RGWSN: Presenting a genetic-based routing algorithm to reduce energy consumption in wireless sensor network

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Abstract

In this paper, a genetic- based routing algorithm to reduce energy consumption in sensor networks is presented. This method, by regarding distance hybrid parameters, energy and density, has created a fitness function which has optimal conditions compared to previous parameters. In the proposed algorithm, a new technique to select several probable cluster heads(CHs) in each area, has been used. The results of simulation indicate that the proposed algorithm has increased network's lifetime, compared to former techniques. Also, we have proved , in the new technique, that the number of alive nodes at the end of each round has increased , compared to previous techniques, and that is the result of proper selection of CH in each area.

Keywords: *Genetic algorithm, Wireless sensor network, Routing, Reduce energy consumption.*

1. Introduction

Wireless sensor networks are increasingly used in military surveillance and civilian usages[1]. These networks are composed of hundreds or thousands sensors which receive data from environment and send them to a Base Station(BS)[2]. One important problem in wireless sensor networks, is creating an effective routing protocol. Generally this kind of network has some constraints in calculation potency, storage capacity, energy, etc .To reduce energy consumption and to increase network's lifetime are the most considerable problems in sensor networks[2,3]. Receiving environment data by nodes and sending them to BS can lead to run out of node's energy and then threaten network's lifetime[4]. One of the techniques used to find the best way of receiving and sending data by nodes is using genetic algorithms(GA)[5].In the routing algorithms other than GA, the problem of optimum consumption of energy is point to point, which causes ignorance of other points, but in GA all points in all phases of running an algorithm can be included, and this leads to good results. GA is a multi-purpose ,optimal search inspired by genetic theory and natural selection . The problems using GA are as a coded chromosome including several genes[5]. The solution is shown by a group of chromosomes related to a population .When the algorithm is repeated, current chromosomes take a genetic operation which includes selection, crossover and mutation. This operation results in the appearance of next generation. These processes are running till finding an optimum, and certain solution. In this research, we try to present a genetic- based routing algorithm to reduce energy consumption of supply source in sensor networks. Routine work is comparing to previous algorithms.

2. Related Works

One of the most important clustering algorithms to LEACH which is based on the rounds each of which includes setup and steady phases. Each node in every round can be or cannot be a CH[6]. Being a CH or not being a CH is based on the following threshold[6]:

$$T(n) = \begin{cases} \dfrac{p}{1 - p*(r \mod \frac{1}{p})} & if \quad n \in G, \\ 0 & otherwise \end{cases} \quad (1)$$

in which :
P: CH decision percentage(percentage of being CH)
R: current round

G: set of nodes not changed to CH in 1/p of the recent round

One other technique to optimize energy consumption in sensor networks, based on genetics, was presented by Ming, Shiyuan Jin, Annie S.Wu and Zhou[7]. In this technique, sensor network is clustered by GA. Some other genetic – based techniques have been presented by Zhou, Jingcheng Ouyang, Jianming Zhang, Yaping Lin, Cuihong[8].

3. Genetic Algorithm

Genetic algorithm (GA) is an optimization technique inspired by nature which operates as numerical, direct and random search .GA is based on repeat and the primary principles thereof are obtained from Genetics .GA , due to using nature, has some basic differences from other searching methods , as follow[5]:

1. GA operates by bit strands called chromosomes, each of which represents all sets of variables, while most search techniques include special and independent variables.
2. GA searches by random selection that leads to non-optimum points, in each round, to be included in next processes.
3. GA, in each repeat, considers some points of search space. So it is less likely to converge into a local maximum.

Each process of repeat in GA is called a generation and a series of solutions or answers is called population .GA starts with some initial points generated randomly or selectively. These points are called Initial Population. After the generation of initial population , genetic operators operate on initial population and create new population. Generating new population is done by fitness function, i.e. fitness function operates on initial population and the new population is generated. Initiating next generation is by means of new populatuion . These processes are run through various generations to obtain the best solution[9].

Generally, GA includes the following stages[5,9]:

1. **Initial stage**: In this stage an n-chromosomes population is generated randomly.
2. **Fitness**: In this stage, for all existing n- chromosomes, a fitness value is defined.
3. Generation of new population through following stages[9]:

A. **Selection**: In this stage the two chromosomes having more fitness are selected as parents. Selection procedures are random. Some current methods of selection includes: wheel roulette selection, sequential selection, competitive selection, Boltzman selection and etc.

B. **Crossover**: In this stage, two parents generated in selection stage bring new children. Generally, crossover is a process in which the old generation of chromosomes crossover and a new generation of chromosomes is generated.

Some current crossover methods are: the combination of single- point, the combination of two- point, the combination of multi-point and uniform composition

C. **Mutation** :In this stage a child having mutation condition mutates. After this stage, children are decoded and compared to fitness function. If , regarding fitness function , the conditions are not optimal , new children in initial population are used and the algorithm proceeds. In this stage, generated chromosomes are considered as initial population and the answers having low fitness are omitted and the algorithm proceeds with n chromosomes . We can refer to Binary and True mutations as two of the most considerable mutation methods .It is noteworthy that to do the above stages needs using an encoding system.

Under the following conditions, we can put an end to running GA[5]:

1. Algorithm reaches a fixed number of generations.
2. No improvement is obtained while algorithm proceeds.
3. The average value of fitness function reaches a certain measure as per several repeats.
4. The greatest fitness rate is gained for children.
5. A combination of the above conditions happen.

4. Network Model

Network model has the following characteristics[6]:

1. All nodes of sensor and BS are motionless and after being established, nodes can not be added or omitted.
2. The base energy of nodes is different.
3. The nodes of sensor are informed of situation , i.e to do this, they need hardwares like GPS.

5. Radio Model

The sensors consume energy while receiving and transmitting data[6,10]. The standard radio model used in WSN, uses free space and multi- path fading model which depend on the distance between transmitter and receiver. This distance is the shortest crossover distance, $d_{crossover}$.

Transmit power equals to[6,11,12,13] :

$$p_r(d) = \frac{p_t G_t G_r \lambda^2}{(4\pi d)^2} \qquad (2)$$

In which:

p_t : transmit power

G_t : gain of transmit antenna

λ : carrier signal's wave-length (in meter)

When the receiver s distance is longer than $d_{crossover}$

transmit power equals to[11]:

$$p_r(d) = \frac{p_t G_t G_r h_t^2 h_r^2}{(d)^4} \quad (3)$$

h_t : transmit antena height in meter

h_r : receiver antena height in meter

To transmit n-bit message in a d- meter distance , radio energy consumption equals to[6,11]:

$$E_{TX}(n,d) = n(E_{elect} + \in_{fs} d^2) \quad d < d_{crossover}$$
$$E_{TX}(n,d) = n(E_{elect} + \in_{mp} d^4) \quad d \geq d_{crossover} \quad (4)$$

To receive an n-bit message radio energy equals to[11,13]:

$$E_{rx}(n) = nE_{elect} \quad (5)$$

$\in_{fs}$ and $\in_{mp}$ are parameters which depend on sensitivity(intelligence) of receiver and noise's shape and E_{elect} is the electric energy depending on such factors as digital code, modulation. Filtering , etc[11].

6. The New Presented Algorithm RGWSN

The new proposed algorithm is based on the rounds each of which includes two phases: steady phase and setup phase. In setup phase, the area where nodes are distributed, are networked and optimum CHs are specified. In the second phase or steady phase, data are transmitted from normal nodes to CHs and from CHs to BS (Base Station). Set up phase starts by an initial manage from BS, including nodes' location and initial energy. Then some nodes having a higher fitness shall be selected and attended in GA to detect optimum nodes as CHs, for data transmission in steady phase to do this, the environment in which nodes are distributed, is divided to separate areas called grides. The selection of nodes in each grid is based on their distance from the nodes' gravity center of each grid. The nodes closer to gravity center in each grid, are selected as initial population, to attend in GA, i.e. initial population includes the nodes that are likely to be optimum CH. (for example if the environment is divided into 8 areas and 3 nodes are selected from each area, the initial population has 24 bits. In this algorithm we used binary coding system. After creating initial population, to select optimum nodes, regarding initial population, we create some random populations and by genetic operators of selection, combination and mutation, we created new children, randomly and binarily, from current population.(For example if we have 50 populations, after binary operation of genetic operators, we have 100 populations.). In the proposed algorithm we use the combination of single-point and binary mutation. For example, if two parents are as P2:10001111, P1=01000011, P=3, the following children are generated.

F1=110011
F2=011110

After running some generations, by applying fitness function on generated populations, the best population is selected, i.e. the population having the lowest fitness (the least average energy of entire network) is selected. For this proposed approach, fitness function equals average energy consumed by entire network. Fitness function is calculated based on the model proposed by Heinzleman. Heinzleman has stated, in a model, that each node, to transmit L bits of data in a distance d from itself, will use energy E_s .

$$E_s = LE_{elect} + L \in_{fs} d^2 \quad d < d_0$$
$$E_s = LE_{elect} + L \in_{mp} d^4 \quad d \geq d_0 \quad (6)$$

In which:

d_0 : The shortest crossover distance

E_{elect} : The Energy required for activation of electric circuits.

$\in_{mp}$, $\in_{fs}$: parameters related to receiver's sensitivity and noise shape.

In the proposed algorithm and set up phase, we calculate fitness value for final population bits and we have supposed bits 0 as representing common nodes and bits 1 as representing CHs. Fitness Function(The energy consumed by entire network) equals:

$$E = E_1 + E_2 + E_3 + E_4 \quad (7)$$

E_1 : Energy necessary to transfer from normal node to CH

E_2 : Energy necessary to receive CH data from normal node

E_3 : Aggregation energy

E_4 : Energy necessary to transfer from CH to BS

Which we have:

$$E_1 = LE_{elect} + L \in_{fs} d^2{}_{distoch} \quad d_{distoch} < d_0$$
$$oR \quad (8)$$
$$E_1 = LE_{elect} + L \in_{mp} d^4{}_{distoch} \quad d_{distoch} \geq d_0$$

$d_{distoch}$: The distance between common node and CH

L: bits number

$$E_2 = LE_{elect} \times N\_Common \quad (9)$$

N_Common : common node number

$$E_3 = LE_{ag} \times N\_ch \quad (10)$$

E_{ag} : aggregation energy

N_ch :CHs number (bits 1)

$$E_4 = LE_{elect} + L \in_{fs} d^2{}_{distoBs} \quad d_{distoBs} < d_0$$
$$oR \qquad (11)$$
$$E_4 = LE_{elect} + L \in_{mp} d^4{}_{distoBs} \quad d_{distoBs} \geq d_0$$

$d_{distoBS}$: distance from CH to BS

In set up phase, after applying fitness function on final population and specifying common nodes and CHs, E_1 for common nodes (bits 0) and E_2, E_3, E_4 for bits 1(CHs) are calculated. At last in steady phase, based on transition ,The energy of nodes reduces. Chart 1 shows flowchart of the proposed algorithm.

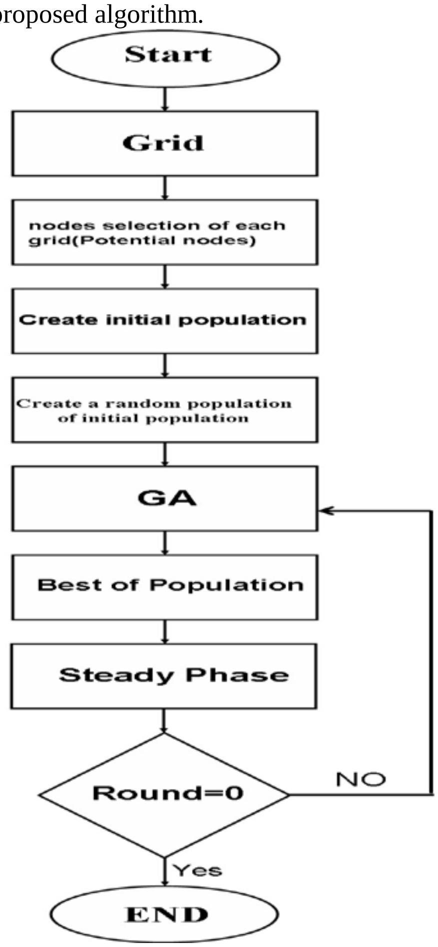

CHART 1 . FLOWCHART OF THE PROPOSED ALGORITHM

7. Simulation

Analysis of the proposed algorithm is done by MATLAB software. The number of alive nodes at the end of each round, the number of grids ,the number of selected nodes in every grid have been considered to generate initial population. Also, the energy of initial nodes, are random measures from 0.2 to 0.5. Other parameters used in simulation are as follow:

1. The nodes are randomly placed in a squared environment.
2. BS position is variable.
3. E_{elect} : 50nj/bit
4. $\in_{fs}$: 10pj/bit/m2
5. $\in_{mp}$: 0.0013pj/bit/m4
6. E_{ag} : 5nj/bit/signal
7. $d_0 = \sqrt{\frac{\in_{fs}}{\in_{mp}}}$

The proposed method is compared to GSAGA,RCSDN,LEACH methods. Figure 1 shows alive nodes at the end of 1000 rounds and figure 2 shows fitness function for the proposed method. Also table 1 shows simulation parameters.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Network size	100*100 m
Base station location	50,50 m
Initial energy for node	rand [0.2,0.5] J
E_{elec}	50nJ/bit
ε_{fs}	10pj/bit/ m2
ε_{mp}	0.0013pj/bit/m4
Data aggregation energy	5nj/bit/signal
Nodes number	100
Grids Number	6
Nodes number of each grid	5
d_0	87m

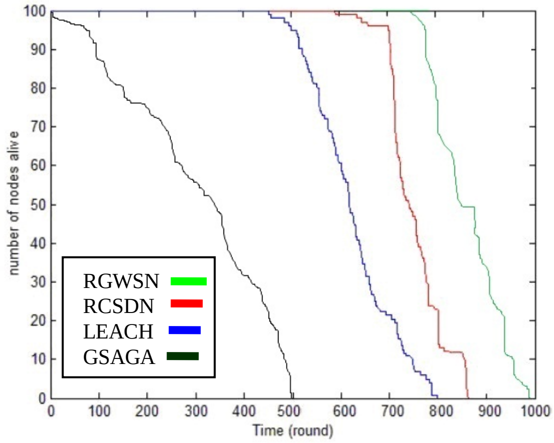

Figure 1. Total number of alive nodes in the RGWSN, LEACH,GSAGA,RCSDN

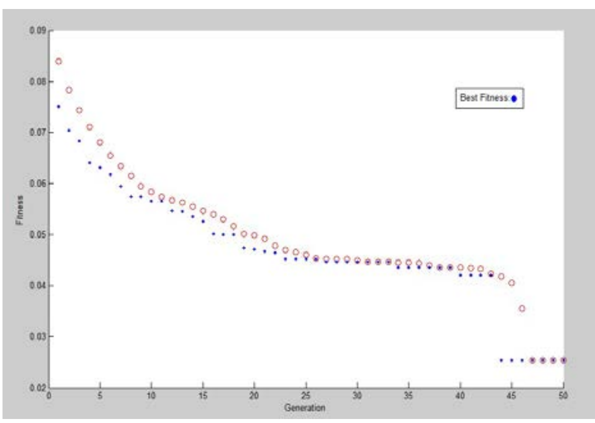

Figure 2. The energy consumed by entire network

As shown by diagrams, after running 1000 rounds, the number of alive nodes in the proposed approach is more than that of GSAGA ,RCSDN ,LEACH .As a result, the network lifetime is longer.

8. Conclusion

In this research, a new method to transmit data from normal nodes to CH and from CH to BS in sensor networks, is presented. The selection of an optimum CH has an effective role in increasing a sensor network's lifetime. By means of multi-simulations, we have shown that the proposed algorithm is different from other presented algorithms, by virtue of reducing energy consumption.

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