



Comparative Evaluation of LEACH based Routing Algorithms for Different Deployment Densities of WSN

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Abstract: This paper considered two algorithms namely LEACH and LEACH-C for evaluating their performance for different node densities. Wireless sensor network (WSN) is simulated using a MATLAB programming and power consumption algorithms take into consideration all aspects of power consumption in the operation of the node. Simulating different algorithm schemes on the same network system, same initial power sources, and routing protocol, a different lifetime and power consumption patterns are demonstrated for different node densities. The performance of LEACH-C routing protocol gives better results in lifetime as well as in network disintegration criterion for all type of node densities. However, higher densities with low covering area fair better for both algorithms.

I. INTRODUCTION

In WSNs, all nodes is fed by a small battery making energy saving as primary goal in designing[13] WSN structure with an objective of maximizing network lifetime as it is impractical to change or replace exhausted batteries. Two competing objectives in the design of WSNs are the capability to exchange large amount of data between nodes and base station and minimizing the energy consumption. We require efficient routing protocols in WSNs to manage these objectives. Therefore, many routing algorithms have been proposed due to the challenges in designing an energy efficient network [3-6]. Out of these hierarchical routing protocols greatly satisfy the limitations and constraints in WSNs. Hierarchical routing protocols consist of two layer architecture where one layer is responsible for cluster head selection and the other works for routing. A cluster head (CH) is a node which is responsible for collecting data from other nodes in the cluster, aggregating or pre-process data and then sending the processed data to the base station.

At present routing in WSNs is a hot research topic, with a limited but rapidly growing set of efforts being published. In this thesis we have conducted a survey of the various latest routing protocols in WSNs assuming underlying base of these protocol as LEACH [1]. There are various evolutionary based (GA, GP, EP, SI, PSO, ACO etc) approaches that are used in the wired networks as well as MANETs and WSNs for the routing optimization and Quality of Service [7-12]. When designing multipath routing algorithms, many parameters (e.g., path length and energy consumption of communication) also need be considered. The optimization of network parameters for WSNs routing processes might be considered as a combinatorial optimization problem.

We considered a comparison of the two routing protocols namely LEACH and LEACH-C. Although the performances of these protocols are comparable, some issues remain to be considered. Till now no research have been made for finding the optimized density for WSN applications which uses LEACH based protocols. This thesis will make an effort toward this.

II. ROUTING PROTOCOLS

The protocol plays important role, which can minimize the delay while offering high energy efficiency and long span of network lifetime. LEACH (Low Energy Adaptive Clustering Hierarchy) and PEGASIS (Power-Efficient Gathering in Sensor Information System) [18] are such typical hierarchical-based routing protocols. A detail survey of protocols is given in [2].

In LEACH the following steps are taken to transfer data.

1. First cluster heads (CHs) are selected randomly. This is called cluster head selection stage.
2. Then each node adds itself to a particular CH based on its distance with CH. This is called cluster formation stage.
3. Once cluster are formed then data is sent from non-cluster head node to CH and then CH to base station BS. This can be simulated by Energy consumption stage in simulator.

LEACH protocol is achieved based on many assumptions, such as assuming that all nodes in the network have the same structure and start with the same energy, and nodes can be aware of their residual energy, and so on. The LEACH improves a lot as compared to direct transmission of data but there remain several problems in this algorithm. Because the election strategy of cluster head is random, it may lead to misdistribution of cluster head

and imbalanced clusters. Thus cluster head load is not balanced consequently this may lead to high energy consumption and early death of individual cluster head.

Clustering is the main factor responsible for the energy conservation in LEACH algorithm. Main objectives of clustering are equal distribution of energy and equal distribution of nodes in space so that less energy is consumed and early deaths of nodes can be delayed. In LEACH both of these objectives can't be achieved. Further to achieve these objectives a Max-Energy LEACH was proposed, in which CHs are chosen based on residual energy instead of random selection. Max-Energy LEACH steps are shown below:

1. Cluster head selection stage: CHs are chosen based on residual energy. Highest energy nodes are selected to work as CH.
2. Cluster formation stage: similar to LEACH.
3. Energy consumption stage in simulator.

Max-Energy LEACH is able to achieve energy equi-distribution but not space equi-distribution because CH can be selected from one region only leading to large energy consumption by nodes to send data to CHs. The clustering algorithm while doing its work should pay attention toward the number of nodes a cluster is having. If we can equi- distribute all nodes to cluster then we assume that it may lead to better energy efficiency.

III. RESEARCH PROBLEM

The proposed work evaluates the performance of LEACH based algorithms for different deployment density for finding an optimal clustering scheme for a particular density parameter thus using less energy and more rounds of transmission to BS. Many improvements have been effected till now in LEACH [3-6], [15-17] but till now nobody has tried to find out the optimal deployment density. The proposed research is supposed to find out the optimal node density to increase the overall network life time of WSN. The plain aggregation of data is used for processing data. So, we set the following objectives for our research work: To implement energy efficient LEACH routing schemes such as random LEACH, LEACH-C to increase the network life, to evaluate different routing algorithms for different deployment density and to suggest routing algorithm for different densities.

IV. EXPERIMENTAL SETUP

To simulate LEACH, we have used randomly placed node networks for our simulations with similar parameters used in. We placed the BS at a far distance from all other nodes. For a 50m x 50m plot, our BS is located at (25,100) so that the BS is at least 50m from the closest sensor node. We use the same energy model as discussed in [1] which is the first order radio model. In this model, a radio dissipates $E_{elec} = 50$ nJ/bit to run the transmitter or receiver circuitry and $E_{amp} = 100$ pJ/bit/m² for the transmitter amplifier. The radios have power control and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. In our simulations, we used a control packet length k of 200 bits to send information from non-CH node to CH node. Size of packet length K of 6400 bits is fixed to send information from CH node to BS with these radio parameters, when d^2 is 500, the energy spent in the amplifier part equals the energy spent in the electronics part, and therefore, the cost to transmit a packet will be twice the cost to receive. It is assumed that the radio channel is symmetric so that the energy required to transmit a message from node i to node j is the same as energy required to transmit a message from node j to node i for a given signal to noise ratio (SNR).

Node Deployment and Node Density

For our experiments we have taken three types of areas and three different numbers of nodes. Areas are 50*50, 100*100 and 200*200 and number of nodes variation in each areas structure is 50, 100 and 200. So following densities can be obtained from these. In every combination every node is having 1Joule energy at initialization. BS is placed outside the network area. Its coordinates are taken as Length*0.5 and Breadth*2. Node Density is taken as number of nodes divided by area.

Energy dissipation

Energy dissipation for nodes is a factor of distance from BS. This decides whether to use free space or multipath transmitter. In our simulation we take a distance d_0 as $d_0 = \sqrt{E_{fs}/E_{mp}}$. This becomes the criterion for using free space energy or multipath energy scenario. Every cluster node consumes its energy for transmission of data in circuitry, receiving of data from non- cluster head nodes, data aggregation and data radiating to BS. While for non-CH nodes energy is consumed in sending data to CH.

V. SIMULATION RESULTS AND ANALYSIS

Two algorithms have been implemented in this paper. In first algorithm i.e. Random LEACH algorithm is implemented where CHs are selected randomly based on a probability function. We have taken this probability as 10%. It is further improved by using a fair distribution of energy by selecting maximum energy nodes to be CHs. This method is called LEACH-C. In this method a fix number of CHs are selected based on the number of nodes that are living. After selection of CHs, each non-CH nodes attach itself to a particular cluster thus making a cluster structure. We measure algorithms' efficiency by assessing total no. of rounds up to which network

survives. A network is assumed to be live if more than 25% nodes are alive with total energy greater than zero. A node is assumed live if its energy is more than 10% of initial energy. We have considered various combination of network with various numbers of nodes. Three network types and three combinations of nodes make total number of densities nine. Densities vary from 0.00125 to 0.08 per meter square. Out of these, two combinations of densities are same at Sr. No. 3, 4 & 6, 7 for LEACH and 12, 13 & 15, 16 for LEACH-C, making total number of unique densities seven.

Table 1: Experimentation Results

Algorithm	Sr. No.	Length (m)	Breadth (m)	Area (m ²)	Nodes	Density	Total Round	Total Energy(J)	% Residual Energy	Residual Energy(J)	Energy Consumed per round per node	First Node Dead	%of Round in which FND	Half node Dead	%of Round in which HND	Full Node Dead	No. Of Packets Sent to BS	Packet Loss	% Packet Loss	Packets sent per round per node
LEACH	1	200	200	40000	50	0.00125	70	50	15	8	0.6060	9	13	46	66	70	707	5	1	0.20
	2	200	200	40000	100	0.00250	80	100	12	12	1.1040	15	19	50	63	80	1453	7	0	0.18
	3	100	100	10000	50	0.00500	1050	50	16	8	0.0399	250	24	681	65	1050	10151	0	0	0.19
	4	200	200	40000	200	0.00500	96	200	13	25	1.8218	10	10	55	57	96	3254	18	1	0.17
	5	100	100	10000	100	0.01000	1000	100	17	17	0.0825	212	21	589	59	1000	18597	0	0	0.19
	6	50	50	2500	50	0.02000	4229	50	13	6	0.0103	2361	56	3649	86	4229	52343	0	0	0.25
	7	100	100	10000	200	0.02000	1256	200	15	29	0.1359	198	16	568	45	1256	41939	0	0	0.17
	8	50	50	2500	100	0.04000	4608	100	11	11	0.0193	2390	52	4027	87	4608	112834	0	0	0.24
	9	50	50	2500	200	0.08000	4547	200	12	23	0.0389	2379	52	3910	86	4547	224868	0	0	0.25
LEACH-C	10	200	200	40000	50	0.00125	192	50	7	4	0.2416	154	80	184	96	192	908	4	0	0.09
	11	200	200	40000	100	0.00250	178	100	7	7	0.5232	143	80	170	96	178	1674	5	0	0.09
	12	100	100	10000	50	0.00500	2345	50	10	5	0.0192	2309	98	2338	100	2345	11684	0	0	0.10
	13	200	200	40000	200	0.00500	205	200	7	13	0.9098	160	78	197	96	205	3887	15	0	0.09
	14	100	100	10000	100	0.01000	2275	100	10	10	0.0396	2243	99	2267	100	2275	22648	0	0	0.10
	15	50	50	2500	50	0.02000	9480	50	10	5	0.0047	9468	99	9476	100	9480	47379	0	0	0.10
	16	100	100	10000	200	0.02000	2344	200	10	20	0.0770	2304	98	2337	100	2344	46679	0	0	0.10
	17	50	50	2500	100	0.04000	9868	100	10	10	0.0091	9855	99.9	9864	100	9868	98635	0	0	0.10
	18	50	50	2500	200	0.08000	9879	200	10	20	0.0182	9863	99.9	9874	100	9879	197468	0	0	0.10

If we consider same type of densities for LEACH and LEACH-C it can be deduced that density only can't decide the energy dissipation factor. Network size has also to be taken into consideration. It is clearly shown from line number 3 & 4 and 6 & 7 of table no 1 that small network area with small number of nodes will result into better network life. Similar view can be taken for LEACH-C protocol for line number 12, 13 and 15, 16. In comparison graph of two algorithms only better results are shown in figure 1. In all of the combinations of density line number 6 for LEACH and line number 15 for LEACH-C again verify this fact. So from our above discussion it can be clearly deduced that we should prefer small area with medium number of nodes. If for a particular application if it is possible to have small areas deployment with multiple number of BS then it is preferable.

Another observation we have made about Network stability. The network stability is measured by counting the number of rounds in which first node is dead called FND, Half node dead called (HND) and Full node dead (FND). If more than 75% nodes are dead then it is assumed that network is dead and so criterion of full node dead occurs when 75% of nodes are dead. LEACH-C has performed better than random LEACH in every situation may be it is first node dead or half node dead or full node dead. In fact LEACH-C doesn't start

disintegrating until 99% of rounds. But once it starts disintegrating it accelerates very fast and within a span of 20 or 30 rounds all the nodes finish their energy. This shows that LEACH-C provides almost complete stability to the network. As far as density is concerned, higher density with small size of area perform better. Third criterion, we have taken for observation is network throughput which is measured using number of packets sent to BS and percentage packets loss and number of packets sent per round and per node. There are very few incidents of packet loss in the densities we have taken. Packets loss occurs specially when network size is very large and that is also in LEACH. There is no incidence of packet loss in LEACH-C. A very high number of packets are sent for high densities. So throughput is not a problem in high density network. LEACH sent more packets as compared to LEACH-C for the same densities however the number of rounds is double in LEACH-C. This disparity may be due to variable and high number of CH selection in LEACH. This may be the reason which explains the high ratio of number of packets per round per node in LEACH as compared to LEACH-C. Figures 1 to 3 show the energy efficiency of both algorithms w.r.t different deployment densities. Figure 1 shows the % residual energy after completion of network simulation. It clearly shows that LEACH-C is better than LEACH for all densities. One more fact from figure1 can be deduced that LEACH-C gives consistent performance for this attribute. Energy expanded per round which is depicted by figure.2 is better for high densities. In high densities best figure for number of rounds per node is given by density .02 with area 50*50. This again shows that better energy efficiency can be achieved by smaller areas..

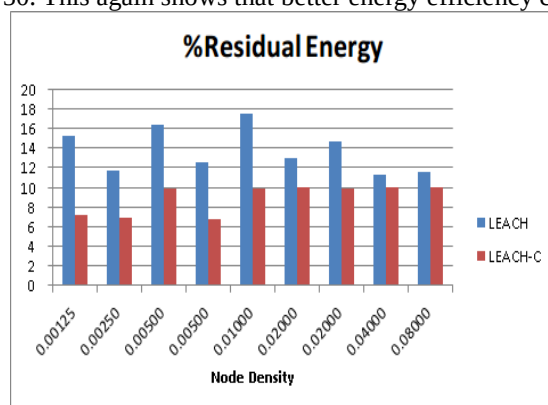


Fig. 1 Percentage residual energy for different densities

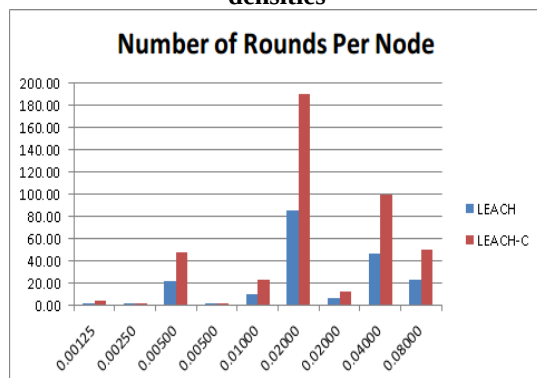


Fig. 2 Packets sent per round per node for different densities

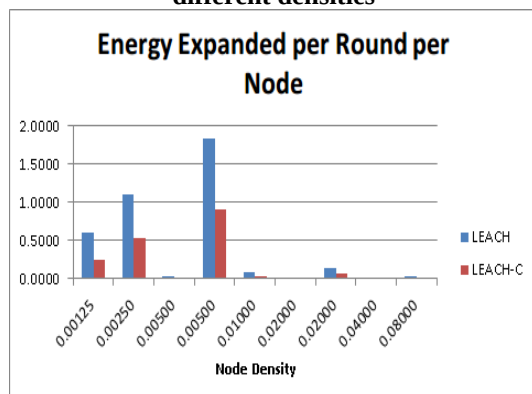


Fig. 3 Energy expanded per round per node for

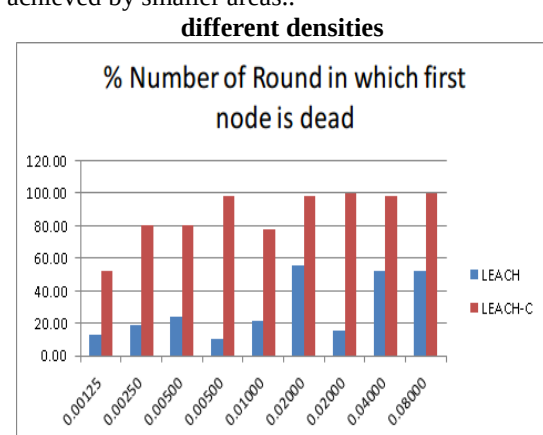


Fig. 4 % number of round in which first node is dead for different densities

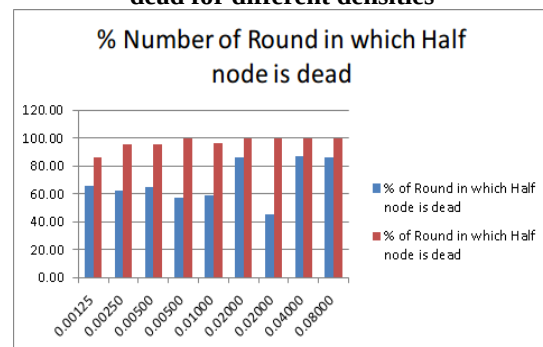


Fig. 5 %Number of rounds in which half node is dead for different densities

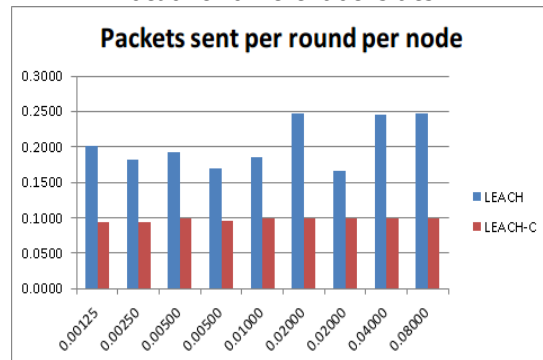


Fig. 6 Packets sent per round per node for different densities

Figure 4 shows the percentage number of rounds in which first node is dead which is given by FND in short. The FND for LEACH-C is much higher than LEACH for all densities especially for higher densities. Of all densities again density 0.02 with network 50*50 perform better than other densities. Similar facts can be deduced by figure 5 for half node dead concept. At last figure 6 shows the packets sent per round per node which is high for LEACH for all density perhaps due to uneven number of clusters made in LEACH

VI. CONCLUSION

We have measured performance of LEACH and LEACH-C algorithms for different node deployment densities in these experiments. Parameters for performance measurements are Residual Energy, Dead Nodes, Packets sent to BS. These parameters are shown in above figures and are plotted against number of rounds. If we consider residual energy and total number of rounds then LEACH-C perform better than random LEACH. The residual energy at the end of total number of round shows that LEACH-C most uniformly distributes energy dissipation among nodes.. For network integration or dead nodes criterion again LEACH-C outperforms other algorithm. However, for number of packets sent to BS criterion the LEACH outperforms LEACH-C. It may be due to uneven number of clusters made. High density deployment performance is better than low density performance specially densities to which low area is associated. This indicates that if it is possible there should be multiple aggregators can be deployed.

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