

A New Positioning Method using Ant Colony Optimization in Wireless Sensor Networks

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Abstract – Network coverage in sensor positioning is an important challenge of wireless sensor networks. This problem is an NP-hard problem and employing an optimization method is needed. In this paper, we propose an efficient method based on Ant Colony Optimization (ACO) to the sensor positioning to gain better performance by trying to increase the coverage area of the network. We also investigate other intelligent techniques for node positioning to increase the coverage of wireless sensor network.

Keywords – New Positioning Method, Wireless Sensor Networks, Ant Colony Optimization (ACO).

I. INTRODUCTION

Wireless sensor network (WSN) is an infrastructure less, dynamic topology, application oriented, multi-hoping network design with small, sensing wireless distributed nodes. A sensor node by itself has severe resource constraints, such as low battery power, limited signal processing, limited computation and communication capabilities, and a small amount of memory; hence it can sense only a limited portion of the environment [1]. The wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, industrial process monitoring, machine health monitoring and in agriculture also [2]. Sensor nodes keep monitoring the network area after placement. When an event occurs, one of the surrounding sensor nodes can detect it, generate a report, and transmit the report to a base station through multi-hop wireless links. The base station can process the report and then forward it through either high-quality wireless or wired links to the external world for further processing. A base station (BS) acts as a gateway. Node positioning is a fundamental issue to be solved in WSNs. A sensor network placement can be divided into 2 groups a dense placement and a sparse placement. A dense placement has a high number of sensor nodes in the given field of interest while a sparse placement would have fewer nodes [3]. The dense placement method is used in situations where it is very important for every event to be detected or when it is important to have multiple sensors cover an area. Sparse placements may be used when the cost of the sensors make a dense placement prohibitive or to achieve maximum coverage using the bare minimum number of sensors. Achieving the maximum coverage of sensor coverage using the minimum number of sensors has been proved to be NP-hard. It means, it is difficult to obtain the precision solution by traditional methods. Thus, employing optimization algorithms in WSNs is emerging as an important field since it allows various adaptive

approaches to solve this problem.[4]

Ant Colony Optimization (ACO) [5, 6] is a meta-heuristic for solving hard combinatorial optimization problems. The inspiring source of ACO is the pheromone trail laying and following behavior of real ants, which use pheromones as a communication medium [7].

Artificial ants used in ACO are stochastic solution construction procedures that probabilistically build a solution by iteratively adding solution components to partial solutions by taking into account (i) heuristic information about the problem instance being solved, if available, and (ii) (artificial) pheromone trails which change dynamically at runtime to reflect the agents' acquired search experience.

This paper proposes an efficient method based on Ant Colony Optimization (ACO) to optimize the node placement of WSNs.

The organization of the paper is as follows. Section 2 reviews the Ant Colony Optimization. Section 3 introduces An ACO approach to the optimal placement of sensors. Experimental results are described in Section 4. Finally, Section 5 concludes this paper.

II. ANT COLONY OPTIMIZATION

In the early 1990s, ant colony optimization (ACO) was introduced by M. Dorigo and colleagues as a novel nature-inspired meta-heuristic for the solution of hard combinatorial optimization (CO) problems. ACO belongs to the class of meta-heuristics [8, 9], which are approximate algorithms used to obtain good enough solutions to hard CO problems in a reasonable amount of computation time. The inspiring source of ACO is the foraging behavior of real ants. When searching for food, ants initially explore the area surrounding their nest in a random manner. As soon as an ant finds a food source, it evaluates the quantity and the quality of the food and carries some of it back to the nest. During the return trip, the ant deposits a chemical pheromone trail on the ground. The quantity of pheromone deposited, which may depend on the quantity and quality of the food, will guide other ants to the food source. In ACO, artificial ants build a solution to a combinatorial optimization problem by traversing a fully connected construction graph. The ACO meta-heuristic is shown in Figure.1.

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Set parameters, initialize pheromone trails
SCHEDULE_ACTIVITIES
ConstructAntSolutions
DaemonActions {optional}
UpdatePheromones
END_SCHEDULE_ACTIVITIES
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Fig.1. The ACO meta-heuristic

Once solutions have been constructed, and before updating the pheromone values, often some problem specific actions may be required. These are often called daemon actions, and can be used to implement problem specific and/or centralized actions, which cannot be performed by single ants. The most used daemon action consists in the application of local search to the constructed solutions: the locally optimized solutions are then used to decide which pheromone values to update.

In next section we employ ACO method to optimize the sensor positioning problem

III. AN ACO METHOD TO THE OPTIMAL PLACEMENT OF SENSORS

In WSNs, sensors can collect information about the area within their detection ranges. They share their information with their neighbor sensors. The performance of a sensor network depends on the positions of the sensors in the area of interest. Therefore, in responding to all system objectives, positioning of the sensors in the mission space is a problem that is called the coverage control or active sensing problem [10].

There is no a priori information about the area of the interest, so initial positioning of the WSNs are chosen randomly. Each sensor knows its position. The coverage ratio of the WSN is calculated by Eq. (1) [11].

$$CR = \frac{\bigcup C_i}{A}, i \in S \quad (1)$$

In Eq. (1), where C_i is the coverage of a sensor i , S is the set of the nodes, and A is the total size of the area of interest.

The aim of the optimization technique is to maximize the coverage of the network, as given in Eq. (1). In this section, an ACO method is introduced to optimize the node placement. At the first, we decode each positioning solution of sensors to one ACO solution. It means each ACO solution can be considered as one solution of WSN positioning.

Each ACO solution represents an array that has m items. Figure 2 shows the solution array. Items of the solution array are (x, y) positions of the mobile sensors in the network.

1	2	3	4	5	6	...	m
(x_1, y_1)	(x_2, y_2)	(x_3, y_3)	(x_4, y_4)	(x_5, y_5)	(x_6, y_6)	...	(x_m, y_m)

Fig.2. Solution array

The steps of the algorithm are as follows.

1. Initialize the parameters: radius of sensors r , size of area of interest A , number of sensors m , global pheromone decay rate, local pheromone decay rate, pheromone sensitivity, visibility sensitivity, pheromone update constant, exploration constant.
2. Generate the initial population of ACO solutions. (Generate some initial configurations of WSN and map them to ACO space)
3. Place m sensors randomly
4. Evaluate the population.
5. Begin the optimization loop
6. Use each solution to update the pheromone for each parameter value

7. Use the probabilities to generate new solutions
- 7-1. Generate probabilities based on pheromone amounts
- 7-2. Local pheromone update
8. Replace the duplicated solutions by new random solutions.
9. Make sure each individual is legal
10. Evaluate the fitness function (coverage of the area) for all of solutions.
11. Sort from best to worst
12. Go to 6 if the termination condition is not satisfied.
13. Map the result (optimize solutions) to WSN space.

IV. EXPERIMENTAL RESULTS

The purpose of this study is to show the fundamental difference between proposed algorithm (ACO) and other intelligent algorithm, like PSO, DE, and ES in node placement. So in this simulation we only consider a simple case in a 2-dimensional grid with 10 points in each dimension for a total of 100 grid points. It means that, size of the area is 10 m by 10 m, and number of nodes is 10. We set radius = 1.5 at all grids.

Figure.3 shows that our ACO method significantly outperforms other mentioned algorithms. Moreover, we can see the coverage of the area is better in high iterations. Number of iterations n in this figure is assumed 500 in (a) and 1000 in (b).

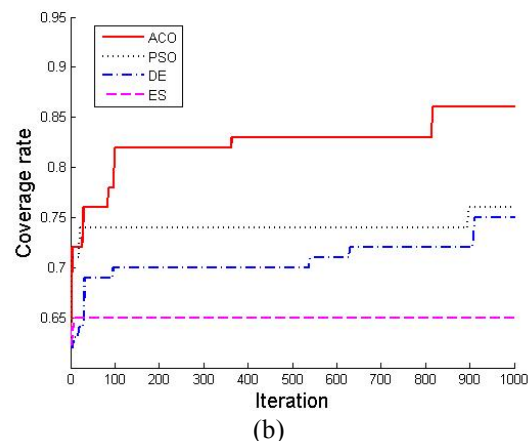
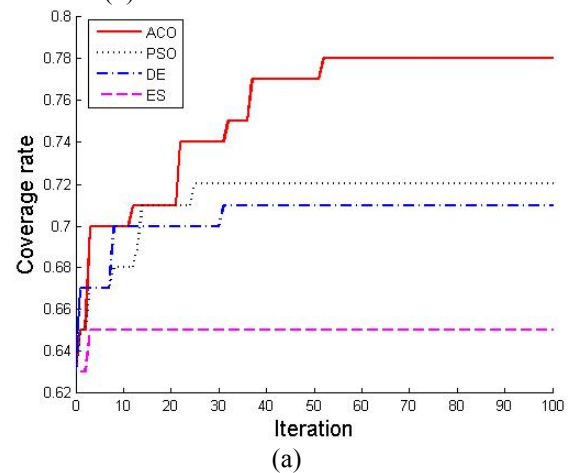


Fig.3. The improvement of effective coverage during the execution of the ACO, PSO, DE and ES, (a) iteration=500, (b) iteration=1000

V. CONCLUSION

One of the most important issues in wireless sensor networks is maximize coverage of the network. In this paper, we introduce a method to optimum position of the sensors (ACO).

Experimental results show that our method out performs other algorithms. We plan to extend our method by adding other objectives of WSNs, like lifetime, as future work

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