Design and Implementation a New Energy Efficient Clustering Algorithm using Genetic Algorithm for Wireless Sensor Networks

Moslem Afrashteh Mehr

Abstract—Wireless Sensor Networks consist of small battery powered devices with limited energy resources. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus, replacement of the energy source is not feasible. Hence, one of the most important issues that need to be enhanced in order to improve the life span of the network is energy efficiency. To overcome this, many researches have been done. The clustering is one of the representative approaches. In the clustering, the cluster heads gather data from nodes and send them to the base station. In this paper, we introduce a dynamic clustering algorithm using genetic algorithm. This algorithm takes different parameters into consideration to increase the network lifetime. To prove efficiency of proposed algorithm, we simulated the proposed algorithm compared with LEACH algorithm using the Matlab.

Keywords—Wireless Sensor Networks, Clustering, Genetic algorithm, Energy Consumption

I. INTRODUCTION

Wireless Sensor Networks consist of a large number of small and cheap sensor nodes that have very limited computation capability, energy and storage. They usually monitor some area, collect data and report to the base station. Recently, due to the achievement in low-power digital circuit and wireless communication, many applications of the WSNs are developed and already it is used in military object, habitat monitoring and object tracking[1][2]. Moreover, the WSN is one of the most important research areas to provide context aware services in the ubiquitous computing environment[3]. Designing the WSNs is very difficult because the sensor nodes have limited computation capability, limited power and small memory size[4][5]. Among these three factors, the energy consumption is the most important one because the battery is not changeable if once the sensor nodes are deployed. The energy is also the major consideration in designing the routing of the WSNs. Hierarchical protocols reduce energy consumption in the networks by clustering. In these protocols, nodes are divided into some clusters and some nodes that have more energy than others are selected as cluster heads[6]. The remaining of this paper is organized as follows: Section 2 gives an overview on related works reported on clustering in sensor networks. In section 3 the proposed protocol is presented. Simulation results are given in section 4 and finally Section 5 is the conclusion.

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II. RELATED WORKS

During the last few years, many clustering algorithms have been proposed as an efficient way to organize communication and data processing in a sensor network. LEACH [7] is one of the clustering mechanisms to achieve the energy efficiency in the communication between sensor nodes. In each round, sensor nodes elect itself as a cluster head based on probability model. To elect a cluster head, each sensor node generates a random number δ between 0 and 1. If the δ is smaller than the threshold value T(n), the sensor node elects itself as a cluster head and advertises this fact to other nodes around the cluster head. The most important problem of LEACH is exchanging clusters and losing energy in comparison to other Algorithms. [8] proposes a distributed and randomized LEACH-like algorithm which provides methods to compute the optimal values of the algorithm parameters a prior and use a multi-hop technique in both intra-cluster and inter-cluster communications. ACE [9] is an emergent algorithm that uses just three rounds of feedback to form an efficient cover of cluster across the network. It uses the node degree as the main parameter to elect cluster heads. [10] proposes a clustering algorithm based on ANTCCLUS [11]. Using this method, the sensor nodes with more residual energy independently become cluster heads. However, it produces much control overhead during iterations. TPC [12] is a novel two-phase clustering (TPC) scheme for energy-saving and delay-adaptive data gathering in wireless sensor networks. Each node advertises for cluster head with a random delay, and the node who overhears others' advertisement will give up its own advertisement. In such a way, the network is partitioned into clusters in the first phase. In the second phase, each member searches for a neighbor closer to the cluster head within the cluster to set up an energy-saving and delay-adaptive data relay link. With the advantages of chain topology, TPC achieves a great tradeoff between energy cost and delay. PEBCES [13] divides the network into several equally distributed sections and then categorizes them into clusters with different sizes. In this algorithm, each node is equipped with GPS and sends its position and remaining energy to the sink directly. In the method proposed in [14], clusters and cluster heads are selected dynamically using genetic algorithm. This method considers distance between nodes and the number of cluster heads as parameters for clustering but didn’t consider the residual energy of the nodes. One of the main parameters for selecting the cluster heads is residual energy of sensor. Gupta in [15] used fuzzy logic to find cluster heads. In this method, during each period, the sensor that has the most chance is selected as
cluster head. Three fuzzy variables are used to calculate the chance including: residual energy of the nodes, the number of neighbors of the nodes, and centrality. In this method, the base station determines cluster heads. In Algorithms proposed in [16] and [17], the selected node has higher characteristic than other nodes in its cluster or the neighbor clusters. This algorithm is improved by LCA2 [18].

In this paper, we propose a clustering algorithm which takes several parameters into consideration for dynamic clustering. This algorithm will balance the energy consumption in the network and prolongs the network lifetime.

III. PROPOSED METHOD

Having control over the position and number of cluster heads and also the number of cluster’s member is always a challenge. In the clustering of the sensor network, solving this problem requires efficient clustering algorithm regarding energy consumption and balancing the energy. Dynamic nature of the network makes the problem more complex due to repetitive change in the clusters and cluster heads which can’t be modeled by the mathematic methods. In the other hand, genetic algorithm is very flexible in solving such a dynamic problems. In this paper, we try to determine clustering and the place of the cluster heads using genetic algorithm in a way that there will be minimum energy consumption while attending the network coverage.

A. Problem Representation

In the proposed algorithm, binary representation is used in which each bit corresponds to one sensor node. A “1” means that corresponding sensor is a cluster head and a “0” means that it is a regular node.

B. Genetic Algorithm Operators

This algorithm begins its work by randomly generated population of chromosomes. Each regular node finds its nearest cluster head and joins to it. Then the algorithm applies the genetic operators.

a) Crossover Operator

In this paper, we use one-point crossover. The crossover operation takes place between two consecutive individuals with probability specified by crossover rate. These two individuals exchange portions that are separated by the crossover point. The following is an example of one point crossover:

Individual 1: 0 1 1 1 0 0 1 1 0 1 0
Individual 2: 1 0 1 0 1 1 0 0 1 0 1

After crossover, two offspring are created as below:

Offspring 1: 0 1 1 1 0 0 1 0 1 0 1
Offspring 2: 1 0 1 0 1 1 0 0 1 0 1

b) Mutation Operator

The mutation operator is applied to each bit of an individual with a probability of mutation rate. After mutation, a bit that was “0” changes to “1” and vice versa. In fact, it is possible that a regular node becomes a cluster head and a cluster head becomes a regular node.

Individual before mutation: 0 1 1 0 0 1 1 0 1 0

Individual after mutation: 0 1 0 0 0 1 1 0 1 0

c) Selection

The candidate individuals are chosen from the population in the current generation based on their fitness. The individuals with higher fitness values are more likely to be selected as the individuals of population in the next generation.

d) Fitness Function

As the purpose of this algorithm is optimizing energy consumption that results in increasing the networks lifetime, so we have to consider the residual energy of the nodes as a main parameter for selecting the cluster head. The second parameter that is considered is the required energy to send a message toward the sink node. The lower the communication distance, the less energy will be consumed during transmission. Finally, since cluster heads use more energy than other nodes, reducing the number of cluster heads has a considerable effect on decreasing the energy consumption. Each individual is evaluated by the following fitness function:

\[
\text{Fitness} = \text{RE} + \text{SE} + (X \cdot D) + (1 - X) \cdot (N - \text{CH})
\]

\[
0 \leq X \leq 1
\]

In this function, \( \text{RE} \) represents the sum of residual energy in the cluster heads, \( N \) is the total number of nodes, \( \text{CH} \) is the number of cluster heads and the SE represent the sum of required energy for sending one message from all regular nodes toward their cluster head toward the sink node and \( D \) is the distance between sensors.

(2)

\[
\text{SE} = \sum \left( \text{RES}_i - (\text{CHE} + \text{CES}) \right)
\]

Where \( \text{RES}_i \) represent the sum of required energy for sending one message from all regular nodes toward the sink node, \( \text{REC} \), represents the sum of required energy for sending one message from all regular nodes toward their cluster head , \( \text{CHE} \) represents the sum of required energy for receiving M messages from all cluster members and finally \( \text{CES} \) represents the sum of required energy for sending one message from cluster head toward the sink node.

(3)

\[
D = \sum \left( \text{DCH}_i - (\text{DCH} + \text{DSS}) \right)
\]
Where DRS, represent the sum of distance from all regular nodes toward the sink node, DRC, represents the sum of distances from all regular nodes toward their cluster head and DCS represents the sum of distances from all cluster heads toward the sink node.

The value of x (0≤x≤1) indicates which factor is more important to be considered: required energy (that is related to the distance) or the cost incurred by cluster-heads.

IV. SIMULATION RESULT

We have simulated the proposed clustering algorithm using MATLAB software and compared it to LEACH protocol. The list of the used simulation parameters and their values are shown in table 1:

<table>
<thead>
<tr>
<th>parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>100</td>
</tr>
<tr>
<td>Sensing range of nodes</td>
<td>10 m</td>
</tr>
<tr>
<td>Network dimensions</td>
<td>200*200 m²</td>
</tr>
<tr>
<td>Initial energy of each node</td>
<td>1 Jules</td>
</tr>
<tr>
<td>Packet size</td>
<td>64 Byte</td>
</tr>
<tr>
<td>Primary population</td>
<td>200</td>
</tr>
<tr>
<td>Crossover rate</td>
<td>0.6</td>
</tr>
<tr>
<td>type of crossover</td>
<td>One-point</td>
</tr>
<tr>
<td>Mutation rate</td>
<td>0.007</td>
</tr>
<tr>
<td>Number of generation</td>
<td>500</td>
</tr>
</tbody>
</table>

In the first experiment, the distribution of the cluster heads in the proposed algorithm is compared to LEACH protocol. Fig.1 shows the result of this comparison.

As shown in this figure, randomly selection of the cluster heads in the LEACH algorithm may Causes unbalanced distribution of them. This distribution is improved in the proposed algorithm.

In the second experiment, we compared the sum of residual energy of nodes in the proposed protocol and LEACH protocol during different rounds. As can be seen in Fig 2, the proposed algorithm consumes energy uniformly and so, prolongs the network lifetime.

In the third experiment, we compared the number of alive nodes in our protocol and LEACH protocol during different rounds. The results of this experiment are shown in Fig 3. It can be observed that the proposed protocol has considerably more number of alive nodes in each round in comparison with the LEACH protocol.
V. CONCLUSION

In this paper, we proposed a clustering algorithm based on genetic algorithm. The proposed algorithm takes different parameters into consideration to increase the network lifetime. These parameters are residual energy of the nodes, required energy to send a message toward the sink node, and number of cluster heads. In order to evaluate our algorithm, we simulated our protocol and compared it to LEACH protocol. The results of the simulations show the effectiveness of the proposed mechanism.

REFERENCES


