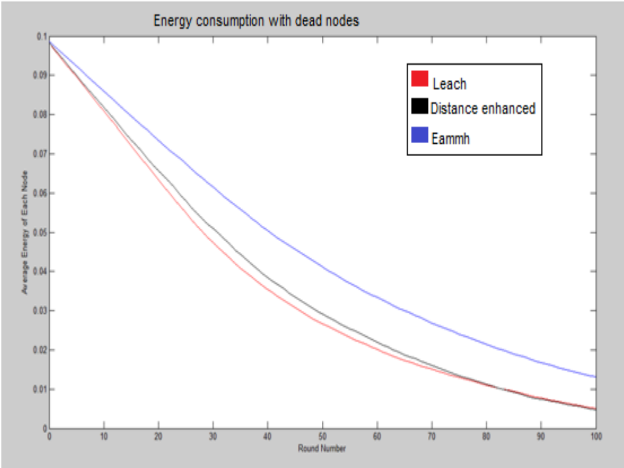


Fig. 6. Dissipation of energy in each node.

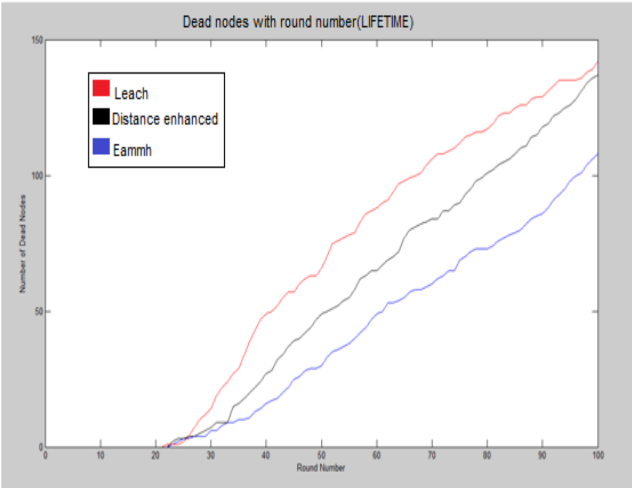


Fig. 7. Number of nodes dying with time

As seen from the above figures Eammh outperforms leach and the proposed scheme in terms of lifetime and using energy judiciously. Throughput, however, is almost the same when we talk of leach and scheme proposed. 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. Although proposed scheme is always better than leach as it takes into account the energy levels of each node and the distance of cluster head from the sensor nodes and the sink.

The following table briefly describes various properties of differences and similarities in these three protocol.

S.no	Property of comparison	Leach	Propos-ed scheme	Eammh
1.	GPS requirement	No	No	Yes
2.	Multi-path routing	No	No	Yes
3.	Multi-hop routing	Yes	Yes	Yes
4.	Failure recovery	Yes	Yes	Yes
5.	Lifetime	Low	Medium	High
6.	Energy Consumption	High	Medium	Low
7.	Energy Distribution	Uniform	Uniform	Uniform
8.	Cluster head selection	Random	Determini-stic	Random
9.	Throughput	Low	Medium	Medium

Fig. 8.Table of comparison

IV. CONCLUSION AND FUTURE WORK

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 a detailed description of Leach, distance enhanced leach(proposed) and Eammh protocols. The factors included in leach are there in the new proposed scheme. Hence the proposed one is improved compared to the previous LEACH algorithm in terms of energy conservation.

If we analyze the new mathematical formula for increasing network lifetime, we will find enhanced results with the new. The new proposed scheme obviously has future scope for betterment of increasing network lifetime. There will be more advancement in placing CH over the cluster to minimize energy conservation.

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