CLUSTER HEAD ELECTION USING IMPERIALIST COMPETITIVE ALGORITHM (CHEI) FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

One of the most important challenges of wireless sensor network is how to prolong its life time. The main obstacle in these networks is the limited energy of nodes. We can overcome this problem by optimizing the nodes' power consumption. The clustering mechanismis the one of the representative approachesto reduce energy consumption, but optimum clustering of wireless sensor network is an NP-Hard problem. This paper proposes a hybrid algorithm based on Imperialist competitive algorithm to overcome this clustering problem. The proposed method, acts on one of the clusters in the network to choose the best sensor in the cluster as a cluster head. To perform this action, the cluster is divided into several sub-clusters, each of which has a cluster head. These cluster heads using Assimilation policies, try to attract the regular nodes to themselves, and Using Imperialistic competition, they compete with each other until one of these cluster heads is selected as the final cluster head. After this stage, the algorithm work ends. This algorithm will balance the energy consumption in the network and improve the network lifetime. To prove efficiency of proposed algorithm(CHEI), we simulated the proposed algorithm compared with two clustering algorithms using the matlab.

KEYWORDS

Wireless Sensor Networks, Clustering, Imperialist competitive algorithm, ICA, Energy Consumption, Cluster Head Election.

1. INTRODUCTION

Recent advances in wireless communications and electronics have enabled the development of low cost, low-power, multifunctional sensor nodes that are small in size and communicate untethered in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks [1].

Energy conservation is an important challenge in the design and operation of these networks. The longer thecommunication distance, the more energy will be consumedduring transmission. So, clustering mechanism is a key way to reduce energyconsumption.

During the last few years, many clustering algorithms have been proposed, but none of these algorithms aim at minimizing the energy spent in the system. LEACH [2] isone of these algorithms 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. The Weighted Clustering

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Algorithm (WCA) elects a node as a clusterhead based on the number of neighbors, transmission power, battery-life and mobility rate of the node [3]. The algorithm also restricts the number of nodes in a cluster so that the performance of the MAC protocol is not degraded. ACE [4] isanemergentalgorithm 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. In [5], the authors propose an algorithm that each node calculates its distance to the area centroid which will recommend nodes close to the area centroid and not the nodes that is central to a particular cluster, cluster centroid. Thus it leads to overall high energy consumption in the network for other nodes to transmit data through the selected node.

[6]proposes a clustering algorithm based on ANTCLUST [7]. Using this method, the sensor nodes with more residual energy independently become cluster heads. However, it produces much control overhead during iterations. TPC [8] 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. PEBECES [9] 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 [10], 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 [11] 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 this paper, we propose a clustering algorithm which takes several parameters into consideration for dynamic clustering. the proposed protocol will balance the energy consumption in the network and prolongs the network lifetime.

The organization of the rest of this paper is as follows:In Section 2, describes the Imperialist Competitive Algorithm. In section 3, the proposed protocol is presented. In section 4, we describe our simulation environment and experimental results. Finally Section 5 is the conclusion.

2. IMPERIALIST COMPETITIVE ALGORITHM

Figure 1 shows the flowchart of the Imperialist Competitive Algorithm. This algorithm starts by generating a set of candidate random solutions in the search space of the optimization problem. The generated random points are called the initial Countries. Countries in this algorithm are the counterpart of Chromosomes inGenetic Algorithm (GA) and Particles in Particle Swarm Optimization (PSO) and it is an array of values of a candidate solution of optimization problem. The cost function of the optimization problem determines the power of each country. Based on their power, some of the best initial countries (the countries with the least cost function value), become Imperialists and start taking control of other countries (called colonies) and form the initialEmpires[12].

Two main operators of this algorithm are Assimilation and Revolution. Assimilation makes the colonies of each empire get closer to the imperialist state in the space of socio-political characteristics (optimization search space). Revolution brings about sudden random changes in the position of some of the countries in the search space. During assimilation and revolution a colony might reach a better position and has the chance to take the control of the entire empire and replace the current imperialist state of the empire[13].

Imperialistic Competition is another part of this algorithm. All the empires try to win this game and take possession of colonies of other empires. In each step of the algorithm, based on their power, all the empires have a chance to take control of one or more of the colonies of the weakest empire[12].

Algorithm continues with the mentioned steps (Assimilation, Revolution, Competition) until a stop condition is satisfied.

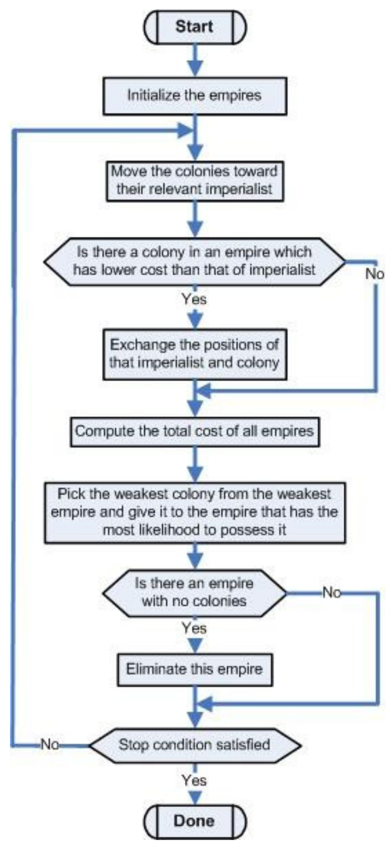

Figure 1. Flowchart of Imperialist Competitive Algorithm (ICA)

3. PROPOSED METHOD

The proposed method, acts on one of the clusters in the network to choose the best sensor in the cluster as a cluster head. To perform this action, the cluster is dividedinto several sub-clusters, each of which has a cluster head. These cluster heads using Assimilation policies, try to attract the regular nodes to themselves, and Using Imperialistic competition, they compete with each other until one of these cluster heads is selected as the final cluster head.

After this stage, the algorithm work ends. This algorithm will balance the energy consumption in the network and prolong the network lifetime.

3.1. Forming the initial Countries

Since our purpose is to choose sensors in a cluster to choose the best sensor as cluster head, so possible responses on this issue, which include all sensors in the cluster and are equivalent to the country in the ICA.

Here, in the starting, random number of these sensorsare considered as the initial Countries and among them,the suitable numbers are considered as initial empires (which here are cluster heads) and other sensors as a colony (which here are equivalent to regular nodes) . To divide initial regular nodes, every cluster head is given a number of regular nodes corresponding to its power.

Since the first time, the energy of all sensors are equal, so we only consider the distance among sensors as the main parameter to select the initial empires:

$$D=\sum_{i=1}^{M}(\mathrm{DRSi}-(\mathrm{DRCi}+\mathrm{DCS}))(14)$$

Where DRS_irepresents the total distance between all regular nodes to the sink node, DRC_i represent total distance from all regular nodes toward their cluster head and DCSrepresents the total distance from all cluster head toward the sink node.

3.2. Implementation the Assimilation Policy

Based on Assimilation Policy, cluster heads using cost function(Equation No. (14)), try to attract regularnodes. As soon as, the sensors starting to activity, the amount of their energy will be reduce, therefore to choose cluster heads, in addition to the distance between sensors, the value of their energy should be taken into consideration.

So, two basic parameters "amount of energy required to send a message" and "residual energy nodes", determine the power of a cluster head to attract regular nodes.

3.3. Exchanging positions of the cluster head and a regular node

since cluster heads use more energy than the others, after a while, their energy is reduced and can not act as a cluster head. So, one of the regular nodes that has the normal conditions listed is selected as a cluster head, and between the previous and the current node displacement takes place and other nodes join the current node.

3.4. Implementation of the Imperialistic competition

According to imperialistic competition, each cluster head that can not evaluat three mentioned basic parametersin the above, are deleted from competition and its member nodes become the members of cluster heads which are near them. Cluster heads will be deleted step by step until we reach one cluster head which is chosen as the final cluster head and all regular nodes will be joined to it.

3.5. Cost Function Parameters

We use a radio model described in [8]. In this model, for a short range transmission such as within clusters, the energy consumed by a transmit amplifier is proportional to d^2, where d is the distance between nodes. However, for a long range transmission such as from a cluster head to the base station, the energy consumed is proportional to d^4. Using the given radio model, the energy consumed ET_{ij} to transmit a message of length k bits from a node i to a node j is given by Equation 15 and Equation 16 for short and long distances, respectively.

$$E_{Tij}=K*E_e+K*€_{fs}*d^2_{ij} \ d < dco \qquad (15)$$

$$E_{Tij}=K*E_e+K*€_{amp}*d^4_{ij}d >= dco \qquad (16)$$

Moreover, ER, the energy consumed in receiving the k-bit message, is given by:

$$ER = k*E_e + k*E_{BF} \qquad (17)$$

where E_{BF} represents the cost of beam forming approach to reduce the energy consumption.
The cost of a country is designed to minimize the energy consumption and to extend the network life time. A few cost parameters are described in this section:

1. E_{Tdrs}, represent the sum of required energy to sending one message directly from all regular nodes toward the sink node. This required energy is defined as follows:

$$E_{Tdrs}=\sum_{i=0}^{n} ETrs + m * ER \ m >= n \qquad (18)$$

Where E_{Trs} represent the sum of required energy for sending one message from all regular nodes toward the sink node and ER, is the radio energy dissipation.

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2. E_{Trcs}, represents the sum of required energy for sending one message from all regular nodes in a cluster toward their cluster head and the sum of required energy for sending one message from the cluster head toward the sink node. This required energy is defind as follows:

$$E_{Trcs}= \sum_{i=1}^{n} ETrc + m * ER + ETcsm >= n \ (19)$$

Where E_{Trc} represents the sum of required energy for sending one message from all regular nodes in a cluster toward their cluster head, (m*ER) represents the sum of required energy for recieving one message from all regular nodes in a cluster and E_{Tcs} represents the sum of required energy for sending one message from the cluster head toward the sink node.

$$SE= E_{Tdrs} - E_{Trcs} \qquad (20)$$

3. LE, represent the at least required energy for receiving a k-bit message by the cluster headand send it to sink. This required energy is defined as follows:

$$LE= E_{Tij} +ER \qquad (21)$$

3.6. Cost Function

because 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. Each individual is evaluated by the following fitness function:

$$\text{Cost Function} = LE + RE + SE \qquad (22)$$

In this function, RE represents the residual energy in the cluster head.

4. SIMULATION RESULT

We have simulated the proposed algorithm using MATLAB and compared it to LEACH protocol and [14]. The list of the used simulation parameters and their values are shown in table 1:

TABLE 1: The values of the simulation parameters

Parameters	Values
Initial Countries	200
Initial Imperialistic	20
B	2
γ	45°
Sensing range of nodes	10 m
Network dimensions	100*100 m^2
Initial energy of each node	1 Jules
Packet size	400 Bits
Number of Iteration	100
E_e	50 nj/bit/signal
$€_{fs}$	10 pj/bit/m^2
$€_{amp}$	0.0013 pj/bit/m^4
d_{co}	10m
Consumption energy for sending a bit	1 nj/bit

In the first experiment, we compared the sum of residual energy of nodes in the proposed protocol to LEACH protocol and [14] during different rounds. As can be seen in Figure 8, the proposed algorithm consumes energy uniformly and so, prolongs the network lifetime.

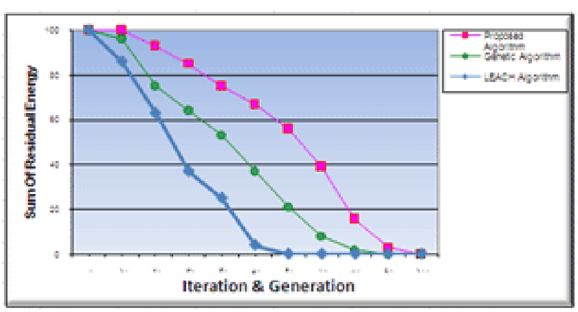

Figure 8. Comparing sum of residual energy

In the second experiment, we compared the number of alive nodes in our protocol to LEACH protocol and [14] during different rounds. The results of this experiment are shown In Figure 9. It can be observed that the proposed protocol has considerably more number of alive nodes in each round in comparison with the LEACH protocol and [14].

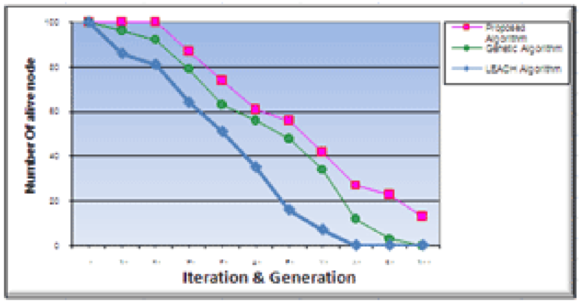

Figure 9. Number of alived nodes in different rounds

In the third experiment, we compared the Response time to reach in our protocol to LEACH protocol and [14]. The results of this experiment are shown In Figure 10. It can be observed that the proposed protocol has considerably more number of alive nodes in each round in comparison with the LEACH protocol and [14].

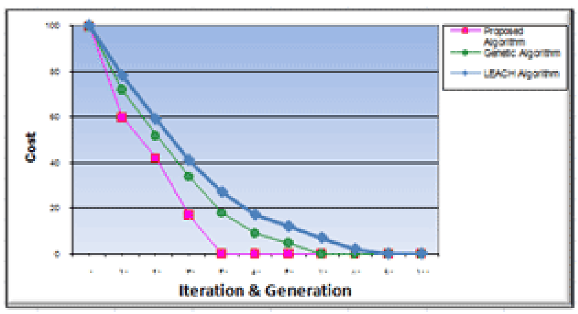

Figure 10. The time to get answers

In the four experiment, the distribution of the cluster heads in the proposed algorithm is compared to LEACH protocol. Figure11, 12 and 13 shows the result of this comparison.

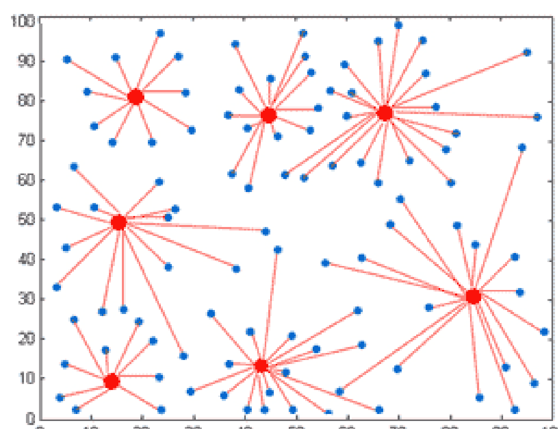

Figure 11. Improper distribution of the cluster heads in the proposed algorithm

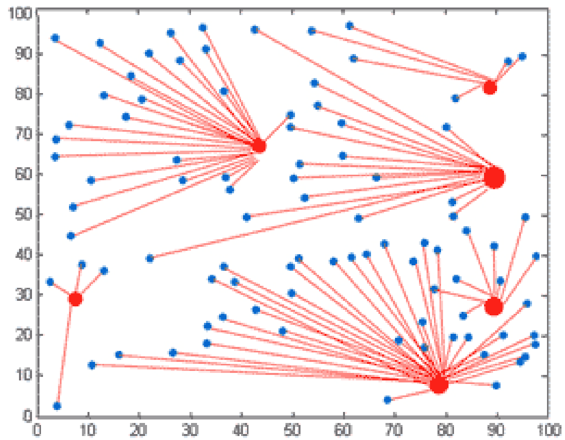

Figure 12. Improper distribution of the cluster heads in LEACH algorithm

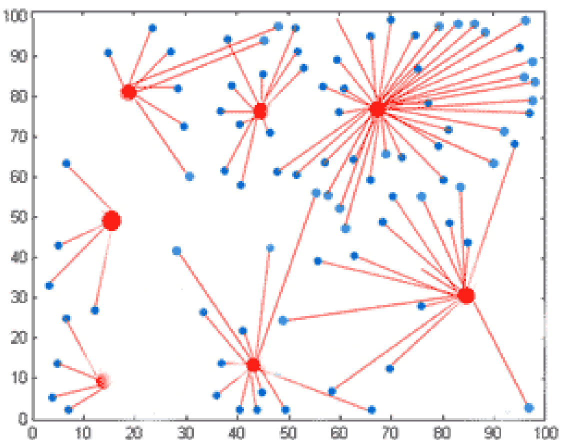

Figure 13. Improper distribution of the cluster heads in [14] algorithm

5. CONCLUSION

In this paper, we proposed a cluster head election algorithm based onImperialist competitive algorithm. The proposed algorithm takes different parameters into consideration to increase the network lifetime. This parameters are residual energy in the cluster head, required energy to send a message toward the sink node and the at- least required energy for receiving a k-bit message by the cluster head and send it to sink. In order to evaluate ouralgorithm, we simulated our protocol and compared it to LEACH protocol and [14]. The results of the simulations show theeffectiveness of the proposed mechanism.

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