Computer Networks 67 (2014) 123–140

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Review Article

Sink discovery in location-free and mobile-sink wireless sensor networks

Wei-Cheng Chu [a,*], Kuo-Feng Ssu [b,c]

[a] Institute of Computer and Communication Engineering, Department of Electrical Engineering, National Cheng Kung University, Tainan, Taiwan
[b] Department of Electrical Engineering, National Cheng Kung University, Tainan, Taiwan
[c] Department of Computer and Information Sciences, University of Delaware, Newark, DE, USA

ARTICLE INFO

Article history:
Received 1 February 2013
Received in revised form 14 March 2014
Accepted 28 March 2014
Available online 5 April 2014

Keywords:
Wireless sensor network
Mobile sink
Location-free

ABSTRACT

Searching for a sink and determining routing paths are challenging tasks in a mobile sink environment, especially in a location-free environment. Updating the sink location frequently by transmitting messages to preserve a route greatly increases the energy consumption of sensors. Therefore, methods to lower updating costs should be investigated. In this study, a cluster-based mobile sink exploration (CMSE) scheme is developed to guide data packets efficiently to mobile sinks. In this scheme, a source node can identify the sink location without knowledge of node locations, and multiple routing paths are established from a sensor to the sink to enhance network longevity. Simulation results show that compared with the use of previous methods, using the CMSE scheme helps save more energy and increases network longevity under various scenarios.

1. Introduction

Wireless sensor networks (WSNs) have a wide range of potential applications such as those in environment monitoring, in smart homes, and in remote medical systems [1–3]. A WSN consists of a sink node (*sink*, briefly) and numerous sensor nodes (*sensors*) that communicate to perform specific tasks. A sensor is an energy-limited device that features the capabilities of sensing and data processing, storing, and transmitting. A sink is an interface between a user and the WSN: the sink allows users to dispatch query packets to sensors or collect data from the sensors.

Because WSNs are typically used in long-term tasks, network longevity is a key consideration. A static sink may limit network longevity because the one-hop neighbors of the sink deliver more packets than do others. These sensors, called "bottleneck nodes," separate the sink from the network when their energy is exhausted. Certain mechanisms have been presented that feature multiple and mobile sinks to address this problem: multiple sinks increase the union size of bottleneck nodes to apportion the traffic load [4–6], and sink deployment, including the locations and number of sinks, critically affects network performance.

In previous studies, mobile sinks have been used to collect data [7–9]. A mobile-sink scheme offers considerable flexibility in balancing traffic load because it can dynamically adjust the set of bottleneck nodes [10]. Therefore, the trajectory of a mobile sink determines how the traffic load in a network is balanced. Identifying a routing path from a sensor to a mobile sink is challenging, especially in an environment in which the sensors do not possess their location information. Hamida classified data dissemination as rendezvous-based and backbone-based approaches [11], both of which are topology-based approaches in which several nodes are selected to maintain the latest sink location. By contrast, in an overhearing scheme, no topology has to

* Corresponding author. Tel.: +886 6 2374532.
E-mail addresses: 491191291@s91.tku.edu.tw (W.-C. Chu), ssu@ee.ncku.edu.tw (K.-F. Ssu).

http://dx.doi.org/10.1016/j.comnet.2014.03.028
1389-1286/

be constructed [12], because the sink location is undated in a hop-by-hop manner in this scheme. However, in the overhearing approach, the scenario in which all sensors are potential sources is not considered.

Flooding is an inefficient method to locate the routing path from a sensor to a mobile sink [13]. Flooding incurs a large amount of control overhead. In previous studies, a backbone was typically constructed to disseminate the latest sink location. Successfully delivering data from a source to the sink incurs two types of costs: (1) the registration cost, which includes the cost of delivering the latest sink location from the sink to the sensors and (2) the exploration cost, which includes the cost of locating the sensor that possesses the latest sink location, and the cost of delivering data from the source to the sink. The backbone nodes have the greatest registration and exploration costs. This unbalanced load reduces network longevity.

We present an efficient mechanism for identifying a routing path from a sensor to a mobile sink, which is called the cluster-based mobile sink exploration (CMSE) scheme. The cluster structure helps reduce the registration cost. To mitigate the traffic load on backbone nodes, in the CMSE scheme, multiple paths are established from a sensor to the sink. Each sensor can choose its next forwarding sensor locally. In the CMSE scheme, no location information is required, and the scheme guarantees that an exploration path (a path used for locating the sink) can successfully encounter the registration web (a cluster set that holds the latest sink location). Thus, each sensor (a potential source) can successfully locate a route to the mobile sink.

The contributions of this study are the following:

- *Balancing traffic load to improve network longevity.* In the CMSE scheme, each sensor maintains several candidate forwarding sensors. If a sensor s does not possess the latest sink location, any of its candidate sensors can forward data toward a sensor that possesses the latest sink location. Alternatively, any of the candidates can forward the data toward the sink. A sensor locally selects the candidate with the maximal remaining energy as its next forwarding sensor. Therefore, multiple potential routes exist from a source to the sink.
- *Adjusting registration-web size to meet various end-to-end delay requirements.* The size of the registration web can be predefined or adjusted dynamically by the sink. In a network that features a small bound of end-to-end delay, the registration-web size is increased to reduce the path length from a source to the sink. By contrast, to lower registration cost, a small registration web is built in a network that contains a large delay bound. The relationship between the size of the registration web and the end-to-end delay requirement is analyzed herein.
- *Maintaining network topology efficiently.* A network topology might change because of sensors being either deleted or added. In the CMSE scheme, a partial topology is reconstructed to ensure regular operations. The maintenance is processed in a small area to reduce the reconstruction cost.

In this paper, work related to this study is discussed in Section 2. Section 3 presents the design of CMSE. In Section 4, the maintenance of CMSE is described and in Section 5 various costs are analyzed. Section 6 discusses the simulation results, and Section 7 presents our conclusions.

2. Related work

The methods developed in previous studies to search for a routing path to a mobile sink can be classified as rendezvous-based and backbone-based approaches [11].

2.1. Rendezvous-based approaches

In a rendezvous-based approach, a virtual infrastructure is constructed, such as a grid structure [14–16]. Each sensor delivers data by using a geographic routing algorithm such as the greedy perimeter stateless routing (GPSR) algorithm [17]. In the two-tier data dissemination model (TTDD) [14], a source divides the network plane into a grid of cells. The nearest sensor to an intersection point of grid lines serves as a dissemination node; this node establishes a routing path from itself to the source along the grid line. When the sink requests data from the source, the sink floods a query to the nearest dissemination node, which delivers the request to the source. After receiving the query, the source returns the data by using the same path to the sink. In the TTDD scheme, a grid structure must be constructed for each source, which makes this scheme unsuitable for an environment in which multiple sources are present.

Instead of a grid topology, a zone was established to store sink locations in certain studies [18,19]. The sink transmits its location information to the sensors in the zone. The data can be delivered to the sink by means of greedy forwarding because each sensor in the zone possesses the latest sink location [20]. In this approach, location information is required to establish the zone and the routes.

Shim used several locaters to relay data and queries between sources and sinks [21]. Each locater functions as a cluster head that contains sensors within its transmission range for use by its members. The sink updates its new location to all locaters after each sink movement, and the sensor obtains the latest sink location by asking its nearest locater. However, deploying the locater incurs an addition cost.

These approaches based on location information are not preferred because localization mechanisms cannot always guarantee the required accuracy [22–24]. Equipping each sensor with a GPS is impractical because the sensors are energy-limited devices. In the CMSE scheme, location information is not required and thus it is more suitable for mobile sensor networks than the rendezvous-based approaches are.

2.2. Backbone-based approaches

A backbone-based approach is a virtual infrastructure constructed for broadcasting, routing, or topology-based applications. The dynamic directed backbone (DDB) scheme is a data-dissemination protocol featuring