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Approximation algorithm for data gathering from mobile sensors

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A B S T R A C T

In Wireless Sensor Network (WSN), sensors are deployed to sense useful data from environment. To prolong the sensor network lifetime in large-scale network, mobile sinks are employed for collecting data from the sensors directly. The major drawback of the system is slow speed of the mobile sinks, which causes long data gathering delay from the sensors. Since, sensors have limited memory and hence it causes buffer overflow in the sensors. Therefore, to avoid buffer overflow the data must be gathered by the mobile sinks within a predefined time interval. Data gathering from mobile sensors using mobile sinks is more challenging problem than data gathering from static sensors. A set of mobile sensors are moving arbitrarily on a set of predefined paths. Our objective is to collect data periodically from all mobile sensors using minimum number of mobile sinks and subsequently the mobile sinks visit a base station (*BS*) for final data delivery. We show that the problem is NP-hard and two approximation algorithms are proposed. We extend the proposed algorithms, where mobile sensors can deliver their sensed data to mobile sink within their circular communication regions and present a recovery algorithm from mobile sink's failure. We analyze the performance and time complexity of the proposed algorithms.

1. Introduction

WSNs have recently emerged as an important research area due to their wide range of applications. It consists of number of sensors and at least one *BS*. A typical problem in WSN is to collect sensed data from individual sensors to the *BS*. Sensors send their sensed data to the *BS* through single-hop or multi-hop communication [1]. Hierarchical or cluster-based routing techniques [2–4] are used for data gathering form the sensors.

In most of previous works, static sink was wildly adopted to conduct data collection in WSNs. Data aggregation and in-network processing techniques [5,6] have been investigated as alternate efficient approaches to achieve significant energy savings in WSN. Many other solutions have been prescribed to reducing the communication overhead such as [7]. But, due to the multi-hop data transmission style, sensors which are closed to the *BS* carried out much more traffic overhead compared to the nodes which are far from the *BS*. Since, sensors have limited battery power, such unbalanced energy consumption causes network partition [8]. To increase the network lifetime of WSN, mobile sinks (e.g., iRobot 510 PackBot [9]) are being used to collect data from the sensors based on one-hop communication. Mobile sink is a vehicle/robot that roams around the sensors positions and collects data from the sensors and finally delivers the collected data to the *BS*.

In recent [10–16] different tour-planning algorithms are proposed for data gathering using mobile sink from static sensors. The speed of a mobile sink is comparatively slower than that of wireless multi-hop communication [17] speed. Therefore, it increases data collection time interval and causes buffer overflow problem on the sensors. It is a major concern

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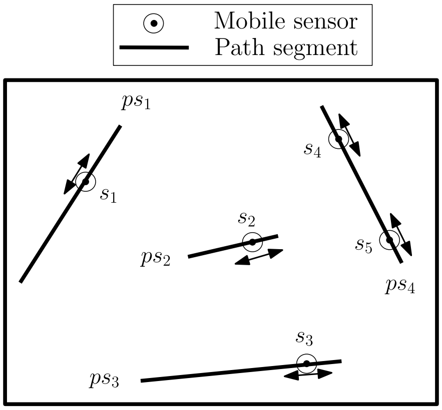

Fig. 1. Path-constrained mobile sensor network.

of mobile sink based data collection techniques. Increasing the speed of the mobile sink will increase the manufacturing cost and energy consumption of the mobile sinks. We have generalized data gathering problem from static sensors to a time bound periodic data gathering problem from mobile sensors. Multiple mobile sinks are used to ensure time bound periodic data gathering. A set of mobile sensors are roaming on a set of predefined paths and mobile sinks are used to collect data from them directly. To the best of our knowledge, there is no existing algorithm for time bound data gathering from mobile sensors. An example of mobile sensor network, where mobilities of the sensors are restricted within a set of path segments, is shown in Fig. 1. Paths of the mobile sensors are denoted by path segments $R = \{ps_1, ps_2, \ldots, ps_4\}$ and mobile sensors are represented by circles $\{s_1, s_2, \ldots, s_5\}$. The mobility of a sensor is confined within the path segment, where it is deployed.

The contributions of this paper can be summarized as follows:
Contribution:

- We propose a time deadline based periodic data collection problem from a set of mobile sensors using mobile sinks.
- We show that the problem is NP-hard.
- Two approximation algorithms are proposed for collecting data by visiting the mobile sensors positions.
- We generalize the algorithms, where mobile sink collects data within the communication range of the mobile sensors. We have described scheme to maintain periodic data gathering in case of mobile sink failure.

The rest of the paper is organized as follows. Related work is reviewed in Section 2. The formal definition of the problem and the network model are described in Section 3. Our solutions are discussed in Section 4. Detail performance analysis of the proposed algorithms are discussed in 5. Section 6 concludes the paper and describes some of its future works.

2. Related works

Somasundara et al. [18] pointed out that in mobile sink based data gathering where some sensors need to be visited more frequently than others to avoid data loss due to buffer overflow. They proposed algorithms to plan traveling paths of the mobile sinks, which allow the mobile sink to visit every sensor with different frequency and can avoid buffer overflow. They prove that the problem is NP-complete and propose heuristic algorithms to solve the problem. In [17], rendezvous points (RPs) based solution is proposed for data gathering using mobile sink, where mobile sink visits only the RPs rather than individual sensors. RPs are selected so that all sensors are able to deliver their data to one of the RPs and the tour length to visit all RPs is minimized.

In [19], a distributed storage management strategy with opportunistic communications between mobile sinks and static sensors is proposed for data delivery from the sensors to base station for disconnected WSNs. To avoid buffer overflow, data gathering interval between subsequent rounds is set to a fixed maximum value which depends on the data generation rate of the sensors and their buffer capacity. The time interval depends on the speed of the mobile sink, data gathering path length, buffer capacity of the sensor and data sensing rate of the sensors. In order to improve the data gathering time interval different strategies have been proposed.

In [20], Mai et al. have investigated a time deadline based load balanced data gathering protocol using mobile sink. In this paper, the authors assumed a maximum trajectory length of the mobile sink. Based on that they find a trajectory and select a subset of sensors as relay nodes. Other nodes are associated with one of the relay nodes based on the corresponding load. Gao et al. [10,11] proposed data gathering algorithms using path constrained mobile sink. Mobile sink moves on a fixed