International Journal of Computer Networks and Communications Security

VOL. 4, NO. 9, SEPTEMBER 2016, 252–258
Available online at: www.ijcncs.org
E-ISSN 2308-9830 (Online) / ISSN 2410-0595 (Print)

Increase the Lifetime of Wireless Sensor Networks by Minimizing Energy Consumption When Selecting Cluster Head uses Meta-Heuristic Algorithms

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ABSTRACT

A wireless sensor network, consist of a large number of the sensor nodes, which are distributed in a particular area, that each of them has an ability to collect information from the environment and sending data collected to the base station.Wireless sensor networks are severely limited resources, limited resources, including the amount of energy, short communication range, low bandwidth,limited memory and processing in each sensor. Hence the use of clustering algorithm that would reduce energy consumption and leads to bandwidth appropriate efficiency, is critical. In this paper ,we are studying LEACH, and ELEACH algorithms. And then we proposed a clustering approach using PSO(Particle swarm optimization) meta heuristic algorithm. The proposed algorithm is examined by simulation of MATLAB that simulation results in heterogeneous environments show that the proposed algorithm improved the network lifetime by more or less 75% than LEACH protocol, and approximately 55% compared to ALEACH.

Keywords: *Wireless Sensor Networks, Lifetime, Hierarchical Clustering, Particle Swarm Algorithm.*

1 INTRODUCTION

With increasing advances in technology and users need to easily obtaining information from different environments and tracking, etc. scientists invented wireless sensor networks [1]. These networks composed of a great bit of small nodes with very little capabilities. These nodes that is called a sensor, can sense particular properties (such as the humidity, temperature, pressure , etc) in its surrounding and send it to its neighbor. In other words, the main features of the sensors, is sensing certain parameters of the environs and the ability to put across other nodes to transfer data obtained from the environment. Although it is possible in some applications, the nodes are linked up by communication cables, but in most applications, a sensor network is completely wireless.accordingly nodes in such networks are generally stable or have very limited movement. Important characteristic of these networks, is the possibility of the failure of the nodes. This failure could be due to various causes. One of the most important reasons,is the completion of a sensor energy . That's why the energy network is a crucial factor[2]. One of the most remarkable of discussions in these networks, is the conservation of energy to enhance the network lifetime.

Compared to traditional wireless telecommunications networks, such as cell systems and mobile ad hoc networks, wireless sensor networks have unique features and restrictions that include [3-5]:

- **Condensed layout of nodes:** The sensor nodes are usually densely arranged in the desired region. The number of the sensor nodes in a sensor network can be several times higher than that of a mobile ad hoc network.
- **Energy supply of sensor nodes by battery:** The sensor nodes, usually fed through the battery. In most cases, sensor nodes are arranged in harsh environments or in war zones, so that replace or recharge batteries is difficult or even impossible.
- **Strict restrictions on energy, calculations and memory:** sensor nodes, severely limited in terms of energy capacities, calculation and storage.

- **Self Configuration:** The sensor nodes are usually arranged randomly and without careful planning and engineering. After initial layout, sensor nodes should be able to independently configure itself in the network.
- **Depending on the application:** sensor networks are depending on application. A network usually designed and set up for a specific application. A network design requirements vary according to its application.
- **Frequent changes of topology:** the network topology frequently changes due to the node failure, damage to the node, add new nodes to the network, discharge of node energy or the channel fading.
- **Lack of national ID:** due to the large number of sensor nodes, usually creating a global addressing plan for sensor networks is not possible, because there was a large overhead for maintaining the identifier.
- **Many to one traffic pattern:** in most sensor network applications, data sensed by the sensor nodes from several source sensor nodes flows to a specific Sink and many to one traffic pattern is produced.
- **Data redundancy:** in most of the sensor network applications, sensor nodes set up in the desired region and are cooperating with each other to run out out a joint task. So sensed data by several sensor node certainly have a level of redundancy or correlation.

All sensor nodes to create a communication network working together to provide reliable network services. Cooperation between the sensor nodes in WSN is very important for two reasons [6-8]:

- Data that have been collected by several sensor nodes can give a valuable inferences about their environment.
- Cooperation between the sensor nodes can create a compromise between the cost of communications and calculation power.

Clustering mechanisms for sensor networks with hierarchical structures to improve network performance while reducing power consumption have been used. Clustering is a cross-section techniques that can be used in almost all layers of the protocol stack. The basic idea is that nodes around a clusterhead that is the issue of status maintenance and communication within the cluster, put in a group. Among the proposed clustering protocol, LEACH protocol for the following reasons is of particular importance in the eyes of researchers [9-11]:

– In this protocol, network clusters are formed as randomized, adaptive, and self-configured.

Randomized: This means that in each round, a certain number of nodes randomly selected as cluster head and the clusterhead has not been considered to a specific node before.

Adaptive: nodes that have the role of the cluster head in the current round, can not be candidate to undertake this role in the next round, so clusterheads candidates are characterized according to the previous round. Thus, expected that at the end of a certain number of rounds, all nodes became clusterhead.

Self-configured: network nodes in this protocol are forming a cluster without the help of any external agent or a particular node in the network, and this helps scalability of this protocol.

In LEACH data transferring was done from the nodes of one cluster to clusterhead and then to the base station with local control .and there is no need to the help of a external agent or a particular node in the network to the data transferring.

– MAC protocol used in LEACH results in appropriate amount of saving energy consumption by the possibility of relaxing sensors.
– The LEACH protocol as other clustering based protocols uses a combination of each cluster data and transmits the compressed data to the base station. Thus, the number of sent and received on the network is reduced and redundant data that are created due to the proximity of a cluster sensors to each other, before being sent to the base station are deleted.

LEACH runs through several stages, that each stage has two phases, launch phase and deployment phase. In the launch phase, each node decides to be the cluster head or not. Each node selects a random number between 0 and 1 that is the probability of selecting a cluster head. If the probability for node n is less than the threshold T(n),then node n is a clusterhead for the current stage. The T (n) is calculated as follows[8, 12]:

Equation (1)

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

Where G is the set of sensor node that wasn't clusterhead in 1/p later rounds. So in the first round, namely round 0, each node has the same probability of being the clusterhead. Parameter T(n) increases for the next round because fewer nodes

remain that are volunteering to be the cluster head. These clusterheads broadcast to all sensor nodes within the network and inform that there are new clusterheads. Other sensor nodes use the strength of received signal from each of these clusterheads for select the appropriate cluster to join it. During the deployment phase, the sensor nodes can start sensing operation and data transferring to clusterheads. Clusterheads, also gathering data from the sensor nodes within their cluster and transferring them to the base station. After a certain period of time of the deployment phase, the network entering to another round of clusterheads selecting. Due to decrease in overhead, deployment phase is longer than launching phase. LEACH disadvantages[13-15]:

- Cannot be exploited for large networks.
- It is not clear that the predefined number of cluster heads (i. e., p) how will distribute uniformly in the network. Indeed, there is no guarantee about the location, or the number of clusterheads in each round. Therefore, it is possible that the selected clusterheads centered in a part of the network, and consequently some of nodes remains without any clusterheads.

ALEACH protocol: ALEACH is based on LEACH [16]that introduces the likelihood for the main threshold (limit)and finally create the equation2 formulation, which determined by two possible and main threshold states. The Node with the highest residual energy is most likely to be a clusterhead

Equation (2)

$$P_i(t)=\begin{cases}\dfrac{k}{N-k(r \bmod N/k)}\dfrac{E_i-current}{E_i-\max} * \dfrac{k}{N} & ,C_i(t)=1\\ 0 & C_i(t)=1\end{cases}$$

Clearly, the threshold (limit) expanded by Equation 2 is very large, and finally leads the distribution of a large number of cluster heads at the beginning of each period and then became smaller then slowly become smaller and because there is small and smaller nodes that are not clusterhead now and will close to zero until the end of the round.

2 PROPOSED ALGORITHEM

We examined our proposed method in two homogeneous (energy of all the sensors is the same at the begining) and heterogeneous environments (energy of half of the sensors are two fold than the other sensors).In general, our method has two phases. In the first phase we are first divided the network environment into two layers, then we consider the top ten percent of the environment as an environment that its sensors act as a gateway. And in the second environment, which is 90% of the environment, we perform clustering operation using Particle swarm optimization. Selected clusterheads began to recruit so that the number of clusterheads are divided into the remaining nodes where the achieved value is the maximum number of members of clusterhead in the desired layer. Initially, each cluster node that was closer to the clusterhead become the member of clusterhead so that the upper limit quantity of members completed and after that the clusterhead that reaches to the defined maximum amount of the members didn't accept any member. When the above stages was completed, routing between cluster heads and choose the best route based on the residual energy of cluster heads and their distance from each other are considered. Clusterheads of the lower layers when gathered data from their members, aggregate them and sending them to the gateway nodes in the first layer that has the best position in terms of the distance from them and finally information will be sent to the base station. In the first layer clustering didn't perform , and only 50 percent of the first layer sensors determined as candidate nodes, that receive the data sent from the bottom layer by Clusterheads and then sent it to the base station and the rest of the nodes which didn't candidates ,send themselves directly to the base station. Sending data from the gateway nodes in the first layer to the base station prevent the rapid depletion of energy in clusterheads.

2.1 How Clustering

We use PSO algorithm to select the clusterhead among existing nodes so that we place the optimized number of clusterheads in entrance of the optimization function of particle swarm then this algorithm select the best nodes to be cluster heads according to its parameters. At the entrance of particle swarm optimization function,we enter the number of layer alive node, and the number of optimal cluster heads, this function first determines the population. First, the total population is randomly selected. That every member of this population, consist of the nodes that will become clusterhead. Every member of the population has a fitness value that is calculated using the fitness function. The process of calculating the amount of fitness for each member of the fitness function is that it is assumed that the member is clusterhead and then clustering operation will be done

according to this assumption. Finally,we included the energy consumption as fitness amount. The lower energy consumption, the higher qualified member to be the cluster. The random values are repeated in a loop and are updated to achieve improved value. To update each member ,the speed parameter is used. In this parameter,a feedback was taken from the best previous satate of the member (Gbest) and best t previous state of e total population (Gbest). Previous values added to speed value and the updated new value is created. The fitness value update is calculated on each iteration and qualified members was specified.Then the most efficient member selected as cluster head node.

2.2 Energy consumption model

Energy consumption in wireless sensor network consists of three parts: data transferring, data acquisition and data processing .The energy model was shown in Equation 3[17].

Equation(3)

$$\begin{cases} P_T(K) = E_{elec} \times K + E_{amp} \times d^y \times K \\ P_R(K) = E_{elec} \times K \\ P_{cpu}(K) = E_{cpu} \times K \end{cases}$$

P_T ، P_R و P_{cpu} represent the energy consumption of sending,receiving and processing k bit of data respectively. E_{elec} ،E_{amp} و E_{cpu} represent the energy consumption for sending per bit in radio radius, the energy required to send with a radius more than E_{elec}energy required to processing per bit. According to Equation 4, total energy consumption k bit is as 2-5 relation.

Equation(4)

$$P_{Total} = P_{send} + P_{\mathrm{Re}ceive} + p_{cpu}$$

$$p_{Total} = k(2E_{elec} + E_{cpu} + E_{amp} \times d^y)$$

In Equation(4) , we'll see about that, energy consumption has a direct relationship with the data length. If the sent data is less at first, we will use less energy. If transmission distance is less than the threshold, energy consumption will relate to d2. If transmission distance is more than the threshold, energy consumption will relate to d4. So if the transmission distance is less, energy consumption can be reduced.

3 SIMULATION AND RESULTS ANALYSIS

In this section we present the results of the new proposed clustering algorithm, analysis and compare the results of the previous clustering protocols. The above mentioned simulation performed using MATLAB software. Initial parameters of the wireless sensor for simulation of 100 nodes are provided in Table 1.

Table1: Initial parameters of wireless sensor network.

Description	Notation
Area used in the simulation in metes	**100*100S quare meters**
Initial energy	**0.5 (J)**
E_{cpu}	**7(nJ/bit)**
E_{elec}	**50 (nJ/bit)**
E_{amp}	**0.659 (nJ/m^2)**
E_{da}	**5(nJ/bit)**
Packet size	**40000Bit**
Position of base station	**100×250**

3.1 Scenario 1

Simulation and results analysis when the network is homogeneous. General assumptions considered in the simulations:

- Network environment,is square, with defined number of the sensor.
- Sensors are distributed uniformly randomly
- Sensors have been constant
- Sensors are aware of their location.
- -Location of the base station outside the network and have already been determined
- Base station is constant.
- The initial energy of sensors is determined.
- every sensors ID is unique
- All sensors are the same and have the same basic energy.

In Figure 1, the network lifetime in the proposed methods was compared with LEACH and ALEACH protocols by considering the assumptions in Table 1.As shown in Figure, proposed methods have increased the network lifetime in comparison with the other protocols.

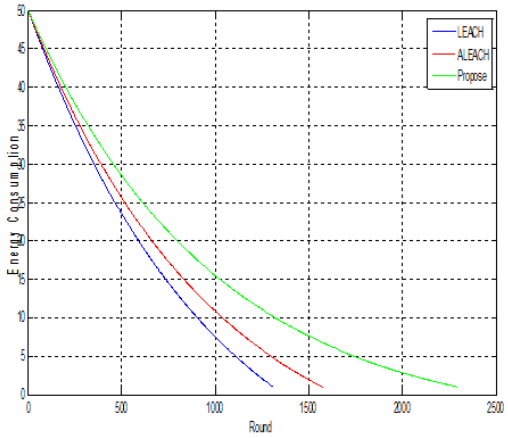

Fig. 1. Comparison of lifetime of the proposed method with LEACH and ALEACH protocols.

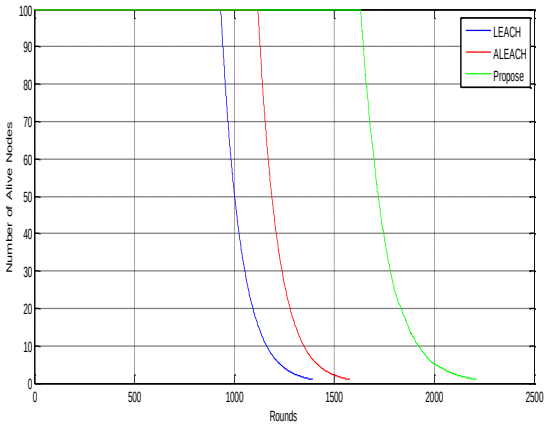

Fig. 2. Comparison of alive sensor in the proposed method with LEACH and ALEACH protocols

As shown in Figures 1 and 2, The proposed approach improve the lifetime of the network by75% more than LEACH and about 55% more than ALEACH.

3.2 Scenario 2

Simulation and analysis of the results when the network is heterogeneous. Assumption considered in this section is as the same as scenario 1 except that the half of the sensors are two fold the others:

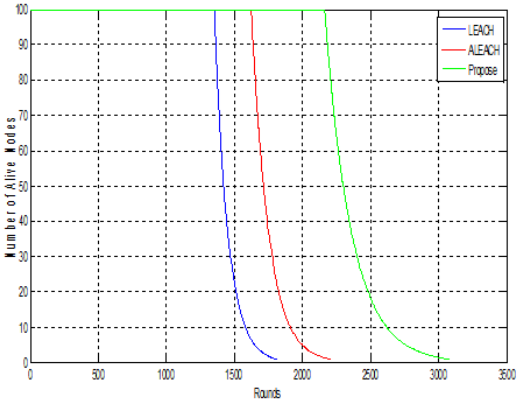

Fig. 3. Comparison of lifetime of the proposed method with LEACH and ELEACH protocols

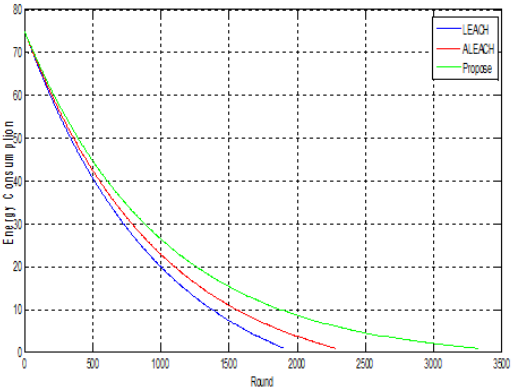

Fig. 4. Comparison of the number of dead sensor in proposed method with LEACH and ELEACH protocols

As shown in Figures 3 and 4, The proposed approach improve the lifetime of the network by60% more than LEACH and about 40% more than ALEACH.

4 RESULT AND FUTURE WORK

In this study, the question Clustering in Wireless Sensor Networks with the aim of reducing energy and maintaining the network coverage has been investigated. To achieve this goal, we attempt to layering the environment to two parts that the first is ten percent of the total environment which is considered as the gateway layer in which a number of nodes candidates receive data from the bottom layer and the remaining node sending its information directly to the base station. In this study, Choosing clusterhead is done using PSO algorithm that defining the best nodes to be clusterheads by using PSO and then began recruiting , clusterhead of the lower layer sending information to the top layer to reach to the base station , in fact using environment layering and

PSO algorithm results in reduced energy waste when sending information.

The results of the simulation of the proposed algorithm using existing parameters in Table 1 shows that in the following algorithm can improve the previous algorithms (LEACH and ALEACH) :

- Increase in Network lifetime in homogeneous environments, is about 75 percent better than LEACH and 55 percent better than ALEACH.
- Increase in Network lifetime in heterogeneous environments, is about 60 percent better than LEACH and 40 percent better than ALEACH.

As future research work that can be done to develop the protocol presented in this study, the following suggestions are presented:

- Combining proposed algorithm with other routing protocols.
- The Use of other metaheuristic algorithms when clustering and routing

Using neural network in the selection of clusterhead node.

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