Solving the Optimal Coverage Problem in Wireless Sensor Networks Using Evolutionary Computation Algorithms*

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Abstract. This paper formulates the optimal coverage problem (OCP) in wireless sensor network (WSN) as a 0/1 programming problem and proposes to use evolutionary computation (EC) algorithms to solve the problem. The OCP is to determine to active as few nodes as possible to monitor the area in order to save energy while at the same time meets the surveillance requirement, e.g., the full coverage. This is a fundamental problem in the WSN which is significant for the network lifetime. Even though lots of models have been proposed for the problem and variants of approaches have been designed for the solution, they are still inefficient because of the local optima. In order to solve the problem effectively and efficiently, this paper makes the contributions to the following two aspects. First, the OCP is modeled as a 0/1 programming problem where 0 means the node is turned off whilst 1 means the node is active. This model has a very natural and intuitive map from the representation to the real network. Second, by considering that the EC algorithms have strong global optimization ability and are very suitable for solving the 0/1 programming problem, this paper proposes to use the genetic algorithm (GA) and the binary particle swarm optimization (BPSO) to solve the OCP, resulting in a direct application of the EC algorithms and an efficient solution to the OCP. Simulations have been conducted to evaluate the performance of the proposed approaches. The experimental results show that our proposed GA and BPSO approaches outperform the state-of-the-art approaches in minimizing the active nodes number.

Keywords: Wireless sensor networks (WSN), optimal coverage problem, evolutionary computation (EC), genetic algorithm (GA), particle swarm optimization (PSO).

* This work was supported in part by the National Natural Science Foundation of China No.U0835002 and No.61070004, by the National High-Technology Research and Development Program ("863" Program) of China No. 2009AA01Z208.
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K. Deb et al. (Eds.): SEAL 2010, LNCS 6457, pp. 166–176, 2010.

1 Introduction

The wireless sensor networks (WSN) is a very new technology which has become a hottest and most challenging research topic recently [1][2]. The WSN consists lots of sensor nodes that monitor the area for specialized applications such as battlefield surveillance, habitat monitoring, environmental observation, health applications, and many others [3]. The environments of these applications are usually not friendly and it is difficult to deploy the sensors determinately. Therefore, a large amount of nodes are randomly deployed in the area, resulting in more sensors than required. The high density of sensors on the one hand compensates for the lack of exact positioning and improves the fault tolerance, while on the other hand may cause the larger energy consumption due to conflicting in accessing the communication channels, maintaining information about neighboring nodes, and some other factors [4]. Therefore, research into optimally scheduling the sensor nodes and making the redundant nodes turned off to sleep in order to save the energy to prolong the network lifetime has become one of the most significant and promising areas in the WSN [5][6].

A considerable number of researches have devoted to address the energy efficient problem in the WSN in order to prolong the network lifetime. Most of the researches transform this issue to the optimal coverage problem (OCP) [5]. The OCP is based on the fact that the WSN contains a large number of sensor nodes with many nodes sharing the same monitored regions, and some of the nodes are redundant and can be turned off to preserve the energy while the others still work to offer the full coverage. The OCP is to find out a minimal set of nodes to monitor the area, and turning off the other redundant nodes to save energy, while at the same time meeting the coverage requirement. This way, not only the nodes can reduce the energy consumption caused by the nodes confliction, but also the network lifetime can be significantly prolonged because the nodes can be scheduled to work in turn [6].

In the literature, different models and assumptions have been introduced to this problem and variant of approaches have been proposed for solution. Xing *et al*. [7] proved that the full sensing coverage of the network can guarantee the connectivity of the network when the communication range is not shorter than twice the sensing range. As many kinds of wireless sensor can meet this condition, many researches only concentrate on the coverage problem of the network. Consequently, only the coverage problem is considered in this paper. Approaches such as coverage-based off-duty eligibility rule [8], time axis dividing node working schedule [9], and probing environment and adaptive sleeping (PEAS) protocol [10] have been proposed to address the OCP in finding out a minimal set of nodes to be active. Among the above state-of-the-art approaches, it should be noted that the approaches in [8][9] can guarantee the full coverage while the one in [10] can not. Our model and approaches are designed to guarantee the full coverage.

The motivations and contributions of our work include the following four aspects.

1) The WSN consists of lots of sensor nodes with very limited energy. It has been a promising and significant research area to solve the OCP in order to save sensor energy and prolong network lifetime.
2) The existing models and their approaches to OCP are always not easy to understand or implement. Therefore, it is significant and promising to design a