MG-LEACH: Multi Group Based LEACH an Energy Efficient Routing Algorithm for Wireless Sensor Network

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Abstract— **Limited energy resource is the major constraint associated with Wireless Sensor Network (WSN). As communication is the major cause of energy depletion in the network so designing of energy efficient routing algorithm is one of the key challenges that need to be address for extending life time of network. In this paper we have taken the deployed redundant nodes in to account which cover major fraction of energy depletion in the network. We presents energy efficient routing algorithm based upon the frame work of LEACH. A lot of redundant data is available in wireless sensor network due to widely deployed nodes. This redundancy of deployed nodes can be used as an advantage for increasing network life time. To check our presented scheme we simulate it using Matlab. Simulation results show that MG-LEACH had outperformed LEACH on the basis of Network life time.**

Keywords— **(WSN) Wireless Sensor Network , Limited Energy Design Challenges, , Routing algorithm, Redundant data, Network life time**

I. INTRODUCTION

Sensing, Processing (Computation), Radio and Power are the four basic components of a Sensor node which normally operates in unattended mode. Mostly sensor Nodes are equipped with non-rechargeable battery that is not replaceable in most of the application. In sensor Node, the main energy dissipation factor is radio communication [1] [2]. Due to limited computational and power capabilities of deployed sensor nodes a lot of research is ongoing to design routing algorithms which are simple so that energy utilization of a sensor nodes remain as minimum as possible.

Clustering based routing protocol is well known solution for enhancing network life time in WSN. In Clustering based routing algorithms a set of cluster-heads (CHs) are selected and the other member nodes are clustered around the CHs. Data sending to CHs from member nodes will be aggregated to reduce data redundancy by CHs before forwarding it to Base Station (BS). A lot of redundant data is available in wireless sensor network due to widely deployed Sensor nodes. This redundancy of deployed nodes can be used as an advantage for increasing network life time.

The Low Energy Adaptive Clustering Hierarchy (LEACH) [3], proposed by Heinzelman, Chandrakasan, & Balakrishnan, is renowned for its success in extending the lifetime of Wireless Sensor Networks. Number of variants for LEACH has been proposed in the recent years. Considering it as a classical routing protocol in Wireless Sensor Network, our proposal is also based on the framework of LEACH. The presented idea is equally valid for all the variants based upon LEACH which claim to prolong network lifetime by addressing the shortcomings associated with it. In the next paragraph we will present the detail explanation of LEACH.

In LEACH, Cluster-heads are randomly selected from deployed sensor nodes, biased by their experience in serving as Cluster-heads. It is a cluster based protocol adapting the stochastic model for randomized rotation of Cluster-heads for energy load balancing among sensor nodes in the network. It is based upon rounds in which sensor nodes transmit data to Cluster-head in their assigned time slot. Cluster-heads send aggregated data to Base Station by single hop transmission. The whole operation can be divided into two phases: set-up phase and steady state phase. The former is for clustering and the latter is for data transmission. The system repeats the clustering and transmission in every round.

A. Set-up Phase

During the setup phase, the CHs are selected based on an elective percentage of deployed nodes also by considering a factor that so far how many times an individual node performed the role of cluster-head. Each node from the group of deployed nodes ***G*** chooses a random number between ***0*** and ***1***. If the number is less than a set threshold ***T (i),*** the sensor node becomes a cluster-head for the existing round.

Where ***T (i)*** is calculated as

$$T(i) = \begin{cases} \dfrac{p}{1 - p \times (r \bmod 1/p)} & \text{If} \quad i \in G \\ 0 & \text{Otherwise} \end{cases}$$

Where ***P*** is configurable parameter specifying the ratio of CHs and total number of deployed nodes ***N***. ***r*** is the round index and ***G*** is the set of nodes not perform as CHs in last ***1/P*** rounds.

Once the percentage of nodes has elected themselves to be Cluster-heads they broadcast an advertisement message (ADV). Each non cluster-head node decides its cluster for current round by choosing the Cluster-head that requires minimum communication energy, based on the received signal strength of the advertisement from each Cluster-head. After choose cluster, it informs the Cluster-head by transmitting a join request message (***Join-REQ***) back to the Cluster-head. The Cluster-head node sets up and broadcast a ***TDMA*** schedule to all member nodes. It completes the setup phase.

B. Steady State Phase

Steady Sate operation is broken into frames, where nodes send their data to the Cluster-head at most once per frame during their allocated slot. Cluster-Head sends the aggregated data to Base-Station (BS) in one hop manner. LEACH is based on rounds and system repeats the clustering and transmission for each round.

LEACH outperforms earlier existing protocols e.g. direct communication protocol, minimum-transmission-energy protocol and static clustering protocol in Wireless Sensor Network. Due to various redundant nodes, which observe similar events much more redundant information is available in wireless sensor network which is subsequently cancelled during aggregation process performed by Cluster-heads. Our aim in the proposed idea is to utilize the redundant deployed nodes and take them as an advantage for prolonging network life time.

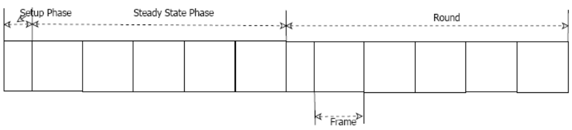

Fig-I

Rest of paper is organized as, Section II covers problem statement and discusses the proposed idea in detail, Section III covers system and energy model, Section IV includes simulation results and analysis while section V concludes the paper.

II. PROBLEM STATEMENT

Routing in WSN that is a primary task for transferring of data from sensor node to Base-Station (BS) when any physical event occurs at sensor node should be energy efficient so that it can surmount related power constraints. As discussed in last section LEACH is energy efficient cluster based routing protocol used in Wireless sensor network.

In LEACH "***n***" number of nodes deployed randomly is a part of a group represented here as ***G***.

$$G = N_1 + N_2 + N_3 \ldots\ldots N_n$$

Where: N_1 ***to*** N_n are the deployed nodes in an area A. In each round group ***G*** excludes nodes that perform a role of Cluster-head in the last 1/p round. In ***G*** there are several nodes that exist so closely in the adjacent area A_1 that they monitor the same event E_1 thus provide the redundant information which is discarded by cluster-head while aggregating the whole data collected from the member nodes before transmit it to Base Station (BS).

We assume that if the whole Square field is divided in to large number of smaller areas $A=A_1+A_2+A_3\ldots A_N$ then such redundant information is a major fraction of energy depletion in the Wireless Sensor Network. We have used this deficiency as a support in our proposed algorithm MG-LEACH. In MG-LEACH, deployed nodes are divided in to Sub Groups ($G_1\ldots G_k$) depending upon their locations. Number of groups are mainly depends upon Node density. These groups are created by the Base-Station at the time of deployment and after every ***"x"*** rounds. This is an additional step used in our proposed algorithm before setup phase and steady state phase and known as Set building phase.

MG-LEACH is comprises of three steps. Two of them are the same as used in LEACH e.g. Setup phase and steady state phase. Before set up phase, set building phase is used at the time of deployment and after every ***"x"*** rounds by BS.

At the time of random deployments of node, each node that is equipped with GPS sends location information to BS directly. BS will use the provided information for every Set building phase. As it has been done only once so it does not consume too much energy.

Set up phase and steady state phase is same as used in LEACH and works in every group separately. These groups do not work simultaneously but on alternate basis e.g. one at a time as per set duty cycle by BS. If Network comprised by Sub Group G_1 is working Nodes of Sub Group G_2 will be in sleep state. The duty cycle is set by BS at the time of Set-building phase. Minimum group of nodes construct at the time of deployment is two but mainly depends upon node density in the entire network.

We have simulated the MG-LEACH and find it much more efficient than LEACH. We have checked the performance by taking different initial energy of deployed nodes also with different value of *p*. MG-LEACH is performed much better than LEACH as increased Network lifetime considerably. We can use this proposed algorithm with any variant based on LEACH [4] [5] [6] in which set threshold has been modified either by addressing the shortcomings in the form of considering residual energy as well as other parameters.

III. SYSTEM AND ENERGY MODEL

Consider a system including ***N*** sensor that are uniformly deployed in an area ***A***. We make some assumptions about the sensor nodes and the underlying network model:

For simulating MG-LEACH, Consider a system including 300 sensor Nodes that are randomly distributed in a square area 200 x 200. We make some assumptions about the sensor nodes and the underlying network model:

1. The Network is homogeneous that all nodes have equal initial energy at the time of deployment.
2. The Network is static and nodes are distributed randomly
3. There exists only one base station, which is placed in the middle (100,100)
4. The Energy of sensor nodes cannot be recharged after deployment of network.
5. Sensor nodes are equipped with GPS so aware about their location
6. No power and computational constraints in Base-Station (BS)
7. Deployed Nodes can use power control to vary the amount of transmission power, which depends on the distance to the receiver

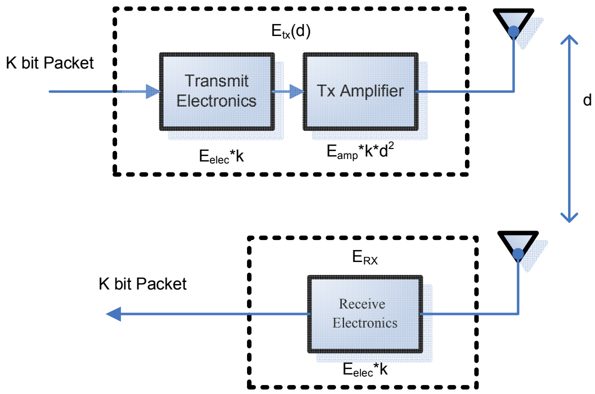

Fig-II

We have used the same Radio energy model as use in [3] block diagram is presented in Fig-II, which uses a 914 MHz radio. The node radio energy consumed in transmission is

$$E_{Tx}(k,d) = \begin{cases} k \times E(elec) + (k \times E_{fs} \times d^2) & d < d_0 \\ k \times E(elec) + (k \times E_{mp} \times d^4) & d > d_0 \end{cases}$$

Where, ***k*** is the number of bits transmitted, ***d*** is the distance between transmitter and receiver and d_o is the constant referred as crossover distance. Depending on the transmission distance both the free space E_{fs} and the multi-path fading E_{mp} channel models are used.

For receiving the ***k*** bit message the node radio consumes

$$E_{Rx}(k) = k \times E(elec)$$

As communication cost is considered to be much larger than computational cost, so the contribution of computations to the energy consumption is considered to be negligible in this analysis. The assumed energy required for running the transmitter and receiver electronic circuitry E(elec) is 50nJ/bit and for acceptable SNR required energy for transmitter amplifier for free space propagation E_{fs} is 100pJ/bit/m^2 and for two ray ground E_{mp} is 0.0013pJ/bit/m^4. The crossover distance d_o is assumed to be 87m. All important parameters of simulation have been specified in table-I.

Table 1: Simulation Parameters

E_{fs} = 100pJ/bit/m2	Transmit amplifier energy dissipation of free space model
E_{mp} = 0.0013pJ/bit/m4	Transmit amplifier energy dissipation of two ray model
EDA = 5nJ/bit/signal	Data aggregation energy dissipation
Pidle = 0J	Energy dissipated in Idle mode
Psleep = 0J	Energy dissipated in sleep mode
d_o = 87m	Crossover distance
E_o = 0.5 & 2 Joule	Initial Energy of Deployed Nodes
G_1	Group-1 of Nodes depending upon Location
G_2	Group-2 of Nodes depending upon Location
Pke_size = 4000 Bytes	Data packet Size
rmax = 8000	Max Number of Rounds

Table-I

IV. SIMULATION RESULTS AND ANALYSIS

We simulate MG-LEACH algorithm in MATLAB to set up a comparative analysis both for LEACH and MG-LEACH proposed in this paper. For the experiment, the random network of 300 Nodes is used. The Base-Station was placed in centre at, location (x=100, y=100). The bandwidth of the channel was set to 1 Mbps. Each data message was 4000 bytes long along with header packet which is 25 bytes long. The radio electronics energy was set to 50 nJ / bit and the radio transmitter energy (E_{fs}) is set to 100pJ/bit/m2 for distances less than 87 and 0.0013pJ/bit/m4 for distances greater than 87m The energy for performing computations to aggregate data was set to 5 nJ / bit / signal. These parameters are recapitulated in Table-I. In order to get improved and quite accurate comments of the algorithm, we establish the same simulation scene for both LEACH and MG-LEACH. For energy model, we assume that each node begins with equal energy and an unlimited amount of data to send to the base station. Once a node runs out of energy, it is considered as dead and can no longer transmit or receive data. The value of ***k*** in set building phase is taken as 20.

Initial energy for each node used in simulation is 0.5 Joule, while the experiment is repeated with 2 Joule energy both for LEACH and proposed MG-LEACH.

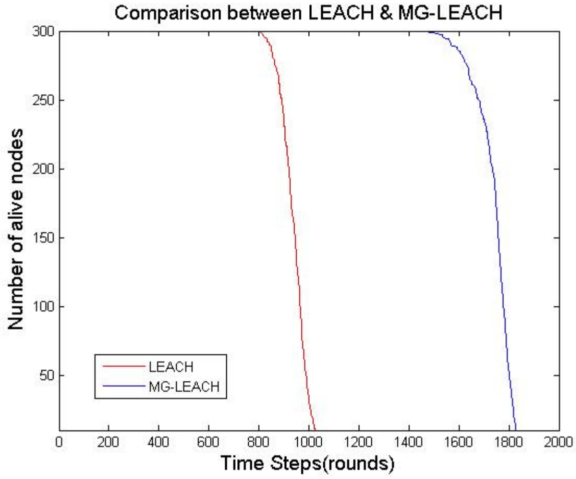

Fig-III

Fig-III illustrates the simulation result that demonstrate relative behaviour of both discussed algorithms with parameters values n =300, p= 0.1, E_o = 0.5 J. It demonstrates Alive Nodes that is taken at y-axis for different time stamps (Rounds) that is taken on x-axis. MG-LEACH performs significantly better than LEACH by extending life time of network.

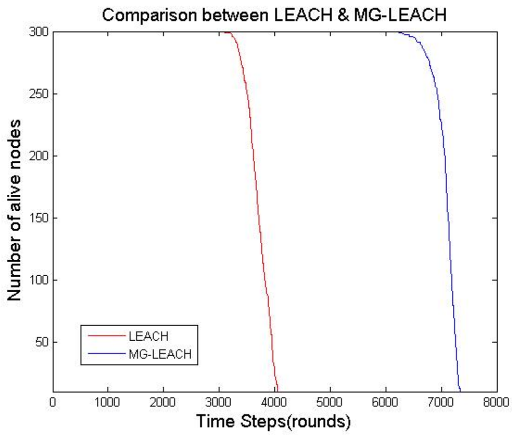

Fig-IV

Fig-IV shows the simulation result showing relative behaviour of both discussed algorithms with parameters values n =300, ***p***= 0.1, $\boldsymbol{E_o}$ = 2 J.

Fig-V gives simulation results when the values of used parameters is set to ***n*** =300, ***p***= 0.05, $\boldsymbol{E_o}$ = 0.5J

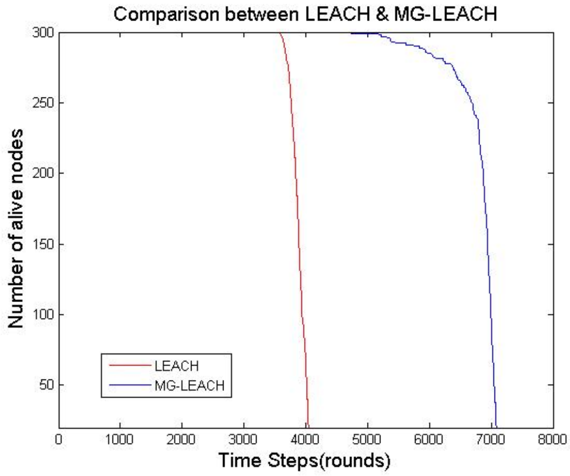

Fig-V

Finally Fig-VI provides behaviour of both discussed routing algorithms, when the values of used parameters is set to ***n*** =300, ***p***= 0.05, $\boldsymbol{E_o}$ =2 J.

Three parameters, the times of the first node dies (FND), the times of the last node dies (LND) and the time of half nodes dies (HND), are considered for measuring and examining the performance of both algorithms for different values of Initial Energy $\boldsymbol{E_o}$ and ***p*** are shown in table-II and table-III.

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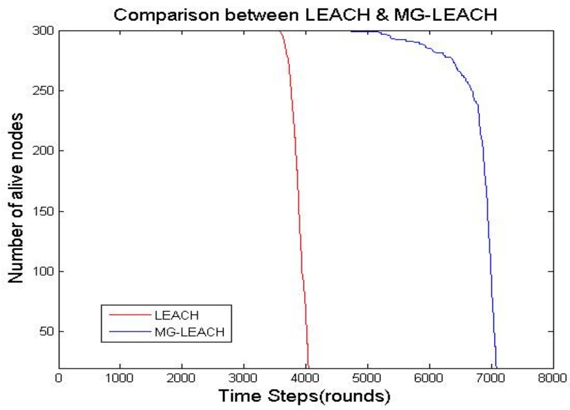

Fig-VI

Table-II Comparative analysis of Network Life Time for p=0.1

Initial Energy		FND	HND	LND
	LEACH	809	944	1023
0.5 J	MG-LEACH	1481	1757	1830
	Percentage	83%	86%	79%
	LEACH	3100	3716	4062
2 J	MG-LEACH	6229	7124	7335
	Percentage	101%	92%	81%

Table-II

Table-III Comparative analysis of Network Life Time for p=0.05

Initial Energy		FND	HND	LND
	LEACH	802	968	1033
0.5 J	MG-LEACH	1235	1693	1754
	Percentage	54 %	75%	70%
	LEACH	3578	3890	4046
2 J	MG-LEACH	4837	6939	7087
	Percentage	35%	78%	75%

Table-III

From table-II and table-III, we can conclude that the network life time is increased considerably. It is an effective way of enhancing the network life time by utilizing redundant nodes present in the network. This technique can easily be utilized for all other clustering base algorithms.

V. CONCLUSTION AND FUTURE WORK

Energy constraint is one of the major research topics in Wireless Sensor Network. Routing consumes the largest amount of energy in WSN so used routing protocol should be energy efficient. Number of variants which based upon frame work of LEACH has been proposed in the last decade. All of them claim to address associated shortcoming of protocol for enhancing network life time. WSN contains plenty of redundant information. The redundant information that are provided by redundant nodes monitoring similar event in the network is discarded by cluster-head before forwarding it to Base-Station. Proposed MG-LEACH is using same redundant nodes present in the system that locate in the same region for enhancing life time of the whole network. Simulation results show enormous increase of network life time. This is a classical idea which can further enhance the network life time by addressing other shortcomings of LEACH. We use this idea on LEACH frame work as it is classical distributed clustering based routing protocol that contains hundred of variants. This idea is equally supportive and functional for other energy efficient algorithms discussed in literature. Our future work will be based upon it. In our future work we will try to apply the same idea on other clustering based routing protocols. Finding out the optimal value of "*k*" in set building phase is very important and our study will also focus it in future.

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