A Region-based Hierarchical Location Service with Road-adapted Grids for Vehicular Networks

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Abstract**—**In VANETs, it is very important to communicate between two vehicles, but how to get the correct position of a vehicle is not easy. Due to vehicles are moving fast, topology in VANETs changes rapidly. As a result, location services processed in VANETs are more difficult than in MANETs. In our thesis, we propose a hierarchical location service system, it provides a low cost and rapid service. First, we select the main arteries to divide network into grids because of there are more vehicles than in normal roads, and then design a mechanism that when vehicles need to send update packets. This mechanism can decrease the number of update packets and still gain correct vehicles' location. Second, we design grids with three levels, the higher the level, the larger the area. Each level stores update packets sent within its area. Vehicles using our system can find the destination vehicle distributedly within a small area; if the target is not within this area, then find within a larger area. Besides, we propose a packets collection method, it can be adjusted with different size of collection area. The simulation results show that our scheme could decrease the number of location update packets effectively, and keep high success rate of location service.

Keywords: Vehicular Networks, location service, divide with road-adapted, region-based

I. INTRODUCTION

In Mobile Ad hoc Networks (MANETs), mobile nodes move around and send/receive packets with others, every mobile node could be a host and a router; sending/receiving and helping forward packets to others at the same time [1, 2]. Vehicular Ad hoc Networks (VANETs) represent a rapidly emerging and challenging class of MANETs; mobile nodes in MANETs are vehicles equipped with Global Positioning System (GPS) including digital map, complete hardware devices, unlimited on the size of storage capacity and energy. It is notable that velocity of mobile nodes is faster in VANETs; packets transmission is much harder.

VANETs was raised in the maintenance of road safety, we can utilize VANETs to send information about road congestion and accidents situation to hundreds of meters outside quickly for alleviating the seriousness of the incident and avoiding more harm [3-7]. Therefore, another well known topic engendered; that is, routing protocol.

However, how to formulate a scalable and robust routing protocol in the environments which have high mobility nodes is another strait problem. In MANETs, greedy perimeter stateless routing protocol (GPSR) utilizes location information of nodes to forward packets, it is a typical example of geographic routing protocol. In GPSR, the source forwards packets to his neighbor which has shortest distance to its destination, each node who receives packets repeats the procedure above until packets are received by the destination [8]. Vehicles in VANETs are always equipped with GPS, position information of source and its neighbors are easily to get. VANETs provide position information suit to GPSR, therefore, GPSR become the most popular routing protocol in VANETs.

Nevertheless, such approaches of routing protocols assumed that sources and destinations know the geographic location of each other, but in fact, vehicles in VANETs have no idea about the location of the destination. The location of the destination is prerequisite to the source, if vehicles that need to send messages obtain accurate location of the destination in advance, the GPSR routing protocol will be more suited to implement in the VANETs. It can also help the vehicle fleet and freight wagons using the same goods vehicle transport system to reduce unnecessary redundant traffic path and waiting time, to reduce cost.

To get the correct location information of vehicles quickly is very important, but how to get the correct position of the mobile nodes is not easy, especially difficult in VANETs, mobile speed is faster. Nowadays most researches in location services are performed in MANETs [9-18], existing protocols fall into two categories: flooding-based location service and rendezvous-based location service [19, 20]. In flooding-based location service, each node broadcasts its location information packet to the network, nodes which received the packets records location information of the sender, like [16]. Contrarily, the source node initiative floods request packet to find the location of the destination in [17, 18]. Since nodes have to broadcast or flood packets to the whole network, it is very wasteful in terms of the networks total bandwidth. Because of a message may only have one destination but it has to be sent to every nodes, this result is in seriously scalability reduction [11, 12, 19, 21].

Rendezvous-based location service can be divided into quorum-based and hashing-based approaches, in the former one, each node periodically forwards its location information packet to a given update quorum, nodes in the update quorum are location servers. A node forwards location request packets to the query quorum when it needs location of any node. However, doing so may increase cost due to one case that getting long distance between a node to its update quorum nodes. The latter one, hashing-based protocols, the location servers are chosen via a strong hashing function, in some hashing-based protocols, they divide the network into hierarchical grids.

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If distance from the sender to the location server is farther than distance from the sender to the destination, the hashing-based protocol will increase the service cost and delay the information. In addition, dividing the network into grids also makes roads divided, which increases complexity and cost.

Due to fast mobility of vehicles and topology varies rapidly; both the quorum-based and the hashing-based location services are not suitable in VANETs. A novel region-based protocol was proposed in [21], the network in [21] is divided into cells with the longitude and the latitude, and cells are designed with hierarchy. To update location, all vehicles send a location information packet to its new/old corresponding cell leader (the center of a cell) when it crosses cell each time. Every 81 cells form a cluster, and the cell in the center is the location service cell (LSC). When vehicles have a location request, the location request packets are sent to a LSC, if this LSC cannot find the destination vehicle, the packets will further sent to others LSC with spiral order. We are afraid that the frequency of sending a location update packet is too high and causing too many packets, because of the network partition is divided with longitude and latitude. Also, the request by a spiral shape route may gain overdue information. In addition, although [21] designs cells with two levels to handle the large number of packets, the packets success transmission rate may still low. Because in a vast area, vehicles-to-vehicles transmission is not reliable.

For recent researches, vehicles have to update their location by sending a location update packet periodically. Vehicles may send a packet when driving every few minutes or every few meters. That is to say, if the update frequency is 50 meters, each vehicle will send 20 location update packets for driving 1000 meters. The total number of the location update packet is proportional with the number of vehicle. If there are 100 vehicles driving within 1000 meters road, then the total number of location update packet is 2000. The large number of update packet certain produces a very high control packet overhead.

Therefore, we propose a Hierarchical Location Service with Road-adapted Grids for Vehicular Networks (HLSRG). We design a road-adapted grid partition method; this method can decreases a lot of packets by restraining most of vehicles from sending update packet frequently. We divide the network into grids on the basis of the characteristics of roads, and choose a virtual point which is an intersection selected from each individual grid to be the grid center. The vehicles information in each grid will be collected to the grid center, and then further periodically gather to the upper level: Road-Side Units (RSUs), which are actually existed and so on. The information are simplified step by step and will be merged together into a largest region information in the top level. We are afraid that the vehicles-to-vehicles transmission may not stable in a large area, and set up RSUs in a small area is waste for cost. Therefore, we propose a novel packets collection method, the procedure can be adjusted with different size of collection area. Our location service combines distributed and centralized location service; vehicles are able to send a request packet to the local collection place or to the centralized collection place.

Owing to the novel network partition method and the location update mechanism, our thesis can decrease the packets volume effectively. Apart from this, our thesis increases the packets delivery ratio. Vehicles which are driving in an intersection region have more opportunity to stop to wait the traffic lights, therefore, we choose the intersection to be a grid center to help packets transmission. The hierarchical level in our thesis admits vehicles send a location request packet to its corresponding lowest grid center or to one in the upper level directly. This approach provides distributed and centralized location service, which can decrease network cost. HLSRG can combine distributed and centralized processing; it is a novel region-based, efficient, hierarchical, road-adapted and location service.

We compare our protocol with RLSMP [21] through simulations. The results show that our protocol could reduce 50% of location update packets and still increase query success rate. In addition, delay time of our query is also lower than RLSMP [21].

The rest of the paper is organized as follows. Chapter 2 is our Region-based Hierarchical Road-Adaptive Location Service, the simulation results are shown in Chapter 3. Finally, we conclude this thesis with some remarks in Chapter 4.

II. THE PROPOSED HIERARCHICAL LOCATION SERVICE PROTOCOL

In this chapter, a Region-based Hierarchical Location Service with Road-adapted Grids (HLSRG) protocol is proposed. We first show the detail of the network model in Section 2.1, including network partition and hierarchical model setting up. Second, in Section 2.2, we elaborate on when the vehicles will send the location update packets and how to deal with these location update packets collection. In the final Section 2.3, the location request strategy of a vehicle and the corresponding location service is explained in the end.

2.1 The Network Model

Two of the features in VANETs are vast range and rapid-changing network topology. If vehicles update their location by sending a packet frequently for keeping information fresh, it must causes numerous packets and increase the difficulty of packets collection. For decreasing the loads produced by handling these packets, we properly divide the network into grids and design the grids into three hierarchical levels, location information are stored in different size region of these levels. We show detailed approach of area partition and hierarchical model in 2.1.1 and 2.1.2 respectively.

2.1.1 Area Partition Procedure

Generally, VANETs has a regional characteristic. For instance, a vehicle fleet must keep following in the same region and the vehicles using the same local freight transport system are working together. Due to this characteristic, we propose a proper and novel Road-adapted Grid partition method, this method collects packets locally in VANETs. Dividing a network into grids is a popular method for recent research, [11, 12, 21] are examples. In [11, 12, 21], they divide the network into grids with longitude and latitude. As a result, the boundaries of grids may cut through buildings and shade trees. Therefore, the success rate of packets transmission may decrease. The main idea of our Road-adapted Grid partition method is to select the main artery to partition the network area into grids; i.e., boundaries of each grids are roads. Our area partition procedure is showed below:

First, examine the whole digital map carefully and select all main arteries, like the big dots lines showed in Figure 2.1. Second, we define size of the grids about to 500m × 500m, the 500m is our vehicles' communication range. Therefore, we have to reject some main artery which had already selected in step one or add other normal roads until size of the grids comply with our provision. The selected normal roads are showed with the gray small dots in Figure 2.1.

Road-adapted Grid partition method divides an area into grids adapt to roads, as a result, the boundaries of grids can avoid to cut through buildings and shade trees. Therefore, our method increases the chance of success transmission indirect. We assume the digital map is well partitioned in advance and loaded to every GPS.

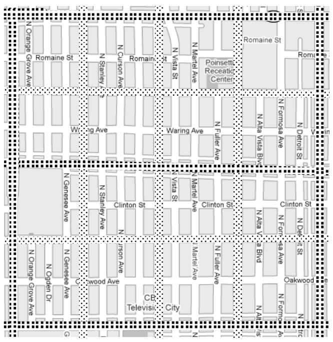
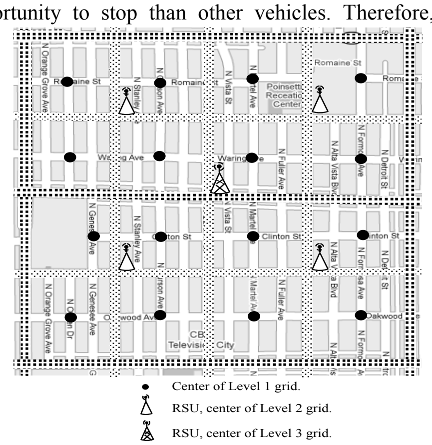


Figure 2.1 A 2km × 2km region with 16 Road-adapted Grids. The big dots lines are selected main arteries and the small dots lines are normal roads.

2.1.2 Hierarchical Framework Model

In order to deal with location update packets collection from a large number of grids in network, we design the whole grids with three hierarchies, Level 1 to Level 3. The 500m × 500m grids are Level 1, four level 1 grids form a Level 2 grid and four Level 2 grids form a Level 3 grid, any level 1 grid can belongs to only one Level 2 grid and Level 3 grid respectively. In each Level 1 grid, we choose an intersection which is nearest to the center of the grid to be the Level 1 grid center. Grid centers are very important; they have to collect location update packets in their grids and transmit the packets to their corresponding upper level. Due to vehicles in an intersection region may have to stop and wait for traffic lights; they have more opportunity to stop than other vehicles. Therefore, we utilize this property to increase the probability of success transmission once again: we choose an intersection to be grid center in each Level 1. Next, we choose an intersection between four Level 1 grids; like the black dots showed in Figure 2.2, to be their corresponding Level 2 grid center. Similarly, the Level 3 grid center is the common intersection of its four Level 2 grids. The central positions of three hierarchical levels are showed in Figure 2.2.



When collecting packets in VANETs, it will be more difficult to collect within a larger area. For handling the large number of packets, [10, 11, 12, 13, 14, 15] divide network into cells/grids and some of them also design the cells/grids with hierarchy. In each level, some given vehicles are assigned to receive and store packets. Nevertheless, vehicles in the top level which are assigned to receive packets may need to store too many packets and increase the failed rate due to the vast collection area. Therefore, we properly set up RSUs to store the large number of information for upper level. RSU has strong computation and communication capabilities; it can play different roles with data aggregation, dissemination and internet access. RSUs can be wired connect and handle large amounts of packets quickly, it is very helpful to VANETs [22]. If there are rare vehicles in VANETs, the transmission of two vehicles must be easy fail. Therefore, we set up RSUs to help our thesis process. RSUs can help data transmission stable in Level 2 and Level 3 grids, but may waste by setting up in Level 1grids. Because of the small region of Level 1 grids, the vehicles driving within a Level 1 grid center can store location update packets sent from this Level 1 grid. In our thesis, the collection method can be adjusted with different size of collection area. We assume there is a RSU set up in each Leve1 2 and Level 3 grid center for their bigger region; and utilize simple vehicles-to-vehicles transmission to collect packets in the Level 1 grid due to its small region. Therefore, we not only decrease the cost for setting up RSUs in a small area but also increase the stability of packets transmission in a large area. Each Level 1 grid and RSU has an unique ID number. In our thesis, RSUs in each Level 2 grid are wired connect to another RSU where is in their corresponding level 3 grid center. The RSUs in Level 3 grids have to find vehicles which are far from its location, therefore, we devise each of them is wired connect to another four by direction east, west south and north in the same level, Figure 2.3 shows wired RSUs within two Level 3 grids.

2.2 Location Update in HLSRG

In order to obtain location of all vehicles, we devise that vehicles have to send a location update packet to the level 1 grid center when crossing a grid or turning right/left. As a result, each level 1 grid center saves location information locally. Packets are collected in each grid apart and then merged to the corresponding upper level orderly. When doing the packets merging procedure, the sender grids send the position information rather than all detail information to its upper level to decrease its load.

2.2.1 Location Update in HLSRG

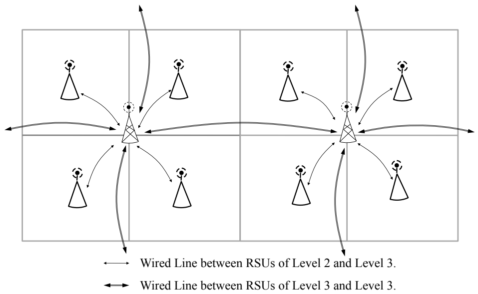


Figure 2.3 Wired RSUs within two Level 3.

One of our goals is to trace location of all vehicles, to achieve this goal, vehicles have to update their location periodically when moving. [21] devises that vehicles have to send their new location information to Cell Leader each time when crossing a cell boundary. But we are afraid that a large number of location update packets will be caused and will bring high location update cost. Nowadays, most of researches design that vehicles have to send a update packet every time when driving a given distance, for instance, every 50 meters. Since vehicles update their location frequently, vehicles' location information will very fresh. Nevertheless, the total number of location update packet is proportional high with the number of vehicles. And the large number of update packet certainly produces a very high control packet overhead.

In order to improve this shortcoming, we design a strategy to keep location information fresh in Level 1 grid center and decrease the number of location update packets at the same time. The main idea is that some given vehicles can stop sending location update packets temporarily. Our method can decrease a lot of packets by restraining most of vehicles from sending update packet frequently. The detail rules are described in next section.

There are always more vehicles on the main arteries. For instance, in Figure 2.1, there are about 107 vehicles within a 1000 meters main artery, but only 11 vehicles within a 1000 meters normal road (We count the number of vehicles from Google Map). The number of vehicles within a main artery is almost tenfold of the number of vehicles within normal roads. Besides, most of the main arteries are selected to be boundaries of grids in our thesis. If we can restrain location update packets which are sent from main arteries, then we decrease the total number of location update packet for a network indirectly. Owning to these properties, we design a rule that vehicles driving on a selected main artery straight do not have to send a location update packet until they turn right/left or cross a boundary of Level 3 grid. Since we decrease the number of location update packet, we are afraid that the location information are not fresh enough. Therefore, for finding a destination vehicle accurately, we find the destination vehicle by geographic broadcasting a packet along the road with a given direction. If we want to find a destination by geographic broadcast a packet along a road, we need its starting location and direction. Therefore, when a vehicle changes its direction to make a turn, it has to send a update packet. In addition, we are afraid that some vehicles driving straight on a selected main artery do not send any update packet for a period of time, and we will lose its track; so vehicles have to update their information when crossing a Level 3 boundary. Those vehicles do not send location update packets every time when cross a boundary, therefore, the number of the packets and the location update cost could be decreased in our thesis. Before we listing the detailed strategy, we divide vehicles into two classes, the first class is vehicles which are driving on the selected main arteries, and the rest vehicles are classed to be the second class. The first class has two situations that vehicles need to send a location update packet. For example, vehicle *X* belongs to the first class, which is driving on a selected main artery. *X* has to send the packet when one of these two situations occurs:

(1) *X* is driving straight and crossing a boundary of Level 3 grid.

(2) Each time *X* turning to other roads, including all main arteries and normal roads.

There are also two situations that vehicles need to send the location update packets in the second class. We assume a vehicle *Y* is driving on a road which had not been selected to be a main artery boundary, *Y* needs to send a location update packet when one of them occurs:

(1) *Y* is driving straight and crossing a boundary of any level.

(2) *Y* is turning to a main artery.

Since there are scarce vehicles in the normal roads, it may decreases our success probability of directional geographic broadcast, therefore, we devise vehicles in the second class have to send the packet every time when crossing any boundary to keep the location information fresh. Due to these vehicles send the packets frequently, their location information are fresh enough. However, if a vehicle is driving on a normal road and turning to a selected main artery, it may drive straight along the road and do not send update packet. Therefore, we devise that they need to update their location when they turn to a selected main artery rather than send the packet each time when they turn right/left. We show the location update strategy with an example routing on Figure 2.4. In our thesis, vehicles send a location update packet by broadcasting packet within its one-hop distance, the Level 1 grid centers in *A*'s communication range have to receive this packet. Our strategy decreases a large number of packets effectively; we show the simulation results in Chapter 4.

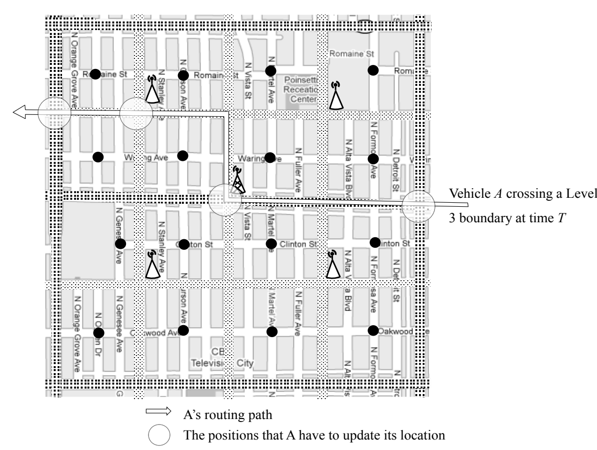


Figure 2.4 An example of location update strategy by vehicle A.

2.2.2 Location Messages Collection between Level 1 to Level 3

We have introduced the location update strategy in Section 3.2.1, in this section, we show in detail that how to deal with the packets collection. In the first level, vehicles driving in the Level 1 grid center have to receive the location update packets which they have heard. The location update packet including location, time, direction, Level 1 grid number and ID information about a vehicle. When a vehicle is going to enter another Level 1 grid and broadcast a location update packet, the receivers in the old Level 1 grid will delete its information from their table. Vehicles driving in a Level 1 grid center record all information in the packet to their table. When they are going to leave this center, they have to examine the data in the table and drop some data that have already been recorded over 2.2 minutes (about 1000m) from the last update. And then geographic broadcast their own table in the range of the intersection, and send the table to their corresponding Level 2 grid center, a RSU. Other vehicles which have received this table in the same intersection will add this information to their own table and record update information continuously. The RSU in the Level 2 grid collects the packets sent from Level 1 grid to its own table, and sends the table to its corresponding Level 3 grid periodically. The information in Level 2 grid and Level 3 grid are saved at most 2.2 minutes (about 1000m) and 4.4 minutes (about 2000m) respectively, which are counted from the last update time. Due to the increasing of the scope for an upper level, items saved in a table of the upper level should be lesser in order to decrease load. We devise that the Level 2 RSUs only record vehicle's ID, time, and sender (ID of Level 1 grid) in the packet sent from Level 1 grid; and the Level 3 RSUs record the sender (ID of Level 2 RSU), vehicle's ID and time in the packet sent from Level 2 RSU. Therefore, only a vehicle in Level 1 grid center can be a location server, Level 2 RSU and Level 3 RSU can only record information and receive location request packets. Since Level 3 RSUs are wired connect, we can assume that any Level 3 RSU owns vehicle's information for a specific region.

2.3 Location Request and Service in HLSRG

In this section, we describe the location request method, including how to send a location request packet and the location service of this request. Our HLSRG performs a location service with short service time, high probability of success and few location update packets.

2.3.1 Location Request Strategy

In our location service system, if a vehicle needs to communicate with another one but has no idea about the location, the source vehicle just needs to send a location request packet to its nearest level center (the nearest level center could be a Level 1 grid, Level 2 grid or Level 3 grid center). After sending the request packet, the source vehicle have to wait an acknowledge (ACK) sent from the destination vehicle and then start to communicate. We show the detail operation of each level after receiving a request packet in the next section, and we use S_v and D_v to represent source vehicle and destination vehicle respectively.

2.3.2 Location Service Strategy

Vehicles/RSUs in each level center may receive a location request packet. Each vehicle/RSU receives a location request packet first checks its table. If there is D_v's information, the vehicle/RSU sends the request to its lower level which has D_v's information. When the request is been sent to the D_v's corresponding Level 1 grid center, this center has to choose a vehicle to be the S_v's location server, because D_v's detail information is only stored in the Level 1 grid center. But if a vehicle/RSU receives a request and has no D_v's information, it sends this request to its corresponding higher level. We show the detailed processes after each level receiving a request packet below.

If the packet is sent to a Level 1 grid center, vehicles in the Level 1 grid center have to choose one of them to be the location server. When they receive this packet, they first check their table whether D_v was recorded before or not. To avoid collision, vehicles which find D_v in their table have to random back-off within 0~15 bit times and the first timeout vehicle is S_v's location server. This vehicle will broadcast within its one-hop distance to announce that it is the S_v's location server. Therefore, other vehicles can stop counting back-off. Each location server has to find its target D_v by broadcasting a notification packet included S_v's location, when D_v receives the notification packet; it has to send an ACK to S_v and then communicate with each other. There are two strategies that a location server finds its target D_v:

(1) The target D_v was driving on a main artery when it sent the location update packet.

In this situation, S_v's location server will geographic broadcast a notification packet along this main artery with direction *dir* recorded in S_v's update packet to find D_v.

(2) The target D_v was driving on a normal roads when it sent the location update packet.

In this situation, D_v is still driving within this Level 1 grid. The location server can find D_v by broadcasting the notification packet within the range of this Level 1 grid.

The Vehicles which can't find D_v's information in their table have to random back-off within 17~31 bit times. If there is no one vehicle could be S_v's location server, the first timeout vehicle will broadcast within its one-hop distance to release other vehicles' back-off, and then send its own table and the S_v's request packet to its corresponding Level 2 RSU. The RSU will gain the most fresh location information and act as the location server of this request.

If a Level 2 RSU receives a location request packet, it has two strategies to deal with the packet:

(1) D_v's information has been recorded in the RSU's table:

In this situation, RSU can look up its table and figure out that which Level 1 grid D_v is belonged to, and then send this request packet to the Level 1 grid center. It is not has to worry about the request sent from Level 1 grid will be sent to Level 1 grid again; because when a Level 1 grid forwards the packet, it will attach with its table. In each level, update their table has highest priority than other events. Therefore, we ensure that the receiver (Level 2 RSU) has the same information with the sender (Level 1 grid) in sender's region.

(2) The RSU cannot find D_v's information from its table:

If there is no D_v's information in RSU's table, it means that D_v has already driven far away or D_v has never been here. The RSU needs to forward the request packet and its table to its corresponding Level 3 RSU.

For a Level 3 RSU, there are two strategies to find D_v, which are decided by the sender of the location request packet.

(1) The sender of the packet is a Level 3 RSU:

Due to Level 3 RSUs are wired connect; we can assume that each Level 3 RSU has the newest information of vehicles. Therefore, if a request packet is sent from another Level 3 RSU, it is means that the receiver has the D_v's information with the latest update time. After the Level 3 RSU confirming the packet is been sent from the same level, it will forward this packet to the Level 2 RSU which D_v is belonged to and has been recorded in its table.

(2) If the request packet is not been sent from the same level:

In this situation, the receiver has to forward this request packet to another Level 3 RSU which has the newest D_v's information.

We devise that a vehicle can send a location request packet to its nearest Level 3 RSU directly if it doesn't receive an ACK after sending a request packet 5 seconds. The Level 3 RSUs have vehicles' location information within vast range, they can find D_v quickly and accurately.

III. SIMULATION RESULTS

In this chapter, we show the simulation results of our protocol. We use ns-2 [23] to simulate the task of wireless communications and VanetMobiSim [24] to simulate the navigation of vehicles. VanetMobiSim help us simulate navigation of vehicles by setting the vehicle velocities, distance between vehicles, time of traffic lights, and road topology by ourselves. The VanetMobiSim can output a vehicle navigation scenario data for ns-2, and ns-2 is able to simulate the wireless communications among vehicles with this output scenario.

We use a Los Angeles map with 2000 meters × 2000 meters, which is showed in Figure 3.1. We randomly create 300~700 vehicles by VanetMobiSim with speed between 0 to 60 km/hr. In each simulation, we randomly choose 10% vehicles to be source vehicles (S_v) and 10% vehicles to be destination vehicles (D_v) respectively, the S_v need to send a location query packet for communicating with D_v. We set traffic lights in red light are 50 seconds. We use ns-2 to simulate the wireless networks, and the communication range is 500 meters, it can be adjusted with Level 1 grids' boundary length. The moving information of each vehicle is provided by VanetMobiSim.

We compare the performance of our protocol with RLSMP [21], which has been mentioned in Chapter 2. RLSMP divides network into cells with longitude and latitude, and the Location Service Cells (LSCs) find D_v by forwarding packets in spiral shape around LSCs. In the simulations, we analyze the location update overhead, location query overhead, the probability of the query packet to be successfully accepted, and how much time does a location query spend.

Figure 3.1 Los Angeles map with 2000 meters × 2000 meters.

In the simulation of location update overhead, we calculate the overhead by counting the number of location update packets. We change the map with three different sizes: 500 meters × 500 meters, 1000 meters × 1000 meters and 2000 meters × 2000 meters in this simulation. The numbers of vehicles in each map are proportionally increased, 31, 125 and 500. Figure 3.2 shows the location update overhead created in our protocol is much lower than RLSMP. RLSMP divides network into cells with longitude and latitude, the vehicles in RLSMP have to send a location update packet every time when crossing a cell boundary. In our protocol, we design main arteries have the highest priority to be chosen as a level boundary. There is almost tenfold vehicle on main arteries than on normal roads. That is to say, all vehicles which are driving on the network are always driving on main arteries. Our thesis design that the vehicles driving on a chosen main artery send a location update packet only when turn right/left or leave a Level 3 grid. Consequently, a lot of location update packets are restrained to send due to our road-adapted grid partition method. Therefore, our protocol produces less location update packets, reduces location update packets about 50%.

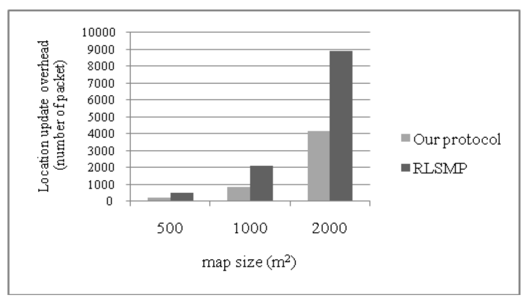


Figure 3.2 Location update overhead.

In Figure 3.3, we show the location query overhead. The scenario is the Los Angeles map with 2000 meters × 2000 meters, the numbers of the vehicles are changed with 300, 400, 500 and 600. In each simulation with different number of vehicles, we randomly choose 10% vehicles; they will send a location query packet to the collector. The vehicles being queried are also chosen by random. Figure 3.3 shows that the more vehicles need to query another vehicle, the more query packets will be produced. In our protocol, we set up RSU in Level 2 and Level 3 grids center. If a Level 3 RSU receives a query packet, the RSU will send this packet to another Level 3 RSU which is the destination belongs to. In this query, when the destination is far away from the source, the RSU can reduce many forwarding query packets. In addition, in a denser vehicular network, GPSR routing protocol can chooses a next forward vehicle which is closer to the destination. Therefore, our protocol produces less query packets, reduces the location query overhead up to 15%.

Figure 3.4 is the query success rate. In RLSMP, when a vehicle S_v need a D_v's location information, S_v will send a location query packet to its corresponding LSC. If the LSC has no D_v's information, it has to wait and aggregate query packets for a specific waiting time. After waiting, the LSC will send the aggregated query packets to others LSC with spiral shape around LSC. Because of the spiral shape routing of LSC-Query causes location information overdue, the query may fail. In our thesis, the location update/query packets are sent to level center immediately, and the RSU can help our system store a large number of packets stably. Therefore, our protocol has higher query success rate.

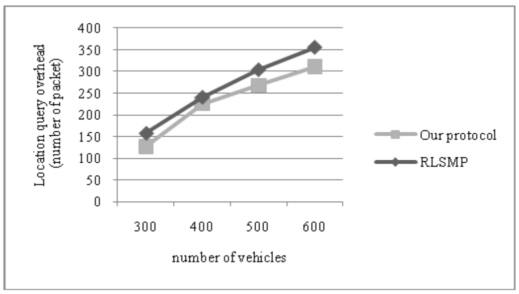


Figure 3.3 Location query overhead.

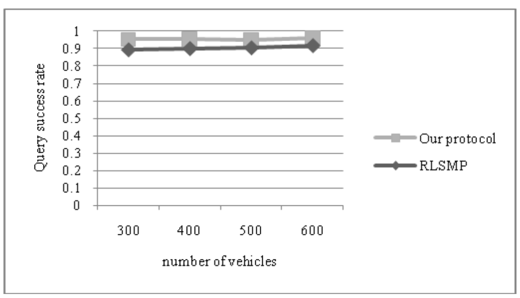


Figure 3.4 Query success rate.

In Figure 3.5 we calculate the average time cost for a query. The result is obtained from the average of 10 simulations. Figure 3.5 shows that our protocol cost less time for each query than RLSMP. In our protocol, if a S_v query a D_v, and they are far away from each other; the query packet must be sent to S_v's corresponding Level 3 RSU. This RSU is able to check its table and find out which area does D_v belongs to, and then sends the query packet to another Level 3 RSU which D_v has registered its information. RSU help our system forward packets for a long distance directly, which cost little time. In RLSMP, when a LSC has no D_v's location information, it has to forward a query packet with spiral shape around LSCs. This query packet may spiral visit all surrounding LSCs, and cost more time than our protocol.

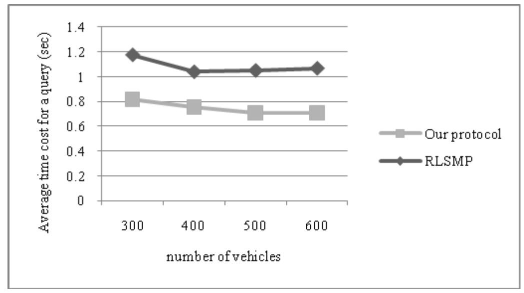


Figure 3.5 Average time cost for a query.

The simulation results show that our protocol has lower control packets overhead and higher query success rate than RLSMP. Our road-adapted grid partition method reduces the location update overhead more than 50%. Because of vehicles driving on main arteries send a update packet with low frequency, and there are almost 90% vehicles are driving on main arteries. RSUs efficiently help our system reduces 15% location query overhead. In addition, RSUs also increase our query success rate and reduce the average cost time of each query. Although the location update packets are decreased more than 50%, we are still able to find the destination vehicle accurately by geographic broadcast a packet along a road with a given direction. RSUs help our system increase query success rate and reduce the query cost time. Our thesis provides a low control packets overhead location service system. Our system provides drivers correctly and quickly find out their desired vehicle.

IV. CONCLUSIONS

Vehicular Ad hoc Networks (VANETs) is a new topic in wireless networks. VANETs can provide driver roads safety information, resource sharing, available parking lots and shops advertisement, etc. Drivers are able to communicate with some specific destination for applications. Therefore, a routing protocol for VANETs and the necessary condition: source/destination location is very important. In our thesis, we propose a novel location service system for vehicles,

We propose a Road-adapted Grid partition method to decrease location update packets, and set up RSUs to store a large number of control packets. Vehicles using our system can find the destination vehicle distributedly within a small area; if the target is not within this area, then find within a larger area. Besides, we propose a packets collection method, which can be adjusted with different size of collection area.

We used ns-2 and VanetMobiSim to simulate our protocol and compare with another protocol RLSMP. The simulation results show that our location query overhead and query delay time are reduced because of our Road-adapted Grid partition method and the strong storage ability of RSUs. Simulation results also show that our protocol could reduce the number of location update packets more than 50% of RLSMP. However, our location service success rate is higher than RLSMP, achieves to 100%.

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