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Improving Energy Efficiency of Wireless Sensor Network with the Fusion of Graph Theory and Genetic Algorithm

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Abstract: In Wireless sensor network (WSN), Energy is a scarcest resource of sensor nodes and it determines the lifetime of sensor nodes. These sensor nodes are battery powered devices. These small batteries have limited power and also may not easily rechargeable or removable. Also due to long distance between sensor nodes and base station in WSN, large amount of energy drains out .Thus energy is a big factor in WSN to be considered. Maintaining energy levels of sensor nodes is a crucial research topic. Various techniques have been invented to optimize energy level of sensor nodes of WSN. As genetic algorithm is best clustering technique and graph theory is best for finding the shortest path for routing data. Thus this paper combines both techniques in order to propose a new simple and efficient approach that significantly improves the energy efficiency of WSN. The proposed approach is divided into three phases. First phase make clusters and perform cluster head election using genetic algorithm. Second phase calculate distance using coordinates of nodes and calculate the shortest path for routing data. Finally transmission of data takes place. Performance results show that the proposed approach can significantly minimize the overall energy cost utilized in data transmission and thus enhances the network lifetime.

Keywords: energy, wireless sensor network, clustering, network lifetime, data aggregation, genetic algorithm, graph theory.

I. INTRODUCTION

A wireless sensor network is such an ad-hoc network that could contain from a couple to many autonomous nodes. Small sensors are attached with these nodes and these sensor nodes have communications capabilities to transmit and receive information [1]. One of the most important features of WSN is that it allows real time data processing at minimal cost. All nodes periodically sense the information from geographical area and then transmitted that information along a network from one node to another until it is collected in a central unit connected to a PC. The concept of wireless sensor networks is based on a simple equation as follow:

Sensors + CPU + Radio = Thousands of potential applications

Typically, a sensor node is a small device that includes three basic components: a sensing subsystem that sense data from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission. These sensor nodes have very small amount of energy resources and hence the number of energy consuming operations of sensor nodes such as data acquisition, transmission and reception should be minimum [2].

Sensor networks may involved many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, and radar. Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, and local control of actuators [3].

Network lifetime is one of the important metrics of efficiency of WSN and network lifetime is totally dependent on battery lifetime. Also it is infeasible to recharge or replace these small batteries or sensor nodes. It has been given in [4] that communication need significant level of energy as compared to computations. Thus energy resource is a crucial factor to be considered in WSN. The main focus is how to prolong the lifetime of WSN, conserve maximum amount of energy and how to improve the reliability of link.

In real world applications WSN have n-tier (n>1) architectures. Two-tier is most widely used n-tier WSN architecture that consist of number of clusters and one base station [5][6]. Several nodes together make a cluster and each cluster have a cluster head (CH) node. The lower tier of WSN involves the member nodes of different clusters and CHs, while base station (BS) and CHs comprises upper tier of WSN. The member nodes of each cluster performing the data sensing task over area of interest while each CH collect data from all their member nodes and further transmit to BS. This paper proposes an energy efficient algorithm for prolonging the lifetime of WSN by considering its two-tier architecture due to its advantages over traditional flat architecture in terms of energy conservation. The top most features are- only CH nodes takes part in transmitting data to BS that mean member nodes need not to communicate with BS, thus all the member nodes only transmit sensed data to their corresponding CHs. Hence energy consumed in data transmission operation is significantly decreases and each CH only route data outside of respective cluster also minimize the energy utilization by avoiding redundancy and collisions appearing between member nodes.

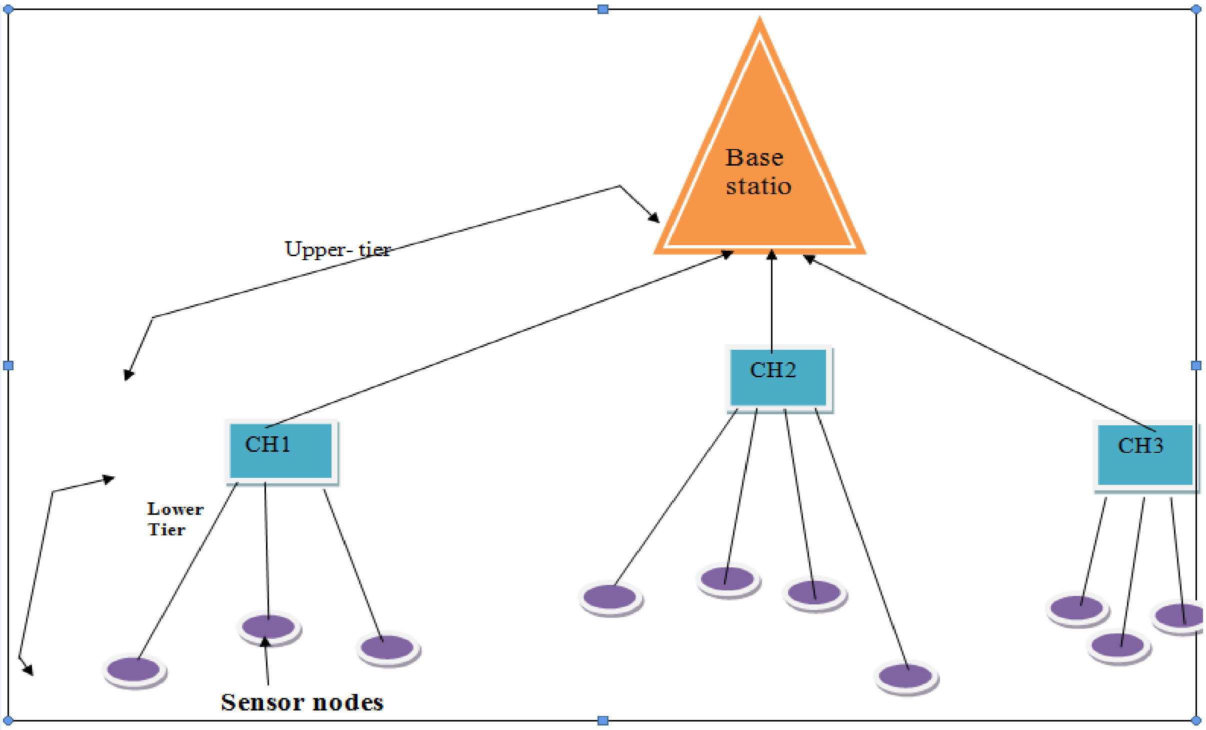


Figure: Two-tier Architecture of WSN

The proposed algorithm minimizes the energy consumption with the combination of genetic algorithm and graph theory, as genetic algorithm is a best clustering algorithm and graph theory is best for finding shortest path. In the first section, by clustering a sensor network is divided into a number of independent clusters using a GA, we can efficiently minimize the total communication distance, thus prolonging the network lifetime and then finding shortest path for routing data from CH to BS.

The remainder of this paper is as follows.

After discussing the related work in section 2, the proposed approach is explained in section 3. Simulations, performance results and analysis are discussed in section 4. Finally, concluding remarks are explained in section 5.

II. Related Work

Sarangi. S in 2011[7] studied that Genetic Algorithm based Mobility Aware Clustering for Energy Efficient Routing in Wireless Sensor Networks. GROUTE algorithm proposed based on a well known genetic algorithm that consider the mobility of nodes and create optimal cluster in more efficient way in order to have energy efficient transmission of data across wireless sensor network. **Kanadhasan. S in 2013 [8]** studied A Graph Theory based Energy Efficient Clustering Techniques in WSNs**.** Graph theory is used to detect shortest path. Whole work is divided into four phases as 1. Distance calculation 2.Energy calculation 3.Shortest path detection 4. Acknowledgement. Finding shortest path to send data from cluster head to base station is based on the distance calculation and energy calculation. **Mathapati Basavaraj S. in 2013** [9] studied Energy Efficient Cluster based Mobility Prediction for Wireless Sensor Networks. Kalman filters are used in this proposal .In this mechanism the cluster head selection is based upon the weight i.e. the sensor node with high weight is selected as cluster head based upon residual energy and transmission range parameters.

III. Proposed Approach

Through the analysis of existing techniques, it seems that WSN is considerably improves by using clustering mechanism that distribute the overall load, data aggregation and efficient cluster head selection. The main objective is to take advantage of the combination of powerful and efficient techniques that had been used independently such as Genetic Algorithm and Graph Theory.

A. Genetic algorithm

Genetic Algorithms (GAs) are global optimization method which may be used to solve search and optimization problems. Genetic algorithms are routinely used to find good solutions for problems that do not yield to standard techniques such as additive approximations. The GA is initialized with a population of these strings, which may be randomly selected from the search space.

- *Basics of Genetic Algorithms [23]*

  The most common kind of genetic algorithm works like this: a population is created with a group of individuals selected randomly. The individuals in the population are then evaluated. Genetic Algorithm uses a fitness function that is given by user or programmer to evaluate the goodness of the solution provided by each chromosome and tells how well they perform on given task. Based on the fitness value, two individuals are then selected. The individuals with higher fitness value will have the higher chance to selection. These individuals will then give opportunities to reproduce new one or more individuals as, which share some features of each parent. The individuals with least value of fitness function will die out as they are not likely to be selected for reproduction. After that the offspring are mutated randomly.

  This process will continue until a optimal or best solution has been found or a certain number of generations have been passed, depending on the requirement of the programmer.

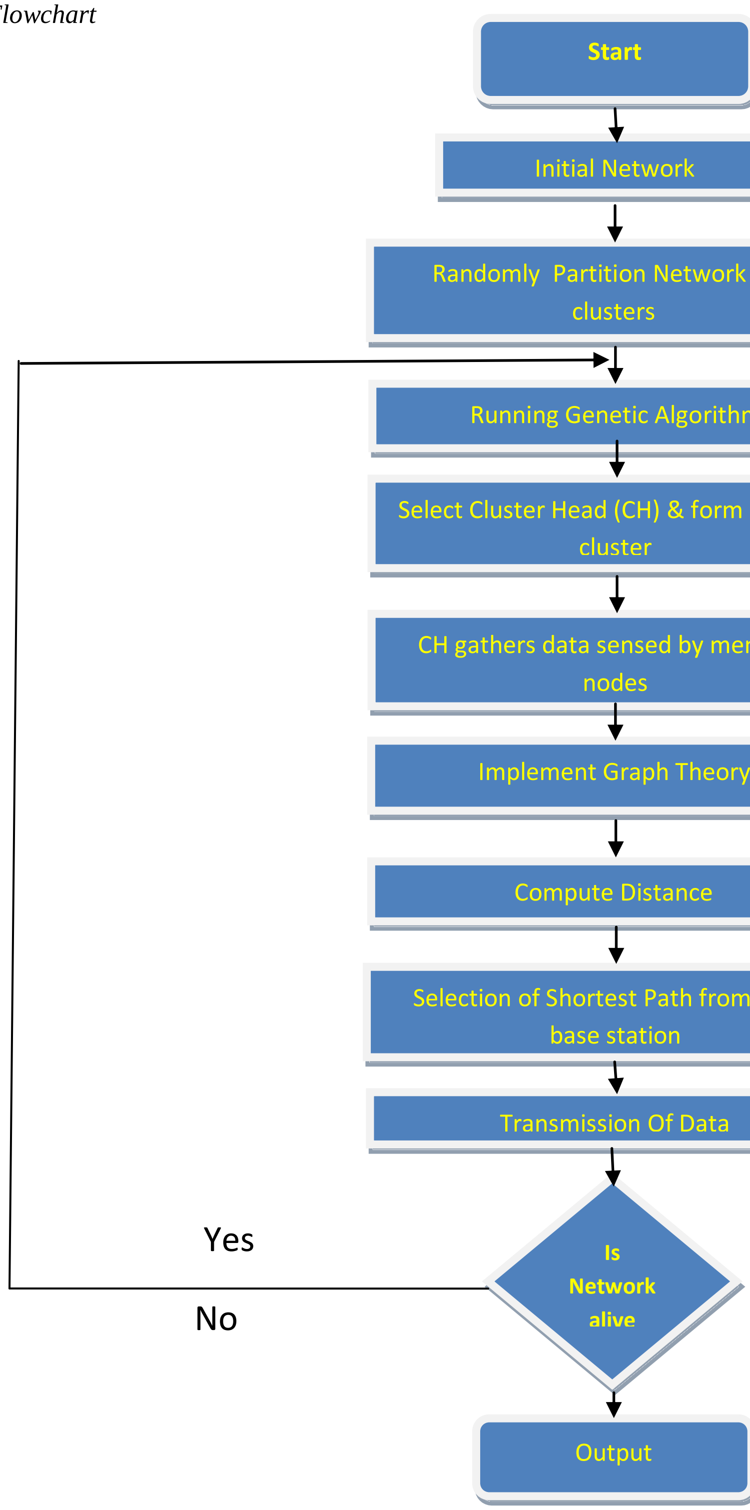
- *Operators of Genetic Algorithm:*

  Cross over is a process of taking more than one parent solutions and producing a child solution from them. A fitness function is a particular type of objective function that is used to summarize how well they perform on given task and how close a given solution is to achieving the target aims.

  The fitness function measures the quality of the representation solution. Fitness function is given by programmer. Two main classes of fitness functions exist: one where the fitness function does not change, one where the fitness function is mutable.

Mutation maintains genetic diversity from one generation of a population of genetic algorithm to the next. Mutation occurs during evolution according to a user-definable mutation probability. This probability should be set low. Mutation prevents the population of chromosomes from becoming too similar to each other.

B. Flowchart



Step1. Start with initial population.

Step2. Initially all sensor nodes are distributed in area of interest.

Step3. First of all randomly partition the initial network.

Step4. Formation of clusters will be done performing the genetic algorithm.

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Step5. Selection of Cluster head (CH) with greater residual energy and the sensor nodes near to that CH will become the members of it. After formation of clusters, clusters gather sensed data from their member nodes.

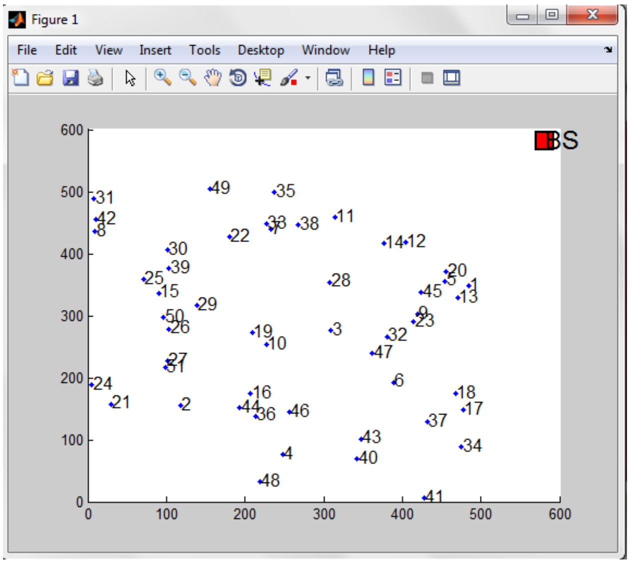
Step6. Now detection of shortest path will be performed by using Graph Theory.

Step7. Calculate the distance and energy and sort these. Select the shortest path to transmit gathered data from CH to base station.

Ste8. Finally transmit data to base station.Step9. If network is still alive then go to step 2.

IV. EXPERIMENTAL RESULTS

In proposed work, we take initial population of 51 sensors i.e. N=51. All sensor nodes have initially 5 joules of energy. There is one base station.



Initial population

At first we perform random clustering. Calculate the distance of each node to base station and sort this distance. The sensor nodes that are nearer to the base station are taken as cluster head (CH) and the sensor nodes that are at minimum distance from CH are become the member nodes of that particular CH.

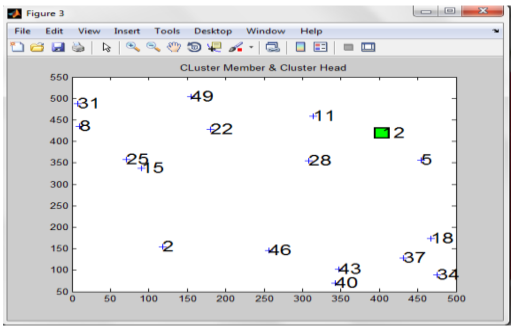
Total number of cluster heads taken is calculated as follows:

Total number of cluster Heads (nch)= N*Prob

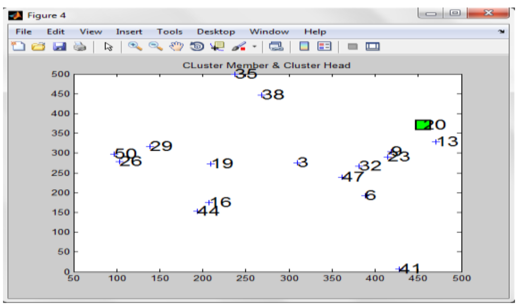
Where prob is 0.05.

Total number of member nodes= (N-nch)/nch)

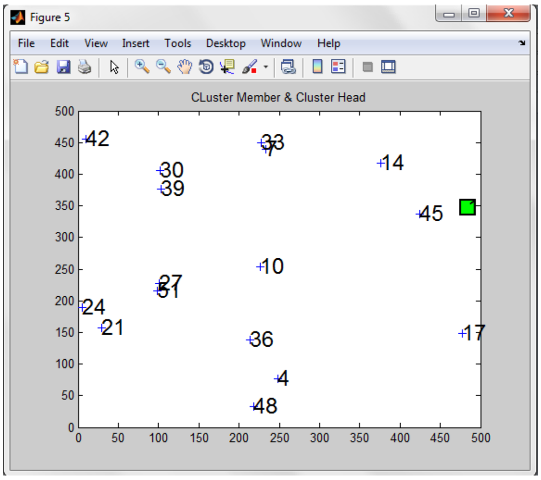
According to above formulas, we have three cluster heads i.e. 12, 20,1nodes and each CH has 16 member nodes.



(a)



(b)



(c)

In above figure (a) 12 node is first cluster head node and sensor nodes 31,8,49,22,2515,,28,11,5,2,46,43,40,37,18 and 34 are its member nodes, figure (b) shows 20 node is second cluster head node and sensor nodes 35,38,29,26,19,16,44,3,47,6,47,32,23,9,41 and 13 are its member nodes and In above figure (c) 1 node is third cluster head node and sensor nodes 45,14,17,4,48,36,33,10,7,39,30,42,24,21,51 and 27 are its member nodes.

The whole work is divided into two sections as given early.

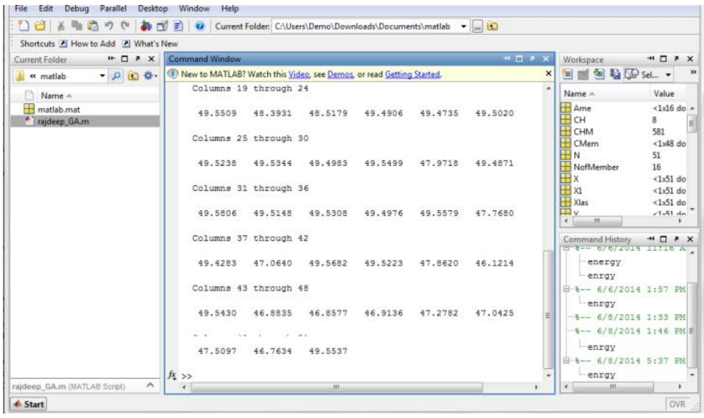
***A. Clustering using Genetic Algorithm*:-** After randomly partitioning the network, we apply GA. The fitness function of our GA is residual energy.

Fitness Function- [Residual Energy= Initial Energy-Consumed Energy*TD]

Where TD is the total distance and calculated by **TD=** $\sum d_i^2$ and we maximize the fitness function. The sensor node who has maximum energy becomes CH. Each sensor node has equal chance of becoming CH. We simultaneously calculate the residual energy of each node. In case any node has zero energy using the mutation operator of GA, we give energy to that node.

Table 1
Genetic algorithm parameters

Total No.of Sensors	51
Fitness function	Residual Energy=Initial Energy-Consumed Energy*TD
Cross over	Random cross over
Mutation	Random
No. of iterations	51



Residual energy of sensors after clustering

All the member sensor nodes sense the data and transmit it to its corresponding CH whose they are member.

B. **Finding shortest path using Graph theory**

After making the clusters using Genetic algorithm at lower-tier, now Graph Theory is applied at upper-tier for finding shortest path to transmit the data from CH to base station. Ultimately there is reduction in Energy consumption. This section has two modules. They are as follows:

- Distance calculation

- Shortest path detection

- **Distance calculation:**

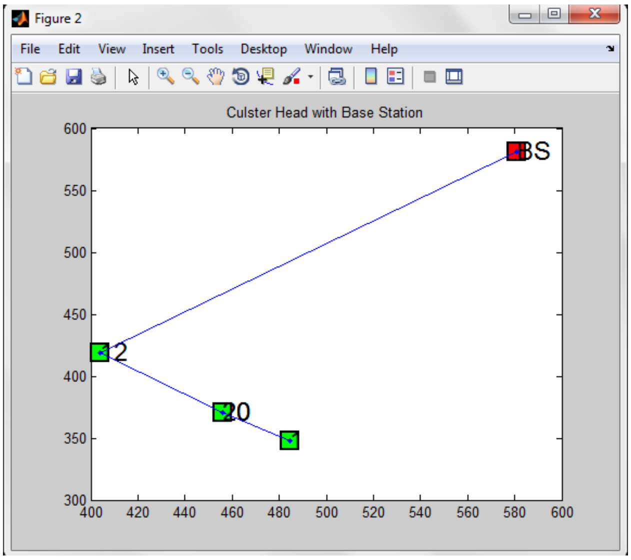
  The distance from each CH to base station is calculated using following formula,

  $D= \{\{X_2-X_1\}+\{Y_2-Y_1\}\}^{1/2}$

  Where D is the distance from (X_2, X_1) and (Y_2,Y_1) and called as Euclidean distance.

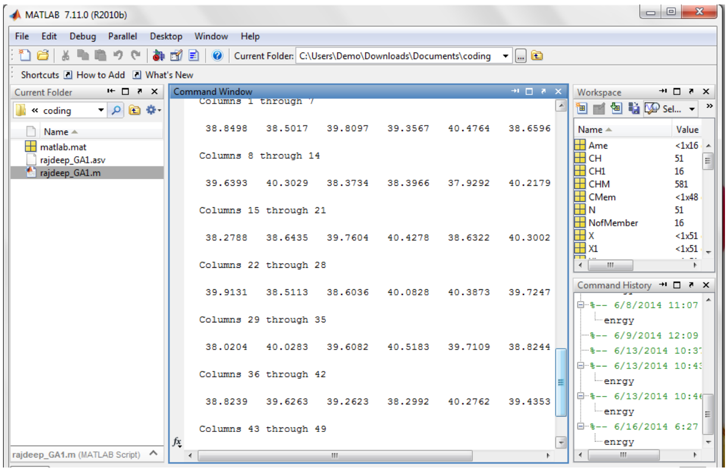
- **Shortest path detection**

  Now sort the distance, and then make link between CH, having shortest distance, and base station.



Shortest path detection

In figure 3 CH 1 will pass its collected data to CH 20 and further 20 will send to 12. Finally CH 20 will transmit all data to base station.



Residual Energy of all sensor nodes after transmission of data

Above figure shows energy of all nodes after transmitted data to base station. All the nodes still have significant level of energy. Thus our approach has better result in minimizing the energy consumption.

V. CONCLUSION

Energy is an important and scarcest element for QOS in applications with WSNs. In this thesis, an effective energy efficient scheme is presented which helps in significantly reducing the power consumption. The efficiency of proposed model is analyzes using MATLAB. Experimental results show that by using GA at lower-tier for making clusters and using Graph Theory at upper-tier for finding shortest path to transmit data from CH to Base station, sensor nodes utilizes extremely less energy and stay alive in network for long time. Hence increase in network lifetime.

VI. FUTURE WORK

There are many possible extensions of this work that can be assumed in future research. Some of them are as follows:

The clustering technique is used to detect shortest path in a network using Fuzzy logic.

There could also be advances in the overhead power used by the sensor nodes, so that as the networks become bigger and bigger, the actual extension of the network life will be maximized as much as possible.

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