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Target Scheduling algorithm for Wireless Sensor Networks: Imperialist Competitive Algorithm Approach

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Abstract

Wireless sensor networks have been deployed for many applications such as surveillance an area or a set of targets and lifetime maximization is one the most important challenges in wireless sensor networks. When a set of sensor nodes dropped into a field by aircraft or manually to monitor a set of targets, scheduling sensor nodes to monitor deployed targets is necessary to prolong network lifetime. Scheduling sensor nodes into cover set is one of the most important approaches to solve this problem. Hence, it is desirable to activate a minimum number of sensor nodes that are able to monitor all targets and turn off redundant nodes to save energy. In this paper, we used Imperialist Competitive Algorithm (ICA) to schedule sensor nodes into cover sets that can monitor deployed targets and increase lifetime and ICA is used as a method to create cover set in network. To study performance of our approach computer simulations conducted and results of these simulations showed that our algorithm can improve network`s lifetime in comparison with similar existing methods.

Keywords: Imperialist Competitive Algorithm (ICA), Scheduling, Target Coverage, Sensor Networks.

INTRODUCTION

Wireless Sensor Networks (WSN) have been using for different applications such as surveillance systems, temperature, and monitoring systems, etc. A sensor networks consists of many small nodes and energy efficiency is one the most critical issues in different protocols. The main constraint of these sensor nodes however is their battery energy which is limits network lifetime. Therefore, energy efficiency is in design of network protocols is one way to prolong network lifetime.

In this paper, we focus on monitoring targets in a sensor network. One of the common methods to reduce energy consumption in a sensor networks and increasing network lifetime is to schedule sensor nodes into subset that can cover all targets in deployed network. Then, each subset can activate in different time to monitor scattered targets and other nodes can switch to low energy consumption modes to save their energy level for next times.

Fundamentally, there are two methods to divide sensor nodes into subset that called disjoint set cover and maximum set cover. In disjoint set cover, each node in subset can only activate for one round and it consumes its full energy in activated time. But, in maximum set cover problem each node in different subset could activate more than once.

In this we proposed an Imperialist Competitive Algorithm based approach to find maximum set cover in deployed network. We assume that the number of deployed sensor nodes is more than it's required. Therefore we schedule proper nodes to monitor deployed targets.

The rest of the paper is organized as follows. In Section 2, we present related works in the field of energy efficiency target coverage problem. Section 3 briefly describes the target coverage problem. Imperialist Competitive Algorithm as a basic strategy used in the proposed method will be discussed in Section 4. In Section 5, the proposed method is presented. Section 6 presents the simulation results and Section 7 concludes the paper.

RELATED WORK

Coverage problem has different definitions and specifications according to the recent researches in the wireless sensor networks. Zhu et al [1] provided a good survey on various coverage and connectivity issues in wireless sensor networks. Coverage problem can be categorized in three main types; target (point) coverage, area coverage, and barrier coverage. The point (target) coverage subject is to monitor a set of deployed target in networks. Targets are either stationary or fixed. The objective of area coverage is to monitor deployed area in networks. Mostafaei et al [10-11] proposed a learning automata based approach to prolong network lifetime in wireless sensor network in which each node in network equipped with learning automata which helps to nodes to select a proper state either active or sleep. The barrier coverage subject is to detect penetrated path by intruders to networks. In [12] authors build barrier sensor with minimum cost in sensor networks. They provided a distributed algorithm to solve minimum-cost barrier coverage problem in asynchronous wireless sensor networks.

In [9] authors proposed a learning automaton based algorithm for dynamic point coverage. They used learning automata to select best nodes to cover dynamic targets. In [2] authors considered target coverage problem and they proposed sub-set based method to divide sensor nodes into different cover set as each cover set can cover all targets in network. Objective of their method is maximizing the number of cover set. Authors [3] proposed learning automata based algorithm to find maximum disjoint set cover. They used learning automata to find best state (active or sleep) of each node in any given time in network.

In [4], authors presented a hybrid approximation approach for complete minimum-cost target coverage problem in wireless sensor networks. They used combination of LP-rounding and set cover selection method to propose their method. Gu et al proposed column generation based algorithm to find near optimal solution for treatment target coverage in wireless sensor networks in [5]. They offered an approach that can guarantee at least $(1-\varepsilon)$ of optimal network lifetime.

Authors in [6] consider a sensor covers targets with users' satisfied probability. They introduce a failure probability into the target coverage problem to improve and control the system reliability. They modeled the solution as α-Reliable Maximum Sensor Covers (α-RMSC) problem and proposed a heuristic greedy method to find maximum number of α-Reliable sensor covers and their algorithm can control the failure rate of whole system which a critical aspect in many applications of wireless sensor networks such as military surveillance systems, and environment monitoring systems.

PROBLEM STATEMENT

In this section, we consider maximum set cover problem in which scattered nodes in networks divide into sub set that are called set covers. The constructed set covers by any approach need not be disjoint. It means that each node in network can be in more than one set cover. We assume that all nodes in network have the same amount of initial energy and have the same energy consumption rate in the active state. The lifetime of a single sensor is assumed as one time unit if it is activated all the time. In the context of disjoint set cover problem, each sensor can only be included into one set cover, and all sensors have the same length of the active interval. Therefore, the network lifetime depends on the number of constructed disjoint sensor set covers. However, if we relax the disjoint constraint such that a sensor can be included in more than one set cover and each set cover can be activated for less than one time unit, then the network lifetime may be extended.

In this section we restate maximum set cover problem. The following example introduced by Cardei et al. [2] provides a good illustration of the network lifetime extension by maximum set covers. As shown in Figure 1, if we partition the sensors into two disjoint set covers, namely, {s1, s2} and {s3, s4}, then the network lifetime is 2. On the other hand, if we relax the disjoint constraint, then we can partition the sensors into four maximum set covers and activate them for different time intervals, namely, {s1, s2} for 0.5 time unit, {s2, s3} for 0.5 time unit, {s1, s3} for 0.5 time unit, and {s4} for 1 time unit. This partition results in a network lifetime of 2.5, which is a 25% increase in network lifetime compared with the disjoint set cover solution.

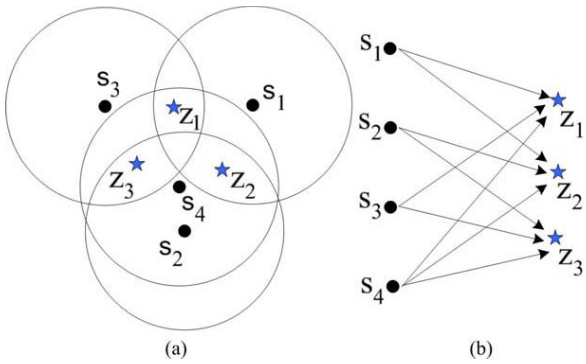

Fig 1. Illustration of a randomly deployed sensor network for covering targets and **b** the corresponding sensor-target bipartite graph

IMPERIALIST COMPETITIVE ALGORITHM

In this section we briefly overview Imperialist Competitive algorithm. Imperialist Competitive Algorithm (ICA) is a new computational method that is used to solve optimization problems in different fields such as computer science, control systems, and etc. 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:

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 [7, 8]. Figure 2 shows the flow chart of ICA.

This movement is a simple model of assimilation policy which was pursued by some of the imperialist states. The total power of an empire depends on both the power of the imperialist country and the power of its colonies. This fact is modelled by defining the total power of an empire as the power of imperialist country plus a percentage of mean power of its colonies.

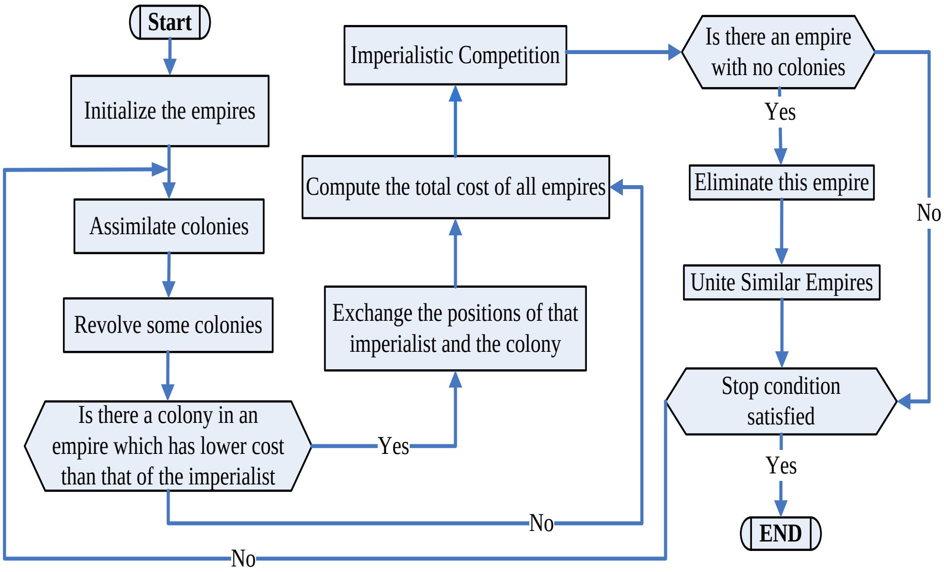

Fig 2. Flow chart of ICA

PROPOSED METHOD

In this section, we describe our proposed method based on Imperialist Competitive Algorithm to solve maximum set cover problem in wireless sensor networks. First, we suppose that all sensor nodes in network are the same and each network can has two nodes type: active node and idle node. We try to select proper active nodes to monitor deployed targets in network area. We also suppose that all sensor nodes and targets deployed randomly and each node has the same sensing range.

First, each node in network senses the environment and detects targets that can cover and its neighbours. Then each node sends an Identification packet which contains ID, neighbour list, and covered targets. We randomly define a series of possible nodes answers as empire. All neighbors node of selected node as empire be the country nodes as a colony of this empire.

Network operations divide into different rounds. In each round, Imperialist tries to assimilate its colony and it absorbs them into itself. In this case, empire of each colony send an ASLEEP packet to those nodes which their targets can be covered by other nodes in network to low energy consumption mode to save their energy for next rounds and other nodes will be active to monitor targets in network. This process will continue until at least a target in network cannot be covered by at least a node.

SIMULATION RESULTS

In this section, we conduct a set of simulations to evaluate the performance of the proposed scheduling mechanism, referred to as ICAMSC, in comparison to the performance of similar existing method. In these simulations, a fixed sensor network is assumed, in which all sensor nodes are randomly scattered throughout a 500m × 500m two dimensional area. A number of fixed targets are also deployed randomly within this area. Sensing ranges of all sensor nodes assumed to be equal. Parameters of the conducted simulations are as follows;

N: Number of sensor nodes. We vary n in the range [20, 80] to study the effect of the node density on the performance of ICAMSC.

- T: Number of targets. We set m to50.
- R: Sensing range of the sensor nodes. We vary R in the range [200, 500] meters.

We compare ICA based algorithm that labeled as ICAMSC with existing work (heuristic Greedy-MSC method) in [2]. We set the number of targets to 50; let the sensing range vary in the range 200 to 500 step by 50, and the number of sensor nodes to 40. We study the effect of the sensing ranges of the sensor nodes on the lifetime of the network in the proposed scheduling mechanism with different sensing ranges. Figure 3 shows the results of this experiment. It can be seen from this figure that the network lifetime is higher when the proposed scheduling mechanism is used rather than heuristic Greedy-MSC method. Next we study the effect of the number of sensor nodes on the lifetime of the network in the proposed scheduling mechanism. Figure 3 displays for sensing range R = 300, N = 280, and M = 50. The results of this experiment, which are given in figure 3, indicate that the network lifetime increases as the number of the sensor nodes increase.

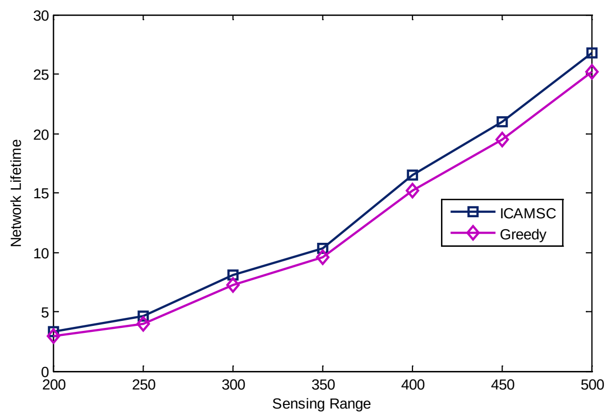

Fig 3. network lifetime with sensing range

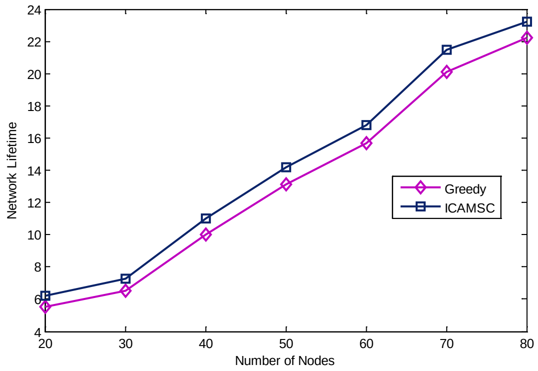

Fig 3. network lifetime with different nodes

CONCLUSION

In this paper, we proposed an imperialist competitive algorithm based algorithm for maximum set cover problem in wireless sensor networks. In the proposed algorithm, network nodes are divided into subset with help of ICA. Empire nodes in deployed network try to help colony to select its best status in any given time of our simulations. Experimental results showed that the proposed algorithm, regardless of the sensor nodes' density, number of the sensor nodes, and sensing radius of the sensor nodes, outperforms the similar existing method in terms of the network lifetime.

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