Finding the Shortest Path for Mobility of Mobile Sensors in K-Covereage Networks by Using Ant Colony Algorithm

Samira Mahzad and Hamidreza Bakhshi

Abstract— Sensor deployment that guarantees suitable coverage with minimum number of sensors is one of the most important challenges in designing mobile wireless sensor networks. In this paper, we have proposed an optimized solution for finding the shortest path to move sensors by adopting ant colony algorithm. In other words, the proposed algorithm not only guarantees the k-coverage of sensor network, but also reduces the sensor node moving distance which saves the network energy. From the simulation results, it could be seen that the consumed energy of the proposed algorithm is 10 times less than other exist algorithms which can prolong lifetime of network by reducing average moving distance of mobile nodes.

Index Terms— Ant colony algorithm, Mobile sensors, Wireless Sensor Networks (WSNs).

1 Introduction

In recent years, one of the key research issues in designing Wireless Sensor Networks (WSNs) is how sensors can efficiency be deployed to cover an area. An optimized deployment is based on the maximum coverage with minimum number of sensors, energy conservation and prolonging the entire network lifetime.

Along with the evolution of wireless sensor networks surfaced a new concept which was mobile WSN (MWSN)[1]. A mobile wireless sensor network owes its name to the presence of mobile sink or sensor nodes within the network. Most of the fundamental characteristics of mobile wireless sensor network are the same as that of normal static WSN [2], [3]. Mobile wireless sensor networks have been shown to demonstrate enhanced performance over static wireless sensor networks. Some of the advantages gained through mobile wireless sensor network are accuracy, flexibility, energy efficiency and extending network lifetime. In addition, there is another concept in WSNs which is named k-coverage. If every location in a region can be monitored by at least k sensors, the region is named k-coverage, where k is a given parameter. A large amount of applications may impose the requirement of k>1 to minimize the impact of sensor failure [4], [5].

Sensor placements for 1-coverage have been studied in several works. For example, the works in [6] and [7] consider placing sensors in a grid like fashion to satisfy some coverage requirements, while [8] suggests placing sensors strip by strip to achieve both coverage and connectivity. Several studies have also considered the sensor placement problem of multilevel coverage. In [9], a hexagon like placement is proposed to guarantee that the sensing field is k-covered, under the assumption that the communication distance of sensors r_c is not smaller than twice their sensing distance r_s.

One of the most important challenges in designing mobile wireless sensor network is reducing energy consumption by finding shortest path. Some solutions for this purpose have been studied in several works. For example in [4] suggests the competition-based and the pattern-based dispatch schemes as an optimal movement solution. The authors in [10],[11],[12],[13] study how sensors can be moved to enhance the coverage of the sensing field by using the Voroni diagram or attractive/repulsive forces between sensors. In [14] the sensing field is partitioned into grids, and sensors are moved from high density grids to low density ones to achieve more uniform coverage. The authors in [2], [15] used the ant colony algorithm to find the shortest path which has the largest pheromone amount. Through long period of research, bionics scientists discover that ants can often find the shortest path between food source and their nest. The principle of this phenomenon is that ants deposit a chemical substance (called pheromone) on the ground, thus, they mark a path by the pheromone trail. An ant encountering a previously laid trail can detect the dense of pheromone trail. It decides with high probability to follow a shortest path, and reinforce the trail with its own pheromone. The larger amount of pheromone is on a Particular path, the larger probability is that an ant selects that path.

In this paper, we proposed more efficient algorithm to optimize the k-coverage sensor deployment by using ant colony algorithm. From the simulation result, it could be seen that the proposed algorithm has good performance in saving energy and reducing average moving distance in a k-coverage sensor network by promoting ant colony algorithm.

The paper is organized in five sections. Next section

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briefly describes more complete solutions to the k-coverage sensor placement problem. Section III adopts the ant colony algorithm for finding the shortest path to guarantee k-coverage networks. Fourth section presents the role of proposed algorithm in reducing consumption energy and simulation results. Section V gives the conclusion.

2 The Optimal k-Coverage Sensor Node Deployment Scheme

In some applications, 1-coverage deployed sensor node could not satisfy the requirement of a wireless sensor network. Therefore, it is necessary to study the ways which leads to optimal coverage in these networks. In this section we consider more complete solutions to the k-coverage sensor placement problem. We proposed two placement solutions for k-coverage placement. The first solution is based on a multiple placement method, while the second one is shown an intercalating scheme which releases the number of sensors.

2.1 The multiple placement method

One simple idea to achieve a k-coverage deployment is to determine the locations of sensors to ensure 1-coverage and connectivity in assumed area and then place k-sensors on each node instead of one. The work in [4], [16] separated the discussion for guarantee 1- coverage placement in two cases, $r_c < \sqrt{3}r_s$ and $r_c \geq \sqrt{3}r_s$. Each sensor has a communication distance r_c and a sensing distance r_s. For connectivity we assumed that two sensors can communicate with each other if their distance is not larger that r_c.in addition, reference [2] addresses how sensors can be arranged to have 1-coverage by assuming $r_c = \sqrt{3}r_s$. For 1-coverage placement sensors are placed in rows which are separated by a distance of r_c. Each row of sensors can cover a belt like area of width 2δ where $\delta = \sqrt{r_s^2 - \frac{1}{4}r_c^2}$ as Fig.1.

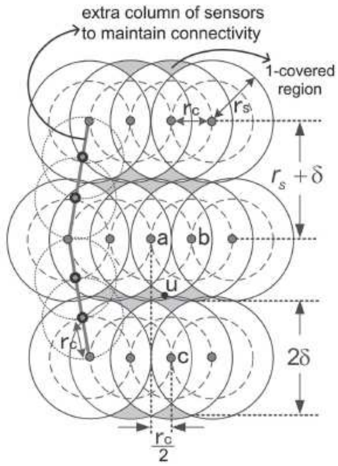

Fig. 1. The 1-coverage sensor placement method proposed in [4].

2.2 The intercalating placement method

The previous multiple scheme may result in some sub-regions that have coverage levels higher than k. consequently, the following intercalating placement method will try to balance the coverage levels of sub regions. According to the relationship of r_c and r_s [4] separated the discussion into three cases:

- $r_c \leq \frac{\sqrt{3}}{2} r_s$
- $\frac{\sqrt{3}}{2} r_s \leq r_c \leq \frac{2+\sqrt{3}}{3} r_s$
- $r_c > \frac{2+\sqrt{3}}{3} r_s$

Where $r_c \leq \frac{\sqrt{3}}{2} r_s$, we add extra row of sensors between each pair of adjustment rows as Fig.2. So, the coverage level of the sensing filed will directly become three. In this case, each extra row is placed above the previous row by a distance of r_s and neighboring sensors in each extra row are still separated by distance of r_c.
To summarize, while the multiple placement requires kx rows of sensors to cover a region, this intercalating placement requires only $(\lfloor \frac{k}{3} \rfloor (2x + 1) + (k \bmod 3).x)$ rows of sensors.

Where $\frac{\sqrt{3}}{2} r_s \leq r_c \leq \frac{2+\sqrt{3}}{3} r_s$, it is necessary add one extra row of sensors (mark as $new\ (i)$) between each new row i and old row i as Fig. 3 shows. Note that these extra rows are shifted horizontally by a distance of $\frac{r_c}{2}$ from the previous rows and neighboring sensors are separated regularly by a distance of $2r_c$. The connectivity between these rows was considered in [4]. Therefore, in this case only requires $(\lfloor \frac{k}{3} \rfloor (2.5x + 1) + (k \bmod 3).x)$ sensors to cover the whole region.

Where $r_c > \frac{2+\sqrt{3}}{3} r_s$, one extra sensor should be added in the $new\ (i)$ to cover every 2-covered region, as Fig3 shows. In this case, if the multiple scheme uses 3x rows of sensors to ensure 3-coverage of a belt like of width $(x-1)r_s + (x+1)\delta$,this intercalating scheme should use 3x+1 rows to achieve the same goal. Since the intercalating placement, we adopt the multiple model in the case of $r_c > \frac{2+\sqrt{3}}{3} r_s$.

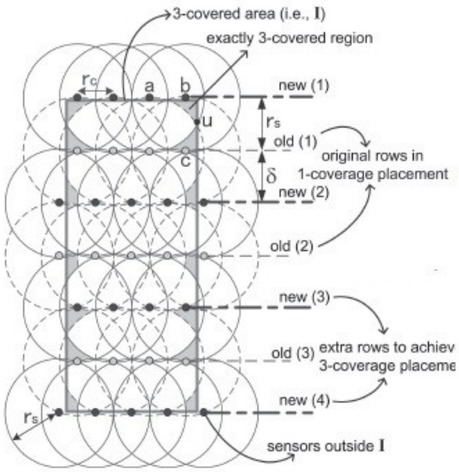

Fig. 2. The intercalating placement scheme in the case of proposed in [4].

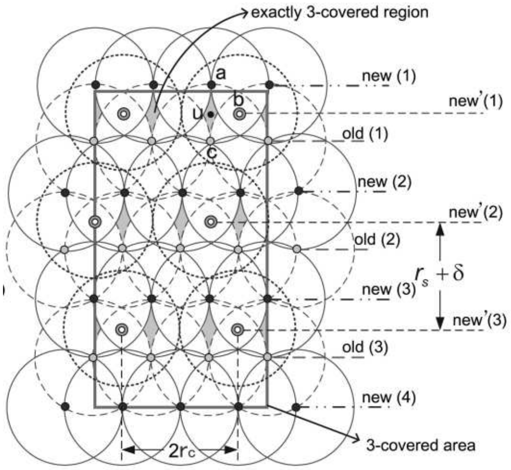

Fig. 3. The intercalating placement scheme for k=3, [4].

3 Shortest Path Sensor Dispatch Algorithm

After determining the locations to be placed with sensors, the next step is how we can move existing sensors in the region. For achieving this purpose we use mobile sensor nodes which can adopt in right positions. As can be seen, the attention of prior works was mainly paid to the use of mobile sensors to improve the topology of mobile WSN but energy consumption and decreasing the average of moving distance are two important issues which we consider in this paper.

Here, we use ant colony algorithm (ACA) as an optimal solution for moving mobile nodes to designated locations. Ant colony algorithm was studied in [2] for only 1-coverage sensor network. Our proposed algorithm not only adopts the ant colony algorithm for finding the shortest path, but also guarantees k-coverage networks that are more efficient in wireless sensor applications.

3.1 The proposed algorithm based on ACA

Our proposed algorithm to find the shortest path in k-coverage problem requires the location information about all sensors which we have found in previous section. After that we produce some random points as initial point in the region and then, execute the ACA. When one ant finds a good path from the colony to a food source, other ants are more likely to follow that path, and positive feedback eventually leads all the ants following a single path[15]. The ant colony algorithm can be run continuously and adapt to change in real time.

3.2 Energy consumption and average moving distance

As a key concept of designing MWSN, is minimizing of energy consumption. In another words, the way which uses the limited resources available at each sensor node more efficiently is very important. Using ant colony algorithm, we can achieve the shortest path and save the network energy. In this model, the energy consumption of each sensor is about 1 joule per meter. In the rest, the value of total energy is considered for 270 to 2100 sensors. The total energy consumption of sensors has a direct relation with the average movement of them. This relationship can be evaluated as follow:

$$E_t = \sum_{i=1}^{n} E_i \, d_i \qquad (1)$$

Where E_t is the total energy of assumed network with n sensors, E_i is the energy cost for sensor i to move in one unit distance (1 j/m) , d_{avg} is the average distance moving of n sensors, d_i is the distance between source and destination of sensor i .

4 Experimental Results

In this section, we present some experimental results to evaluate the performances of the proposed algorithm. We design a field A as a 300m*300m sequence region and sensors are initially concentrated inside of the interest area. The value of r_c and r_s are assumed as shown in table1.

For designed coverage level k=3, there will be 300, 600, 900, 1200, 1500, 1800, 2100 sensors needed to be dispatched to A area. The moving speed of each sensor is set to 1 m/s, the moving energy cost e_i of a sensor i is randomly selected as [0/8 j, 1/2 j] per meter. Fig. 4 shows the average moving distance of sensors and Fig. 5 shows the total moving energy. Fig. 6 illustrates the total moving energy of three scenarios which were described in [4], geedy, competition, centralize scenario and our algorithm. In comparison with our result of proposed algorithm, it can be seen that the total consumption energy is much less than others. Fig. 7 is the experimental result of average moving distance with our proposed algorithm, in comparison with others described in [4].

TABLE 1. THE ASSUMED VALUE OF AND

	1	2	3	4	5	6	7
r_c	34.7	24.1	19.3	16.7	17.9	13.4	12.5
r_s	20	13.9	11.1	9.62	8.6	7.71	7.16

5 CONCLUSION

In this paper, we studied systematical solution to the k-coverage sensor placement problem and then we have proposed a new algorithm to find out a way which lead to saving energy of sensor nodes and increment the life time of MWSN. Proposed algorithm is based on ant colony algorithm for optimize the moving path of each sensor. True the analyzes of the simulation we did, and compared with the other works, our proposed algorithm not only decrease the energy consumption but also reduce the average moving distance of the wireless sensor network.

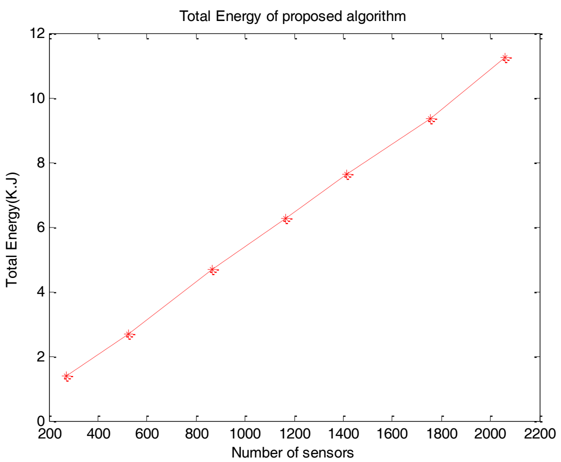

Fig. 4. Total moving energy of sensors

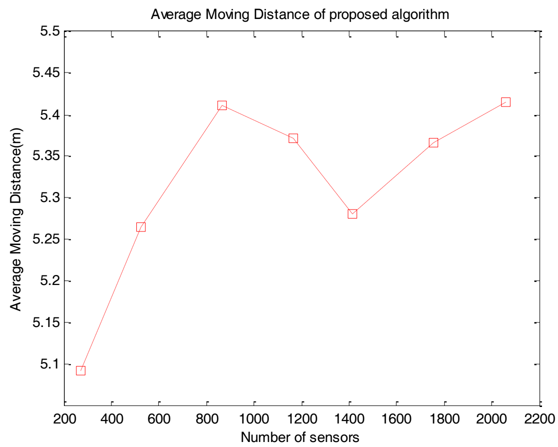

Fig. 5. Average moving distance

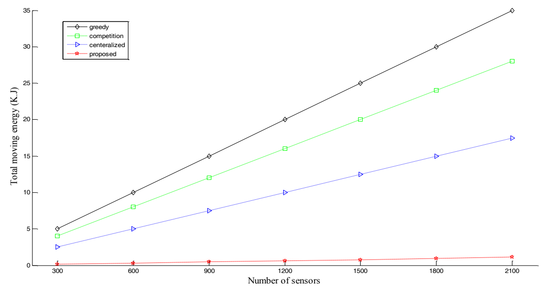

Fig. 6. Total moving energy with proposed algorithm, in comparison with other algorithms

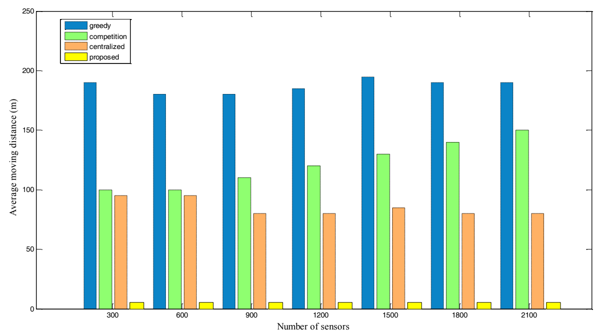

Fig. 7. Average moving distance with proposed algorithm, in comparison with others

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