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Reviewing the New Methods of Routing for the Reduction of Energy Consumption in Wireless Sensor Network

Amir Abbas Baradaran[1], Hassan Heidari[2], Hamed Qamsarizadeh[2], Mehrdad Hassanzadeh[2]

[1]Member of Department of Computer Science, Azad University (Natanz branch), Natanz, Iran,
[2]Student of Department of Computer Science, Azad University (Kashan branch), Kashan, Iran,

ABSTRACT

One of the most important issues in wireless sensor networks is reducing energy consumption [40, 37and 47]. This matter has forced many researchers to look for methods to solve this issue. In recent years, so many methods have been proposed. And in this research, the most recent ones have been studied. Different issues such as lifetime of the network, primary energy, node density, type of transfer (multi hops or single hop) have been considered here for they are the key factors in energy consumption as well as the lifetime of a wireless sensor network. It has also been tried to examine issues such as FND, LND as the main ones. Having considered the weak and strong points of the previous studies, new ways have been presented to control the energy consumption while to increase the efficacy of network lifetime. This study has been aimed to recognize the advantages and disadvantages of previous methods and to present suggestions for future efforts Surveying similar methods of 2011 and 2012 [21, 32, 38, 40 and 47] has been looked at as one of the aims of this study,

KEYWORDS: Wireless Sensor Networks, Genetic Algorithms, Routing, Reduce Energy Consumption

INTRODUCTION

Wireless sensor network (WSN) consists of a large number of small nodes [1, 2, 3, 4, 27 and 28]. These nodes are dispersed in the environment to collect data and transfer the collected data to a base station called BS in order to be processed.[12,27 and 28] This transfer can be direct (single-hop) or indirect (multi-hops) [1, 4, 12, 17, 27 and 28]. In both kinds of transfer, the environment is divided into clusters. Then, one of the nodes in each cluster is selected as candidate and named cluster head (CH) [1, 2, 4, 18, 27 and 28]. After that, CH gathers data of the rest of the nodes and transfers them to BS [1, 2, 3, 4, 12, 27 and 28]. In single-hop transfer, CH data transfer directly to BS, but in multi-hop transfer, CH transfers the collected data to a higher level, nearer to the base station [1, 27 and 28]. Figure 1 shows the stages of multi-hop transfer.

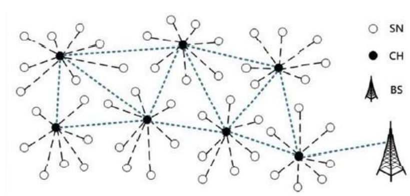


Figure 1.Multi-Hop Transmission [27, 28]

This type of network is mostly used in monitoring health equipment, electronic equipment, military application of wireless sensor network such as monitoring wars or military forces, recognizing fire in forests, controlling patient conditions, recognizing and finding vehicles, etc. One of the main problems of this kind of network is the storage of sensor network lifetime [1, 2, 4, 15,27 and 28]. That is because of energy consumption of nudes during data collection and sending them to BS. This results in the death of nodes and network lifetime [10, 27 and 28]. One of the methods used in recent years for the reduction of energy consumption in this kind of network in the presentation of routing algorithms. Routing means finding the optimal direction from the beginning point to the destination. Among the best methods of routing in wireless sensor network, flooding algorithm, gossiping, direct dispersion, SPIN, LEACH can be mentioned [1, 2, 3, 11 and 17].

A.Flooding algorithm:

In this method, a node sends a copy of giving data to each of its adjacent nodes in order for part of data to be dispersed in network while a node received a new data, sends it to its adjacent node except the one from which data was received [29,30].

***Corresponding Author:** Amir Abbas Baradaran, Member of Department of Computer Science, Azad University (Natanz branch), Natanz, Iran, Mobile:+989133623329 amirbaradaran24@yahoo.com).

This process continues until all nodes receive a copy of data. In this method the time for a group of nodes to receive and send some data is called a round [21, 22, 24, 29 and 30]. Figure 2 shows the flooding method.

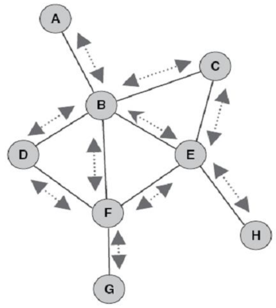


Figure 2. Flooding Method

This method –in addition to its application- has some shortcomings which are as follows:

- Implosion: in this method one node sends data to its adjacent nodes without considering whether they have received the data. This causes accident. Figure 3 shows this issue [21, 22 and 31].

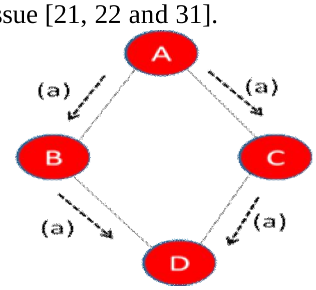


Figure 3. Implosion in flooding method[31]

As figure 3 shows, node A begins data transfer to its adjacent nodes B and C. B and C receive the data and both send it to D.

- Overlap: sensors usually cover common geographical areas and usually collect and transfer the environmental data common between two nodes. Figure 4 shows how the two nodes A and B collect common data and transfer it to their common adjacent node [21, 31].

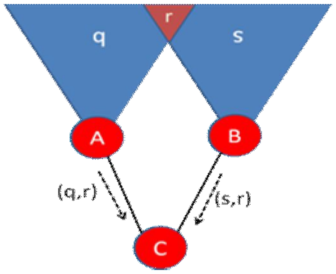


Figure 4. Overlap[31]

B. Gossiping method:

This method uses accidental process to save energy and can be a useful alternative for all-dispersion method. In this method, data is sent accidentally to one adjacent node instead of equal sending of data to all adjacent nodes. If a node receives data from its adjacent node, it can send that data to the same node if being elected accidentally. The reason is shown in figure 5[29].

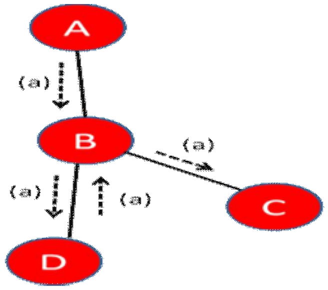


Figure 5. Gossiping Method

As shown in figure 5[31], if node-D never sends its data back to node B, node C will not receive any data. Although this method transfers data rather slowly, energy consumption reduces. This method prevents accident to a great extent, but presents solution for overlap [21, 24].

C.SPIN method:

Two key solutions of SPIN protocols for removing the above-mentioned problems in all dispersion method are using discussion and comparison of resources [32]. In order to remove accident and overlap, SPIN nodes use discussion with each other before sending data [24, 25]. Also nodes evaluate their resources before sending data. Each sensor nodes has its own special resource manager that monitors energy consumption. Application programs evaluate resource manager before sending or processing data. This helps sensors to stop some special activities at the time of energy constraint. Meta data produced in SPIN as data agents must have smaller volume in comparison with data of which Meta data is agent. Also, if two pieces of data are separate, their Meta data must have this feature too [24, 25and 31].

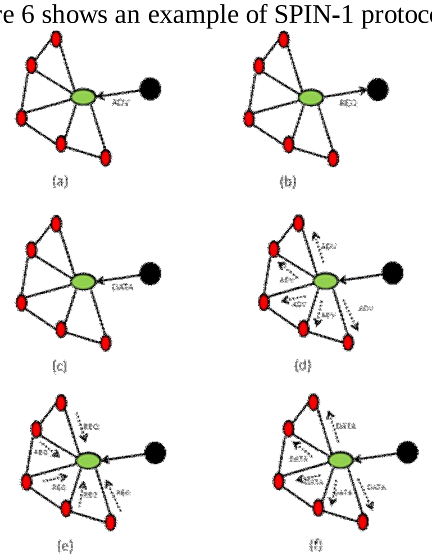
B.1: SPIN message

Nodes in SPIN use three massages to communicate with each other:

- ADV: It is used for the propagation of new data. When a node of SPIN has data to share, it can do this by sending the relevant Meta data.
- REQ: It is used for calling data. A SPIN node uses this message when real data is needed.
- DATA: It contains data message. DATA messages contain real data collected by sensors. They consist of a series of Meta data.

B.2: SPIs-1 method:

Three-phase hand-shaking: this method is a simple method of hand-shaking for dispersion and wasting data in network. It acts in three phases. In each phase, it uses one of the messages described in B.1. The protocol starts when a node gains new data and wants to disperse it. The node names the new data and sends an ADV message to its adjacent nodes. When receiving the ADV message, adjacent node examine if they have received such data. If not, the adjacent node sends a REQ message to the transmitter as response in order to send the recalled data. Protocol is completed by sending the given data i.e. sending DATA message in response to REQ message. Figure 6 shows an example of SPIN-1 protocol [24, 25].



Fugure 6.Hand-Shaking [31]

Receiving an ADV message through node A. node B examines whether or not it has all propagated data. Otherwise, node B sends back an REQ message to node A in which all data node B needs is listed. Having received an REQ message, node A extracts the requested data and sends them to node B by a DATA message. Then node B produces a new ADV message in which it propagates its received new data to its all adjacent nodes, but it does not send ADV message to node A. That is because node B knows that node A already has the data. Then, these nodes send the propagations of new data to their adjacent nodes and protocol continues. The most important advantages of SPIN-1 are its simplicity, locality, and non dependence to a special discipline. This advantages result in the simple application of this method in any network [24, 25].

D.The conducted dispersion method

In this method, transmitters as well as receivers use attributes to specify the produced or required data [30, 33]. The aim of this method is to find an efficient multi-directional route between transmitters and receivers. In this method, each duty is reflected as a request in which a collection of attribute-value pairs to fulfill a duty is dispersed in the environment [33]. In this method, each node remembers the node from which it has received the data. Some features of conducted dispersion methods in network which make distinguish them from the traditional ones are as follows:

1. Data conducted dispersion method is a database method and is based on this fact that all communications in a sensor network use interests to specify the named data.
2. In contrast to traditional networks that have end-to-end transmission method, this method uses pitch-to-pitch or adjacent node-to-adjacent node communication.
3. In data conducted dispersion method, nodes don't have an overall equal address, but each node must be locally separable from its adjacent node. Because each node can process data, the volume of data in network can be reduced and data can be sent briefly.
4.

E. LEACH method

LEACH method is a self-organized protocol with dynamic grouping which uses random method to distribute energy consumption between nodes in a balanced way [1, 2, 4, 26 and 27]. In this method, nodes organize themselves as local clusters and one node plays the role of base station [2, 4, 26 and 27]. If cluster heads (CH) are elected constantly on the basis of a priority and remain constant during lifetime, it is apparent that cluster head sensor will die soon and the useful lifetime of all nodes in cluster will end.[2,9,11,12,26,27] This is why LEACH algorithm uses random replacement of cluster heads between energetic nods in order for the change of a given node not to be offloaded.[2,12,26,27] The operations carried out in LEACH algorithm are repeated periodically and each round has some phases. Each round begins with a phase of primary regulations and continues toward a constant phase. In this phase, data is sent to the central station.[1,2,26]In order to minimize data overhead, duration of constant phase must be longer compared with the primary regulation phase.[1,2,4,9,12,26]the phases of LEACH algorithm are as follows:

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

E-1: SET UP phase

At first, when clusters are formed, each node decides whether to be a cluster head in current phase [1, 2, 26, 27, 34and 41]. This decision directly relates to the proposed percentage for the number of cluster heads and must be determined in advance. [2]Also, another effective factor in this decision making is the number of times a node has already been elected as cluster head. Node n selects a random number between 0 and 1 to make this decision. If the selected number is less than a threshold called T(n), it well be elected as cluster head.[1,2,4,12,26and 27]In relation , P is the given percentage of cluster heads and G is the collection of nodes which have not been cluster head in the last 1/p of a round. R is the number of rounds. Using this threshold, each node in 1/p of a round will be cluster head in one round. In later rounds, the probability of but each node after being cluster head cannot be a cluster head again at least for 1/p of a round. In later rounds, the probability of election of nodes which were not being elected as cluster head increases in a way that in round P, T equals 1. [2, 4, 26, 27]

E.2: Steady Phase

When clusters are formed and each node is specified to a given cluster, data transfer begins [2, 26 and 27]. Normal nodes can transfer collected data to cluster heads in the least amount of energy. The radio set of transmitter of each node, not being elected as cluster head, can remain off until the time of data sending of that node [2, 7, 15, 26 and 27]. In this method, it is supposed that all nodes always keep its receiver on in order to receive all data from nodes in its cluster. After the complete receiving of data, cluster head node can use the operation of signal processing to compress all data as one signal. Then, the produced signal is sent to the central receiver [1,2and 41]. Regarding the probable long distance of base station, this process will need too much energy [1, 7, 10, 14, 26 and 27].

Related works

One of the proposed algorithms in wireless sensor network is the hierarchical adaptive clustering algorithm [2,17and 19].The main idea of this algorithm is based on the primary data of node primary energy. This algorithm has been able to optimize the node first death and node average death [2, 17, 20, 31 and 35].Cluster head election is simpler in comparison with similar previous methods such as LEACH, A-LEACH, and LEACH-C [2, 26].Also, this algorithm is based on LEACH. It means it has two phases of set up and steady [2, 27].In set up phase, clusters are formed and in steady phase data is transferred. In this method, CHs are used periodically [1, 2, 17, 19, 26 and 27]. Figure 7 shows the number of clusters in LEACH-SWDN method in comparison with similar previous methods [20, 34].

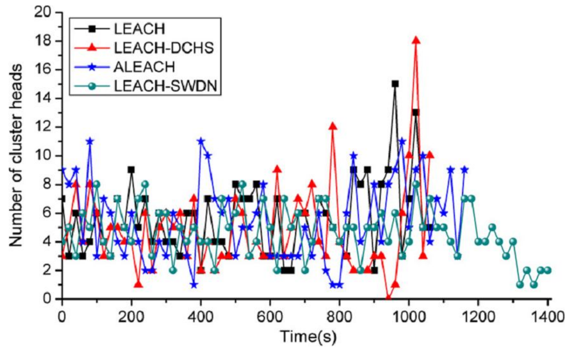


Figure 7.Number of CHs[2]

Figure 7 shows, CHs selection have better balancing rather than previous similar methods.

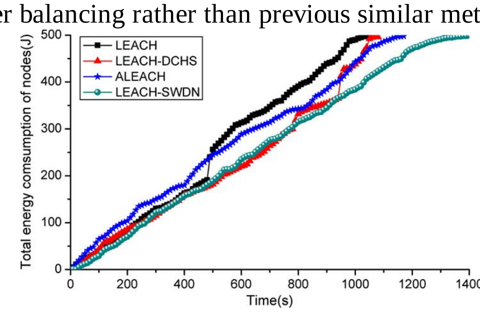


Figure 8.Energy Consumption in Nodes [2]

Figure 8 shows an optimization in energy consumption for each node in comparison with similar previous methods [2, 17and 35]. One of the important shortcomings of LEACH-SWDN is the constant number of nodes for simulation. Nowadays, it is better that different number of nodes to be simulated. Also, the energy is constant for all nodes. In wireless sensor networks the primary amount of energy is distributed randomly and is usually between “0.2 to0.5” J. Now suppose that this proposed energy in this method be carried out with this amount of proposed energy (5 Jul) for 1000 nodes [2]. 5000 Jul of energy is needed .It is not economical, but by random election of 0.2 to 0.5 Jul of energy, the maximum amount of 500 Jul is needed. The other shortcoming of this method is that the length of environment in which nodes are distributed as well as the situation of base station are constant, while it is better for them to be variable [2]. Of course, it is probable that designer of this algorithm has used different simulation parameters and not mentioned them in the table of parameters. But we assume that if so, all constant amounts must have been described in the essay [2, 35].

RGWSN Algorithm

The other proposed algorithm for optimal routing is RGWSN algorithm [3].In this method, clustering is carried out by genetic algorithm [1, 3, 4, 39 42 and 45]. RGWSN algorithm has been able to optimize lifetime in two dimensions of distance and energy [1, 2, 3, 4, 12 and 25]. Table 1 shows the simulation parameters in RGWSN method [1].

Table 1: Simulation parameters in RGWSN Method

Parameter	*Value*
Network Size	***100*100 m***
Position of BS	***(50,50) m***
Initial Energy	***Rand[0.2-0.5]***
Number Nodes	***100***

Of course the parameters of network size, base station situation and the number of nodes are as variables in this method. The above-mentioned table shows some of these parameters. Figure 8 shows the network lifetime in RGWSN method in comparison with the previous methods.

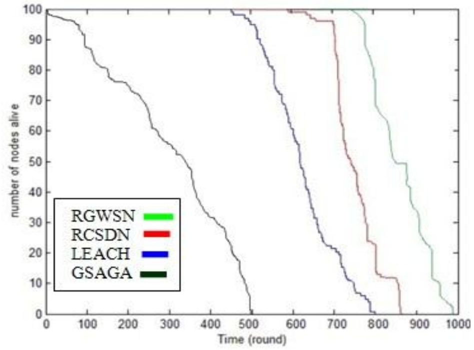


Figure 9.Number of Alive Nodes in Different Methods and RGWSN [3]

As shown in figure 9, in this method network lifetime and first death have been improved [3, 4]. The important shortcoming of this method is that RGWSN has not solved the problem of density in network. Also, this method has not been able to select optimum cluster heads in dense areas [1, 3, 4 and 14]. The other method of routing in wireless sensor network is CRCWSN algorithm which uses the idea of genetic algorithm and re-clustering for routing [1, 3, 4 and 42]. In this method, single-hop transfer has been used [1, 3, 4 and 17]. This method carries out clustering and cluster head election based on density, distance, and energy. It uses a probable process to find the optimal route [1,3, 4 and 17]. The simulation results show that CRCWSN has improved network lifetime in comparison with the similar previous methods [1]. CRCWSN method is the improved version of RGWSN. It means that it reduces the costs of implementing RGWSN algorithm by re-clustering process [1, 3, 8 and 12]. This method has also been able to solve the problem of density compared with RGWSN method [1, 3 and 4]. Table 2 shows the simulation parameters in CRCWSN method [1].

Table 2: Simulation parameters in CRCWSN Method

Parameter	*Value*
Network Size	***100*100 m***
Position of BS	***(50,50) m***
Initial Energy	***Rand[0.3-0.5]***
Number Nodes	***100***
Number of Grids	***5***
Number of Probability Nodes	***6***

As shown in figure 9, network lifetime in CRCWSN method has been improved in comparison with similar previous methods.

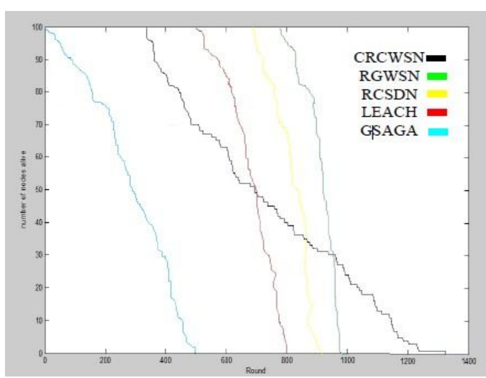


Figure 10. Number of Alive Nodes in Different Methods and CRCWSN [1]

Figure 10 shows, network lifetime in CRCWSN is better rather than previous similar methods. The other feature of CRCWSN method is the improved balanced clustering during different periods [1, 3, 4, 8, 12, 13 and 14]. Figures 11 and 12 shows the number of clusters in different periods in CRCWSN and LEACH.

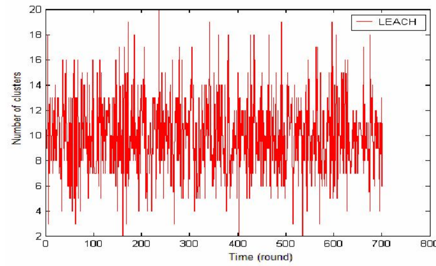


Figure 11.Number of Clusters in LEACH[1]

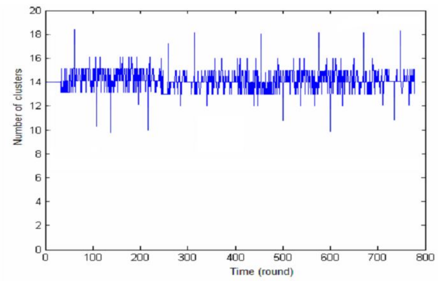


Figure 12. Number of Clusters in CRCWSN[1]

As shown in figures 11 and 12, it is obvious that the balance of energy in CRCWSN is better than of LEACH algorithm. Although network lifetime is improved in CRCWSN in comparison with RGWSN method, but node first death occurs too early in this method. Figure 9 shows the first death in CRCWSN method compared with similar previous method. Also, this method uses only single-hop transmission [1, 3, 4, 12, 23 and 25]. The other method of routing in wireless sensor network is KGAWSN method [4]. In this method, genetic algorithm finds the optimal CH and carries out routing by means of cluster heads and K-means algorithm [1, 3, 4, 39 and 45]. Simulation results show that factors such as network lifetime, balanced clusters, and the energy consumption of each node have been improved in this method [1, 2, 3, 4, 7, 9 and 14]. In this method, some probable nodes which are better than others in case of energy, density, and distance have been elected for clustering. K-means algorithm carries out the clustering. KGAWSN is the completed method of CRCWSN and RGWSN methods [1, 3 and 4]. KGAWSN method uses both single-hop and multi-hop transfer [1, 3, 17, 23and 25]. Although this method is an improved version of CRCWSN and RGWSN methods, it has solved one of their problems (the number of rounds in RGWSN method and first death in CRCWSN method). [4, 23and 24] This can be a shortcoming of KGAWSN method [1, 2, 3, 4, 12 and 17]. Some researchers have proposed new ideas for the reduction of energy consumption in wireless sensor network. One of these ideas is ECRPW method [5]. This method has been able to improve network lifetime through graph weighing (graph coloring). ECRPW method turns the network graph to a tree based on weigh. Heads of the tree specify the optimal route .This method has been able to balance clustering in comparison with the previous methods. Also, the network lifetime and first death have been improved [4, 5 and 14]. Figure 13 shows alive nodes in ECRPW method and similar pervious methods.

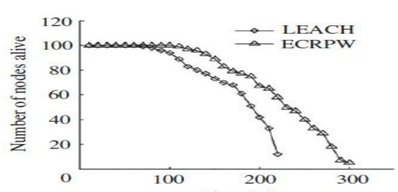


Figure 13.Relation of Between Alive Nodes and Network Lifetime[5]

As shown in the above figure, it is obvious that ECRPW method has improved network lifetime compared with the similar previous methods. One of the most important shortcomings of this method is that it has only been compared with the old basic LEACH algorithm and has not used the new ideas of the years 2011 and 2012. Figure 14 proves this claim [1, 2, 3, 4 and 5].

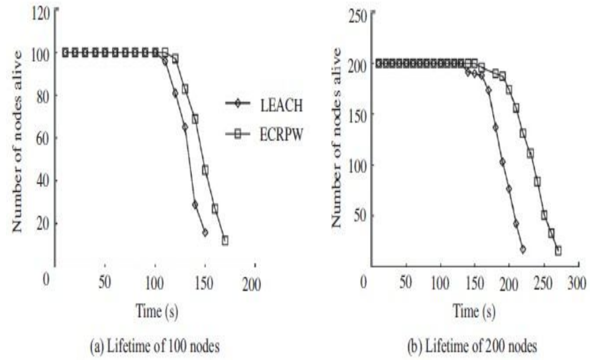


Figure 14.lifetime protocols[5]

In same methods in sensor network, moving factors are used. One of these methods is EBMA method [6]. This method has been able to make a good balance between energy consumption and data collection [4, 6]. The below table show the simulation parameters in EBMA method.

Table 3: Simulation parameters in EBMA Method

Parameter	*Value*
Network Size	***10^6 m^2***
Initial Energy	***50j***
Energy Consumption in Each Round	***50nj/bit***
Energy Consumption for Each Data	***10nj/bit***

As shown in table 3, one shortcoming of this method is the high amount of network primary energy. The other method of routing which in addition to routing process, takes data collection into consideration is EEHA method [7, 10]. This method uses the idea of collecting safe data. This method has presented an efficient model of energy and a method of high efficiency for data aggregation in wireless sensor network [7, 10and 26]. The main idea of this method is that the collected data in each mode be transferred in a safe manner. In addition to safe transfer, the best route is also used. The simulation results show the better efficiency of this algorithm in comparison with the similar previous methods. EEHA method uses a fine timing to receive and transmit data. Also, the problem of data aggregation has rather been improved in this method [7, 10, 15and 26,]. An important shortcoming of this method is that it is not clear whether the network lifetime and first death are improved.

The other method of routing is EADC method [12]. In this method a routing protocol based on cluster and re-clustering is presented for wireless sensor network [1, 4, 8, 9 and 12]. The network knows the energy level in each implementation of this algorithm. In this method energy consumption for intra-cluster communications and intra-cluster communications has been taken into consideration simulation results show that the type of data transfer (single-path or multi-path) in the network energy consumption average has been improved [1, 4, 7, 8, 12 and 17]. Regarding simulation parameters, this method has these shortcomings:

- The primary energy of nodes is high [1, 2, 4, 7, 12, 15 and 26].
- The number of nodes and base station situation are constant for simulation [1, 4 and 12].
- This method has only been compared with the old method of LEACH [4, 12].
- The lifetime important of this method is only calculated in 600 seconds [12].
- The first death has occurred too early [2, 9, 12 and 41].

Conclusion and Suggestions

1. Algorithms based on physical distance

The first effectors in the field of wireless sensor networks, especially the reduction of energy consumption, were made only the basis of physical distance [30, 32and 47]. Considering only physical distance in general state cannot be a good criterion for the reduction of energy consumption. Considering physical distance is only suitable for the environments in which there are a few number of nodes and the nodes are dispersed in a balanced way in the environment. As mentioned in the previous section, simulation results were shown in different environments with different number of nodes. It was observed that methods such as LEACH and LEACH-C, considering density, cannot improve network lifetime [1, 2, 9, 12, 26 and 27]. The other problem of distance-based algorithms is that they improve network lifetime only the basis of distance; therefore, they do not consider the primary energy of nodes [1, 2, 6, 9, 14 and 18].

As mentioned before, if there are lots of nodes in an environment and a rather high amount of primary energy is defined for nodes; all nodes need a huge source of energy for a long time [2]. This is not economical. For example in methods such as EBMA and CACPSH, the primary energy of nodes are defined 50j and 5j respectively [6, 9]. This is a shortcoming of these methods, because in an environment with too much nodes, a huge source of energy is needed [7, 11and 26].

2. Energy-based algorithm

Allocating too much energy for nodes is not economical. Some researchers try to take the issue of energy of nodes into consideration. It means that they use the lesser amount of energy. Methods such as EADC, KGAWSN, CRCWSN and RGWSN consider the primary energy a random amount between 0.2 to 0.5j and 1j to 3j [1, 3, 4and 12]. An advantage of this random allocation of energy is that energy consumption in the environments with too much nodes is low [1, 2, 4, 7and 26]. This is economical, but it may also cause problems. For example, because of random allocation of energy, all nodes may receive the least amount of energy. In this case, nodes will have little energy and each reception and transmission of data results in loss of some energy. Because the energy of nodes is low, they die soon [1, 3, 4,7 12, and 15].

3. Density-based algorithms

Dense area refers to a part of the environment in which node dispersion is more in comparison with the other parts [1, 4and 8]. It is obvious that in such dense environments, nodes selected as CH must be optimum from all points of view, because they receive and transmit more information [1, 4, 8, 9, 12, 14, 18, 27, 34, 36 and 41].

4. Combined algorithms

They are algorithms which consider different factors for optimal routing such as distance-energy based density-energy based, distanced-density based and distanced-density-energy based algorithms. Generally, methods which consider more than one dimension are called two-dimensional or multi-dimensional algorithms. Methods such as KGAWSN, CRCWSN and ECRPW are examples of multi-dimensional algorithms [1, 4and 5]. For example, ECRPW and CRCWSN are two-dimensional distance-energy based algorithms and KGAWSN and EBMA are three-dimensional density-distance-energy based algorithms [1, 4, 5and 6]. Generally new methods presented during 2010 to 2012 are based on more than one dimension [1, 4, 5 and 6]. Nowadays, researchers try to find optimal routing based on factors of more than two-dimensions.

5. Optimal routing by means of new algorithms

By new algorithms, we mean to combine some parameters of other methods and present new algorithm. This effort results in finding multi-dimensional routing algorithms. Some algorithms may consider only the dimension of distance, or energy, or density [1, 4, 5 and 6]. For example, Ant Colony algorithm is an algorithm which considers only the dimension of distance in optimal routing, or Bee Colony algorithm considers only the dimension of energy in optimal routing. We can combine these algorithms and present a new two-dimensional algorithms based on energy and distance. It will absolutely be more optimal in comparison with previous one-dimensional algorithms. For example, CRCWSN algorithm considers the two dimensions of energy and distance and ECRPW algorithm considers the two dimensions of energy and transmitted package size. Combination of these two algorithms can result in three-dimensional energy-distance-transmitted package size algorithm [1, 5].

6. Using genetic algorithms for the reduction of energy consumption in wireless sensor network

Generic algorithm uses a random operation. This random operation by the use of its operators causes the best amount during a number of generations to be gained [1, 3, 4 39and 42]. An advantage of generic algorithm is that in each operation, non-optimal points of the previous operation are deleted and contributed again in next phase or phases [3, 39, 42and 45]. The results of researches in 2007 to 2010 show that genetic algorithm can improve node election in dense areas. Methods such as CRCWSN and KGAWSN have been able to select better cluster heads in dense areas by the use of genetic algorithms [1, 3, 4, 8, 13 and 45].

7. Using supportive nodes for the reduction of energy consumption in wireless sensor networks

It is obvious that in areas of high density in network, nodes receive and transfer more data. This needs a powerful cluster head. In case of high density, cluster head will soon lose its energy. This problem can be solved to some extent by replacing supportive nodes. The process is as follows: during the implementation of algorithm, for all dense areas, supportive nodes are defined (for example, if there are ten areas in the network and three of them are dense, three supportive nodes are defined at the beginning of algorithm implementation). Then, during algorithm implementation, as soon as the loss of CH energy in dense area, supportive nodes are replaced [1, 2, 4, 7 and 12].

8. Using the improved methods in other methods

Considering the presented methods of optimal routing in recent years (2008, 2012), it is observed that most methods have made some changes in the parameters of other methods and have caused the improvement of network lifetime [1, 3, 4, 5, 6, 7, 9 and 10]. For example, in proposed methods it may be possible that clustering integral be selected from one method and data transfer integral and energy consumption integral be selected from another method. Simulation results show the good efficiency of this method in some cases. Although this method may result in new formulas, it does not present a new idea [1, 2, 4 and 19].

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