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A Multi Hop Clustering Algorithm For Reduce Energy Consumption in Wireless Sensor Networks

Mohammad ahmadi[1], Mahdi darvishi[2]

[1] Sama technical and vocational traning college, Islamic azad university,malayerbranch,Malayer,Iran
Ahmadi.srbu@gmail.com

[2] Sama technical and vocational traning college, Islamic azad university,malayerbranch,Malayer,Iran
mahdi.darvishi61@gmail.com

Abstract

This paper introduces an energy efficient clustering algorithm for sensor network based on the leach protocol. The proposed algorithm adds features to leach and aims to reduce power consumption of the network resources in each round of data gathering and communicating. The proposed algorithm is a cluster_ based routing algorithm that exploits the redundancy properties of the sensor networks in order to address the traditional problem of load balancing and energy efficiency in the wireless sensor network. The algorithm then forms two layers of multi hop communication. The bottom layer which involves intra cluster communication and the top layer which involves inter cluster communication.

Keywords: Energy based clustering, Efficient inter cluster routing, bacterial algorithm, wireless sensor network

1. Introduction

The most important different between wireless sensor networks and other wireless networks is in the restrictions in their resources. The most important restriction is the energy, which is resulted from the small size of the sensors and their batteries. Monitoring is from environments to which human access is too difficult and impossible. The probability of replacement or recharge of dead nodes is very low. One of the important challenges in these networks is the need for the constant control of the network life-time and the coverage of the network. Therefore, even increasing the lifetime of the network without considering the network coverage is not desirable. Due to the above-mentioned reasons, the most important challenges in wireless sensor network s are the rate of consumed energy and the balanced distribution of energy all over the network. The balanced distribution of energy all over the network results in the balance of dead nodes rate all over the network. One of the ways of reducing energy consumption is the management of energy resources. In [1], several algorithms are suggested for reducing energy consumption. Routing in wireless sensor network is challenging task, firstly because of the absence of global addressing schemes, secondly data source from multiple paths to single source, thirdly because of data redundancy and also because of energy and computation constraint of network [2].

The conventional routing algorithms are not effective in wireless sensor networks. The efficiency of the existing routing algorithms for wireless sensor network different from one to another. There for, there is an urgent need for developing routing algorithm which can be used in a wide range of applications. Routing algorithms are divided into two groups. Group one is based on protocol performance. Cluster-based routing in wireless sensor networks is a typical instance of hierarchical routing. Hierarchical routing is a combination of clusters in which the nodes with less energy are used for performing sensing operation, and the nodes with more energy are used for performing transmission action. Cluster heads perform calculation operation such as data gathering and data compression for reducing the number of transmissions to the sink. This causes the decrease of energy consumption. Leach [3] is one of the first hierarchical routing algorithms for wireless sensor networks. The routing algorithm in leach algorithm includes two phases: setup phase and steady state phase. In setup phase, the cluster heads are selected randomly. And in steady state phase transmission of packets is done. In leach-f [4], the cluster is kept constant and the nodes of each cluster are selected as the cluster head rotationally. This results in saving energy and the increase of the wireless operation strength. The weak point of this algorithm is the reduction of network scalability. The algorithm teen [5] is suitable for time-critical application. This algorithm is able to respond to the sudden changes in the sensed data. In this algorithm, cluster_ heads make use of two thresholds: hard threshold and soft threshold. Hard thresholds the minimum value of the attribute that triggers the transmission from node to the cluster head and soft

threshold is small change by an amount equal to or greater than the soft threshold. In this algorithm, if there is no considerable change in the sensed data, the number of transmissions by the soft threshold will be reduced. Apteen protocol [6] is an extension to teen which is a hybrid protocol for both periodic data collection and also for time critical data collection. The protocol in [7] presents multi gateway architecture to cover large area of interest without regarding the service of the system. This algorithm balanced the density of clusters at the time of clustering. In this algorithm, two kinds of nodes are used. In this algorithm, the gateways keep the sensor nodes in an optimal condition using multi-hop routs. The weak point of is the static of the cluster heads. This causes the energy of the nodes closer to the cluster head to finish sooner than the energy of the other nodes. In the group of location-based routing, the sensor nodes are determined based on their location. In this kind of algorithm, the environment is divided into virtual girds. The nodes existing in the same grid have the same value in routing. And only one active node is needed at each time. The most famous protocol in this regard is [8]. Hierarchical or cluster based routing protocols, as potentially the, most energy efficient organization, have shown wide application in the past few years [9, 10] and numerous clustering algorithm have been proposed for energy conservation such as [11, 12].
The rest of the paper is organized as follows. Section 2 illustrates the leach protocol. Section 3 illustrates the bacterial algorithm that is used for finding shortest path. In section 4 provide the proposed algorithm and the simulations and results are described in section 5.
.

2. Leach protocol

Leach is an algorithm for clustering and saving energy for wireless sensor networks [13]. The basic features of this protocol are as follows:

- The base station is away from the sensor nodes.
- The base station is fixed.
- All the sensor nodes have the same initial energy.

Leach has a dynamic mechanism for clustering. In this algorithm, time is divided into different rounds. In each round the cluster heads are produced again, and the clusters are formed again. At the beginning of each round, each sensor nodes produces a random number in [0, 1] and compare it with a pre-determined threshold Ti. If random< Ti, then the sensor node will be selected as a member of cluster. Suppose that p percent of the cluster heads are in the network. We define:
H=1/p m=current round the network is running
G= set of nodes that have not been cluster head in the last n rounds.
According to [15], the value of threshold for a sensor is:

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

When a node is selected as a cluster head, it broadcast a message for its neighbors. And the nodes receiving this message decide about joining one of the cluster heads based on the respective signal strength. Then the sensed data are sent to the related cluster heads according. After gathering and compression of the data, the cluster heads send them toward the sink.

2.1 Problems of leach

Leach algorithm assumes a homogeneous distribution of nodes. The selected cluster heads are also assumed to be away from one another. This scenario is not possible in the real world.
For instance, sensors distribution is considered to be according to figure 1, and most of the nodes are located near one or two cluster heads. (Cluster head A and B)

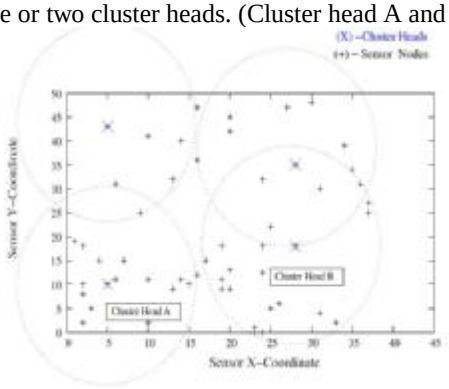

Fig. 1 sensor distribution in leach algorithm

In this scenario, cluster heads A and B send a message to their neighbors. And many of the nodes will receive this message. This will result in cluster with a great number of members, and this causes the energy to finish faster in cluster heads A and B. as a result, a part of the network loses its connection with the rest of the network.
We will introduce a multi hop routing algorithm for internal and external connections of clusters. In this proposed algorithm, bacterial algorithm is used to find the shortest path for sending the data.

3. Bacterial based routing algorithm

Bacterial optimization algorithm is a random procedure for optimal solution of combinational problems such as routing. This algorithm is obtained from the behavior of bacteria during their life. The application of bacterial algorithm in sensor networks for getting the shortest path is as follows:

In the proposed algorithm, bacterial algorithm is used to find the shortest path between source and destination. At first the source node produces some bacteria and spread them in it' radio range. The nodes existing in the radio range of the source node, each will receive a bacterium. Each bacterium send sits new location id (the current node at with it is located) along with its distance from the destination to the source node. After receiving these packets, the source node saves the distance parameter existing in each packet, and identifies the bacterium which is the closest to the destination based on distance parameter, and spreads the id existing in the selected bacterium in its radio range again. The sensor node existing in the radio range of the source node receives the spread id, and then they compare the receiving id with their own id. If the two ids are the same, the node reproduce its bacterium and the bacterium existing in the other nodes are eliminated. (In other words, the closest node to the destination is selected as the next source, and the operation of bacterium proliferation is performed). This process is repeated until the node selected as the next source is the destination itself. After the arrival of the first bacterium at the destination, the other bacteria are eliminated. The rout taken by this bacterium is considered as the shortest path. This path is saved in the memory table of the bacterium in the form of a series of ids. Finally, the source sends its data using this table.

4. Proposed algorithm

The purpose of this proposed algorithm is to solve the problems existing in leach algorithm. The proposed algorithm has the following capabilities.

- Applying the parameters of the remaining energy rate and the number of members of a cluster head for joining a node to a cluster.
- Applying routing algorithm base on bacterial algorithm for finding the shortest path for sending data in internal and external connection in cluster.

We assume that nodes are aware of the physical location of their nodes. The node have a processor, a memory , and hardware needed for perfuming sensing operations, data gathering and establishing connections. The clustering mechanism in the proposed algorithm is similar to the one in leach algorithm. However, it has some basic differences.

In leach algorithm, nodes select their cluster heads based the received signal. This issue causes the cluster heads that are located in areas with high density to have high overhead. The proposed algorithm operates based on the confidence value broadcasted by cluster heads.

The confidence value broadcasted by the cluster heads is based on the following parameters.

- The distance between cluster head and node
- The number of member nodes of cluster head
- The current remaining energy of cluster head

The cluster head with the highest confidence value has highest probability for new nodes to join it.

Confidence value has a direct relationship with the rate of the remaining energy of the number of current members of cluster, and the distance between the node and cluster head. At the start of each round, each node saves the message received from the cluster heads in its memory. The cluster head with the highest confidence value is selected as the desirable cluster head.

```
R      ⟵ 1/cluster-ration.
Th     ⟵ threshold
B-T    ⟵ battery-threshold
MCM    ⟵ max- cluster-members
While (current-round < total-rounds) do
  For (I=0 to total-nodes) do
    If (node_i ! = head in last r rounds) then
      If (random < Th and node_i .battery > B.T) then
        Node_i ⟵ Head
      End-if
    End-if
  End-for
For (I, k=0 to total-nodes) do
 If (node_k ! = head and node_i =head) then
      D = bacterial-dist (node_i ⟷ node_k)
      B= battery (node_i)
      CM= Cluster-members (node_i)
If (CM>MCM) OR B < Battery (to support CM+ (node)) then
    Confidence value=0
Else
      Confidence value ⟵ B/ (MC*D)
End-if
End –i f
End –for
End –while.
```

Therefore, this algorithm can be summarized as follows:

- Random distribution of the sensors
- Cluster formation phase
- selection of cluster heads according to leach

- Ø selection of cluster head for typical nodes. The nodes select the optimal cluster head based on the parameter of confidence value.
- ü Data transmission phase
  - Ø transmission of data from typical nodes to the related cluster heads (by means of bacterial algorithm)
  - Ø gathering the data and sending the packets from cluster heads to the sink (by means of bacterial algorithm)
- ü Repetition of phases 2 and 3 until the energy of all nodes is finished.

5. Results and simulation

In this section, the efficiency of the proposed algorithm is estimated. After the selection of cluster heads, the clusters are formed and data transmission phase starts. Figure 3 shows the main phases of the algorithm in both states of internal and external connections.

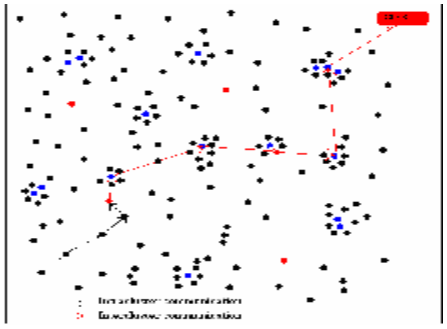

Fig. 2 Data transmission intra cluster and inter cluster

The parameters used in the algorithm are shown in table.1

Table 1: Parameters of simulation

parameter	Scene1	scene2
N	100	400
Area	100*100	
Location of B.S	(100,100)	
$d_{crossover}$	87m	
Initial energy	0.05	
e_{elec}	50nj/bit	
ε_{fs}	10pj/bit/m2	
ε_{mp}	0.0013pj/bit/m4	
EDA	5nj/bit/signal	
Packet size	4000bit	

The efficiency of the proposed algorithm is compared with that of leach in two scenarios mentioned in table2. The comparison is made based on the following three parameters: 1) the number of round when first node dies. 2) The number of round when half of nodes die 3) the number of round when last node dies. The results are shown in table2.

Table 2: Comparison of Algorithms Results.

	Algorithm	First death	Half death	last death
Scene1 Number of nodes=200	Proposed Method	54	200	395
	LEACH	81	116	270
Scene2 Number of nodes=400	Proposed Method	52	205	400
	LEACH	76	114	301

In figure 3 and 4, the proposed algorithm and leach algorithm is compared base on the parameter of the rate of energy existing in the network. As shown in the figures, the proposed algorithm has more efficiency than leach.

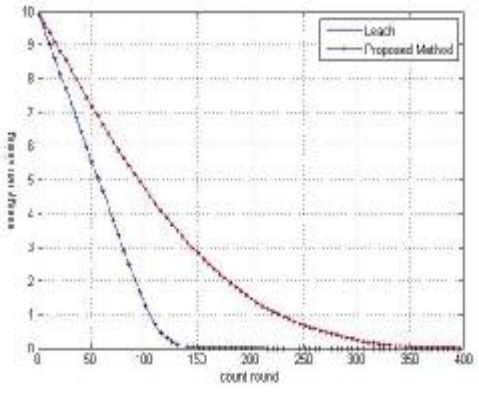

Fig. 3 Energy Remaining Comparison of the two Algorithms in First scene.

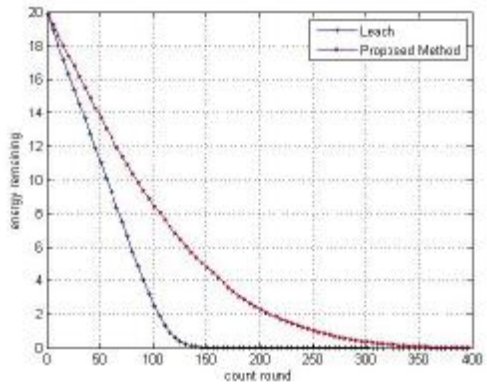

Fig. 4 Energy Remaining Comparison of the two Algorithms in Second scene.

In figure 5 and 6 the proposed algorithm and leach algorithm are compared based on the parameter of the number of alive nodes. As it is observed, the proposed algorithm is more efficiency than leach algorithm.

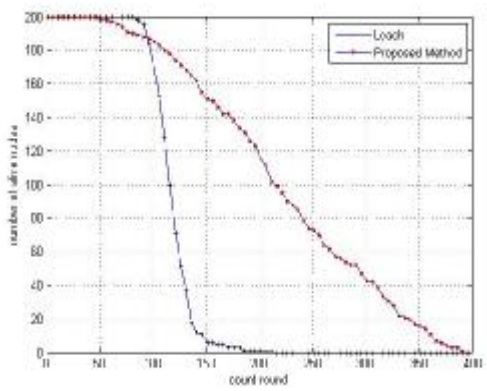

Fig. 5 Alive Nodes Comparison of the two Algorithms in First scene.

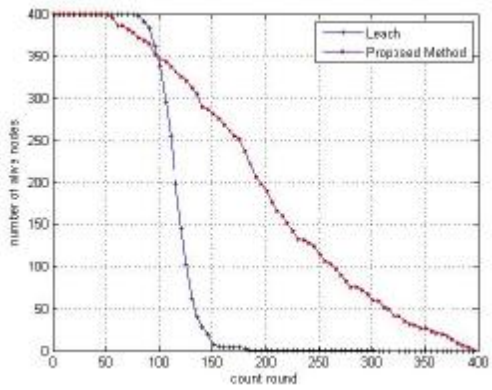

Fig. 6 Alive Nodes Comparison of the two Algorithms in Second scene.

6. Conclusions

Energy consumption in wireless sensor network is of such a great importance that can lead to the increase of network life time. In this paper, new algorithm is proposed, that using the parameters of remaining energy rate and the number of members of a cluster head for joining a node to a cluster and Applying routing algorithm base on bacterial algorithm for finding the shortest path for sending data in internal and external connection in cluster. As it can be seen the proposed method compared with LEACH method has a good result in number of alive nodes and energy remaining in the network.

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