CRCWSN: Presenting a Routing Algorithm by using Re-clustering to Reduce Energy Consumption in WSN

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Abstract:
In this paper, we have presented an algorithm, based on genetics and re-clustering, to reduce energy consumption in Wireless Sensor Networks. Algorithm CRCWSN could be best used by selected chromosomes in different states. In this algorithm, a new technique of selecting cluster head(CH) has been initially used by genetic algorithm. These CHs have been used individually in each round to transmit data. In this research, considering distance and energy parameters, we have created a target function having more optimum conditions, compared to previous techniques. The created target function has been evaluated by input chromosome, and the combination of chromosomes has been done by a new technique having more efficiency compared to previous similar techniques. Consequently, the timing of generation repeat is based on local distribution in chromosomes, and their using in sending data from source to destination that decrease generations' repeat, compared to previous methods .Results by simulation show that, at the end of each round, the number of alive nodes in the suggested algorithm increases, compared to previous methods, which increases network's lifetime.

 Keywords: Genetic algorithm, wireless sensor network (WSN), routing, reduce energy consumption, re-clustering.

1 Introduction

Recently, Wireless Sensor Networks have widely been considered[1].These networks include some nodes receiving environment data and then sending them to a Base Station(BS)[2,3].Generally, in these kinds of networks, nodes have batteries of limited energy which guarantee network's lifetime[1,2,3,4]. The most important problem in wireless sensor networks is to create effective routing protocols in order to decrease energy consumption and increase network's lifetime[2,4,5]. So many methods, having advantages and limitations have been presented , to find the best route and transmit data to BS. One of the most effective ways of finding optimum route and data transmission from common nodes to BS, is using Genetic Algorithm(GA)[2,6]. An important advantage of routing by using GA, is a multi- purpose search rather than a point to point search, which leads to using all points in all processes of running GA. This causes non-optimum points in previous stages, to be attended in next stages[2]. To solve the problems, GA uses a group of chromosomes related to one population. In each running of GA, current chromosomes take a genetic operation for next generation to be appeared. This operation includes selection, composition and mutation[2,3,5]. Optimum route is created by GA, after running several generations. In this research, we try to present a genetic and re-clustering based routing algorithm to reduce energy consumption of sensor network. Routine is comparing to previous methods.

2 Related Works

One of the most important re-clustering algorithms is LEACH which is based on some rounds[2,3,5]. Each round includes two phases; setup and steady. In setup phase, clusters are

formed and common nodes and CHs are determined and in steady phase, data are transmitted from common node to CH and from CH to BS. In LEACH algorithm; in each round, each node can be a CH or a common node. Whether a node can be a CH or not depends on the following threshold[2,7,8,9]:

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

in which :

P: CH decision percentage(percentage of being CH, for example p=0.05.);

R: current round;

G: a set of rounds not being CH in 1/p of current round;

Another routing way by GA, is the algorithm presented by Annie S.Wu,Ming Zhou, Shiyuan Jin[10].

In this algorithm, selecting and clustering nodes is done by GA. Of other methods of routing by GA, we can refer to the RGWSN algorithm [2]. In this algorithm, clustering and selection of optimum CHs are done by GA. Another genetic- based method, presented by Jianming Zhang, Yaping Lin, Cuihong Zhou, Jingcheng Ouyang could reduce energy consumption of sensor networks by considering distance and energy parameters[11].

2.1   Genetic Algorithm

GA is a method, based on natural inspiration, which numerically does direct and random search. Finding an optimum solution is based on repeat and differs from other search methods in applying natural selection[2]. GA includes bit strands named chromosomes, each bit of which is called a gene. Chromosomes, represent the entire set of variables and GA, in each repeat, will use non-optimum points of previous repeat[2,12]. One important advantage of GA , in comparison with other searching methods, is multi-point selection rather than one-point selection, in searching space. So GA, in searching and finding an optimum solution, is less likely to converge into a local maximum. GA includes some stages. Each stage in GA is called a generation and a series of solutions is called a population[2,5,9]. GA initiates with initial population and after operations of genetic operators including selection, composition and mutation, a new population is created. The creation of new population is done by fitness function , i.e. after applying fitness function on created population , by termination of each generation, a new population is created. The processes are running through different generations to find optimum solution. Generally, GA includes the following stages[2,6,12]:

1. **Selection:** in this stage, two chromosomes having higher fitness, are selected as parent.

2. **crossover:** in this stage, two parents selected in the previous stage, are composed and new children are created.

3. **Mutation:** In this stage, the child having mutation conditions, mutates. After this stage, children are decoded and compared to fitness function. If, by regarding fitness function, conditions are not optimum, new children will be used in initial population and algorithm proceeds. In this stage, generated chromosomes are treated as initial population and answers of low fitness are omitted, and algorithm proceeds by n chromosomes.

Under following conditions GA can come to an end[2,6]:

1. The best degree of fitness for children is achieved.

2. No improvement achieved by running the algorithm during several generations.

3. Mean value of fitness function reaches a fixed measure as per several repeats(e.g. during 50 generations).

4. The number of generations reaches a fixed value after several repeats.

5. A combination of the above- mentioned items occurs.

2.2   Network Model

All sensor nodes and BS are motionless and after establishment can not be added or omitted. Also the base energy of nodes differs and sensor nodes are informed of situation , i.e. they need hardware 's such as GPS to do this.

2.3   Radio Model

Sensors, when receiving data or transmitting data, consume energy[7,13]. Standard radio model used in WSN, uses free space and multi-pass fading models depending on the distance between sender and receiver . This distance is the shortest crossover distance $d_{crossover}$[7,9]. Transmit power equals[14]:

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

In which:

p_t: transmit power;

G_t: gain of transmit antenna;

λ: wave length of carrier signal (in meter).

When receiver distance is longer than $d_{crossover}$, transmit power equals[7,9]:

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

h_t: height of sender antenna (in meter).

h_r: height of receiver antenna (in meter).

To transmit an n-bits message in d meter distance, radio energy consumption equals[7,9]:

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

To receive n-bits message radio energy equals[9]:

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

$\in_{fs}$ and $\in_{mp}$ are parameters depending on sensitivity(intelligence)of receiver and noise shape and E_{elect} is an electric energy depending on some factors as digital code, modulation, filtering[9].

3   The New Presented Algorithm CRCWSN

The new proposed algorithm includes some rounds each of which has two setup and steady phases. Clustering is formed in setup phase and data transmission is in steady phase. Setup phase initiates with an initial message from BS, including the nodes' position and initial energy, and after running GA, some generations having lower fitness than other generations , are selected (optimum generations), and common nodes and CHs are selected from available nodes in selected generations. (For example, if GA stops after running 50 generations, the 5 generations having lower fitness than other generations are selected). In the proposed method, a binary coding system has been used and we suppose 0 bits representing common nodes and 1 bits representing CHs. After selection of common nodes and CHs, data are transmitted in steady phase. The routine in setup phase is as follows: the distributive environment of nodes is divided into separated areas called grid. Then some nodes, likely to be optimum CH, from each grid are selected. The way of selecting nodes of each grid is based on the distance from gravity center of nodes of each

grid, and the initial energy thereof, i.e. the nodes having more initial energy and short distance to gravity center are better selected.

Then the nodes selected as chromosomes 'bits are attended in GA. For example, if the environment is divided into 10 grids and 4 nodes from each grid are selected, the chromosomes attended in GA will have 40 bits(0,1). Routine in GA is as follows: Firstly, from initial chromosome which is initial population, some random populations are created and then randomly by using genetic operators of selection , composition and mutation, new children are created binarily from created populations. For example, if we create 50 new populations from initial populations, we will have 100 new children after applying genetic operators. After creating children, we apply fitness function on new population to select some populations(for example 5 populations) having lower fitness , as optimum generations. This trend will be proceeded for several generations until GA stops. (when GA reaches a fixed number of generations). For proposed methods, fitness function equals mean energy consumed by entire network in each population. Fitness function is calculated , regarding Heinzelman model. Heinzelman has stated, in a model, that each node, to transmit L bits of data in d distance from itself, consumes E_t energy.

$$
\begin{aligned}
E_t = LE_{elect} + L \in_{fs} d^2 \quad d < d_0 \\
E_t = LE_{elect} + L \in_{mp} d^4 \quad d \geq d_0
\end{aligned}
\tag{6}
$$

In which:

d_0: the shortest crossover distance.

E_{elect}: energy required to activate electronic circuits.

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

Also the energy to receive L bits of data equals:

$$
E_r = LE_{elect}
\tag{7}
$$

In the proposed algorithm and setup phase, we compute fitness value for the bits in final selection, and suppose that 0 bits representing common nodes and 1 bits representing CHs. The total consumed energy of network equals:

$$
E = E_1 + E_2 + E_3 + E_4
\tag{8}
$$

In which:

E_1: energy necessary to send from common node to CH;

E_2: Energy necessary to receive CH data from common nodes;

E_3: Aggregation energy in CH;

E_4: Energy necessary to send from CH to BS.

Which we have:

$$
\begin{cases}
E_1 = LE_{elect} + L \in_{fs} d^2_{distoch} \quad d_{distoch} < d_0 \\
oR \\
E_1 = LE_{elect} + L \in_{mp} d^4_{distoch} \quad d_{distoch} \geq d_0
\end{cases}
\tag{9}
$$

In which:

$d_{distoch}$: distance from common node to CH;

L: number of bits.

$$
E_2 = LE_{elect} \times N\_Common
\tag{10}
$$

N_Common: common node number

$$
E_3 = LE_{ag} \times N\_ch
\tag{11}
$$

E_{ag}: aggregation energy in CH

 N_ch: CHs number (bits 1)

$$E_4 = LE_{elect} + L \in_{fs} d^2_{distoBs} \quad d_{distoBs} < d_0$$
$$oR \hspace{8cm} (12)$$
$$E_4 = LE_{elect} + L \in_{mp} d^4_{distoBs} \quad d_{distoBs} \geq d_0$$

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

In setup phase, after applying fitness function on final populations(population of selected optimum generations) and specifying common nodes and CHs,$E_1$for common nodes(0 bits) and E_2,E_3, $E_4$for 1 bits, are calculated. Finally in steady phase nodes' energy is reduced, based on transmissions. For example if we want to run algorithm in 1000 rounds and 5 optimum populations (population resulted by 5 optimum populations)are selected in setup phase, second round with second population, third round with third population, fourth round with fourth population, and fifth round with fifth population, is run. Similarly, the sixth round with first population and the seventh round with second population is run. Code I shows the proposed method. Also Chart 1 shows flowchart of the proposed algorithm.

Code I. Proposed method:

1. state = normal

2. Grid

3. Node Selection of each grid

4. create initial population

5. create a random population of initial population

6. Running GA

7. Selection 5 optimum selected generation

8. Running steady phase

9. if round = 0 go to 10 else go to 6

10. END.

4   Simulation

The proposed algorithm analysis has been done by MATLAB software. In this analysis, some indices as alive nodes at the end of each round, number of grids, number of selected nodes in each grid are considered to compose initial population. Also initial nodes' energy, are random measures between 0.3 to 0.5.

Other parameters used in simulation are as follow: 1. nodes are randomly placed in a square –shaped 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;
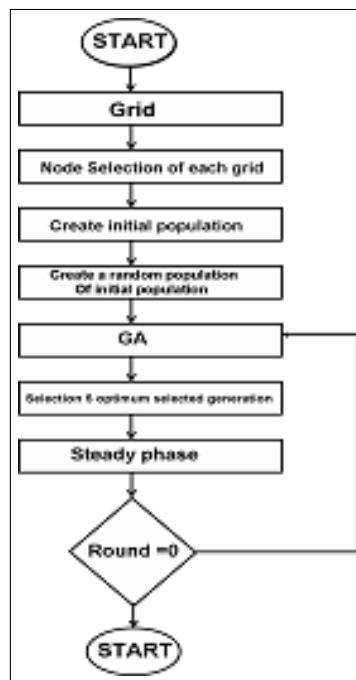
$$7. d_0 = \sqrt{\frac{\in_{fs}}{\in_{mp}}}$$

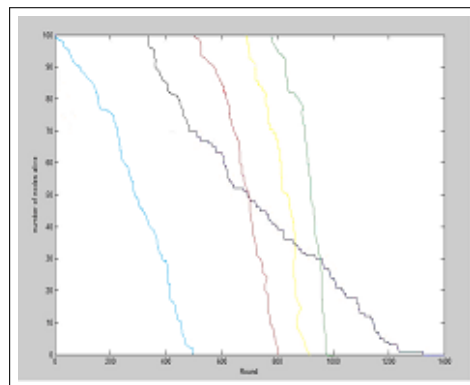Figure 1: Flowchart of the proposed algorithm

Figure 2: Total number of alive nodes in the RGWSN, LEACH,GSAGA,RCSDN,RGWSN

The proposed method has been compared to LEACH, RCSDN, GSAGA , and RGWSN methods. Figure 1 shows the number of alive nodes at the end of 1400 rounds and figure 2 shows fitness function for population of 5 optimum selected generation. Table 1 shows simulation parameters.
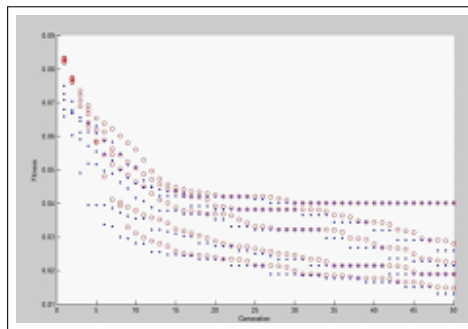
Total number of cluster in different round in LEACH.

Figure 3: The energy consumed by entire network for 5 optimum selected generation
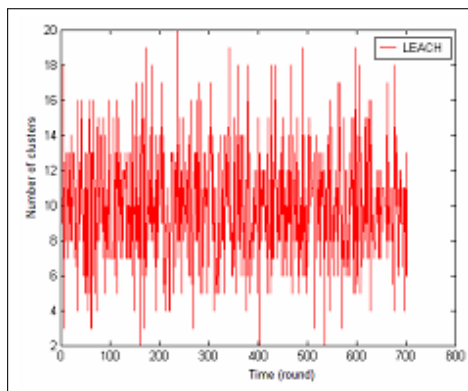

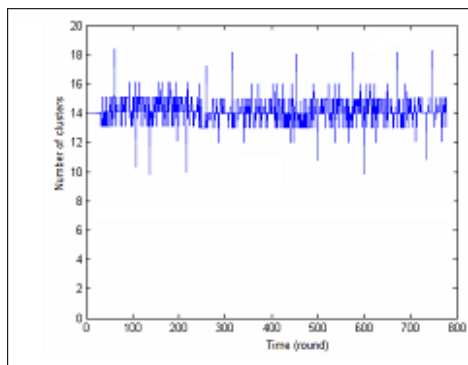Figure 4: Total number of cluster in different round in LEACH

Figure 5: Total number of cluster in different round in CRCWSN

TABLE I.Simulation Parameters

Value	Parameter
100*100 m	Network size
50,50 m	Base station location
rand [0.3,0.5] J	Initial energy for node
50nJ/bit	E_{elec}
10pj/bit/ m2	ε_{fs}
0.0013pj/bit/m4	ε_{mp}
5nj/bit/signal	Data aggregation energy
100	Nodes number
6	Grids Number
5	Nodes number of each grid
87m	d_0

1. The energy consumed by entire network for 5 optimum selected generation.

As shown by diagrams, after running 1400 rounds, the alive nodes in the proposed algorithm are more than those in LEACH, RCSDN,GSAGA, and RGWSN methods. So the network's lifetime increases. In this method, we also compare the number of clusters in various rounds, to LEACH methods. Figures 3,4 show the number of clusters in LEACH and proposed methods.

Total number of cluster in different round in CRCWSN.

As shown by diagrams, in the proposed method, clusters formation in different rounds is more balanced than in the LEACH method.

5   Conclusion

In this paper, we presented a new method of clustering to transmit data from common nodes to CH and from CH to BS in sensor networks. Selection of optimum cluster play an effective role in increasing sensor network's lifetime. We show, by multi simulations, that the proposed algorithm differs from other proposed algorithm in reducing energy consumption and can significantly increase network's lifetime compared to similar previous methods.

Bibliography

[1] GAO De-yun, ZHANG Lin-juan, WANG Hwang-cheng, Energy saving with node sleep and power control mechanisms for wireless sensor networks,in: National Engineering Laboratory for Next Generation Internet Interconnection Devices, School of Electronics and Information Engineering, Beijing Jiaotong University, China, 18(1):49-59, 2011.

[2] A. G. Delavar, A. Abbas Baradaran, J. Artin, RGWSN: Presenting a genetic-based routing algorithm to reduce energy consumption in wireless sensor network,International Journal of Computer Science Issues, Vol. 8, Issue 5, No 1, 54-59, September 2011.

[3]]Y. Zhu, W. Wu, J. Pan, Y. Tang, An energy-efficient data gathering algorithm to prolong lifetime of wireless sensor networks, *Comput. Commun.*, 33:639-647, 2010.

[4] CHENG Hong-bing, YANG Geng, NHRPA: a novel hierarchical routing protocol algorithm for wireless sensor networks, *Journal of China Universities of Posts and Telecommunications*, 15(3): 75-81, 2008.

[5] A.H. Mohajerzadeh, M.H.Yaghmaee, H.S.Yazdi,A.A.Rezaee, A Fair Protocol Using Generic Utility Based Approach in Wireless Sensor Networks, *Ultra Modern Telecommunications & Workshops, 2009. ICUMT '09. International Conference on*, pp. 1-4, 2009.

[6] S.Yussof, R.Z. Razali, O.H.See, A Parallel Genetic Algorithm for Shortest Path Routing Problem, *2009 International Conference on Future Computer and Communication*, DOI 10.1109/ICFCC.2009.36, 2009.

[7] A.G. Delavar,J.Artin,M.M.Tajari, RCSDN : a Distributed Balanced Routing Algorithm with Optimized Cluster Distribution, ICSAP 2011, 3rd International Conference onSignal Acquisition And Processing , 26-28, February, 2011, Singapore

[8] A.G. Delavar, J.Artin, M.M.Tajari, PRWSN: A Hybrid Routing Algorithm with Special Parameters in Wireless Sensor Network, in: A. Özcan, J. Zizka, and D. Nagamalai (Eds.): WiMo/CoNeCo 2011, CCIS 162, pp. 145–158, 2011.

[9] Heinzelman, W.R., Chandrakasan, A., Balakrishnan, H., Energy efficient communication protocol for wireless sensor networks, *Proc. of the 33rd Hawaii International Conference on System Science*, vol. 2, DOI: 10.1109/HICSS.2000.926982, 2000.

[10] Shiyuan Jin, Ming Zhou, Annie S. Wu, Sensor Network Optimization Using a Genetic Algorithm, School of EECS University of Central Florida Orlando, FL 32816

[11] Jianming Zhang,Yaping Lin,Cuihong Zhou,Jingcheng Ouyang, Optimal Model for Energy-Efficient Clustering in Wireless Sensor Networks Using Global Simulated Annealing Genetic Algorithm, DOI 10.1109/IITA.Workshops.2008.40

[12] V.Purishotham Reddy, G.Michael, M.Umamaheshwari, Coarse-Grained ParallelGeneticAlgorithm to solve the Shortest Path Routing problem using Genetic operators, *Indian Journal of Computer Science and Engineering*, ISSN : 0976-5166, 2(1):39-42, 2011.

[13] Wang, Q., Yang, W. Energy consumption model for power management in wireless sensor networks, In *4th Annual IEEE communications society conference on sensor, mesh and ad hoc, communications and network*, DOI:10.1109/SAHCN.2007.4292826, 2007.

[14] T. Rappaport, *Wireless Communications: Principles & Practice*, NJ, Prentice Hall, 1996.