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A Positioning Method in Wireless Sensor Networks Using Genetic Algorithms

Mojtaba Romoozi[a],Hossein Ebrahimpour-komleh[b]

[a]Member of Young Researcher Club ,Islamic Azad University,Kashan branch, I.R.Iran
Mojtaba.Romoozi@gmail.com
[b]Faculty of Engineering,,The University of Kashan,Kashan, I. R. Iran
Ebrahimpour@kashanu.ac.ir

Abstrac

The recent area of Wireless Sensor Networks (WSNs) has brought new challenges to developers of net-work protocols. Energy consumption and network coverage are two important challenges in wireless sensor networks. We investigate intelligent techniques for node positioning to reduce energy consumption with coverage preserved in wireless sensor network. A genetic algorithm Is used to create energy efficient node positioning in wireless sensor networks. The simulation result shown that the proposed intelligent algorithm can extend the network network lifetime for different network positioning method.

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Keywords: Sensor network, Genetic algorithm, Energy consumption, Network coverage, Clustering

1.Introduction

Wireless and mobile networks are suitable options for cases in which we are not able to access conducted environment, and in such cases, data processing would be challenging. Wireless sensor networks are important in the case of accessing the regions that user cannot enter or collect data directly. A wireless sensor network contains similar small nodes which interact in a limited area. Each node needs a battery as a source of energy. The life time of batteries determine the life period of the network, so the energy efficiency is an important factor for having a longer network life time [10,5]. To reach this goal we can use a clustering method.

There are several existing methods for this purpose. Heinzelman et al.[1] introduced Leach protocol, an idea for self-organized heuristic clustering, in which network is divided into several clusters. Each

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cluster has a special node as a cluster head and several other nodes. Nodes collect data and transmit them to the cluster head, cluster heads deliver gathered data to the sink using TDMA[1]. This idea had been employed by T.Voigt et al. [6] and developed as SolarLeach clustering algorithm. There are other ideas for clustering using heuristic algorithms. For example, HCR algorithm[8,7] by Matin and Hussain in which nodes introduce themselves to cluster head using Round Robin technique. Considering that the sensor nodes are in fixed positions in network, nodes clustering can be performed so that factors such as energy, network coverage, distances between clusters, communication between nodes and etc. are likely to optimize.

In this paper, we propose a novel method for node localization using genetic algorithm and clustering using K-means method. The rest of the paper is organized as followed: first we describe genetic algorithm and how to use it in brief. Then we propose a pattern for node positioning regarding fitness factors.

Finally, stimulated results are shown and compared to another existing method in section 4.

2.Genetic Algorithm Background

Genetic algorithm is one of the varieties of evolutionary algorithms inspired from biology. Information is formed as chromosomes and is combined by special operations such as inheritance, mutation, selection, and crossover. The best chromosome in population is selected considering a fitness function which is closely correlates with the problem's goal [9]. A typical optimization method by genetic algorithm may have the following components:

2.1.Population

Genetic algorithm works on a set of solutions which is named population. Individuals in population are a series of numbers called chromosome and contains binary data of the solution's parameters.

2.2.Fitness function

It gives us an index for individual's performance in problem area. For example, in a problem, which its objective is minimization, the best individual is one with the lowest value. This raw information usually is applied as a middle stage for determining individual's relative efficiency in genetic algorithm.

2.3.Selection

Selection is the process that determines how many times each individual can participate in reproduction stage. In other words, the number of children that each parent can reproduce is determined in this stage.

2.4.Crossover

Crossover is the main agent in developing new generation. Resulting children from this stage, like chromosomes in nature, carry portion of information of their parents. Many crossover techniques exist, the simplest form is one-point crossover and the other kind is multi-points crossover.

In one-point crossover each parent is divided in two sections from a specific place, and then two children are made by swapping one part of each parent.

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[1] Time division multiple access

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In multi-point crossover, several fraction points on chromosomes are selected. Each parent is divided into the several sections based on the number of fraction points.

2.5.Mutation

In nature, mutation is a process in which one part of chromosome is changed randomly. In genetic algorithm, it is considered that the probability of mutation in chromosomes is about 0.01 to 0.001. Using this agent, it is hoped that good chromosomes, removed in selection or reproduction stages. Mutation also guarantees that the population is not too similar to each other, so GA can avoid of getting in local minima.

3.Our Proposed Approatches

Jin et al.[4] presented a genetic algorithm based method which decreases the communications between nodes in a pre–positioned network in order to gain minimum energy. Ferentinus et al. [12] improved this idea by changing fitness function. In their algorithm, cluster heads in each cluster are selected based on energy and level of their communications with other sensors.

In wireless sensor networks, if nodes are fixed, it is possible to solve some problems such as energy consumption and network coverage by a proper positioning at the initializing the network. We can decrease communication cost between nodes by proper positioning. There is a trade off between energy consumption of nodes and network coverage. In this paper, a suitable solution for reaching best positioning of nodes is presented using genetic algorithm. This method will select best positioning based on two fitness functions. After we find the best arrangement of the nodes by GA, we employ K-means algorithm [3] to cluster them. Closer nodes form a group (cluster). The center of gravity of the cluster is considered as cluster centre. In the initial stage, every two closer nodes form a cluster for the first time. Other nodes join the clusters incrementally, until the number of clusters reach to a specific number. All nodes have the same amount of energy at the beginning. The node having closest distance to other nodes in the cluster, is defined as a cluster head. There are two parameters effective in formulation of our fitness function, which are explained as followed:

3.1.Energy of transmission

Energy of transmission is one the most important factors for measuring efficiency of the network positioning. This energy can be divided to three parts: the energy of transmission for

each node($E_{T_{jh}}$), the energy of receiving packets by cluster head (E_R) and the energy of data transmission from cluster head to sink ($E_{T_{hs}}$), as shown in eq (3).

$$E = \sum_{j=1}^{k} \varepsilon_i \times E_{T_{jh}} + k \times E_R + E_{T_{hs}} \tag{3}$$

k is the numbers of nodes in a cluster; ε_i is a vector of traffic coefficient in network, which describes the density of packets transmitting/receiving in that area. In the model presented here, if two nodes are in a short range, the energy for the communication is related to d^2, where d is the distance between two nodes. Otherwise the energy can be calculated by factor of d^4 [11]. Based on these assumptions, energy of transmitting L bit data from node i to mode j is calculated as followed:

$$ET_{ij} = L x Ee + L\varepsilon_s d_{ij}^2 \qquad \text{Transmitting energy for short distances}$$

$$ET_{ij} = L x Ee + l\varepsilon_L d_{ij}^4 \qquad \text{Transmitting energy for long distances}$$

consumed cost for receiving L bit data is calculated as followed:

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$$ER = LxEe + LxE_{BF} \quad (5)$$

E_{BF} is a constant with amount of 50pJ/bit/m^2; ε_s and ε_L are constant measures considered in radio model with amount of 10 pJ/bit/m^2 and 0.0013 pJ/bit/m^4.[11]

3.2.Network coverage

Network coverage is another important factor of fitness, normally Voronoi diagram [2] is used to calculate the network coverage. In this diagram, cluster head is considered as the centre of Voronoi polygon and the boundaries between clusters are diagram edges. Then areas of resulting shapes would be calculated and their difference is considered as output of relevant fitness function.

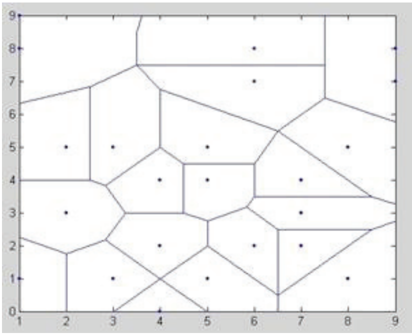

Fig.3.1. an example of a Voronoi diagram

To formulate the fitness function, we need to combine the above fitness factors. This combination can be formed as a weighted summation of the two fitness factors .this weights are static and importance of each factor related to value of this weight. The generated fitness function can be used in the GA to evaluate the fitness of each chromosome.

4.Simulation

For simulating of this algorithm, we have selected a rectangle area with 200m in length and 200m in width, and initially positioned 100 nodes in it randomly. The length of each transmission packet is 32 bytes. The radio range for each sensor is 40m. Also the position of the sink is considered in the upper right corner of the area. The simulation parameters are shown in Table4.1.

Table 4.1. Simulation parameters

Network	200*200m
Node number	100
Initial Energy	0.5 J
E_{elect}	50 nJ/bit
ε_{es}	10 pJ/bit/m2

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Dcrossover	100m
E_{bf}	5 nJ/bit/signal
Packet length	32 Bytes

Table 4.2 also shows the parameters of genetic algorithm.

In this genetic algorithm each chromosome is a vector of nodes' coordinates in the network. Figure 4.1 illustrates the network traffic, some parts of this area are colored regarding network traffic and each color has a specific coefficient.

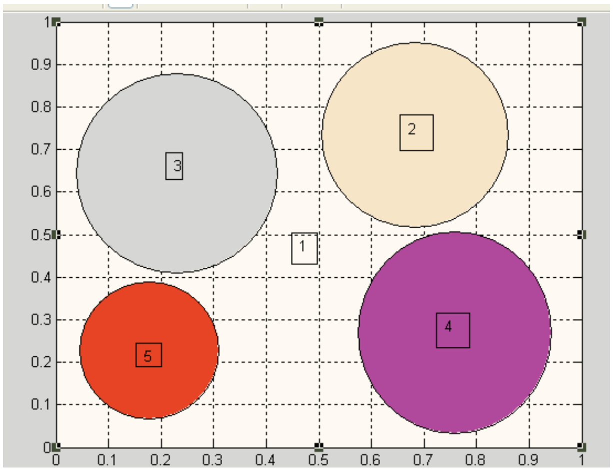

Fig. 4.1. a sample traffic of a network

The right part of Fig. 4.3 shows the arrangement of nodes in one generation and left part shows the clusters of the same arrangements.

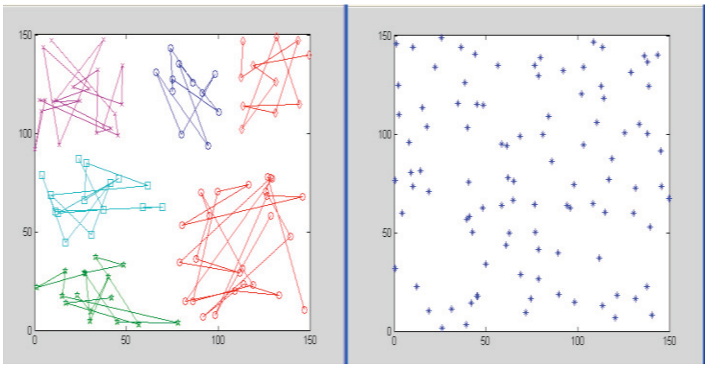

Fig. 4.3. Positioning of nodes in network

The best chromosome which is generated after 100 iterations is shown in Fig. 4.4.

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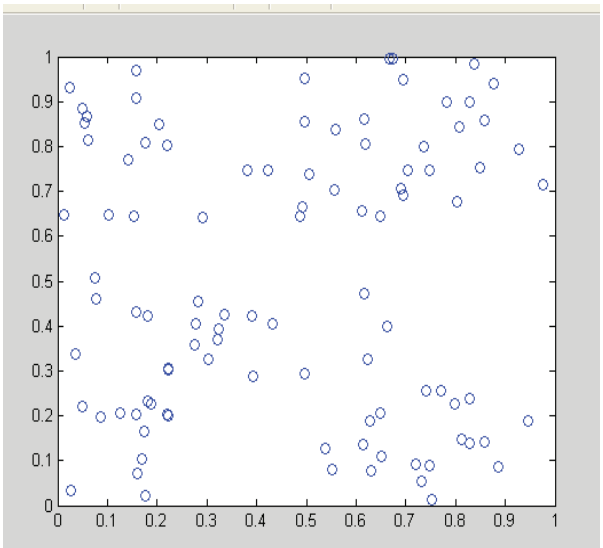

Fig. 4.4. Final position of nodes in network

In a comparison to other algorithms, we found that the life time of the network in our method has been increased against the normal LEACH [1] algorithm. This relates to nodes positioning based on fitness function in genetic algorithm; if nodes has been positioned properly regarding expected energy consumption and network coverage, network's life time would be increased considerably. This is shown in Fig. 4.5.

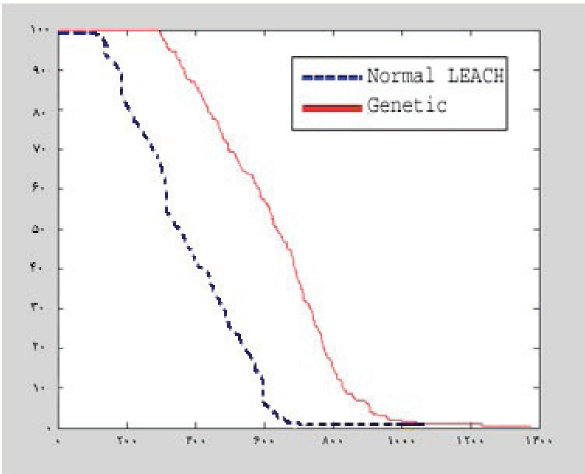

Fig. 4.5. The comparison of number of active nodes in network

In Fig. 4.6, the presented algorithm and LEACH algorithm have been compared in terms of decrease of rate of energy consumption in 150 periods of transmitting and receiving data. As it is shown, our algorithm makes the rate of decrease in energy consumption of network smoother and more constant comparing to other algorithm. Inconstant decrease of energy and imbalance in consuming energy makes network's life time shorter.

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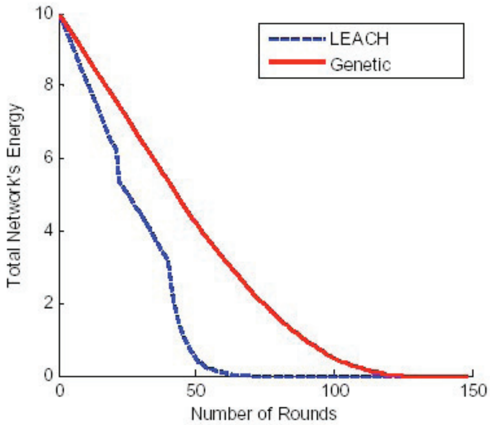

Fig 4.6. Rate of decrease in network's energy in its long life

5.Conclusion

One of the most important issues in wireless sensor networks is optimum consumption of energy. If it is considered properly, network's life time would be increased. In this paper, we introduce a method to decrease communication energy by clustering nodes and positioning them in closest possible distance in each cluster. In this work, nodes are positioned in network using genetic algorithm. The nodes have been divided into specific cluster using K-means clustering algorithm. In this algorithm, sufficiency has been done based on two factors including transmission energy and network coverage. Our accomplishments in this work are balanced and constant consumption of energy of nodes, increasing network's life time, and maintaining the coverage of the sensor network.

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