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Improving Clustering in WSN by Using Imperialist Competition Algorithm

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Abstract: Clustering is an effective topology control Approach in wireless sensor networks, which can prolong the lifetime and also improve the capability of networks. The main difference between different clustering protocols is the way in which to elect the CH (cluster head).This paper introduced several different phases in a round of a clustering protocol and how to determine the number of the clusters, analyzed the CH election approaches of three classical clustering protocols, interpreted how CH distributing influence the energy consumption, how to reduce the clustering overhead and the energy consumption in data communication phase, then Proposed the design principle of CH election.

Keywords: Imperialist Competitive Algorithm; Cluster head election; Wireless sensor networks; energy consumption.

I. INTRODUCTION

Wireless Sensor Network (WSN) comprises of micro sensor nodes, which are usually battery operated sensing devices with limited energy resources. In most cases, replacing the batteries is not an option [1, 2, 3]. In order to extend the network lifetime, many routing protocols have been devised. One of these is network clustering, in which network is partitioned into small clusters and each cluster is monitored and controlled by a node, called Cluster Head (CH). A CH is responsible for conveying any information gathered by the nodes in its cluster and may aggregate and compress the data before transmitting it to the base station (BS). Other nodes send the data sensed from the environment to these CHs. However, the added Responsibility results in a higher rate of energy drain at the CHs, and thus power-efficiency is important in designing clustering protocols. LEACH (Lower Energy Adaptive Clustering Hierarchy) [3], which is one of the most popular Clustering mechanisms, addresses this by probabilistically rotating the role of CH among all nodes. However, its cluster-head selection mechanism is based on a kind of hard threshold. This kind of selection mechanism causes that a Node cannot continue to participate the cluster-head election process, once it has acted as a CH in the current 1/p rounds. Therefore, as the algorithm continues, the nodes which can be chosen as CHs will become fewer and fewer. This paper focuses on how to resolve it by developing a novel approach of cluster head selection. The rest of this paper is organized as follows: Section 2 presents a brief description of the related work. Section 3 describes the limitations of the current LEACH algorithm and our algorithm on cluster-head selection in detail. Finally, simulation results are presented in Section 4, while Section 5 concludes the paper.

II. RELATED WORK

Cluster-based approaches are suitable for continuous monitoring applications [2,3]. For instance, Heinzelman et al. [2] describe the LEACH protocol, which is a hierarchical self-organized cluster-based approach for monitoring applications. The data collection area is randomly divided into several clusters, where the number of clusters is pre- determined [3,4].

Based on time division multiple accesses (TDMA), the sensor nodes transmit data to the cluster heads, which aggregate and transmit the data to the base station. Bandy opadhyay and Coyle [5] describe a multi-level hierarchical clustering algorithm, where the parameters for minimum energy consumption are obtained using stochastic geometry.

Hierarchical clustered based wireless sensor networks can distribute resources in a balanced way and are with special advantages related to scalability, efficient energy consumption, and simple data aggregation. The system model used in this work is based on the model presented in [2], where the energy dissipation is mainly from transmitting and receiving data. The radio module energy dissipation Es is:

$$E_s = \begin{cases} \mathrm{lE_{elec}} + \mathrm{l}\varepsilon_{\mathrm{fs}}\mathrm{d}^2 \ \mathrm{d} < \mathrm{d_{co}} \\ \mathrm{lE_{elec}} + \mathrm{l}\varepsilon_{\mathrm{mp}}\mathrm{d}^4 \ \mathrm{d} > \mathrm{d_{co}} \end{cases} \quad (1)$$

Where the Elect (J/b) is the energy dissipated to run transmit or receive electronics and amp (J/b/m2) is the energy dissipated by the transmit power amplifier to achieve an acceptable at the receiver. D0 is the path loss in open space on transmissions between two sensors apart from each other d meters and is a value between 2 and 4. L is the packet length [1- 4].

The main objective of the hierarchical cluster-based routing protocol is to generate energy-efficient clusters for randomly deployed sensor nodes, where each cluster is managed by a set of associates called ahead-set. Using round-robin technique, each associate member acts as a cluster head. CH receives messages from the cluster members and transmits the aggregated messages to a distant base station (BS). As all the transmissions are single-hop, cluster members transmit short-range broadcast messages and CHs transmit long-range broadcast messages. The head-set approach can be a good solution for clusters where the CH dies during a round. Since the role of a CH is energy consuming, after a specified number of transmissions, a new set of clusters is formed. In other words, the clusters are maintained for a short duration called a round. A round consists of an election phase and a data transfer phase. In an election phase, the sensor nodes self-organize into a new set of clusters, where each cluster contains head-set. In data transfer phase, the head-set members transmit a specified number of long-range transmissions to BS.

A. Election Phase: During an election phase, clusters are created using a threshold function as given in (2).

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times (r \bmod \frac{1}{p})}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad (2)$$

Where p is the desired percentage of cluster head in the sensor population, r is the current round, and G is the set of nodes that have not yet become head-set members for the last 1/p rounds. First, each node generates a random number, which is between 0 and 1. If the random number is less than T (n), the node becomes a head-set member and acts as a CH for this election phase. Second, each selected CH broadcasts a short-range advertisement. The sensor nodes may receive Advertisements from one or more CHs. Third; each sensor node chooses its CH on the basis of the signal strengths of the received advertisements. Fourth, the sensor nodes transmit short-range acknowledgments to inform their CHs about their decision. At this stage, the clusters for the current round are determined and each head-set has one associate member.

Fifth, the CHs that have relatively large cluster sizes select a pre-defined number of additional head-set members for their clusters; the additional head-set members are chosen based on the signal strength of the acknowledgment messages. The selected head-set mem bers cannot become head-set members until all the remaining nodes have become CHs. Iteration is defined as a duration in which all the nodes have become CHs. Sixth, each CH creates a TDMA schedule for the head-set members, as well as the remaining cluster members. Seventh, CHs broadcast their TDMA schedules to their members.

At the end of election phase, each head-set member checks if it has sufficient energy for next round. If the energy of any head-set member falls below the given threshold value, it is removed from the head-set; the remaining head-set members update their schedules accordingly.

B. Data Transmission Phase: During data transmission phase, the member nodes transmit data to their CHs and the CHs transmit aggregated data to the base station. First, member nodes transmit data according to their TDMA schedule. Fig.1

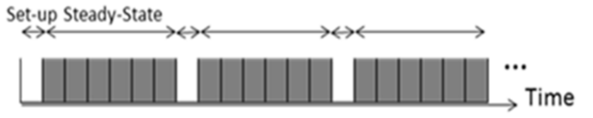

Figure 1. TDMA Schedule in the LEACH

Second, CH receives the messages from the member nodes. As head-set members become CH on round-robin basis, only CH receives the messages and the remaining head-set members turn off their radios. Third, CH transmits the aggregated data to the base station. Fourth, CH checks the remaining energy. If the energy level is less than the given threshold value, CH will remove itself from the head-set. Fifth, the outgoing CH informs the incoming CH about its decision to remain the head-set member or become a cluster member. If the outgoing CH withdraws from the headset, the remaining head-set members update their schedules accordingly.

At the end of round, all the clusters are not destroyed; however, each cluster is retained for the number of rounds equal to the head-set size. In other words, the nodes of clusters with the head-set size of 1 become candidates in the next round but the nodes of the clusters with the head-set size greater than 1 do not participate in the next election. This approach reduces the number of elections and the burden of long-range transmission is more efficiently distributed among the nodes. Moreover, for the next election, the percentage of headers is decreased according to the number of retained clusters. The retaining of clusters has shown a significant amount of improvement as compared to the LEACH protocol.

For performance evaluation, hierarchical cluster-based routing-1 represents a protocol that contains a head-set but energy-efficient clusters are not retained. Whereas hierarchical cluster-based routing represents a protocol that contains the head-set members and energy efficient clusters are also retained.

III. IMPERIALIST COMPETITIVE ALGORITHM (ICA)

Imperialist Competitive Algorithm is a new evolutionary optimization method which is inspired by imperialistic competition [6- 11]. Like other evolutionary algorithms, it starts with an initial population which is called country and is divided into two types of colonies and imperialists which together form empires. Imperialistic competition among these empires forms the proposed evolutionary algorithm. During this competition, weak empires collapse and powerful ones take possession of their colonies. Imperialistic competition converges to a state in which there exists only one empire and colonies have the same cost function value as the imperialist.

The pseudo code of Imperialist competitive algorithm is as follows:

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1) Select some random points on the function and initialize the empires.
2) Move the colonies toward their relevant imperialist (Assimilation).
3) Randomly change the position of some colonies (Revolution).
4) If there is a colony in an empire which has lower cost than the imperialist, exchange the positions of that Colony and the imperialist.
5) Unite the similar empires.
6) Compute the total cost of all empires.
7) Pick the weakest colony (colonies) from the weakest empires and give it (them) to one of the empires (Imperialistic competition).
8) Eliminate the powerless empires.
9) If stop conditions satisfied, stop, if not go to 2.

After dividing all colonies among imperialists and creating the initial empires, these colonies start moving toward their relevant imperialist state which is based on assimilation policy [6, 7, 9].

Fig. 2 shows the movement of a colony towards the imperialist. In this movement, θ and x are random numbers with uniform distribution as illustrated in formula (3) and d is the distance between colony and the imperialist.

$$x \sim U(o, \beta \times d), \theta \sim U(-r, r) \quad (3)$$

Where β and γ are parameters that modify the area that colonies randomly search around the imperialist. In our implementation β and γ are considered as 2 and 0.5 (Radian) respectively.

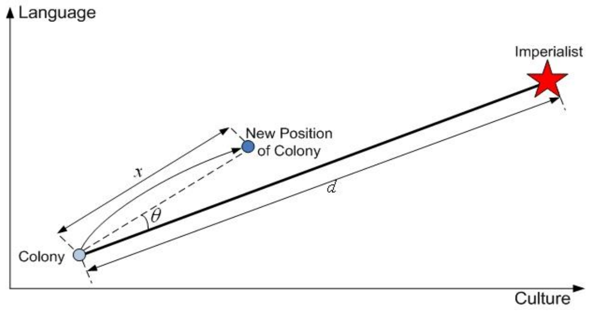

Figure 2. Motion of Colonies Toward Their Relevant Imperialist

In ICA, revolution causes a country to suddenly change its socio-political characteristics. That is, instead of being assimilated by an imperialist, the colony randomly changes its position in the socio-political axis. The revolution increases the exploration of the algorithm and prevents the early convergence of countries to local minimums.

The total power of an empire depends on both the power of the imperialist country and the power of its colonies which is shown in formula (4).

$$T.C._n = cost(imperialist_n) + \xi mean\{cost(colonies\ of\ empire_n)\} \quad (4)$$

In imperialistic competition, all empires try to take possession of colonies of other empires and control them. This competition gradually brings about a decrease in the power of weaker empires and an increase in the power of more powerful ones. This is modeled by just picking some of the weakest colonies of the weakest empires and making a competition among all empires to possess these colonies.

Fig.3 shows a big picture of the modeled imperialistic competition. Based on their total power, in this competition, each of the empires will have a likelihood of taking possession of the mentioned colonies. The more powerful an

Empire, the more likely it will possess the colonies. In other words these colonies will not be certainly possessed by the most powerful empires, but these empires will be more likely to possess them. Any empire that is not able to succeed in imperialist competition and cannot increase its power (or at least prevent decreasing its power) will be eliminated.

Imperialistic

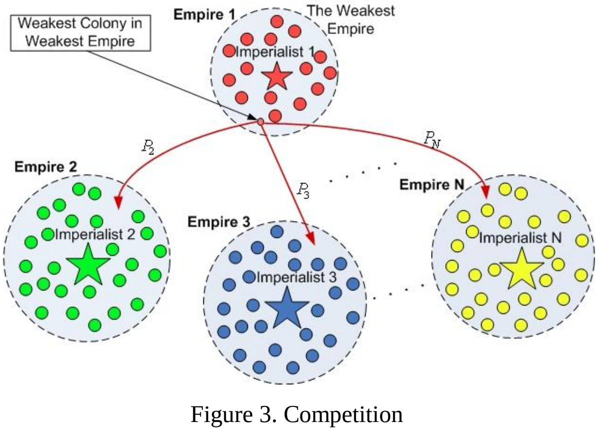

Figure 3. Competition

ICA as a new evolutionary method which is used in several applications, such as designing PID controller [8], achieving Nash equilibrium point [9], characterizing materials properties [10], error rate beam forming [11], designing vehicle fuzzy controller [11], etc. In this paper, we have applied this algorithm for optimizing the weights of ANN and compared the results with other optimization methods which have previously used in this regard.

IV. PROPOSED METHOD

In this method, we suppose that all network sensor nodes are the same and each network node can have two modes: cluster head Node (CH) and normal nodes

(N). With considering the energy consumption in cluster head nodes is greater than usual nodes; we try to choose cluster head in a way that need less energy in transferring the data to the base station.

First, we randomly define a series of possible answers as a country. Each country includes the nodes ID which is going to select as cluster head and suggests away for nodes clustering. It means that the nodes which their ID is define by the country would be cluster head and the rest of should join to the nearest one.

Countries are divided into categories. The most powerful country in each category will be regarded as imperialist and other countries will be known as colonies. Imperialists in each period, try to assimilate their colonies. So by making the changes in their colonies structure, they absorb them toward themselves. During the act of absorption, little change is made and a colonial power maybe outweighs the Imperialist. In this case they exchange their positions. It is assumed that all the clustering operations are performed in base station. Then cluster head nodes will be informed and also they send a message for inform the other nodes.

In each country k specifies cluster head ID nodes number (number of clusters) which their energy is higher than average of network energy. Function f that shows the cost of each country is defined as follows:

$$Cost = \frac{\sum_{i=0}^{k} \sum_{\forall x \in c_i} d(x_i, ch_i)/([c_i]-1)}{k_{opt}} \quad (5)$$

In the base station user can determine the number needed to cluster head. Also, each base station energy aware nodes, so the network can calculate the mean energy.

In formula 3 Ci is ith cluster. [Ci] is the number of nodes in ith cluster; chi is the cluster head of Ci. d(x, chi) is the distance between each node (x) to cluster head, $\sum_{\forall x \in c_i} d(x_i, ch_i)/([c_i]-1)$the nodes of cluster to cluster head, k is the optimal number of clusters and $\frac{\sum_{i=0}^{k} \sum_{\forall x \in c_i} d(x_i, ch_i)/([c_i]-1)}{k_{opt}}$ is average distance of all nodes to their cluster heads.

The cost of each country is related directly to its proposed method energy consumption for nodes clustering. It suggested better optimal method and it's more powerful. After several periods we can select the most powerful imperialist as final answer.

V. SIMULATION

For simulating of this algorithm, we have selected an area with different dimensions 100*100, 300*300, 500*500, 600*600, 800*800 and 1000*1000 initially positioned 100 nodes in it randomly. The length of each transmission packet is 50 bytes. The radio range for each sensor is 40m. Also the position of the sink is considered in the upper right corner of the area. The Parameters of simulation are listed in Table 1.

Parametrs	Value
Node Number (N)	100
Efs	10 pJ/bit/m2
Eda	5 nJ/bit/signal
Packet length(L)	50 Bytes
Initial Energy	0.1 J
Node Number(N)	100
BS Position	(100,750)

To simulate the proposed algorithms, we applied the NS-2 software and the consumed energy is less of leach algorithm. This entry is show in fig. 4. And life time is more of leach algorithm. This entry is show in fig. 5.

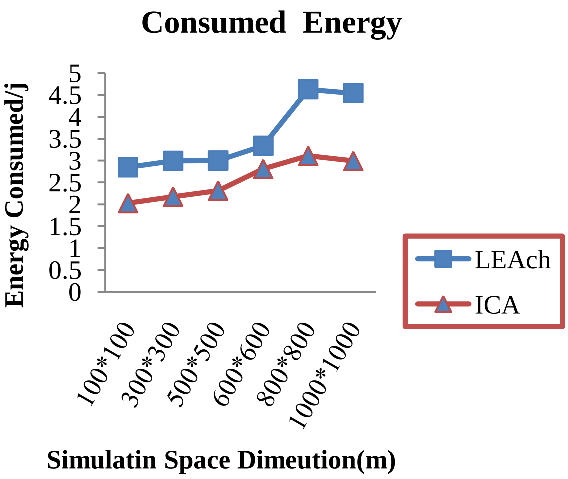

Figure 4. Consumed Energy of Proposed Method With LEACH Protocol.

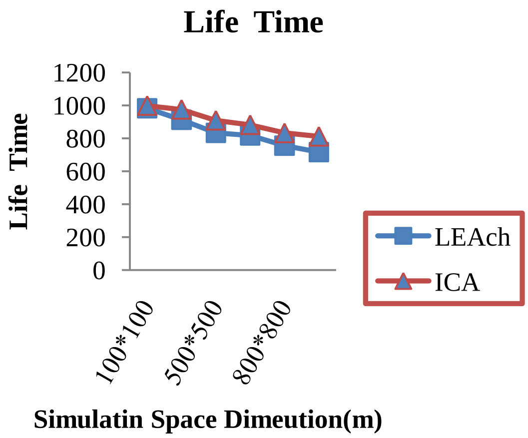

Figure 5. Life Time of Proposed Method With LEACH Protocol.

VI. CONCLUSIONS

Energy efficiency in wireless sensor networks is important, so that the useful duration of the network is depended on it. In this paper, using algorithms that form the focus of colonial rivalry in the base station runs. And consider the remaining energy nodes, cluster head the way we have determined the minimum energy consumption and thus increasing its length storage life and performance have increased.

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