MGI-LEACH: Multi Group LEACH Improved an Efficient Routing Algorithm for Wireless Sensor Networks

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Abstract—**The wireless sensor networks (WSN) are composed by a large number of micro sensors that are randomly deployed in an area of interest to supervise or monitor various phenomena (temperature, pressure, humidity ..). The wireless sensor nodes are typically powered by non-rechargeable batteries which makes them constrained in terms of energy. As communication energy represents the largest part of the energy consumed in sensor nodes [1], so energy efficient routing is one of the main issues to prolong lifetime of wireless sensors networks.**

This paper proposes a hierarchical routing protocol called MGI-LEACH for homogeneous wireless sensor networks based upon the framework of LEACH such as the network is divided into multi groups to prevent the concentration of cluster head in a particular area of the network, and the cluster head selection is based on high residual energy and a short distance from the base station (BS) in each communication round, which minimizes the communication energy of wireless sensor nodes, and hence, increases lifetime of the whole network.

Simulations using MATLAB software show improved lifetime in different levels of Grouping compared to the classical algorithm LEACH.

General Terms—**Algorithms .**

Index Terms—**Wireless Sensor Networks, Network Lifetime, Sensor Node, grouping .**

I INTRODUCTION

A wireless sensor network is composed by a large number of micro sensors called nodes communicating with each other through radio links independently and randomly distributed over an area of interest. Sensors are powered by batteries, which is impossible to get recharged after deployment. As a large part of energy is consumed when communications are established, so it is imperative to develop an energy efficient routing protocol, taking into account the constraints by these sensors.

In flat routing, when the number of nodes increases, the traffic control dominates real communication. This increases the latency and overload routing tables. To overcome these limitations, hierarchical routing protocols have been introduced. These protocols allow the reduction of the number of messages transmitted, thus reducing energy consumption of sensor nodes. Furthermore, the transmission of data to BS via a single hop becomes impossible when the size of the network increases. To remedy this problem, the multi-hop routing is the mode of communication adopted to transmit data to the BS.

In this paper, we propose an energy efficient routing protocol based on the principle of clustering algorithm. We have modified the LEACH(Low-Energy Adaptive Clustering Hierarchy protocol as the CH selection is done by the predictive energy and the smallest path to BS.

The remainder of the paper is structured as follows: Section 2 describes The Sensor Node. In section 3 We propose an overview of LEACH protocol's. Section 4 describes problem statement, section 5 describes The Proposed Routing Protocol Algorithm. Simulation Setup and Scenarios and Simulation Results are interpreted in section 6 and 7. We draw the conclusion in Section 8.

II THE SENSOR NODE

2.1 Sensor Node Architecture

Principally a wireless sensor node consists of four basic units [2] (See Figure 1):

- Acquisition Unit: converts a physical signal into an electrical one.
- Processing Unit: responsible for all arithmetic operations and storage.
- Communication Unit: consists of a transmitter / receiver for communication between network nodes using a radio channel .

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- Power supply unit (battery): it powers the units that we have mentioned and it is generally not rechargeable or replaceable.

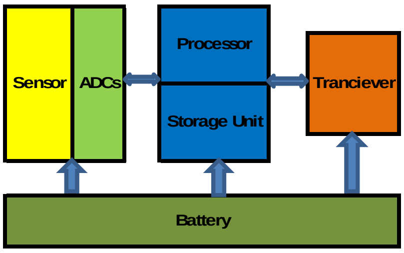


Fig 1: The components of sensor node

Based on the architecture above, the energy consumed by a sensor node is mainly due to the communication unit, it represents the greatest portion of the energy consumed by a sensor node .

III Overview of LEACH Protocol's

We start by giving an overview of LEACH protocol's which partitioned the network into groups (clusters). Nodes transmit their data to representatives of groups called cluster heads (CH), which in turn send the data after processing and aggregation to the desired destination or base station (See Figure 2).

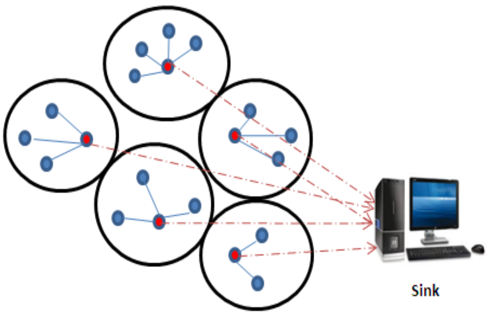
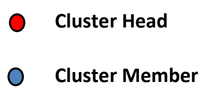


Fig 2: Clustering nodes in LEACH protocol's



In LEACH, the nodes self-elect to be CHs. They are based on the desired percentage of CHs and the number of rounds during which a node took the role of CH. Thus, a node n takes a random value between 0 and 1. If this value is less than the threshold T (n), the node becomes CH. The CHs inform their neighbors of their election. Each normal node decides to join the nearest CH[7].

$$T(n) = \begin{cases} \frac{P}{1-P*(r*mod\ 1/P)} & si\ (n \in G) \\ 0, & si\ non \end{cases} \quad (01)$$

Where :

P : The percentage of the cluster head nodes in all nodes.

r : The number of rounds.

G : The collections of the nodes that have not yet been head nodes in the first 1/P round.

The optimal number of clusters is in general 5%.

3.1 Advantages

- Self-cluster configuration is independent of the BS (distributed algorithm).
- The data are aggregated to reduce the amount of information transmitted to the BS.
- Energy consumption is shared across all nodes, thus extending the lifetime of the network.

3.2 Disadvantages

- The further away from the BS, CHs die more quickly than those that are close to the BS.
- Without justifying their choice, the authors fix the optimal percentage of CHs for the network to 5% of the total number of nodes. However, the topology, the density and the number of nodes may be different in other networks.
- The use of probabilistic model to select CHs can generate CHs too close in an area of the network.
- The remaining energy and distance of nodes are not taken into account when electing CHs, it can give the CH role to node with discharged battery.

IV Problem Statement

The radio energy dissipation model used in our protocol (See Figure 3) is called first order radio model [3]. Each sensor node consists of a transmitter and receiver electronics. Energy is dissipated when nodes transmit or receive data.

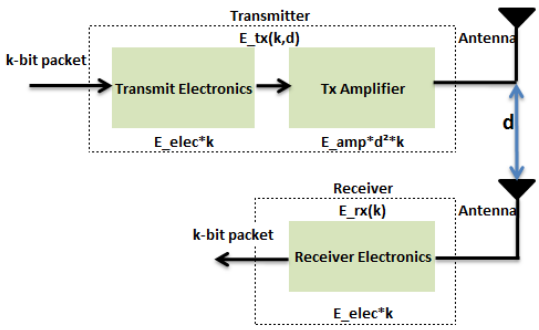


Fig 3: Radio energy dissipation model

The node radio will consume the following E_Tx amount of energy to transmit a k-bits packet over distance d [4]:

$$E\_Tx_{(k,d)} = \begin{cases} E_{elec} * k + E_{fs} * d^2 * k & \text{if } d < d_0 \\ E_{elec} * k + E_{amp} * d^2 * k & \text{if } d > d_0 \end{cases}$$

(02)

And $\mathbf{E\_{rx}}$ amount of energy to receive this k-bits packet:

$$E\_rx_{(k)} = E_{elec} * k \quad (03)$$

Where ,

E_tx (k,d) : energy dissipated per bit at transmitter;

E_rx (k) : energy dissipated per bit at receiver;

Efs , Emp : amplifier parameters of transmission respectively in free space (with d2 power loss) and multi-path fading (with d4 power loss) channel models;

E_{elec} : Energy dissipation to run the radio ;
k : number of transmitted data bits;
d : distance from a sender node to a receiver node or BS.
d_0 : is the threshold distance between multi-path fading model and the free-space model.

$$d_0=\sqrt{\frac{E_{fs}}{E_{amp}}} \quad (04)$$

Considering a wireless sensor network that is composed of N nodes randomly deployed over a square area M * M.

We will calculate the total energy consumed during one round of LEACH routing protocol :

$$E_{round} = \sum_{i=1}^{L}(E_{CHi}) + \sum_{j=1}^{N-L}(E_{NCHj}) \quad (05)$$

where $\mathbf{E_{CHi}}$ is the consumed energy when CH of the cluster labelled i, receives, aggregates, and transmits data to the base station. Whereas $\mathbf{E_{NCHj}}$ is the consumed energy by a non CH labelled j, and L is the total number of cluster heads.

the $\mathbf{E_{CHi}}$ is defined by:

$$E_{CHi}= E_{CHtoBS\,i} + E_{Recepti} + E_{Aggregi} \quad (06)$$

Where,

$$E_{CHtoBS\,i}=k.\ E_{elec} + k.\ E_{mp}.d^4_{toBSi} \quad (07)$$

$$E_{Recepti} = |Si|.k.\ E_{elec} \quad (08)$$

$$E_{Aggregi} = |S_i|.k.\ E_{DA} \quad (09)$$

With :

- $E_{CHtoBS\,i}$ is the energy required for the cluster head of the cluster labeled i to transmit its data to the base station.
- $E_{Recepti}$ is the total energy consumed when the cluster head of the cluster i receives data from its cluster member.
- $E_{Aggregi}$ is the total energy needed, by the CH of the cluster i, to process data.
- $|S_i|$is the cardinal of the set enclosing nodes of the cluster labeled k.

Hence,

$$\sum_{i=1}^{L}(E_{CHi})=\sum_{i=1}^{L}\left(E_{CHtoBS\,i} + E_{Recepti} + E_{Aggregi}\right) = L.k.\ E_{elec} + L.k.\ E_{mp}\ .d^4_{toBS} + N.k.\ E_{elec} + N.k.\ E_{DA} \quad (10)$$

in the same way the $\mathbf{E_{NCHj}}$ is defined by:

there are N-L nodes non CHs, assume that l number of the latter work on multi-path fading mode while the others operate on the free space mode.

$$\sum_{j=1}^{N-L}(E_{NCHj}) = (N-L).k.\ E_{elec} + (\sum_{i=1}^{l} d^4_i).k.\ E_{mp} + (\sum_{j=1}^{N-L-l} d^2_j).k.\ E_{fs} \quad (11)$$

where $d_j < d_0$ and $d_i \geq d_0$

E_{round} is minimal if the following term :

$$L.\ E_{mp}\ .d^4_{toBS} + (\sum_{i=1}^{l} d^4_i).\ E_{mp} + (\sum_{j=1}^{N-L-l} d^2_j).\ E_{fs} \quad (13)$$

is minimal. However, it is known that the amplifier energy in a multipath fading channel model is greater than the amplifier one in a free space model (i.e $d_j < d_0 \leq d_i$ and $E_{fs} < E_{mp}$)

thus, to minimize the formula given in equation (13), all non CH nodes must operate in a free space model, it means direct communication between CHs and Cluster members .

And to minimize the term L.k. $E_{mp}\ .d^4_{toBS}$, the communication between cluster heads and the base station must be in multi-hop routing, thus multi hops-LEACH protocols is adapted.

V The Proposed Routing Protocol Algorithm

To overcome the constraints of LEACH protocols, we propose a new routing protocol called MGI-LEACH which consists, to partition the network into several equal areas A=A1+A2+A3….AN.

Deployed nodes are divided into sub groups (G1+G2+G3….GN) in which the modified LEACH protocol is applied. Number of groups mainly depends upon nodes density. These groups are created by the BS at the time of deployment.

The CHs selection in each group Gi is based on the selection of the cluster head with a high residual energy and a short distance from the base station in each communication round [5] .

In our protocol MGI-LEACH the threshold T(n) of LEACH protocol becomes :

$$T(n) = \begin{cases} f(cur).\left[\frac{p}{1-p.\left(r.mod\frac{1}{p}\right)} + p.h(D_{toBS})\right], & n \in Gi \\ 0, & n \notin Gi \end{cases} \quad (14)$$

With :

$$f(cur) = \frac{E_{cur}}{E_{ave}} \quad (15)$$

$$h(D_{toBs}) = \frac{D_{max}-D(n)}{D_{max}-D_{min}} \quad (16)$$

where ,

E_{cur} : the current energy of node.
E_{ave} : the average remaining energy of all nodes in the current round.
D_{max}, D_{min} :present the maximum and minimum of the distance between all nodes and the base station respectively.
f(cur) : function which measures the current residual energy of the node.
$h(D_{toBS})$: function which measures the distance between elected node and base station.

With this new threshold formula T(n) advantage is given to nodes that have a large amount of residual energy and close to the base station to be cluster head.

After the cluster head formation, normal nodes should optimize their choice to join optimal cluster head based on the cost function, this is done as follows :

- If the node is closest to the base station, no optimal cluster-head will be selected and it will directly send its data packages to the base station.
- Otherwise, the non-cluster head node chooses the optimal one among the candidate cluster-heads according to the cost function.
- the cluster head whose cost function is minimal, will be chosen as the optimal cluster-head.

The cost function of the normal node ni joins in the cluster with the cluster-head cj. This can be shown as:

$$cost(i,j) = \frac{d_{ij}}{d_{max}} . \frac{E_{cur(i)}}{E_{cur(j)}} . \frac{D_{(i)}}{D_{ave}} \qquad (17)$$

Where ,

d_{ij} : the distance from the node ni to cluster-head cj.

d_{max}:the maximum of the distances from ni to the candidate cluster-heads.

E_{cur} (i), E_{cur}(j) : the current residual energy of node ni and cluster-head cj .

$D_{(i)}$: the distance from cluster-head cj to the BS.

D_{ave} : the average distance between cluster-heads and the BS .

VI SIMULATION SETUP AND SCENARIOS

This paper uses Matlab7.14 as a simulation platform to emulate 200 immobile sensor nodes randomly deployed in 200m x 200m square area, the BS is fixed and located at (0,0) position. The coordinates of X and Y are measured in meters.

6.1 Simulation Parameters

Simulation scenarios in this paper are:

1. Sensor nodes are randomly distributed in a square region;
2. The energy of nodes which is limited, may be homogeneous. The nodes location is fixed after deployment;
3. Nodes communicate with base station via single-hop or multi-hops.
4. Sensor nodes are equipped with GPS to make them aware of their location.

TABLE 1.
SIMULATION ENVIRONMENT PARAMETERS

Parameter	Quantity
Nodes number	200
Rounds number	600
Node initial energy	2 joules
d_0	87.7 m
Packet size (k)	100 byte
Rounds number	200
BS location	(0,0)
E_{elec}	50 nJ/bit
E_{DA}	5nJ/bit
E_{fs}	10 nJ/bit/m²
E_{mp}	0.0013pJ/bit/m⁴

6.2 Simulation Scenarios

We propose to compare our proposed method MGI-LEACH to the classical algorithm LEACH with the same simulation parameters mentioned in Table 1. With which our method is tested for three levels of grouping (one, two and three group formation) (See Figure. 4 to 6).

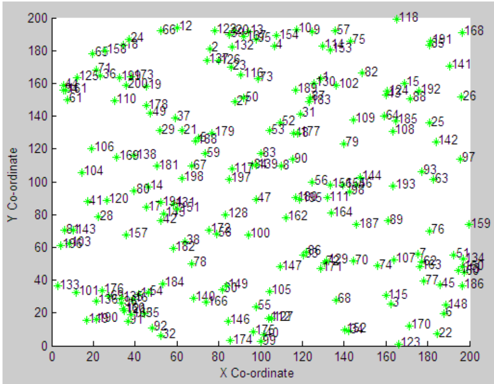


Fig 4 : One group formation

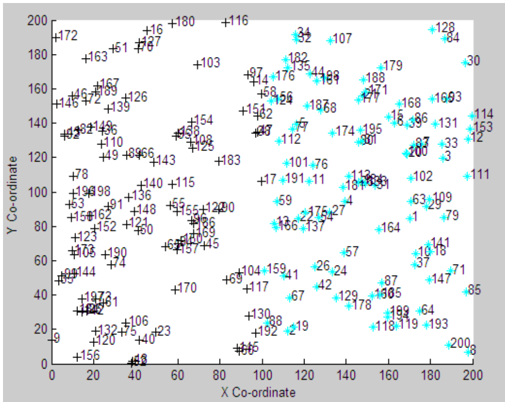


Fig 5 : Two groups formation

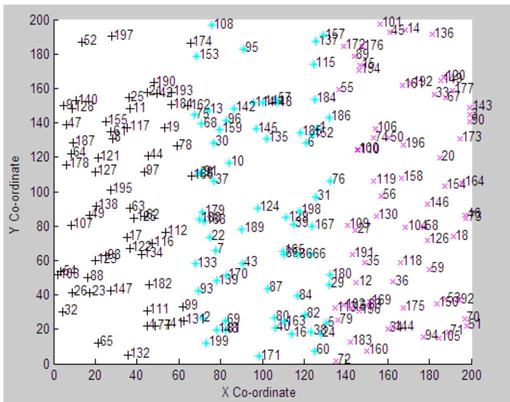


Fig 6 : Three groups formation

Using simulation parameters mentioned in Table 1, using the first order model equation of energy dissipation in sensor nodes, and applying the criteria to select the cluster heads and cluster formation to evaluate both MGI-LEACH and LEACH algorithms for one, two and three group formation. The cluster head(s) formed aggregates the data received from normal nodes and transmits them to the next hop cluster head closer to the BS or to the BS depending on the cluster formation and the shortest distance between the cluster head and the BS. At every transmission or reception made, energy reduction occurs for every node, thereby cluster head rotation is utilized to extend the lifetime of the WSN.

VII Simulation Results

It can be proved that the proposed MGI-LEACH routing technique offers good results when compared to the classical LEACH. We investigated the advantage of the proposed technique by comparing the time in which the first node dies during the 600 rounds of simulation (network lifetime) to that of LEACH routing technique.

The network lifetime is shown in Figure 7. We observed that the first node dies faster in LEACH since all nodes tend to send captured data via their selected cluster head per round to the BS.

From Figure 7, we observe that the LEACH technique had an estimated lifetime of 20 rounds, MGI-LEACH for one group formation had an estimated lifetime of 80 rounds, MGI-LEACH for two group simulation had an estimated lifetime of 100 rounds and MGI-LEACH for three group simulation had an estimated lifetime of 150 rounds. The progressive increase of network lifetime employed by our proposed technique offers efficient energy usage for each node in the entire network.

The impressive increment in lifetime of the network from our proposed hierarchical technique is seen as a result of efficient routing decision and optimization of energy in cluster head selection of each cluster formed.

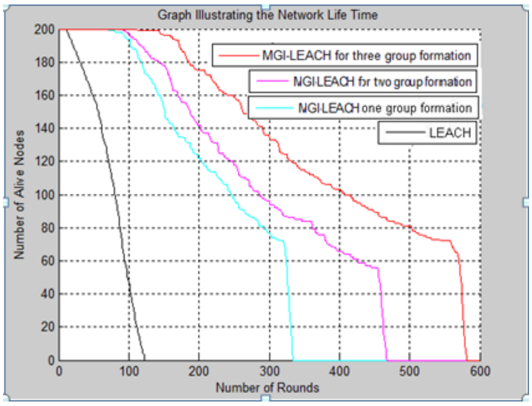


Fig 7: Network lifetime graph (number of alive nodes for a particular round of simulation) in one, two & three group formation

VIII Conclusion

In this paper we have proposed MGI-LEACH, an energy efficient routing technique for homogeneous wireless sensors based on LEACH technique. In which the network is partitioned into small equal areas to avoid the concentration of cluster heads in particular parts of the network. The cluster head selection is based on the residual energy prediction, for each sensor node and the shortest distance from sensor node to base station, this is the role of threshold T (n). Normal nodes choose their optimal cluster head in terms of energy using cost function. The simulation part indicates by comparing the time in which the first node dies, the MGI-LEACH performance is better than that of the classical LEACH.

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