



An Energy Efficient Improving the LEACH Protocol Scheme in Wireless Sensor Networks

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Abstract

Data gathering is a common but a critical operation in many applications of wireless sensor networks. So, innovative techniques that improve energy efficiency to prolong the network lifetime are highly required. In this research, we analyze the reduction of energy consumption in wireless sensor networks. A sensor network consists of a large number of limited-energy sensor nodes, which are widely distributed in an environment that sense and collect the environmental information. In most applications of wireless sensor networks, there is no possibility of charging node batteries. In these types of networks, the most important challenge is the power constraint that directly affects the lifetime of the sensor network. Protocols designed in these networks should be accompanied by efficient energy consumption. The LEACH protocol is one of the well-known protocols that are widely used in this field. In this study, we use genetic algorithm and fuzzy clustering for improving the LEACH protocol. Our results show that the proposed algorithm has needs energy consumption in comparison with the original version. This leads to a prolonged network lifetime, which is one of the most important issues in wireless sensor networks.

Keywords: Wireless Sensor Network, Network Lifetime, Genetic Algorithm, LEACH Protocol, C-means Clustering.

1. INTRODUCTION

The recent years have witnessed the advances in wireless sensor networks which were made to propose protocols in different applications, either military or civilian applications such as target tracking, surveillance, and security management. Since a sensor is small, lightweight, untethered, battery-powered device, it has limited energy. Therefore, energy consumption is a critical issue in sensor networks. We are interested in sensor networks in which a large number of sensors are deployed to achieve a given goal. As all data obtained by sensors are transmitted to a sink or data collector, the

longer communication distance, is identical to the more energy is consumed during the transmission.

There have been numerous protocols and methods which aim to reduce the energy consumption by sensors and so make the network longlife. Clustering the network's sensors and sending the data of clusters to base station instead of transferring data individually by each sensors can decrease the transmitting energy, especially when the base station is located in far distance [1]. Clustering means partitioning the network into a number of independent clusters, each of which has a cluster-head that collects data from all nodes within its cluster.

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These cluster-heads compress the data and send it directly to the sink. Clustering can greatly reduce the communication cost because they only need to send data to the nearest cluster-head, rather than directly to a sink that may be located in further away.

The purpose of this research is to increase the sensor lifetime of a wireless network by using the LEACH protocol [2], which has been improved by genetic and fuzzy clustering algorithm [3]. Finally, the result of the proposed model is compared with other state of art papers.

The rest of the paper is organized as follows. Firstly, Section 2 describes the LEACH protocol. Then the detailed data analysis has been outlined in Section 3. Section 4 explains methods and shows the performance of an implementation with the fuzzy clustering algorithm, the LEACH protocol and the improved protocol with a combination of fuzzy clustering and genetic algorithm. Finally, Section 5 and Section 6 are dedicated to results, discussion and conclusions.

2. THE LEACH PROTOCOL

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first energy efficient routing protocol. It reduces the energy significantly. The LEACH protocol forms clusters in the sensor networks and randomly selects the Cluster-heads for each cluster. Non cluster-head nodes sense the data and transmit to the cluster-heads. The cluster-heads aggregate the received data and then forward the data to the sink. This protocol facilitates the nodes with more residual energy have more chances to be selected as the cluster head. In order to extend the lifetime of the whole sensor network, energy load must be evenly distributed among all sensor nodes so that the energy at a single sensor node or a small set of sensor nodes will not be drained out soon.

The basic principle is that it assigns overall energy consumption of the network uniformly to each sensor node through periodically selecting different nodes as cluster-head. This makes the survival time of nodes close to the network life

time. Thus, the energy consumption can be reduced and the lifetime of the entire network can be prolonged. There are two phases in LEACH protocol called setup phase and steady-state phase. In setup phase, the clusters are formed and the cluster-heads are selected. In the steady-state phase, the data from non-cluster heads are transmitted to the sink. The sensor nodes communicate to the cluster-heads using TDMA schedule. The nodes communicate to the cluster-head only in their allotted slots. It avoids collision. The cluster-heads are selected randomly for every round [4]-[6].

Although LEACH protocol prolongs the network lifetime in contrast to plane multi-hop routing and static routing, it still has problems. The cluster heads are selected randomly, so the number and distribution of cluster heads may not be optimum. On the other hand, the nodes with low remnant energy have the same priority to be a cluster head as the node with high remnant energy. Therefore, those nodes with less remaining energy may be chosen as the cluster heads which will result that these nodes may die first. However, the cluster heads communicate with the base station in single-hop mode which makes LEACH cannot be used in large-scale wireless sensor networks for the limit effective communication range of the sensor nodes [5]. For the reasons mentioned, in this paper, we used genetic algorithm [7] and fuzzy clustering algorithm [8], in order to improve the selection of head of clusters and sensors clustering as well.

3. DATA ANALYSIS

In this research, the simulation of the LEACH protocol is done by using the R2014b MATLAB software. Table 1 writes the parameters and the initial values.

After defining the parameters, sensors in the 2D coordinate space are generated, and each sensor receives 0.5 Jules of energy as its primary energy. Additionally, the sensor's distance from the main station, located at the center of the network, is obtained.

Table 1. List of primary parameters for defining sensors in a hypothetical network.

Parameter Name	Initial Value	Description
N	90	Number of sensors
ETX	$50 * 0.000000001$	The amount of energy to send and receive packets by
ERX	$50 * 0.000000001$	Maximum number of rounds to run
rmax	2500	

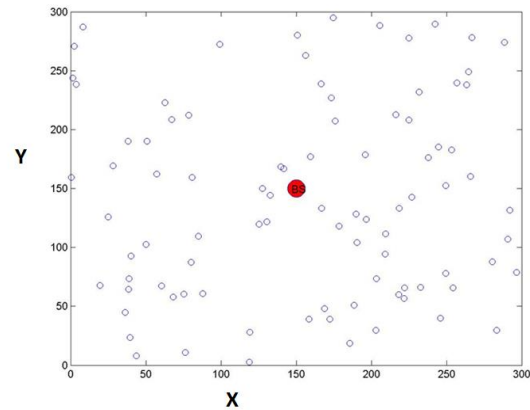
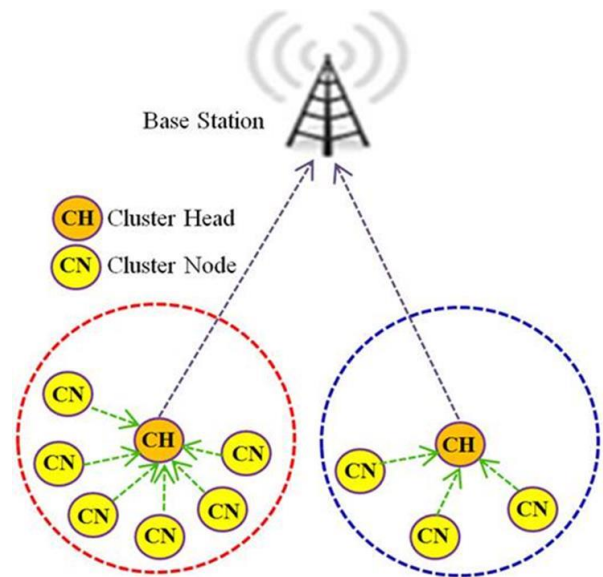
To construct a network and evaluate the proposed method, in the first step, once sensors were randomly distributed through the considering network, the distance to the main station, the type of sensor, Cluster Node (CN), Cluster head (CH) or base station (BS), and the initial energy of the sensor were determined. Figure 1 indicates a considering network in which normal sensors and BS are depicted by blue and red circles, respectively. Also, the horizontal and vertical axes represent coordinates x and y of each sensor of the network.

Figure 2 illustrates that the LEACH nodes (sensors) send their information to their corresponding cluster head, then cluster heads collect and compress the received data, integrate and send data to the BS (or sink).

Each node uses a random algorithm to determine whether it was the cluster head in the current loop.

As transferring information consumes energy, in initialization mode of the network, an initial energy is allocated to each cluster node to communicate and this leads to limit the cluster nodes' life span. When each sensor's energy was finalized, the sensor is deactivated. Figure 3 shows the inactive and active sensors, where a blue dot turns red if a sensor dies.

The network lifetime can be measured based on the number of rounds. At the beginning of each round, different set of cluster head is determined and information is exchanged among sensors. At the end of each round, the number of sensors which survived through the current round were calculated. From the information supplied during the rounds, three parameters have been

**Fig. 1.** Distribution of sensors in search space.**Fig. 2.** Sending packets from network's sensors to the BS.

employed to evaluate the performance of proposed method, which indicate three different points of the lifetime of wireless networks:

1. First Node Dead (FND). The time or the round in which the first node of the network is deactivated.
2. Half Node Dead (HND). The time or round in which half of the network sensors are dead.
3. All Node Dead (AND). The time or round in which whole sensors in the network are deactivated. In other word, the life span of the network is finalized.

Table 2 shows the parameters and their values which have been used in the modified method.

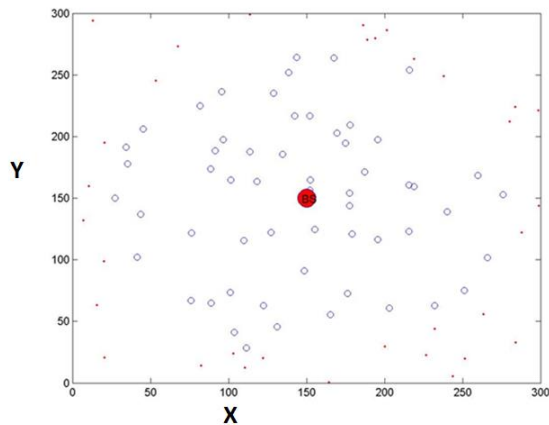


Fig. 3. Distribution of inactive and active sensors.

4. METHODOLOGY

In this research, the LEACH protocol has been improved through employing genetic algorithm and fuzzy clustering algorithm to achieve an optimal set of cluster heads and cluster the networks' nodes, respectively.

Figure 4 shows the procedure of the optimized LEACH protocol. The improved method has been optimized through two steps. At beginning, the genetic algorithm was utilized to select an optimal set of cluster heads. The cluster-heads are then collected the data from member nodes. Following this, to improve clustering of the networks sensors, fuzzy clustering was employed.

According to the diagram, the process of the improved LEACH is composed of the following steps:

1. Construction of the considering network. In this step, sensors are randomly generated. Moreover, the location of the BS is determined. In this research the location of BS is the center of the network. The network contains 90 sensors and the initial energy for each of them is 0.5 Jules.
2. Initialization. The parameters of each network sensor are initialized, namely primary energy for sending and receiving packets. Each sensor is allocated 0.5 Jules of energy as primary energy. During the execution, this energy is consumed by sending and receiving packages. When the

Table 2. Genetic algorithm parameters.

genetic algorithm parameters	Values
Mutation population percentage	5%
Crossover population percentage	95%
Population	30
Maximum repeat	10
Length of each chromosome (Number of sensors)	90

energy expires, the sensor's lifetime ends and so it inactivates.

3. Selection of an optimal set of cluster heads. As mentioned, in this research, a genetic algorithm is used to select cluster heads [9]. Table 2 writes the values of the parameters used for genetic algorithm implementation.
4. Clustering the member nodes. The Sensor clustering step is applied based on cluster heads obtained from the genetic algorithm. Once cluster heads were selected by genetic algorithm, the sensors are clustered according to the head of cluster from the previous step. In other words, the clustering phase aim to partition the network by considering the cluster heads as the center nodes.

The last step is transmitting the packets. After cluster-head selection and clustering, normal sensors send packets to cluster heads. Subsequently, the packets are gathered, processed, integrated and sent to the base station by cluster heads [10], [11].

Steps 3 to 5 are executed until reaching to a certain number of rounds or all sensors die. In other words, if the energy of the sensors is consumed before the predetermined number of rounds and all sensors will die, the algorithm stops. In this paper, the total number is considered 2500.

5. RESULTS AND DISCUSSION

The results obtained in these simulations confirm the successful performance of our proposed approach. In this simulation, the half-life criterion

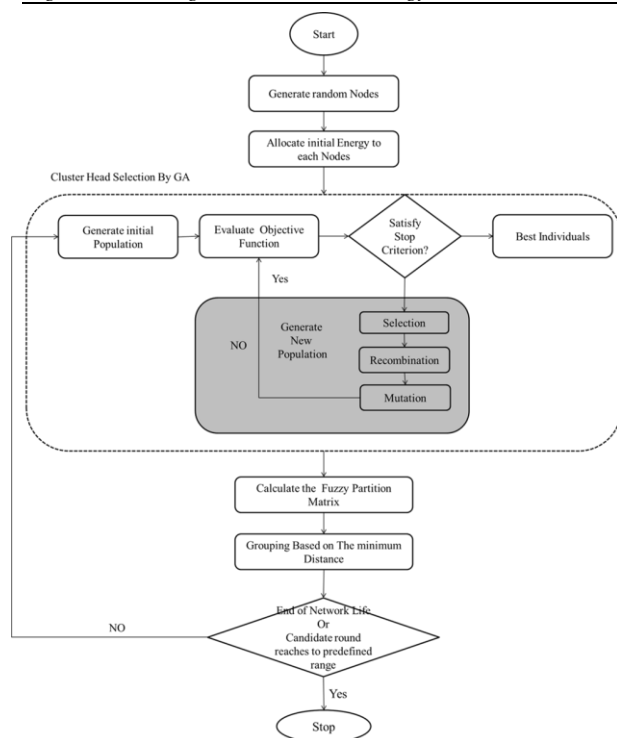


Fig. 4. General steps to improve the LEACH protocol.

was used as a comparison criterion, which is an estimated value for repetition in which half of the sensor nodes die. This metric is very useful in sensor networks application. In these graphs, the vertical axis represents the number of sensors and the vertical axis represents the number of rounds. The weakest type of the algorithm does not take into account the remaining energy level of the sensor nodes during clustering. We examined the distribution of alive sensor nodes according to the number of rounds for each algorithm.

Figures 4, 5 and 6, respectively, show the results of the implementation with the fuzzy clustering algorithm, the LEACH protocol, and ultimately the improved protocol with a combination of fuzzy clustering and genetic algorithm. The graphs represent the number of dead nodes during the simulation. The genetic algorithm has greatly improved energy and lifetime of the network by balancing the number of nodes in the cluster head, as well as the gap between the cluster heads and the main station.

In the LEACH protocol, due to the selection of cluster head in random form and lack of attention

to nodal energy, the number of dead clusters has also increased. So, the network lifetime in the cluster head reduce, wasted energy increase and finally the received data in the sink decrease. The wasted energy is equal to the energy consumed by member nodes for data transmission to the cluster head, But the cluster head node cannot send data after receiving the data due to lack of energy.

Moreover, reduction of wasting energy in the fuzzy clustering algorithm not only increases the lifetime of the sensor network, but also maximizes the number of packets received by the sink.

Another benchmark used in this paper is the Energy Consumption Index; this concept is equal to the sum of the packets reached to the destination to the sum of the energy consumption of the sensor network nodes.

Figure 7 compares the energy efficiency for assuming algorithms. The lower consumed energy and the higher the packets received at the destination and as a result the higher the energy efficiency. The proposed algorithm has the highest energy efficiency based on the above definition.

6. CONCLUSION

In this research, an efficient method for data aggregation and reliable delivery of data based on the LEACH algorithm with fuzzy clustering and genetic algorithm is presented.

In the clustering of sensor networks, one of the important indicators that influence the amount of data received in the sink, increases network lifetime and reduces the energy loss, is the choice of appropriate cluster head. But in most evolutionary clustering-based algorithms, only optimal clusters have been addressed and this important indicator has not been considered. In this paper, the selection of suitable cluster head based on the remaining energy of the node, the density of the neighboring nodes and the distance between the node and the sink are also considered. The achieved results show that the genetic algorithms and fuzzy clustering are appropriate for improving the performance of LEACH algorithm in terms of maximizing network lifetime, intaking

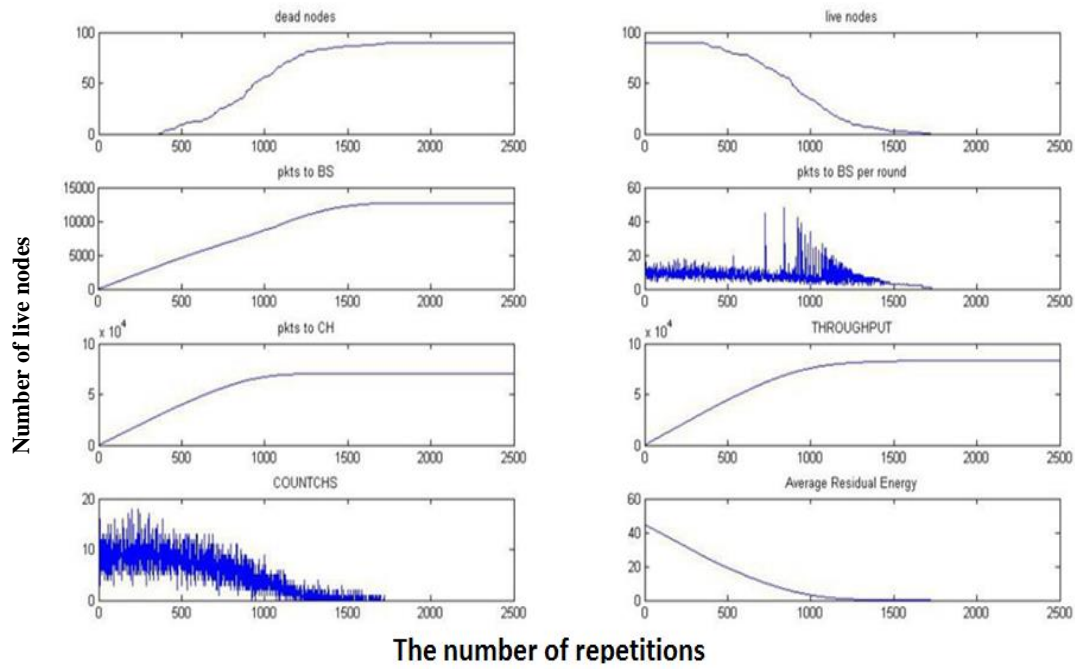


Fig. 5. The results of the run with fuzzy clustering algorithm.

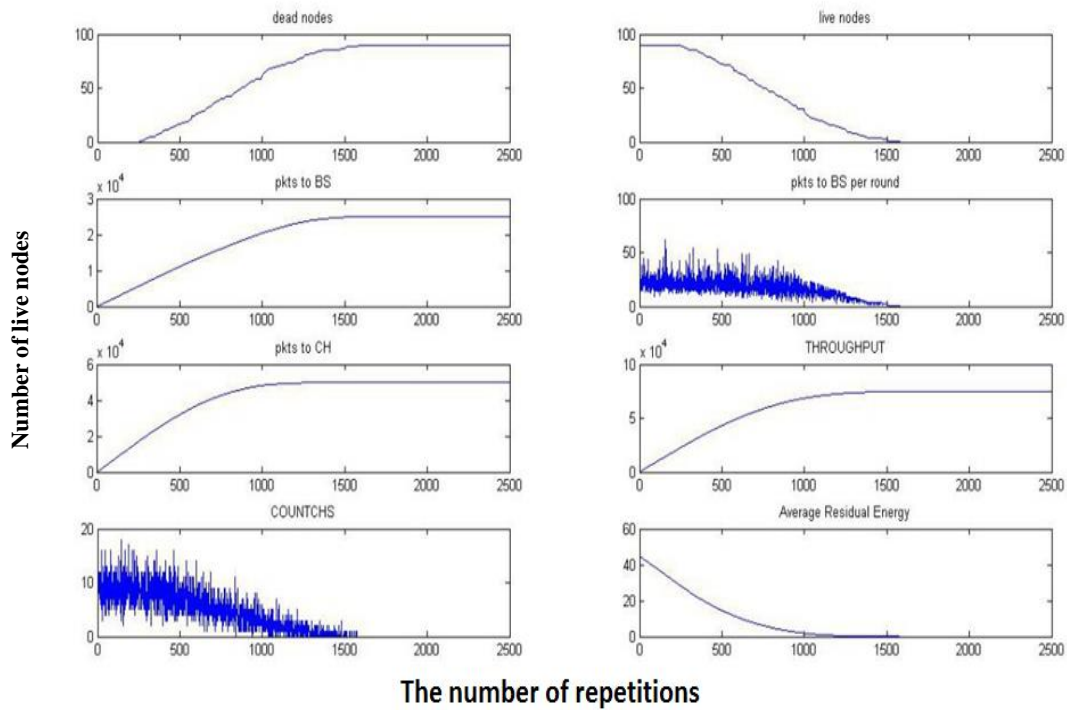


Fig.6. Run results with LEACH algorithm.

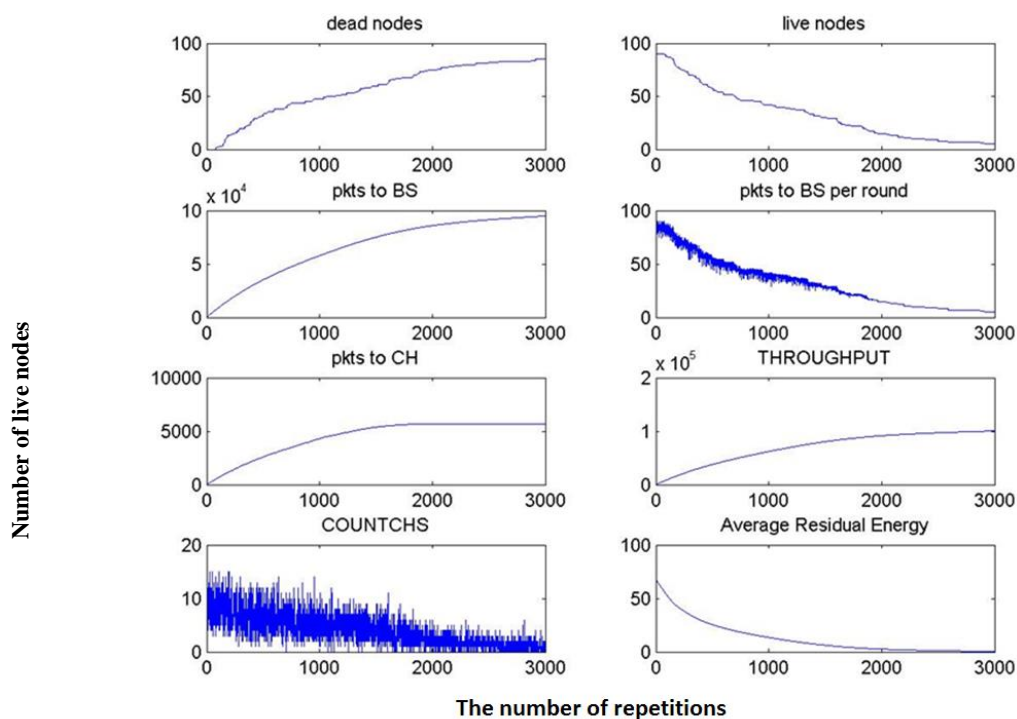


Fig. 7. Results of improved LEACH protocol with fuzzy clustering and genetic algorithm.

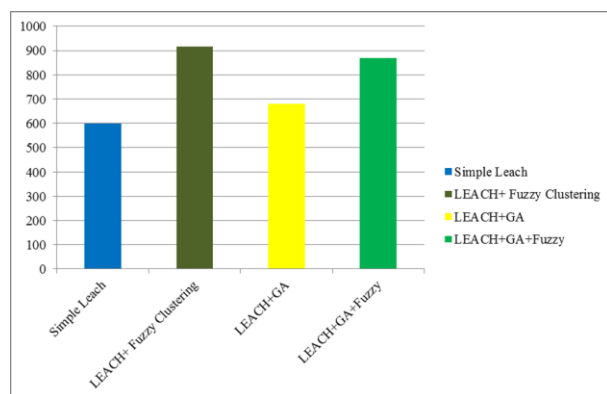


Fig. 8. Comparison of results of different methods of LEACH

data in the sink and minimizing wasted energy. It also helps to improve and restore the clusters.

The simulation results confirm that our proposed method can significantly increase the network lifetime, reduces network latency and improves communication reliability.

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