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Genetic algorithm approach for *k*-coverage and *m*-connected node placement in target based wireless sensor networks

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ABSTRACT

In target based wireless sensor networks (WSNs), coverage and connectivity are the two most important issues for guaranteed data forwarding from each target to a remote base station (BS). Given a set of target points, finding minimum number of potential positions to place sensor nodes fulfilling both coverage and connectivity is an NP-complete problem. In this paper, we propose a genetic algorithm (GA) based scheme to solve this problem. Keeping in mind that the sensor nodes are prone to failure, the proposed scheme provides *k*-coverage to all targets and *m*-connectivity to each sensor node. Our GA based approach is presented with efficient chromosome representation, derivation of efficient fitness function along with the usual GA operators. The scheme is simulated extensively with various scenarios of WSN. The simulation results are compared with some related existing algorithms to demonstrate the efficacy of the proposed scheme.

1. Introduction

1.1. Background

Wireless sensor networks (WSNs) have drawn enormous attention for their wide range of potential applications in environment monitoring, disaster warning systems, health care, defense, surveillance systems and target tracking [1]. In such applications, the sensor nodes sense data from a target area and send the sensed data to a remote base station (BS) usually by multi-hop communication [2].

The sensor nodes are deployed in the target area either in ad-hoc or pre-planned manner [3]. Ad-hoc deployment of the sensor nodes is useful for the harsh environment which are hard to access such as in deep forest, under water and so on. However, this approach requires deployment of a large number of sensor nodes to ensure full coverage of the target region. The pre-planned or manual deployment is used for easy accessible region. This kind of deployment brings better network management and saves sensor's energy. Moreover, it minimizes the overall network cost as covering an area with minimum number of sensor nodes can be possible in manual deployment. However, in both the deployment strategies, maintaining desired coverage and connectivity of the whole network is extremely important. This is a challenging issue because 1) the sensor nodes have limited

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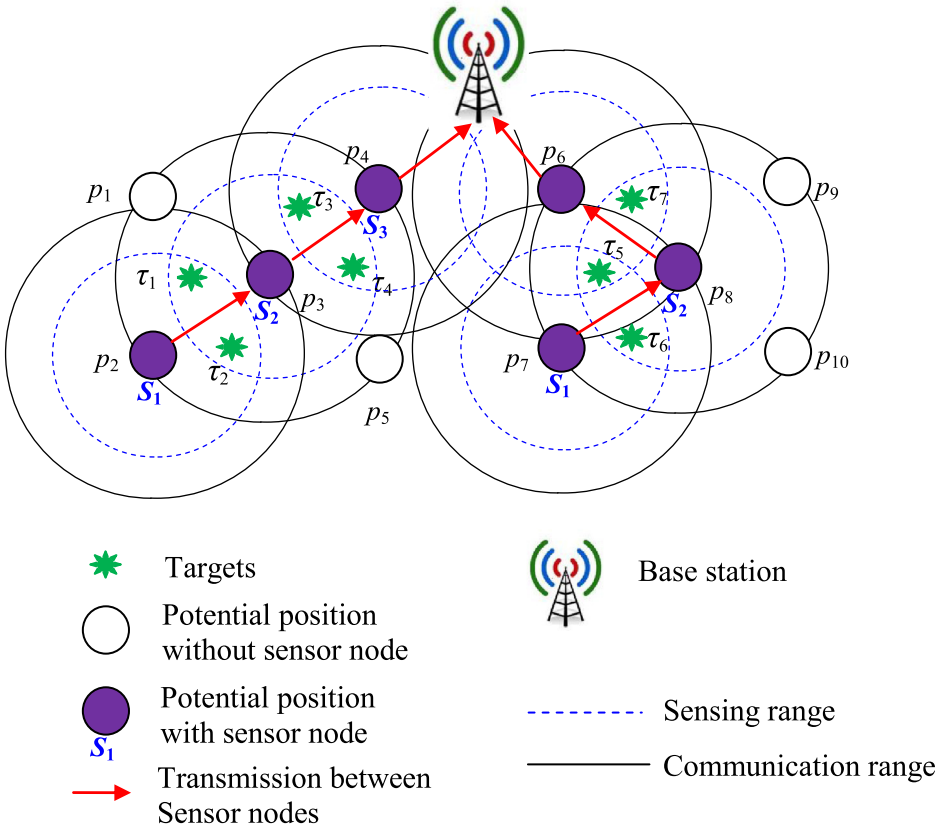

Fig. 1. An example of two-covered and one-connected network.

transmission range, 2) they have limited and irreplaceable power source and so their energy may be exhausted after certain rounds of operation, 3) there may be malfunctioning of hardware components (such as a processing unit, transceiver etc.) or they may be damaged by an external event. Moreover, connectivity between two nodes may be affected due to the failure of wireless link. Therefore, it is important to ensure coverage of the target points and connectivity between the sensor nodes so that the network can still be operational even if certain number of nodes fail.

In this paper, we address the following problem. Given a set of target points and a set of pre-fixed potential positions, we have to select minimum number of potential positions to place sensor nodes so that it will fulfill k-coverage of the targets and m-connectivity of the sensor nodes. We say that a target is covered if it is within the communication range of a sensor node and the sensor node will be able to communicate with the base station directly or via other sensor nodes. As an example, a target based network with 10 potential positions, $\{p_1, p_2, p_3, \ldots, p_{10}\}$ and seven targets $\{\tau_1, \tau_2, \tau_3, \ldots, \tau_7\}$ is shown in Fig. 1in which sensor nodes are placed on six selected potential positions out of 10. Note that the target τ_2 in this figure is covered because it is within the communication range of the sensor node placed at the potential position p_2 and this sensor node is able to communicate with the base station via the senor nodes placed at the potential positions p_3 and p_4. By the k-coverage of the targets, we want to mean that each of the target points must be covered by at least k sensor nodes. In other words, a target will remain covered even if k-1 sensor nodes fail. By m-connectivity of the sensor nodes, we want to mean that each sensor node is directly connected with m other sensor nodes, i.e., a sensor node will remain connected even if m-1 sensor nodes fail. For example, the network in Fig. 1 has two-coverage of the targets and one-connectivity of the sensor nodes.

This is noteworthy that the node deployment with N targets and K potential positions is a NP-complete problem [4,5]. Therefore computational complexity of finding optimal node deployment providing coverage and connectivity for a large WSN seems to be very high by a brute force approach. Moreover, a reasonable amount of memory and computational resources would be required by an optimization technique and yet finding out good results is desirable. Thus a metaheuristic approach is highly desirable to obtain an approximate solution of the node deployment problem.

1.2. Our contribution and organization of the paper

In this paper, we propose a metaheuristic approach based on genetic algorithm (GA) to identify the potential positions for placing sensor nodes so that all the target points are k-covered and all the sensor nodes are m-connected. Our main contributions are summarized as follows:

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