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Vehicle location service scheme based on road map in Vehicular Sensor Networks

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ABSTRACT

Vehicular Sensor Networks (VSNs) are merging for supporting communications between roadside sensor nodes and vehicles on for notifying environment events on roads to drivers and passengers. Geographic routing has been considered as an efficient and scalable approach to send sensing data from sensor nodes to vehicles. Fundamentally, geographic routing requires sensor nodes to be aware of the location information of vehicles. Since sensor nodes are deployed around roads and vehicles move on the roads, this field property of VSNs brings about a challenging issue to provide location service of vehicles. In this paper, we propose a quorum-based location service scheme to provide sensor nodes with the location information of vehicles in VSNs. For providing the location service, the proposed scheme exploits a crossing point between a quadrangular path quorum of a location update and a line path quorum of a location query by using the road map information. Then, the proposed scheme is extended to accommodate several considerations such as voids, multiple vehicles and sources, and energy depletion. The effectiveness of the proposed scheme is analyzed and validated by extensive numerical and simulation results.

1. Introduction

Nowadays, vehicles have been demanded a lot of information about roads around them for their safety and convenience, and a great number of sensor nodes have been developed to detect events around them. According to this situation, Vehicular Sensor Networks (VSNs) are recently merging for supporting communications between roadside sensor nodes and vehicles on roads [1,2]. In VSNs, roadside sensor nodes detect environmental events on roads and send reporting data to vehicles which are interested in such events. A lot of applications from emergency warning to road monitoring have been introduced for VSNs [3]. For example, in a damaged road detection application, sensor nodes detect the damaged roads and send the information such as the location of the damaged roads to road management vehicles.

In VSNs, data communication patterns are from sensor nodes to vehicles [2,4,5]. Until now, a great number of routing protocols have been proposed in wireless sensor networks and vehicular ad hoc networks [6]. Such routing protocols are generally categorized into a topology-based routing approach and a geographic routing approach. The topology-based routing is known to be efficient in a small and static network due to the management overhead of the network topology to find routing paths. In VSNs which consist of a number of sensor nodes and mobile vehicles, the geographic routing has been considered as an efficient, simple, and scalable routing approach since it exploits pure local location information instead of global topology information to route data packets from sources to destinations [7,23]. Fundamentally, the geographic routing in VSNs requires sensor nodes to be aware of the location information of vehicles which are intended as destinations.

Many researches have been studied to provide source nodes with the location information of destinations in ad hoc and sensor networks [8]. They can be categorized into a flooding-based location service approach, a hash-based approach, and a quorum-based approach. Especially, a quorum-based approach [9–12] has been proposed for (1) solving the large control overhead of flooding-based approach, (2) solving the hash function and server management overhead of hash-based approach, and (3) providing the location service in the network of irregular shape. The quorum-based approach exploits crossing points between a location update quorum and a location query quorum for providing location service. However, the existing quorum-based location service schemes have problems and limitations in VSNs because they ex-

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ploit algorithms and theorems that are inefficient and inappropriate in VSNs. XYLS [9] constructs location update and query quorums even to network boundary nodes to guarantee a crossing point and ZGLS [12] constructs location update quorums to the whole network to reduce the length of location query quorums. As a result, XYLS and ZGLS have high quorum construction overheads. QSLS [10] gathers the location information of network boundary nodes to determine the paths of location update and query quorums to make a crossing point, and thus has high information gathering overheads. CLLS [11] could not guarantee a crossing point because it uses a theorem with circle quorums which might be difficult to make in roads. Thus, new quorum-based location service scheme should be designed by considering the field property of VSNs and the communication overhead of quorum construction.

In this paper, we propose a novel quorum-based location service scheme to provide source nodes with the location information of vehicles in VSNs. As new theorem to provide location services, the proposed scheme uses a crossing point between a quadrangular path quorum of a location update from a vehicle and a line path quorum of a location query from a source node (i.e., a sensor node detecting an event). These quadrangular and line quorums are simply and efficiently constructed on roads by using the road map information to guarantee a crossing point between them. As a result, the proposed scheme does not require to construct quorums to network boundary nodes or to gather the location information of network boundary nodes, different from the existing schemes. Then, five phases of the proposed scheme is presented for providing the location service and data delivery from a source node to a moving vehicle: location update, location query, location reply, data dissemination, and mobility support. The location update, query, and reply phases describe the process that a source node efficiently finds the location information of a vehicle interested in its reporting data through our location service scheme. The data dissemination and mobility support phases describe the process that the source node delivers its reporting data to the moving vehicle through a geographic routing and our mobility support scheme. Next, we consider several challenging issues such as voids with no sensor node, multiple vehicles and sources, and energy depletion of sensor nodes in VSNs. The void issue might generate the problem that the proposed scheme does not construct quorums. The issue about multiple vehicles and sources means whether the proposed scheme can handle large-scale communication pairs. The energy depletion issue is caused by unbalanced energy consumption of sensor nodes due to performing their different duties. Accordingly, the proposed scheme addresses these issues and is extended to accommodate them without including many additional functions. For the performance evaluation of the proposed scheme, we lastly compare it with two quorum-based location service schemes, a well-known one called XYLS [9] and a state-of-the-art one called ZGLS [12] through numerical analysis and extensive simulations. Our analysis is numerically calculated to compare communication overheads of the three schemes to construct location update and query quorums, and the analysis results show that the proposed scheme has lower communication overhead than XYLS and ZGLS. Our simulations are conducted in various environments, and the simulation results show that the proposed scheme outperforms both XYLS and ZGLS in terms of the number of transmitted and received packets, the energy consumption, and the location service delay.

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

- We propose a novel quorum-based location service scheme with new theorem which exploits a crossing point between a quadrangular quorum and a line quorum. These quadrangular and line quorums can be efficiently constructed on roads by using their map information.
- We present five phases of the proposed scheme: location update, location query, location reply, data dissemination, and mobility support. The five phases can efficiently provide the location service and data delivery from a source node to a moving vehicle.
- We consider several challenging issues such as voids with no sensor node, multiple vehicles and sources, and energy depletion of sensor nodes in VSNs. The proposed scheme is extended to accommodate these considerations without including many additional functions.
- We compare the proposed scheme with XYLS and a ZGLS through numerical analysis and extensive simulations. Our analysis and simulation results demonstrate that the proposed scheme outperforms both XYLS and ZGLS in terms of the number of transmitted and received packets, the energy consumption, and the location service delay.

The remainder of the paper is organized as follows. In Section 2, we briefly overview the related work about the proposed scheme. Then, Section 3 presents the network model and basic idea, and next describes the design and implementation for our scheme in detail. The extension of the proposed scheme is provided to handle several considerations in Section 4. The proposed scheme is evaluated through numerical analysis and simulation results in Section 5. Last, Section 6 concludes the paper.

2. Related work

Vehicular Sensor Networks (VSNs) [1,2] consist of a number of sensor nodes and many vehicles which are deployed and move on roads. In VSNs, geographic routing has been considered as an efficient and scalable routing approach for data forwarding from sensor nodes to vehicles [7]. Geographic routing can route data packets only through local location information instead of global topology information [15]. Many geographic routing protocols have been proposed in wireless ad hoc networks and wireless sensor networks [27,28]. Recently, many protocols have been proposed to achieve geographic routing on roads in vehicular environments [26].

Generally, geographic routing requires three necessary conditions. First, every node must know its own location information. GPS devices or other localization techniques can fulfill this requirement [16,17]. Second, each node must know the location information of its one-hop neighbor nodes. This requirement can be fulfilled by periodically exchanging beacon signals [15]. Third, a source node must know the location information of a destination node. This requirement can be fulfilled by location service schemes.

A number of location service schemes have been proposed in the literature. The location service schemes can be categorized into two main approaches: Flooding-based approach and Rendezvous-based approach. The flooding-based approach provides the destination location to the sources via the location flooding of destinations and also can be divided into two approaches: Full network flooding [18] and Local network flooding [19]. In full network flooding [18] a destination disseminates its new location information to the entire network by flooding. This scheme ensures that any source in the network can be provided with the destination location. However, full network flooding can lead to large energy consumption of the sensor nodes and collisions in wireless transmissions. To avoid the full network flooding, the local network flooding, named TTDD [19] was proposed. TTDD exploits a crossing point between a global grid structure of location query quo-