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Proactive data routing using controlled mobility of a mobile sink in Wireless Sensor Networks☆

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A R T I C L E I N F O

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A B S T R A C T

Stationary sink based Wireless Sensor Networks (WSN) have issues like sink neighborhood problem, end-to-end delay, data delivery ratio, network lifetime, etc. Although several routing approaches with mobile sink have been introduced to mitigate those issues across the network, very few, have considered delay requirements of applications. In this paper, we propose an efficient virtual grid based hierarchical routing approach suitable for delay bound applications, which judiciously selects a mobile sink's path by considering both hop counts and data generation rates of the sensor nodes, which reduces the overall energy consumption for multi-hop data communication. Data aggregation at each level of the hierarchy aims to reduce data traffic and increase throughput. The performance of the proposed protocol has been evaluated using simulation based on different metrics and compared with an existing routing protocol. Results have demonstrated that it performs better than the existing one while it still meets delay constraints of applications.

1. Introduction

Wireless Sensor Networks (WSN) contain some battery powered tiny sensor nodes that are deployed over a region. Each sensor node is capable of sensing, processing, and wireless communication with other sensor nodes. Applications of WSN include intrusion detection [1,2], target tracking [1], disaster management [1], tactical surveillance [1], weather-monitoring [1], habitat monitoring [2] etc. In most of the cases, sensor nodes remain unattended post-deployment. So, wasteful consumption of battery power may lead to premature death of sensor nodes. That could create many disconnected segments in a sensor field from where sensor data collection is not possible using a static sink.

Mobile sink solves problems like sink neighborhood problem [1], end-to-end delay, disconnected networks problem, etc. those arise in WSN with stationary sink, however, it has disadvantages too. It may not visit each of the stationary sensor nodes either due to the hindrance caused by the physical terrain or due to the increase in the time required to collect all the sensed data from the whole sensor field as it has a limited speed. In the latter case, it could easily fail to meet the requirements of delay bound applications. Many mobile sink based routing protocols have been proposed to balance energy consumption across the entire sensor field and reduce the average end-to-end delay of sensed data routing, most have overlooked requirements of time-sensitive applications.

Controlled mobility is defined as selecting the path of a mobile sink in such a way that meets some constraints on network state information. State of a network could be considered as a combination of parameters like delay, throughput, power consumption, hop counts, etc. This mobility model has the capability of dynamically adjusting the path of a mobile sink upon a change in network state.

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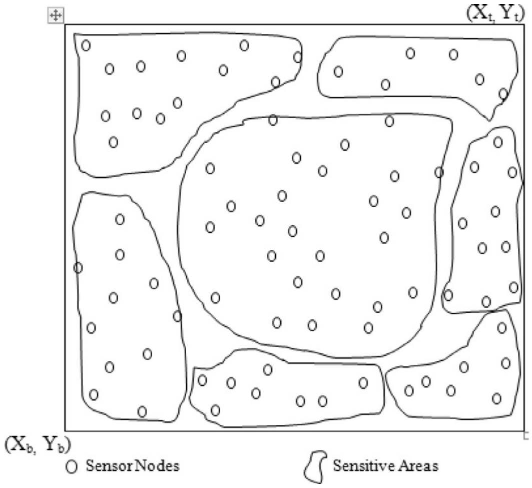

Fig. 1. Sensor field.

That is why this model is superior to random mobility model and predicted mobility model that cannot adapt according to network state that is ever changing.

Proactive routing is a table-driven routing approach in which each sensor node has prior information about its upstream node. This information is gathered at the time of network setup. So, sensor nodes do not waste time to find their upstream nodes when they have data to forward.

In this paper, a WSN is considered where GPS-enabled [3] stationary sensor nodes are densely and uniformly deployed. Each sensor node is constrained by limited memory, processing capability, and battery power. The sensor field is defined by two co-ordinates – the bottom left corner (X_b, Y_b) and the top right corner (X_t, Y_t) (refer to Fig. 1). Each sensor node knows its Data Generation Rate (DGR) that could be statically assigned at the time of installation and later updated by a mobile device. Neighbor sensor nodes having same data generation rate can be thought of as forming a logical group. Thus, a sensor field can be considered as a set of non-overlapping logical groups (called sensitive areas). Two or more sensitive areas may have same data generation rate, but they are not adjacent for sure. Then, a virtual grid structure [4] having square grids is laid out over the sensor field, and a candidate sub sink (CSS) is selected from each grid. Each candidate sub sink collects sensed data from all other sensor nodes of its grid and then aggregates it with its own sensed data. After that, a subset of candidate sub sinks is selected as sub sinks (SS) which are actually visited by the mobile sink within a given time period of an application such that the total data routing cost is reduced. Unvisited candidate sub sinks send their aggregated sensed data to their nearest sub sinks along the established shortest routing paths. Sub sinks then reaggregate it with their own aggregated sensed data. At last, sub sinks deliver all the reaggregated sensed data to the mobile sink when it passes by (refer to Fig. 2).

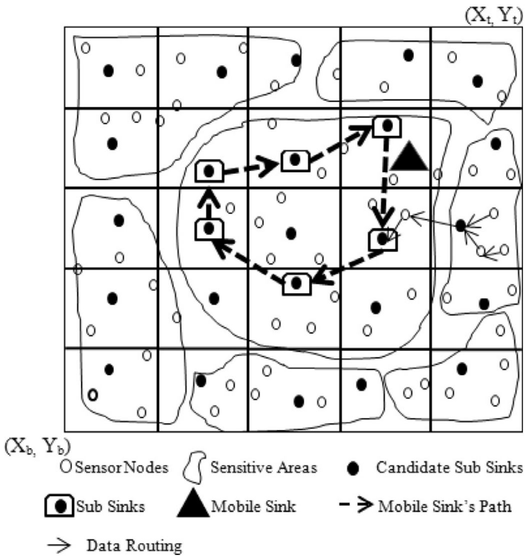

Fig. 2. Data routing in the sensor field.