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An Advanced Lifetime Enhancement Algorithm in Wireless Sensor Networks Utilizing Clustering Approach Based on Genetic Algorithm

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ABSTRACT

Today, significant development has been occurred in the field of Electronics and Telecommunications. One of these developments is sensor that can monitor the operational environment. These sensors can monitor a short board of the environment but in the operational environment, they can report results to sink by sending data, hand to hand. Clustering is and efficient method in this field. There are several algorithms for clustering and each of them investigates different measures of the network. in this paper, a clustering method is proposed by using genetic algorithm and its efficiency is compared with LEACH, LEACH-M algorithms. The simulation results indicate that the proposed algorithm is this paper lead to increase the network lifetime and improve the network coverage in comparing with these two algorithms.

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Introduction

Recent developments in the field of electronics and wireless communication bring this ability to design and crate sensors with low consumption power, small size, good price and different applications. These tiny sensors can perform actions such as receiving different environmental information (based on the sensor type) and information processing and sending and they lead to an idea to create and expand networks such as wireless sensor networks.

Previous works

Generally, initial concepts of the wireless sensor networks will be discussed by an accurate investigating of protocol stack of sensor networks. In fact, the original alphabet of WSNs is its protocol stack. Protocol stack for wireless sensor networks composes of five layers which include: Application layer that makes the hardware and software of lower layers, transparent for management applications of sensor networks. Also this layer manages demand broadcasting in sensor networks. [1] transport layer provides a bridge between network and application layer and reliable data transferring between source and sink, network layer in which different routing are introduced for sensor networks, link layer ensures to provide a reliable communication link in wireless sensor networks to transmit packets between neighbor nodes and physical layer that contains components and functions and in fact they are transmit and receive between radio wireless waves. And digital data processing is located in the upper layers.

Clustering algorithms in sensor networks

Usually wireless sensor networks are composed of many sensor nodes. Clustering is an efficient way to manage and control a large number of sensors. Furthermore, several clustering algorithms are studied in wireless sensor networks. In term of scalability, these two algorithms are divided in two Variable Convergence Time Algorithms and Constant Convergence Time Algorithms, and in the following we will study them.

Varaiable Convergence Time Algorithms

Time is one of the major factors in the convergence of this clustering algorithm. Some of these algorithms are RCC[2], LCA[3] and CLUBS[4] and their time complexity is O(n) and n is the number of sensor nodes in network. When the number of sensor nodes is not too high in network, these algorithms are appropriate for implementation. The convergence time in this algorithm is increasing by network node increasing, dramatically. [5] finally, variable convergence time algorithms are more able to control the clustering properties in compare with constant convergence time algorithms.

Constant convergence Time Algorithms

These clustering algorithms have a constant convergence time, without considering the population size of nodes. These algorithms are usually looking for a focused strategy. And their cluster members are determined based on their current position and the position of their neighbors. Genetic algorithms are a part of developments in the computer filed and they have a rapid development space in the field of Artificial intelligence. By taking an accurate look to evolution process than means a process that nature use it to solve its problems, we can reach to interesting and practical ideas. The obtained information during thousand years from nature in chromosomes and in lower level is stored on genes and DNAs.

Chromosome

Whole the body of living things is composed of cells and in each cell, there is identical set if chromosome. A chromosome contains genes which are blocks of DNAs. Each gene encrypts a specific protein to a code and it means that it encrypted it.

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Basically, it can be stated as follows that each gene has a characteristic and encode a specific sign.

Search Space

When we want to solve some problems, often we are looking for a solution which is better than others. The space of all possible solutions is called search space. Each node in the search space indicates a possible solution , each solution is characterized by different values such as fitness function. There are many solutions to find appropriate solution (not necessarily the best solution) that one of them is using genetic algorithm. In genetic algorithms, search space is called genetic population.

Fitness Function

Chromosomes chances for survival are determined based on their merit. It means that chromosomes that have high fitness level, will have a greater chance of survival and reproduction. Therefore, to determine the extent to which responses are appropriate, the fitness function is used. This function receives a chromosome and return a number as output. This number will demonstrate the fitness amount of chromosomes as a solution.

Chromosomal Encoding

The first step in chromosome construction is chromosome encoding. The most common encryption methodsare used in the genetic algorithm.

Binary representation: representing a member can be done by using values of 0 or 1. Binary encryption is the most common type of encryption method, because mainly the first issues about genetic algorithms are using chromosome encryption. In this method, chromosome is shown as follows.

1010101011110011

Displaying with true value: if the solution that we are seeking is a list of real numbers,encryption will be a list of real numbers.

Sequencing displaying: this type of displaying is used for sorting or ordering problems. The famous problem is the salesman problem in which each city has a unique value from 1 to N.

Tree display: in this display type, the members are as a tree. Each term can be drawn as a tree of functions and terminals.

Genetic Operators

Genetic operator is a set of actions than are used in genetic algorithm and by using current population, the next population can be built. Always, chromosomes are selected among current generation based on their fitness. Then, genetic operators are done on them and then they moved to a new population.

Cut Operation

After selecting the type of encryption, a step can be taken in the direction of cutting. In this operation, genes are selected of parent chromosomes and a new child is created. The simplest way to doing it is two point random selection. With this action, different compositions of available genes are created in current population. Cut operation can be as follows.

First chromosome:11011 | 00100110110
Second chromosome: 11011 | 11000011110
Child 1 chromosome 11011 | 11000011110
Child 2 chromosome:11011 | 00100110110

Termination conditions of genetic Algorithm

This type of algorithm should have a termination condition as well as any other algorithm. This condition can be one of the following conditions or a combination of them.

1-utmost, creating several generation by genetic algorithm
2-passage time from the beginning of genetic algorithm
3-creating some sequential generation, so that there is no any better chromosome.
4-greater than or equal of fitness of one of the chromosomes than a threshold value

In this section, we provide a new clustering algorithm that is implemented by using genetic algorithm. And according to the output from the simulation, we have achieved the desired results. After clustering and formation of head clusters, the proposed algorithm investigates the clusters to find additional sensors (sensors that their covered environment is covered by other sensors). And Sleep/wake up mechanisms is run for these sensors. Considered parameters in genetic algorithm for selecting cluster heads in the proposed algorithms are:

In the proposed algorithm, Genetic algorithm investigates to select cluster heads, the following parameters:

- The distance between the internal nodes
- distance between cluster heads
- number of clusters

Clustering by using Genetic Algorithms

To obtain wireless sensor network where energy consumption is reduced, other known algorithms such as cluster selection based on cluster head can be used. At it can be appear from its name, clustering is done by cluster head and we do not divide the cluster nodes. And in the proposed algorithm, we used genetic algorithm to select these cluster heads. To select the cluster heads, several parameters are used in fitness function which ultimately led to use of multi-criteria problems. Multi-criteria problems are the kind of problems which the output of problem is determined according to several parameters from input. In fact, we can assume that we are searching for each of the input parameters in one dimension of search space. For example, determining optimal output in a single input problem means that to search the optimal answer, we should find the optimal place on a line. In a problem with two inputs, to obtain optimal answer, we should search in a 2-dimensional plane. Also in a problem with N inputs, we should search in a N-dimensional space for answer.

The Proposed Algorithm

The new method is based on this idea that instead of initial clustering, we should choose efficient cluster heads. And then we place the near nodes to this cluster head in the cluster. After selecting cluster heads, to each node, membership command is issued. And according to the distance of node with cluster heads to the nearest cluster, each node issues its demand to confirm the membership. After selecting cluster heads by genetic algorithms and cluster formation, additional sensors are identified in each cluster and for these sensors, we will use Sleep/Wake up mechanisms. The new method ensures that clusters have nodes with a nearer distance to other clusters, so required energy to data transmission to the cluster head will be save compared to other clustering modes. Amount of energy consumption for transmit K bit data is obtained from the following equations:

$$Et = Ee + Ed * k \quad \text{equation(1-4)}$$

Where K is the sent bit and $E_e$is the consumption energy by electronic and electric equipment which are in the sensor and E_d is energy consumption per the sensor distance to destination sensor and its value is derived from the following equation:

$$Ed = \begin{cases} E_{Amp} \times d^2 , & d < d_r \\ E_{Amp} \times d^4 , & d > d_r \end{cases} \quad equation(2\text{-}4)$$

In this equation, dr is considered as threshold distance. Threshold distance is dependent to the technology of sensor construction and this distance usually is a short distance.

The main criteria used in the proposed method

The main criteria used in this proposal are given blow: The number of selected cluster heads. The main objective of this

proposal is to obtain the optimal number of clusters. Because each cluster head represent a cluster so choosing K cluster head is in fact selection of K cluster.

Distance between cluster heads

If the distance between cluster heads is low, clusters will be formed compatibly and by a high-density. While in other word, clustering node will be from with low density. On the other hand, the distance between cluster heads should not exceed the limit. Because creating data exchange paths through cluster heads can result in trouble. And based on equation (), the consumption energy has squared relation with distance and it is influenced by this method.

$$S_{Head(i)} = \sum_j \left(\sqrt{(Xi - Xj)^2 + (Yi - Yj)^2} \right) \quad \text{equation()}$$

The inner distance of clusters

The inner distance of clusters represents the node closeness to each other. If the inner distance of a cluster is a small number, it represents that nodes are in density and this density ensures data abundant integration.

Final network fitting based on the parameters

For final fitting parameters, we should combine the obtained parameters at different stages with each other.to have a point for a state of network. Now, the fundamental problem in parameter combination is that they don't have any heterogeneity with each other. It means that parameters are not same. For parameter combination, there are three methods that in the following, we briefly mention to them.

Simple Composition

In this method, we combine parameters linearly. The main problem in this method is the unfair parameters combination. For example, in composing the second parameter with third parameter, due to the larger amount of ranges of third parameter compared to the values of the second, in compare with the values of second parameter, second parameter does not actually effect on final fit. And third parameter will be dominant to the final result. To solve this problem, the second method is recommended.

Parameter Normalization

In the method of parameter normalization we map the parameters in the range of [0,1] and then combine them. This method is reasonable, because all parameters have the same context.

Data normalization with impact factor

This method is an extension of second method. In this case, for each normalized parameters, a coefficient is considered. And, if necessary, the effectiveness of each parameter can be controlled. In the proposed method, normalization is used with impact factor.

Selecting additional sensors in each cluster

At this point (after choosing cluster heads by genetic algorithm and cluster formation) a number of sensor nodes are selected for sleeping. To do this, the following steps are done:

-each node broadcasts a message as follows:

Msg(ID NODE, POSITION NODE, REMAIN ENERGY)

-each node has a table that contains a list of concerned neighboring nodes. According to the received message, the ID of a node that issues the message is stored in its neighboring table, node u is the neighbor of node v, if d(u,v)<=R

And R is the communication range and D(u,v) is the communication between nodes (u,v).

-according to the position of sensors and Id of nodes in their neighborhood table, it calculates the degree of overlap with its neighboring sensors.

-a sensors whose coverage area is fully covered by its neighbors is considered as an additional sensor.

- a sensor that is considered as additional sensor, we choose it as sleep state.

-to set the sleeping time of slept sensor nodes, we should set their activation time based on the amount of remained power and neighbor nodes. Due to their neighbors in the table, slept sensors, it chooses the least remaining energy as the activation time. When a neighbor with lowest energy exited from a network due to energy completion, it sends a message to sleeping node to active this node, again.

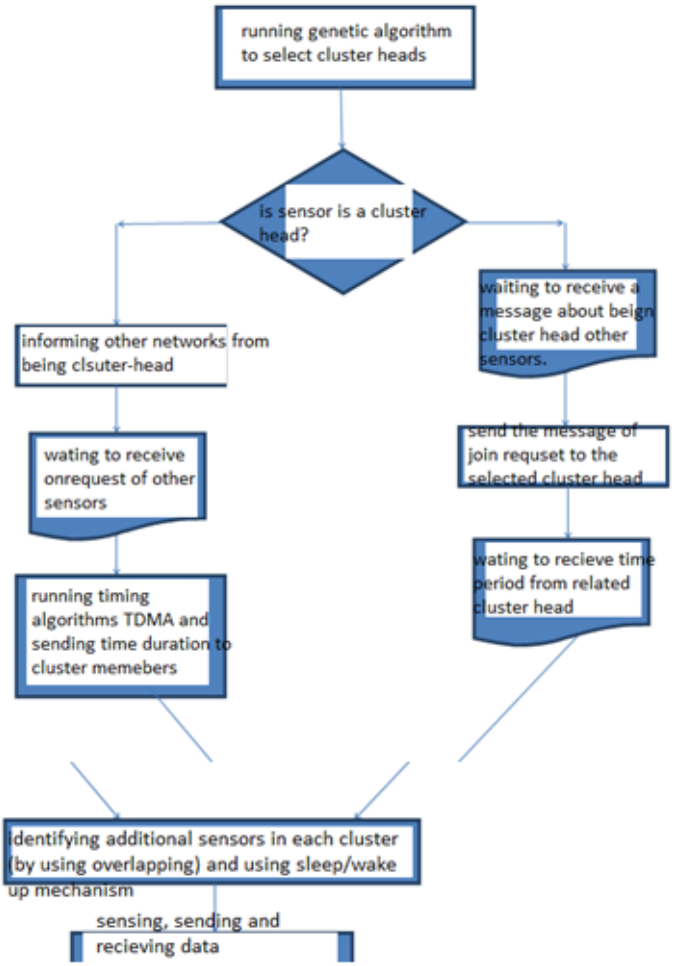

Figure 1. Operations of proposed algorithm

Network simulation, evaluation and comparison of the proposed algorithm

The initial model and default of wireless sensor network which is presented in this proposal is as follows:

-network has N sensor node and they broadcast in a predetermined environment , randomly.

-all sensors have the same initial energy,

-sensors and sinks has a fixed place and don't have mobility feature.

-all sensors are identified based on their unique ID.

-only by the received signal power, nodes can be aware from their position.

-the provided algorithm in sink is implemented and the results are sent to nodes.

-algorithm can be run, periodically or by deleting node, it can be executed again. Implementation method is based on genetic algorithm and it is implemented and analyzed. To implementing proposed algorithm , we use MATLAB software. In this implementation, all parameters are assumed as dynamic

parameters that algorithm can be designed and implemented for each desired parameter. The benchmark of consumption energy is in sending a few thousand random event in sensor network. The amount of consumption energy to send K bit data is obtained from equation(4-4).

$$Et = Ee + Ed * k \qquad \text{equation(4-4)}$$

K is the number of sent bit, E_a is consumption energy by electronic and electric equipment in the sensor and E_d is the consumption energy based on the sensor distance of destination to source sensor and its amount is obtained from the following equation:

$$Ed = \begin{cases} E_{Amp} \times d^2 , & d < d_r \\ E_{Amp} \times d^4 , & d > d_r \end{cases} \text{(5-4) equation}$$

In this equation, dr is considered as threshold distance

Finally, simulation is done based on assumption given in table 1. To compare differences in proposed algorithm with Leach-M and Leach algorithms, we compare the clustering method and selecting cluster head and implemented algorithm in different scenario and parameters with Leach and Leach-M. In the new propose method , network lifetime is evaluated as follows and at first, network faces with different events in different parts, randomly. Each sensor that is created near event, senses it. Then sensor sends obtained information to the nearest cluster head. Now, according to the number of send information and distance of sensor node with cluster head, amount of energy sensor is reduced. In the meantime, due to the abundance of events, by time passing, the energy of some sensors has been completed and then we are not able to send data, this is often called sensor dying. So we can store the live nodes in each of the periods. According to the same criteria, figure() shows the number of live nodes in each period for network.

Table 1. basic parameters

m 100 * 100	**Implementation environmment**
sensor 100	Number of sensors
7 meter	Threshold distance (dr)
1 nano J	Consumption energy for each sent node
2000 random event	Number of events

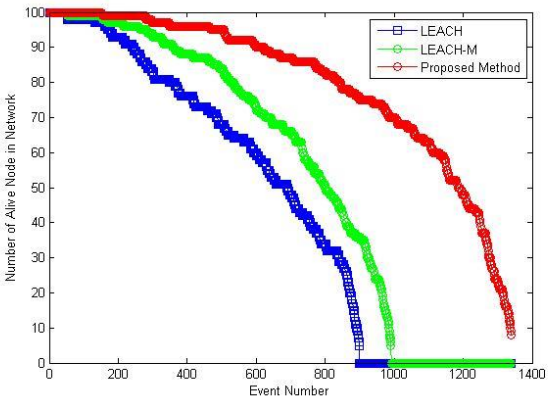

Figure 2. Comparing the number of live nodes in each round

In the figure (2), the highest curve is for new proposed method. This output indicates the prolonging network lifetime. other curves are related to the output of Leach and Leach-M algorithms. In figures (3) and (4), the energy consumption related to proposed algorithm Leach and Leach-M are displayed. Figure (3-4) shows the average energy consumption of network and figure (4-4) shows the final energy consumption of network. When we reach to the first dying node in each of the algorithms, the program implementation is completed. For example, as it can be seen in Leach algorithm that total network energy is 87 J but in round 55, the first empty node is removed of network and empty. But in the proposed algorithm, the first node exited in round 150 and by considering total energy of 84 J in network and this indicates that proposed algorithm in consuming the energy of network sensors have more balancing and resulted of the balanced clustering algorithm.

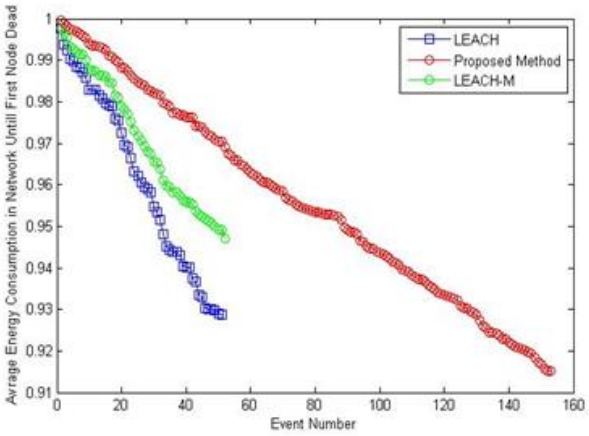

Figure 3. Average energy consumption to the first dying node

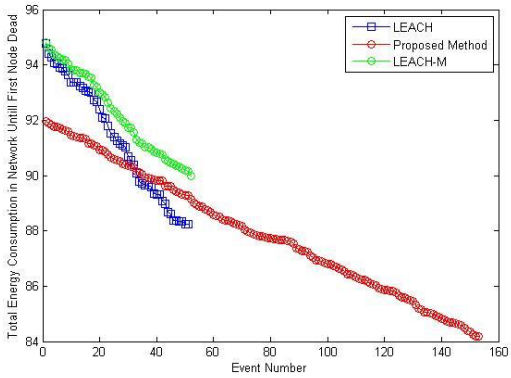

Figure 4. Comparing energy consumption to the first dead node

Figure (5) shows the final energy consumption of the network .algorithm will end when all nodes in networks are without energy. As it can be seen, proposed algorithm have more performance in compare with two other algorithms. And this issue lead to increasing the network lifetime and maintaining coverage in the network.

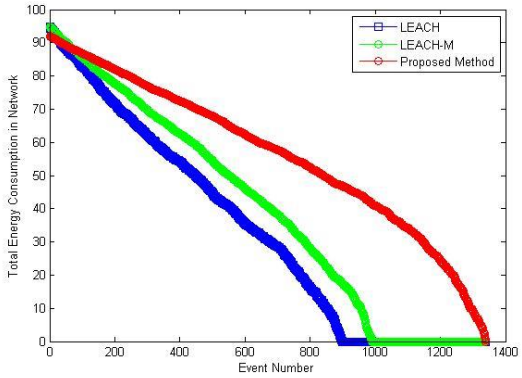

Figure 4-5. comparing the amount of consumption energy in the total network

In figure (6), the proposed algorithm and Leach and Mleach algorithms, in the available minimum energy parameter between network nodes are compared in sequence rounds. As we can see, for example in Leach algorithm in round 20, the weakest sensor (sensor with lowest energy) has 0.45 Joules

energy but in the proposed algorithm, the weakest sensor has more remained energy.

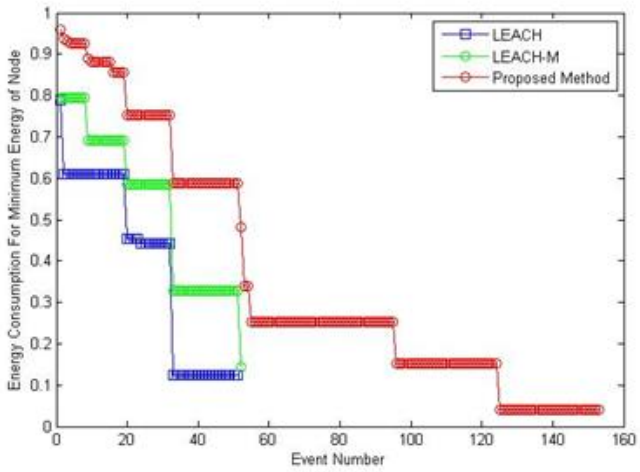

Figure 6. the remaining energy in sensor with minimum energy in different periods

Conclusion

In this scenario, clustering was performed on the basis of various parameters. These parameters include the number of cluster head selection, the distance between the cluster heads, the distance between the inner clusters. After applying the above parameters, the output of final clustering is a form that all parameters are effective in it and according to the obtained output of new proposed algorithm and energy consumption diagram in nodes, it can be found that proposed algorithm leads to prolonging the network lifetime and since sensors have more lifetime so it lead to this that covered area will be covered with more sensors in the next periods and this lead to maintain higher amount of coverage in next periods.

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