Energy-Efficient Target Coverage in Wireless Sensor Networks Based on Modified Ant Colony Algorithm

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ABSTRACT

One of the major issues in Target-coverage problem of wireless sensor network is to increase the network lifetime. This can be solved by selecting minimum working nodes that will cover all the targets. This paper proposes a completely new method, in which minimum working node is selected by modified Ant colony Algorithm. Experimental results show that the lever of algorithmic complication is depressed and the searching time is reduced, and the proposed algorithm outperforms the other algorithm in terms.

KEYWORDS

SCP, ACA, WSN, BS.

1. INTRODUCTION

Wireless sensor networks (WSNs) has become the foundation of a broad range of applications related to national security, surveillance, military, health care, and environmental monitoring. Here sensors are deployed to monitor a set of targets. As defined in [1], the goal of target coverage concept in WSN is to have each location in the physical space of interest within the sensing range of at least one sensor. To maximize network coverage and to provide a reliable, energy-efficient monitoring depends on selecting minimum number of sensors in active mode to cover all the targets. So this power saving technique can be regarded as Set Covering Problem (SCP). By using modified ant colony algorithm this paper solved the minimum set covering, designed for a minimum set of nodes where node selection procedure is based on the energy of each node in a set, provide energy-efficient sensor network. The performance analysis through simulation results show that the algorithm proposed in this paper selects less working nodes than the other algorithms and maximize the network lifetime as well.

The rest of the paper is organized as follows. In section 2 we present related works on this topic.

Section 3 defines problem description and section 4 presents the simulation results of the algorithm and in section 5, we conclude the paper.

2. RELATED WORK

The coverage problems can be classified in the 3 types: (1)area coverage [2, 3, 4, 5], where the sensors cover an area, (2) point coverage [6, 7, 8],where the sensors cover a set of targets, and (3) coverage problems that have the objective to determine the maximal support path that traverses a sensor field [9].An important method for extending the network lifetime for the area coverage problem is to design a distributed and localized protocol that organizes the sensor

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nodes in sets. The network activity is organized in rounds, with sensors in the working set performing the area coverage, while all other sensors are in the dormancy mode. Set formation is done based on the problem requirements, such as energy-efficiency, area monitoring, connectivity, etc. Different techniques have been proposed in the literature [2, 3, 4, 5], for determining the eligibility rule, that is, to select which sensors will be active in the next round. In [1], to prolong network lifetime, maximum set covering (MSC) was selected. In [10], selecting the minimum number of nodes in area coverage problem was addressed as set cover problem (SCP). There are many method of looking for the least set covering. It is the least set covering problem, which selecting the least number of working node cover the all sampling points in inspected region. In literature [11], greedy algorithm was used to seek the least set covering. But, greedy algorithm cannot obtain approximate optimal solution. In [10], area coverage problem was solved by improved ACA, but that cannot ensure energy-efficiency of the network. In this paper, we solved energy-efficient target-coverage problem [1] by modified ACA to select the minimum number of set of nodes to obtain approximately optimal solution.

3. PROBLEM DESCRIPTION

In wireless sensor networks, usually, more sensors are deployed than required to cover a point or region. One of the major issues in WSN is power scarcity. In order to increase the survival time of network, optimize control for random deployment of network topology along with reducing the number of active nodes under the premise of performance in maintaining coverage is needed. In the target coverage problem, the goal is to maximize the network lifetime of a power constrained wireless sensor network where sensors are deployed for monitoring a set of targets with known locations and organized into a number of sets, such that all the targets are monitored continuously[1]. In this method, the minimum number of sets of sensors is selected where at least one sensor is BS connected to prolong the network lifetime.

The problem definition is given below:

3.1. Target Connected-Coverage Problem

Let us assume a homogeneous sensor network comprised of N sensors s1, s2,. . . , sN randomly deployed to cover (monitor) M targets r1, r2,..., rM. Each sensor has an initial energy E where it consumes some energy per time unit for sensing and for communication purpose. Among the sensors, some are BS connected, known as reference sensors send the sensed information for processing. The other ordinary sensors communicate with the BS through the reference sensors. To prolong the network lifetime, the reference and ordinary sensors are scheduled alternatively between active and sleep mode such that all the targets are monitored continuously. So, our target is to select the minimum sets of sensors that would be active for covering all the targets.

3.2. Basic Ant Colony Algorithm for Set Covering

The Set Covering problem is one of the optimization problems. It is usually defined as follows:

Suppose S is a set, $S1$, S_2 ,.., S_m are subsets and coverage of S, namely, $\bigcup_{i=1}^{p}(s_i)\ where\ p \in m$, solve the minimal covering.

In [12] and others first used ant colony algorithm to solve the SCP. The basic ant colony algorithm model for set covering is as follows:

At the initial moment, all subsets S_1, S_2,…, S_m are selected; Ant will be randomly placed on the m-subsets, assuming that the initial information of each subset is $\tau_j(0) = C$ (constant). The probability $p_{ij}(t)$ of ant k transfer from the subset i to the subset j is:

$$p_{ij}(t) = \begin{cases} \frac{[\tau_j(t)]^{\alpha} \times [\pi_{ij}]^{\beta}}{\sum_{l \in N_i^k} [\tau_j(t)]^{\alpha} \times [\pi_{ij}]^{\beta}}, & if\ j \in N_i^{\ k} \\ 0, & otherwise \end{cases} \qquad (1)$$

Among them, k is the ID(k =1,2,3,..,m)for the ants; t is the iteration number; $N_i^{\ k}$ $r$epresentatives the next subset allowed to select for ant k ; $\tau_j$said the pheromone strength of subset $j;$ $\pi_{ij}$is the inspired degree of ant k shifted from subset i to the subset j ,this volume is

changeable in the operation system of Ants; These two parameters α and β , are accumulation of information and inspired information in the process of ant's sports, reflects the relative importance of ants to choice the next subset.

According to equation (1), the inspired degree π_{ij} of ant k shifted from subset i to the subset j defined as follows:

$$\pi_{ij}^{\ k}(t) = \frac{\left|U_i^k(t) \cap s_j\right|}{M} \qquad (2)$$

Where, M is the number of elements in the S. $U_i^k(t)$ said the element sets not covered after ant k select subset i in the cycle t; S_j said the number of not covered elements in subset j after ant k select subset i in the cycle t; After select subset p , Ant will stop when the elements that the selected subset contained meet $U_{i=1}^{p}(s_i) = S$, this will mark the end of the cycle. After all the Ants have completed a cycle, the pheromone of the subsets adjusted according the under equation:

$$\tau_j(t+1) = \rho\tau_j(t) + \sum_{k=1}^{n} \Delta\tau_j^{\ k} \qquad (3)$$

$$\Delta\tau_j^{\ k} = \begin{cases} \frac{Q}{j^k}, & \text{if } j \in \text{sloution of ant k} \\ 0, & \text{otherwise} \end{cases} \qquad (4)$$

Among them, $\Delta\tau_j^{\ k}$is the pheromone increment of ants k released in the subset j ; (1- ρ) is the attenuation coefficient of the pheromone, usually installedρ <1 to avoid unlimited accumulation of informational on subset; J k said the number of subset ant k selected in this cycle; Q is the pheromone strength, it affected the convergence speed of algorithm in a certain extent.

3.3. Energy-Efficient Target Coverage using ACA

To solve energy-efficient target coverage problem, minimum number of sets of sensors are required. So target coverage problem is similar to SCP. Since SCP can be solved by ACA, target coverage problem can be solved by ACA and to make it energy- efficient some modification on BACA are required. Algorithm steps are as follows:

Step 1 Initially, ants were placed on those subsets where at least one of the sensors are BS connected. Initialize τ_j and $\Delta\tau_j$.

Step 2 Each ant selects the next subset using equation 1. The parameter α known as accumulated information is initialized with default value and the parameter β known as inspired information is defined as follows:

$$\varphi = \frac{E_i}{\sum_{l=1}^{c} E_l} \quad (5)$$

$$\beta = \begin{cases} \varphi, & if\ \varphi < 2 \\ 1.5, & otherwise \end{cases} \quad (6)$$

Here, c is the number of subset and .E is the energy of each subset i.e. each ant will select the next subset based on the current energy of each set of sensors.

Step 3 When all the ants will complete one cycle, the pheromone of the subsets adjusted using the equation 4

Step 4 The iteration will be stopped when the solution set meet the condition of monitoring all the targets.

4. SIMULATION RESULTS AND ANALYSIS

In this section , the performance of the algorithm are implemented on the PC of memory 1 GB, Celeron 1.5G by using MATLAB 7.We simulate a stationary network with sensor nodes deployed in the target region of 100mx100m square region. We also initialize battery energy of each sensor is 500 mWh and the sensing radius Rs of each node is 20m.

In the simulation, we also consider some changeable parameters such as the number of sensing node N, number of target nodes M .and the communication radius Rc .We changed the number of sensing nodes between 20 and 100 and the number of target nodes between 10 and 50. We also vary the communication range between 80m and 200m.

We take compared test on the basic ant colony algorithm (BACA) and modified ant colony algorithm (MACA). The default value of ant colony algorithm parameters set to α =.6, ρ=0.9 and Q=30. The main performance metric we pointed out here is the number of working nodes under different communication range and deployed nodes. We also focused on the number of coverage ratio determined by different algorithms which indicate the network lifetime of the WSN.

4.1. Impact on the number of WNs

In the first set of experiments we compare the number of WNs required in WSN under BACA and MACA. Found through the experiments that approximately 10 to 30 more number of WNs is required in BACA. Table 1 shows the comparison table and corresponding graph is shown in Figure 1.

The communication range of sensor nodes impact the number of WNs selected. We compare the WNs achieved in MACA and BACA in Figure 2.

TABLE 1. Comparison table of working nodes under different algorithm

Number of Node	**WNs in BACA**	**WNs in MACA**
20	*14*	*9*
30	*19*	*12*
40	*25*	*18*
50	*29*	*21*
60	*35*	*25*
70	*43*	*30*
80	*52*	*37*
90	*57*	*43*
100	*66*	*47*

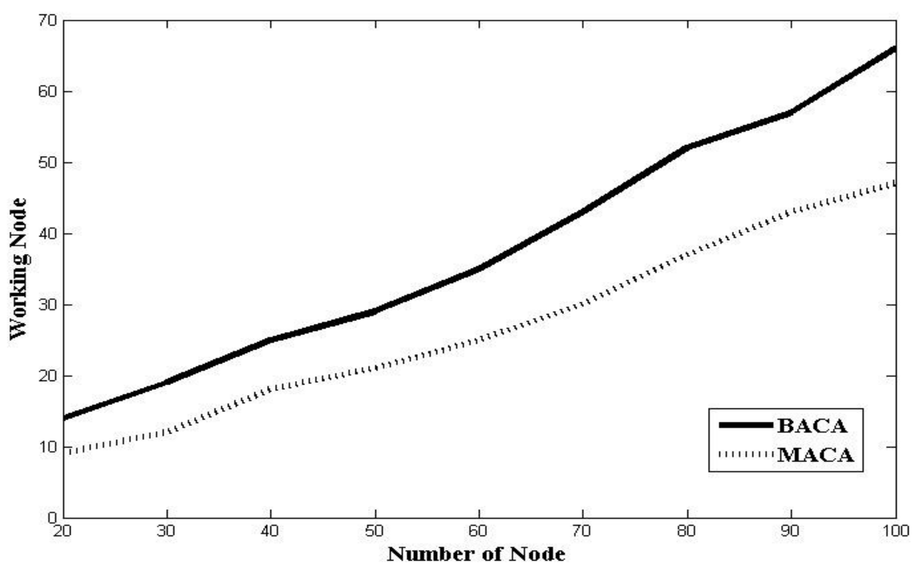

Figure 1. Number of WNs selected in BACA and MACA

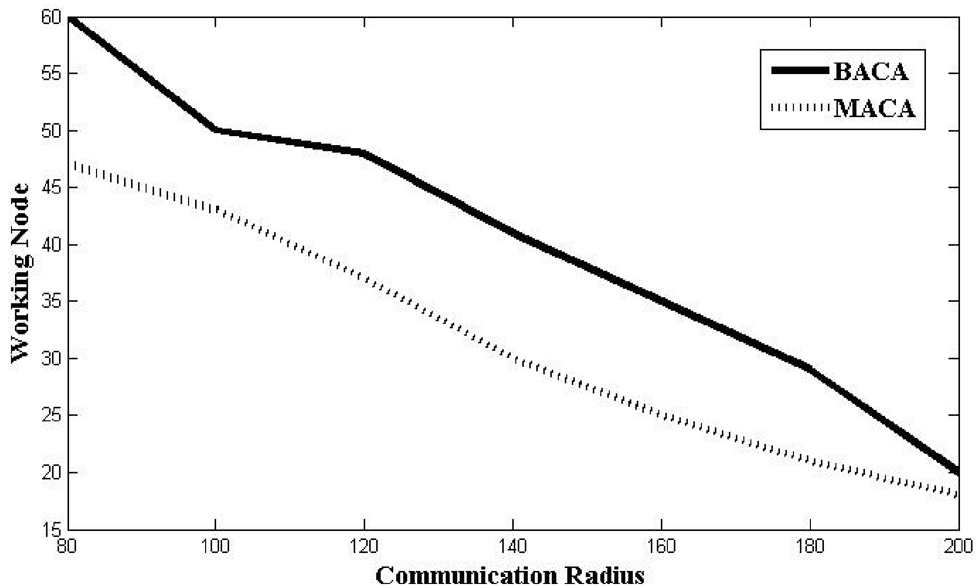

Figure 2. Number of WNs in different communication radius

4.2. Impact on the coverage ratio

The ratio of the target coverage indicates the network lifetime of the WSN. Using the algorithm in this paper approximately 87% of the coverage can be obtained in the needs of only 9 WNs among 20 Sensors when targets are fixed as 10 .It is also observable that sensor with higher density yield more covers. Result is shown in Figure 3.

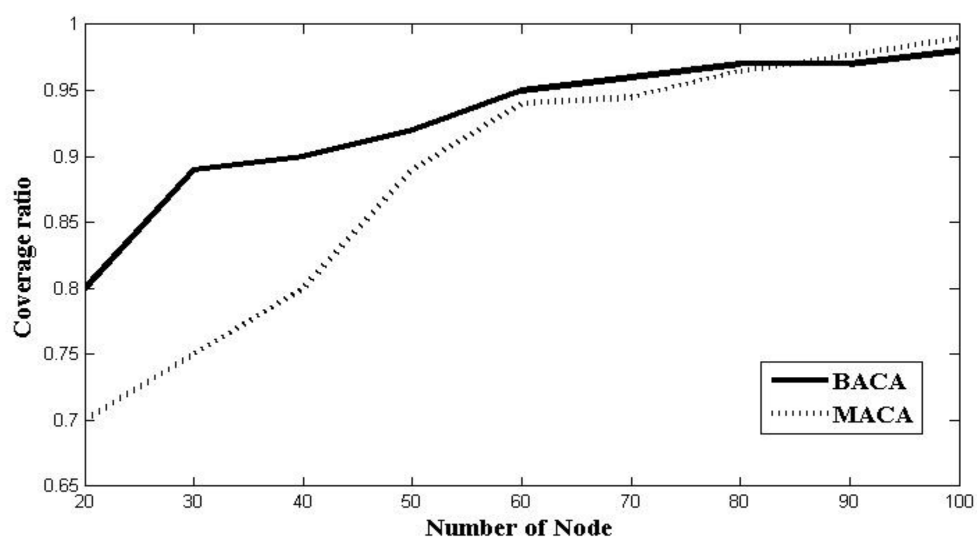

Figure 3: Coverage ratio in different algorithm

5. CONCLUSION

In this paper target connected-coverage problem have been optimized by making it energy-efficient using modified Ant Colony algorithm. The objective of this paper is to determine the coverage ratio of all targets which have been significantly improved in comparison with the Basic Ant colony algorithm. Our future work is to apply the same approach on heterogeneous wireless sensor network where the energy consumed by each sensor is different.

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