

Approximation Algorithms for Sweep Coverage in Wireless Sensor Networks

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Abstract

Coverage is one of the most important issues in wireless sensor networks (WSNs) and it is a well studied research area. To ensure coverage, a set of sensors continuously monitor the subject to be covered. Sweep coverage is a recent development for the applications of WSNs where periodic monitoring by a set of mobile sensors is sufficient instead of continuous one like traditional coverage. In this thesis, we remark on the flaw of the approximation algorithms (Mo Li, Wei-Fang Cheng, Kebin Liu, Yunhao Liu, Xiang-Yang Li, and Xiangke Liao, Sweep coverage with mobile sensors, IEEE Trans. Mob. Comput., 10(11):15341545, 2011.) for sweep coverage for a set of points. We propose a 3-approximation algorithm to guarantee sweep coverage for the vertices of a weighted graph, where vertices are considered as the set of points. When vertices of the graph have different sweep periods and processing times, we propose a $O(\log \rho)$ -approximation algorithm as a solution, where ρ is the ratio of the maximum and minimum sweep periods among the vertices. If speeds of the mobile sensors are different, we prove that it is impossible to design any constant factor approximation algorithm to solve the problem unless P=NP.

Energy is an important issue for the sensors. To incorporate it, an energy efficient sweep coverage problem is proposed, where a combination of static and mobile sensors are used. The problem is NP-hard and cannot be approximated within a factor of 2 unless P=NP. An 8-approximation algorithm is proposed to solve it. A 2-approximation algorithm is also proposed for a special case of the problem, which is the best possible approximation factor. Energy utilization for the mobile sensors is restricted as they are battery-powered. Considering the limitation, an energy restricted sweep coverage problem is defined and a $(5 + \frac{2}{\alpha})$ -approximation algorithm is proposed to solve this NP-hard problem. Periodic patrol inspection is important to detect illegal movement across national border. A portion of border can be modeled as a finite length curve. With this model, we introduce barrier sweep coverage concept for periodic monitoring of finite length curves in two dimensional plane. A solution is proposed to sweep cover a finite length curve with optimal number of mobile sensors. An energy restricted barrier sweep coverage problem is introduced and proposed a $\frac{13}{3}$ -approximation algorithm for a finite length curve. We prove that finding minimum number of mobile sensors to sweep coverage for a set of finite length curves is NP-hard and cannot be approximated within a factor of 2. For that a 5-approximation algorithm is proposed. A 2-approximation algorithm is also proposed to solve the problem for a special case, where each mobile sensor must visit all points of each curve. We formulate a data gathering problem by a set of data mules and prove that the problem is NP-hard. A 3-approximation algorithm is proposed to solve it. Through simulation, performance of the algorithm for multiple finite length curves is investigated. We introduce area sweep coverage problem and prove that the problem is NP-hard. A $2\sqrt{2}$ -approximation algorithm is proposed to solve the problem for a square region. For arbitrary bounded region \mathcal{A} the approximation factor is $2\left(\sqrt{2} + \frac{2r\mathcal{P}}{\text{Area}(\mathcal{A})}\right)$, where \mathcal{P} is the perimeter of \mathcal{A} and r is sensing range of the mobile sensors. Through simulation, we analyze performance of the algorithm for area bounded by arbitrary simple polygons. We propose a distributed sweep coverage problem, where static sensors are placed at the location of PoIs, one for each. In our proposed algorithm, the static sensors themselves decide number with initial positions as well as movement strategy of the mobile sensors through message passing. The mobile sensors visit the static sensors once in a given time period to sweep cover the PoIs. The proposed algorithm achieved an approximation factor of 4. A 2-approximation algorithm is also proposed for a special case of the problem.