Quorum-based Location Service in Vehicular Sensor Networks

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Abstract*—Geographic routing in Vehicular Sensor Networks (VSNs) has been considered as an efficient and scalable approach since it exploits location information instead of topology information to route data packets. Geographic routing requires sources to be aware of the location information of destinations. Many solutions have been proposed to provide the location information of destinations in ad hoc and sensor networks. However, they are not suitable and energy-efficient for VSNs because the field property of VSNs is very different from that of ad hoc and sensor networks. In VSNs, sensor nodes are deployed on roads and vehicles also moves on the roads. Thus, we propose a quorum-based location service scheme to provide source nodes with the location information of the vehicles in VSNs. The proposed scheme exploits the property of the road map in VSNs. For providing location service, a location query makes a quadrangular path quorum and a location update makes a line path quorum. Then, the proposed scheme guarantees a crossing point between the quadrangular path quorum and the line path quorum. A sensor node on the crossing point sends a location reply to source nodes. The source nodes deliver their data to the vehicle via geographic routing. For data delivery to the moving vehicles, we also propose a mobility supporting scheme. Simulation results shows that the proposed scheme has better performance than the existing scheme in terms of the number of transmitted and received packets and the location service delay.

Keywords-Vehicular Sensor Networks, Geographic Routing, Location Service

I. INTRODUCTION

RENCENTLY, Vehicular Sensor Networks (VSNs) are emerging for supporting communications between roadside sensors and vehicles on roads [1, 2]. In VSNs, roadside sensors detect environmental events on road and send data to vehicles which are interested in such events. There are a lot of applications from emergency warning to road monitoring for VSNs [3]. For example, in a damaged road detection application, sensors detect the damaged roads and send the information such as location of the damaged roads to road management vehicles.

In VSNs, data communication patterns are from sensors to vehicles [2, 4, 5]. Until now, a grate number of routing protocols have been proposed in wireless sensor networks and vehicular ad hoc networks [6]. In VSNs which have a number of sensor nodes and mobile vehicles, 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 [7]. However, geographic routing requires sensors to be aware of the location information of vehicles which are intended as destinations in VSNs.

Much research has been studied to provide the source nodes with the location information of the destinations in ad hoc and sensor networks [8]. Especially, quorum-based approach has been proposed for solving the large control overhead of flooding-based approach and the Hash function and server management overhead of hash-based approach and for providing the location service in the network of irregular shape [9, 10, 11]. The quorum-based approach exploits crossing points between a location query quorum and a location update quorum for providing location service. However, the existing quorum-based location service schemes do not guarantee a crossing point or are very inefficient in VSNs because the field property of VSNs is very different from that of ad hoc and sensor networks. In VSNs, sensor nodes only are deployed on roads and vehicles also moves on the roads.

Thus, we propose new quorum-based location service scheme which can provide the source nodes with the location information of the vehicles in VSNs. The proposed scheme exploits the property of the road map in VSNs. For providing location service, the proposed scheme uses the crossing point between the location query quorum of sensor nodes and the location update quorum of vehicles. The location query makes a quadrangular path quorum and the location update makes a line path quorum. Then, the proposed scheme guarantees a crossing point between the quadrangular path quorum and the line path quorum. A sensor node on the crossing point sends a location reply to the source node. The source node disseminates its data to the vehicle via geographic routing. For data delivery to the moving vehicles, we also propose a mobility supporting scheme in our scheme. For the performance evaluation, we compare the proposed scheme with the well-known scheme, XYLS through the QualNet network simulator. Simulation results shows that the proposed scheme has better performance than XYLS in terms of the number of transmitted and receiving packets, the energy consumption, and the location service delay.

The remainder of the paper is organized as follows. Section II presents the related work. We present the network model and basic idea for our scheme in Section III. We propose the design and implementation for our scheme in Section IV. We evaluate our scheme in Section V and Section VI concludes the paper.

II. Related Work

Vehicular Sensor Networks (VSNs) consist of a number of sensor nodes and many vehicles [1, 2]. 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 [12]. Many geographic routing protocols have been proposed in wireless ad hoc networks and wireless sensor networks. Recently, some protocols have been proposed for achieving geographic routing on the roads in vehicular environments.

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 [13, 14]. Second, each node must know the location information of its one-hop neighbor nodes. This requirement can be fulfilled by periodically exchanging beacon signals [12]. 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 loc to the sources via the location flooding of destinations and also can be divided into two approaches: Full network flooding [15] and Local network flooding [16]. In full network flooding [15] 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 [16] was proposed. TTDD exploits a crossing point between a global grid structure of location query quorum and a local flooding of location update quorum within grid cell size.

To avoid flooding, the rendezvous-based approach exploits rendezvous nodes where location updates will be stored and location queries will be looked up. This strategy also can be divided into two categories: Hash-based [17, 18] and Quorum-based [9, 10, 11]. The hash-based approaches such as GLS [17] and GHT [18] allow rendezvous nodes or areas to be exclusively chosen based on a hashing function. They require much less space for state storage compared with the quorum-based approach. However, they introduce considerable processing overhead for building and managing the hash overlay, more than can be handled by simple sensor nodes.

The quorum-based approach has been proposed to overcome the limitations of the flooding-based approach and of the hashing-based approach. The quorum-based approach exploits the crossing point between a location query quorum and a location update quorum for providing location service. In the simplest quorum-based scheme (the so-called column-row method) a destination sends a location update packet from its location in the north-south direction while a source sends a location query packet from its location in the east-west direction. However, the simple column-row method can only guarantee a crossing point in a network of rectangle shape. It cannot guarantee a crossing point in real life, irregular sensor networks, characterized by void areas or non-rectangle shapes such as circle, ellipse, convex, and concave shapes. XYLS [9] provides a crossing point by augmenting the simple column-row quorum method with the perimeter routing on network boundary nodes. QSLS [10] divides the region in four sectors and for each sector creates anchor nodes on network boundary. It guarantees a crossing point between a location update quorum and a location query quorum connecting anchor pairs of two opposite sectors. CLLS [11] provides a crossing point between a location update quorum on a circle path and a location query quorum on a line path.

In summary, existing quorum-based schemes either do not guarantee a crossing point or are not suitable for VSNs that include mobile nodes (i.e. vehicles) and sensors deployed on roads. The network boundary routing in XYLS and the anchor node management in QSLS would cause high communication overhead in our VSN. The circle path in CLLS cannot be easily constructed in VSNs where some of the nodes (vehicles) move and the network fields have noncircular roads. This has motivated the design of a new quorum-based location service that accounts for the unique properties of our VSN.

III. Network Model and Basic Idea

In this section, we first describe the network model for our scheme in VSNs. Next, we present the basic idea of our scheme for providing location service in VSNs.

A. Network Model

As a network model of VSNs, we consider a network where a lot of sensor nodes are deployed on roads of the network and vehicles freely move on the road for performing their own missions. In our model, we define sensors as source nodes and vehicles as destination nodes. One of applications for our model in VSNs is a damaged road detection application. In this application, a sensor node detects a damaged road and sends a notification packet with the location information about the damaged road to a road management vehicle which freely moves in the network. Each node can know its own location information by using GPS devices or other localization techniques [13, 14]. Every node periodically exchanges a Hello packet with its location information with its one-hop neighbor nodes [12] and thus contains their location information in its Neighbor List Table. By programing by network operators before the network deployment, all sensor nodes know the location information of the Center Intersection Point (CIP) which is located in the middle part of the network. They also know the location information of neighbor 8 intersections of CIP: North, North-East, East, East-South, South, South-West, West, and West-North intersections. We call these CIP's 8 neighbor intersections candidate intersections.

B. Basic Idea

The existing quorum-based sink location service schemes have been proposed to guarantee at least one crossing point between a location update quorum and a location query quorum in the network of irregular shape. For guaranteeing at least one crossing point, they exploit the perimeter routing [9], the network boundary partition information [10], or the circle and line paths [11]. However, when they are applied in VSNs, they do not guarantee the crossing point or are very inefficient because VSNs consist of a number of roads and intersections different from ad hoc and sensor networks.

Thus, we design new quorum-based location service in VSNs. Unlike the existing schemes, we consider the network properties of VSNs for our scheme. For guaranteeing at least one crossing point between a location update quorum and a location query quorum, our scheme is supported by following theorem:

Theorem: *Given a quadrangle and a line, if one end of the line is inside the quadrangle and the other end of the line is outside of the quadrangle, then the quadrangle and the line have at least one crossing point.*

In our scheme, a vehicle makes a line quorum of a Location Update (LU) packet, and a source node makes a quadrangle quorum of a Location Query (LQ) packet. We prove the theorem in our scheme that the LU quorum and the LQ quorum have at least one crossing point. In the next section, we explain in detail how our scheme is implemented to prove the theorem.

Figure 1. The overview of the proposed scheme which is consists of five phases: Location Update, Location Query, Location Reply, Data Dissemination, and Mobility Supporting

IV. The Proposed Scheme

In this section, we explain our scheme to provide location service in VSNs. Figure 1 shows the overview of the proposed scheme which consists of five phases: Location Update, Location Query, Location Reply, Data Dissemination, and Mobility Supporting. We describe these five phases in the next subsections, respectively.

A. Location Update

While moving, a mobile vehicle sends out its ID as well as its location information. Before a vehicle sends a Location Update (LU) packet with its ID information, it tries to find the closest sensor from itself by exchanging Hello packet and register itself with the LU packet to the closest sensor. We will call this sensor the Registered Sensor. We will describe this registering system in the mobility supporting section. When the closest sensor receives the LU packet, it stores vehicle's ID information into the Vehicle-Registration-List. Each sensor manages its own Vehicle-Registration-List that contains nearby vehicles in its one hop distance, so that it can directly communicate with the vehicles in its one hop distance.

When a registered sensor receives a LU packet from a vehicle, it includes its location information in the LU packet. As a result, the LU packet includes the ID information of that vehicle and the location information of the registered sensor. Then, the registered sensor makes two copies of the LU packet. One copy is Location Update packet to the CIP (LUC) and the other copy is Location Update packet to the Opposite way from the CIP (LUO). The LUC packet will be sent to the closest sensor toward predefined Center Intersection Point (CIP), and will be relayed with the same algorithm until it arrives to the CIP. The LUO packet will travel to a boundary sensor by choosing the farthest sensor from the CIP. Sensors on paths for the LUC and LUO packets store the vehicle location information into Vehicle-Location-List but they use the location of Registered Sensor instead of using vehicle's real location. By sending the LUC and LUO packets to two opposite way, the Location Update path will be drawn as a line between CIP and one boundary sensor. Figure 1 shows the process of spreading LU packet.

B. Location Query

If each sensor node detects an event related with its mission, it becomes a source node and generates a data packet about the event. When it needs to send the data packet to an interesting vehicle, it has to know the vehicle's location information. First, the sensor will search its Vehicle-Location-List to find the vehicle's location information. If it doesn't have the location information, it will send a Location Query (LQ) packet with its location information to obtain the vehicle's location.

When a source sends a LQ packet, it selects one among the predefined candidate intersections. The selected one is the farthest one from the source. For example, if the source is located in the West-North part of CIP, it selects the East-South neighbor intersection of CIP as the farthest candidate intersection. Then, the source forwards the LQ packet to the farthest candidate intersection. Initially, the LQ packet travels to the farthest candidate intersection with having a horizontal-first and vertical-last rule. This means that the LQ packet first travels along the horizontal path and then it travels vertical path to the farthest candidate intersection. If a sensor node on the farthest candidate intersection eventually receives the LQ packet, it sends the LQ packet to the source node by the same horizontal-first and vertical-last rule. As a result of the LQ packet traveling, a quadrangle quorum is made on roads connecting the source and the farthest candidate intersection and includes the CIP within it. All sensor nodes on the quadrangle quorum of the LQ packet save the location information of the source by this process.

C. Location Reply and Data Dissemination

As shown in Fig. 1, a line quorum of a LU packet is made between the CIP and a network boundary sensor. A quadrangle quorum of a LQ packet is made on roads in the network, and includes the CIP inside itself and the network boundary sensor outside itself. In other words, a side of the LU quorum is inside the LQ quorum and the other side of LU quorum is outside the LQ quorum. As a result, a crossing point is guaranteed between the LU quorum and the LQ quorum. Thus, the theorem for guaranteeing at least one crossing point motioned in the section III is proved in our scheme.

If a sensor node on the crossing point receives both a LU packet of a specific vehicle and a LQ packet of a source for that vehicle, it generates a Location Reply (LR) packet with the location information included in the LU packet. Then, it sends the LR packet to the source by geographic routing protocols such as [7, 12].

When a source receives a LR packet from a sensor node on the crossing point between LU and LQ quorums, it sends its data packets with the location information included in the LR to the location of the sensor node which sends the LU packets in the behalf of a vehicle. Then, the data packets are forwarded to the sensor node by geographic routing protocols. When the sensor node receives data packets from the source, it sends them to the vehicle if the vehicle is located in the transmission range of the sensor node. However, since a vehicle can move after registering a LU, we present a data forwarding method to the moving vehicle in the next subsection.

D. Mobility Support

Since a vehicle can move on roads, when it sends a LU packet to receive data packets, it registers itself to its closest neighbor sensor. When a sensor is registered by a LU packet from a vehicle, it stores the vehicle's ID information into a Vehicle Registration List and includes its location information in the LU packet instead of the vehicle's location information to receive data packets from sources. Thus, if it receives data packets for that vehicle from sources, it sends the data packets to the vehicle.

A vehicle can move out of the transmission range of its registered sensor. Then, it finds its new closest neighbor sensor and changes the new sensor to new registered sensor by sending a reregistration packet. This reregistration packet contains the previous registered sensor's ID and location information. This new registered sensor stores the vehicle's ID information into its Vehicle Registration List and sends a Relay Registration packet to the previous registered sensor. Then, as the previous registered sensor knows to where the vehicle has moved, it can relay data packets for the vehicle to the new registered sensor. Figure 2 shows the process that a vehicle connects between the previous registered sensor and the new one. This process continues whenever the vehicle moves out of the transmission range of new registered sensor. By this registration process, a vehicle can receive data packets from sources by the data relaying between registered sensors while moving on roads.

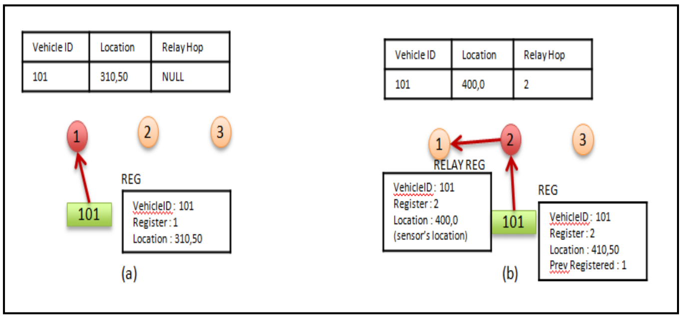

Figure 2. Vehicle Registration List of sensor 1. Initially it has Vehicle 101 in its Vehicle Registration List. As 101 moves to sensor 2, the vehicle sends Register packet to sensor 2 and sensor 2 sends Relay Register packet to sensor 1. Now sensor 1 knows Vehicle 101 is registered to sensor 2.

V. EXPERIMENTAL RESULTS

In this section, we compare our quorum-based location service scheme with the well-known quorum-based location service scheme, XYLS [9] for the performance evaluation by simulations. We first describe our simulation model and performance evaluation metrics. We next evaluate the performance of the proposed scheme and XYLS through simulation results.

A. Simulation Model and Performance Evaluation Metrics

We implemented the proposed scheme and XYLS in the QualNet simulator ver.4.5 [19]. As a network model of roads with intersections, we use a grid-based model for running our simulations. The size of a basic grid module is 100m x 100m. Different network sizes are created for our simulations: 7x7, 15x15, 21x21, 31x31, and 41x41 grids. Thus, there are 49, 225, 441, 961, and 1681 sensors in each grid size, respectively. A sensor is randomly selected as a source every 10 seconds and sends a LQ packet. In our simulation, a vehicle moves along the grid lines with an average speed of 20m/sec and moves along a random direction in the intersections. The vehicle sends a LU packet every 10 seconds. The intersection in the center of the network is used as the Center Intersection Point (CIP) in our simulation. All nodes know its location, its neighbors' location, and CIP location information. As a MAC protocol, we use IEEE 802.11 DCF. The transmission range of nodes is omnidirectionally 150m. All packets of LUs, LQs, and LRs are 36 bytes and data packets are 64 bytes. We run the simulation for 150 seconds. We use two metrics to evaluate the performance: the number of transmitted and received packets and the location service delay. In our results, all the presented figures are based on the average performance of 5 simulation runs in each network configuration.

B. Evaluation 1: the Number of Transmitted and Received LU packets for various grid sizes

Figure 3 shows the number of transmitted and received Location Update packets for various grid scenarios. We tested on 7 x 7, 14 x 14, 21 x 21, 31 x 31 and 41 x 41 grid networks. The simulation result shows that our scheme requires the less number of packets when compared to XYLS. It is because

XYLS makes LU packets forward along the boundary of the network. However, our scheme makes LU packets forward to only Center Intersection Point (CIP) and a network boundary node. As the network size increases, the performance gap between our scheme and XYLS also increases.

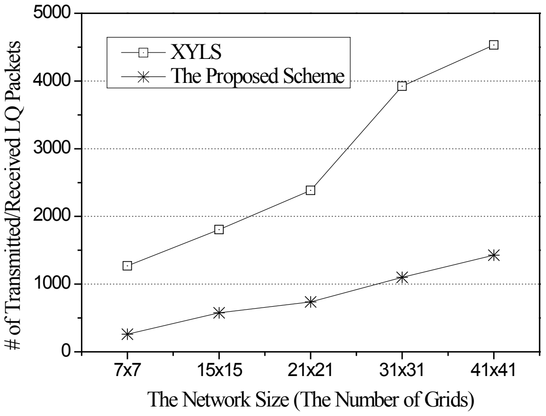

Figure 3. The number of tranmitted and received LU packets for various network sizes

C. Evaluation 2: the Number of Transmitted and Received LQ packets for various grid sizes

Figure 4 shows the number of transmitted and received Location Query packets for various grid scenarios. We tested on 7 x 7, 14 x 14, 21 x 21, 31 x 31, and 41 x 41 grid networks. In terms of LQ packets, our scheme also has the less number of transmitted and received packets than XYLS. As the network size increases, our scheme has better performance than XYLS. It is because XYLS makes LQ packets forward along the boundary of the network but our scheme makes LQ packets forward only to a quadrangle path on roads in the network. However, the performance gap between our scheme and XYLS is not big when compared to the result of LU packets.

D. Evaluation 3: the Number of Transmitted and Received packets by Location Service for various grid sizes

Figure 5 shows the total number of transmitted and received packets for all of LU, LQ, LR, Data Dissemination (DD), and Mobility Support (MS) in location service for various grid sizes. The proposed scheme has less number than XYLS for providing location service. It is first a reason that he proposed scheme has less number than XYLS for LU and LQ as shown in Fig. 3 and 4. It is also another reason that the proposed scheme has less location service delay than XYLS as shown in Fig. 7 so that the proposed scheme reduces the number of packets for LR and MS compared with XYLS. If the grid size increases, because these two situations are more severe, the performance gap between the proposed scheme and XYLS increases.

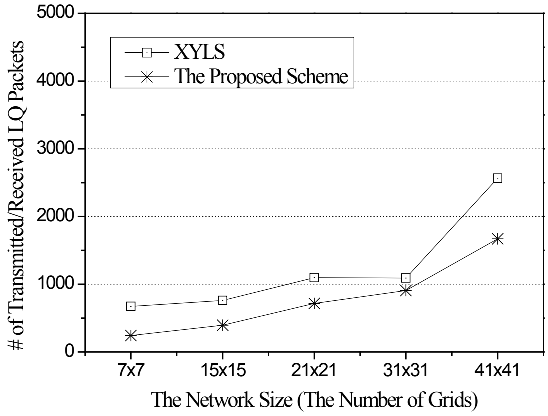

Figure 4. The number of tranmitted and received LQ packets for various network sizes

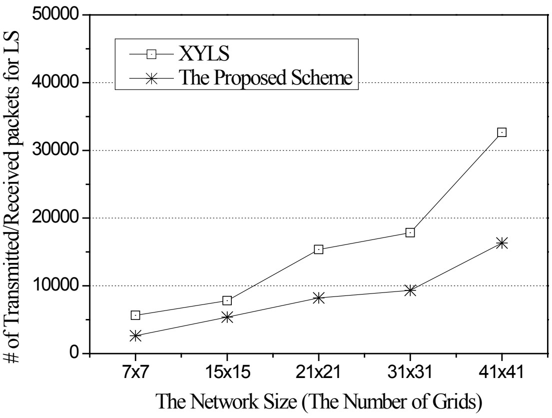

Figure 5. The total number of transmitted and received packets for all of LU, LQ, LR, DD, and MS in location service

E. Evaluation 4: the Number of Transmitted and Recevied Packets in Each Sensor Node

Figure 6 shows the number of transmitted and received packets for providing location service in each sensor node for a 7x7 grid network. We can see that XYLS consumes more number of packets for all the sensor nodes involved in the grid network. It is because XYLS uses more sensor nodes for providing location service than the proposed scheme. In other word, XYLS makes LU and LQ packets forward toward east-west direction and north-south direction and along the network boundary.

F. Evaluation 5: the Location Service Delay for various grid sizes

Figure 7 shows the location service delay for various grid sizes. We tested on 7 x 7, 14 x 14, 21 x 21, 31 x 31, and 41 x 41 grid networks. Although our scheme reduces much more packets than XYLS, simulation result shows that our scheme has less location service delay than XYLS. Our scheme tries to make crossing points to the areas near to the network center (CIP). However, by the road property of vehicular networks, XYLS can make crossing points to the areas near to the network boundary. Thus, our scheme can reduce the location service delay when compared with XYLS.

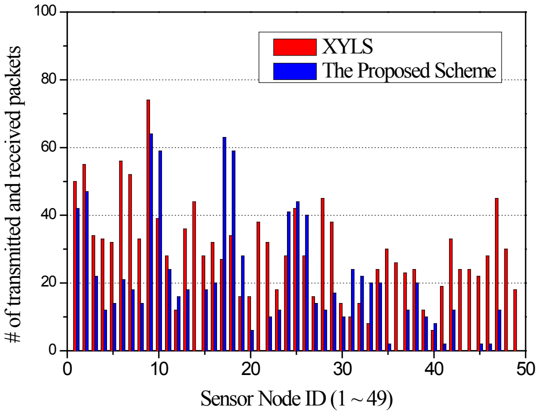

Figure 6. The number of transmitted and received packets in each sensor node for various network sizes

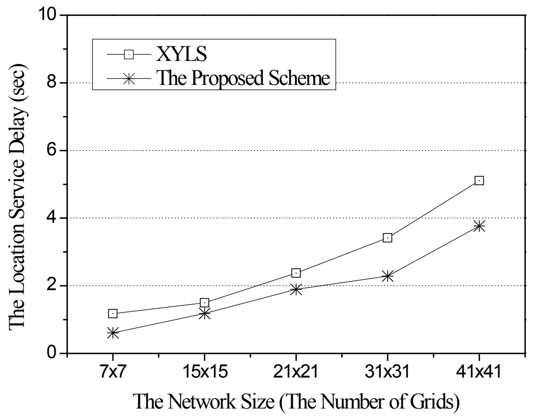

Figure 7. The location service delay for various network sizes

VI. Conclusion

In this paper, we proposed a quorum-based location service scheme in Vehicular Sensor Networks (VSNs) consisting complex roads. Our scheme provides the location information of a vehicle to sensor nodes by a crossing point between a quorum of a Location Update and a quorum of a Location Query. Unlike the existing schemes, we exploit the property of roads for the location service in VSNs. For guaranteeing at least one crossing point in our scheme, we make a LU quorum in a line path and a LQ quorum in a quadrangular path on roads. Our scheme includes a LU, LQ, LR, DD, and MS process for supporting location service and data dissemination. Simulation results show that our scheme has better performance than the well-known quorum-based location service scheme, XYLS in terms of the number of transmitted and received packets and the location service delay.

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