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An energy-efficient path determination strategy for mobile data collectors in wireless sensor network ☆

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ABSTRACT

In wireless sensor networks, introduction of mobility has been considered to be a good strategy to greatly reduce the energy dissipation of the static sensor nodes. This task is achieved by considering the path in which the mobile data collectors move to collect data from the sensors. In this work a data gathering approach is proposed in which some mobile collectors visit only certain sojourn points (SPs) or data collection points in place of all sensor nodes. The mobile collectors start out on their journey after gathering information about the network from the sink, gather data from the sensors and transfer the data to the sink. To address this problem, an algorithm named Mobile Collector Path Planning (MCPP) is proposed. MCPP schema is validated via computer simulation considering both obstacle free and obstacle-resisting network and based on metrics like energy consumption by the static sensor nodes and network life time. The simulation results show a reduction of about 12% in energy consumption and 15% improvement in network lifetime as compared with existing algorithms.

1. Introduction

Wireless Sensor Networks (WSNs) are a popular source of data-collecting and sensing mechanism for a wide range of applications, such as military, agriculture, environment monitoring, smart transportation, and health [1]. Each sensor node collects data from the environment and forwards this sensed data to one or more sink nodes via a wireless link in either single-hop or multi-hop manner. This data-gathering and forwarding property of the sensor nodes dominate the main energy consumption factor of a network. These sensor nodes being equipped with low power batteries which may be difficult to replace, making it a major research area to design energy-efficient protocols [1]. Energy management in Wireless Sensor Networks (WSNs) is of paramount importance for the remotely deployed energy stringent sensor nodes [2].

Now, in multi-hop communications due to heavy overload of relaying messages, the nodes which are near a sink tend to die earlier than those which are farther away. This leads to the formation of energy hole in the network [3] resulting in the Hot-Spot problem [4,5]. As a result the sink loses connection with other nodes.

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To mitigate this problem, the concepts of mobile sink and mobile data collector were introduced. Luo and Hubaux [3] employs one or more mobile sinks to collect data directly from the sensor nodes. The mobile sinks move along the periphery thereby maximising the network lifetime.

There are many ways in WSNs in which a mobile sink goes about collecting data from the sensor nodes. Ghafoor et al. [6] uses Hilbert Space Filling Curve to determine the trajectory of the mobile sink. One method is to visit each sensor node individually to collect the sensed data. This is the well-known travelling salesman problem (TSP). Kumar et al. models the tour of a mobile data collector (MDC) based on TSP and use Range Constrained Clustering to determine the stop points of the mobile collectors [7].

In this work, we have presented a new mechanism wherein some mobile collectors collect data from the static sensors based on the buffer overflow time of the sensors. Somasundara et al. [8] also uses sensors buffer overflow time to schedule the visit of a mobile element where single nodes are visited depending on the strictness of the deadline of the nodes as opposed to this work where the mobile collectors visit a cluster to collect the data from the sensors. This work presents some mobile collectors (which are equipped with powerful transceiver, battery and large memory) go around the network to collect data from the static sensor nodes by stopping at specific stop points in the network. The aim is to minimise the number of stop or sojourn points, while ensuring that all the sensors are covered. The mobile collectors start from the static data sink and ultimately transfer the data to the sink via a wireless link using either 802.15.4 or 802.11. E.g., 802.11n provides about 74–300 Mbps, with ranges of about 70–250 m [7]. A path is determined for each of the mobile collectors in which they will traverse. The buffer size of the sensors is the main contributing factor for determining this path. Based on the buffer overflow time of the sensors, the mobile collectors collect data from them. The novelty of this work lies in the fact that other than sensing, transmission and receiving of data in single-hop communication, the sensors are not involved in the determination of either the sojourn points or the obstacle avoiding path of the mobile collectors. This way the energy utilisation of the sensors are minimised. To the best of our knowledge none of the previous works have used this concept of energy optimisation in their work. Also, using sensor buffer to determine the trajectory of a mobile collector in the presence of obstacles is an area which is yet to be fully explored. The paper is thus summarised as follows:

- At first, some data collection points (sojourn points (SPs)) are determined where the mobile collector will stop during its journey to collect data. The motivation is to conserve energy which is lost due to multi-hop transmission of data from the sensors to the collector. The procedure is described later in Section 4.
- After the determination of the collection points, Mobile Collector Path Planning (MCPP) algorithm based on the buffer size of the sensors and the data collection capacity of the mobile collectors is proposed.
- More than one mobile collectors are employed for the data collection purpose.
- The path determination algorithm is considered for both obstacle-free and obstacle-resisting environment.
- Extensive simulations are carried out to verify the effectiveness of our proposed algorithm by comparing with other data-gathering algorithms.

The rest of the paper is organised as follows: Section 2 discusses the related works done so far in this area. Section 3 gives the problem formulation for the proposed model. MCPP is presented in Section 4 along with the sojourn point determination. The simulation results are given Section 5. Finally, Section 6 concludes the paper.

2. Related study

Mobility patterns can be categorised into the following [9]: (i) Random mobility, (ii) predictable mobility and (iii) controlled mobility. The different categories of mobility patterns indicate the variety of data collection protocols used in each case. Animal-based nodes are used in [10] to collect data in wild environment. This is an example of a random mobility pattern. In such a model it is extremely hard to control and predict the movement of the nodes. In [11] a predictable mobility model is introduced wherein sensor nodes know the path that will be used by the mobile sink and thus to save energy the nodes go into sleep mode until the predicted time for data transfer. After that, the sensor nodes regain their active mode and transfer data to the mobile sink.

Gao et al. [12] use controlled mobility to propose a data collection scheme called the Maximum Amount Shortest Path (MASP) to improve the network lifetime by optimising the assignment of sensor nodes. Somasundara et al. [8] have also used controlled mobility. Based on the assumption that a mobile element visits each sensor node, a path planning for a mobile sink was formulated as the mobile element scheduling (MES) problem. The main drawback where a mobile element visits each sensor node to collect data is the increased delay in the data collection process as the mobile sink has to be within the transmission range of each sensor to collect data. [13] use a set of rendezvous points (RPs) to address this issue. These RPs buffer data from the static sensors and transfer them to the mobile element when they come in the RPs vicinity. An algorithm RD-VT is proposed in [14] with the objective that the travelling path of a mobile sink will be shorter in duration than that of the packet delivery time. Weighted Rendezvous Planning (WRP) is proposed in [13] to find a near-optimal trajectory path of