A Novel Group-Based Location Service Management Scheme in VANETs

Jung-Shian Li and Chuan-Gang Liu

***Abstract*—One of the major concerns in VANETs is to design a scalable and robust routing protocol, which usually depends on the ability of tracking the locations of vehicles in VANETs. The location information service in VANETs helps to find the destination vehicle effectively. However, vehicle mobility and lack of adequate location information management scheme for vehicles in large scale VANETs are the main challenges. In this paper we proposed a novel group-based location information service scheme that places Location Information Points on the roadside to provide up-to-date location information and resolve lookup query of vehicles in the network. Furthermore, our proposed scheme groups LIPs into hotspot or non-hotspot groups. Hotspot LIPs will construct a P2P overlay network which facilitates the resolution of the query message in VANETs. Comparing to previous schemes, our scheme can perform location update and reply to lookup query on each LIPs well with less communication overhead in large scale VANETs.**

***Index Terms*—VANETs, group-based, location information management, overlay network**

I. Introduction

Vehicular Ad hoc Network (VANET) is a rapidly emerging technology. This network has many similar characteristics with Mobile Ad-hoc Network (MANET). Nodes in both of them are moveable and self-organization. However, contrasts to MANET, nodes in VANETs are vehicles which move at much higher velocity than nodes in MANETs. With such high mobility, links among nodes become unreliable; the packet transmission in VANETs is much harder than MANET. To propose a reliable transmission scheme in VANETs is a popular topic nowadays.

Recently, applications in VANETs include not only safety issue but also infotainment and these are potential and hot topic in the future. However, the implement of these applications depends on the reliable communication among vehicles [1], [2]. As above description, vehicle is a node moving at a high speed and to design a reliable transmission should be an urgent and hard goal. A robust routing protocol can achieve this goal. In VANETs, routing protocols usually depend on accurate location information of mobile node. Hence, location information provision is a basic and important service.

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There are two components in location information provision of VANET vehicles. One is location-based systems and the other is location information management. For location-based systems, Global Positioning System (GPS) usually provides a feasible solution to search the locations of vehicles in VANETs. However, employing GPS in a vehicle encounter the limit of the use in some applications [17]. Hence, there are a number of localization technique developed, namely Map Matching, Cellular Localization, Dead Reckoning and Image/video Localization Services. All of them have their pros and cons. No single localization technique can meet all localization features [17]. Combination of multiple localization techniques possibly provides a way to meet more localization feature. However, combining multiple localization techniques may be too complex and costly to be a feasible technique. To develop a localization technique by focusing on important features may be an alternative way.

For location information management (LIM), it mainly concerns about how to mitigate traffic overhead and improve the speed of location provision. In the mechanisms of LIM, there is usually a location server, which is responsible for storing location information and replying to location queries from other nodes in a region. Location servers must ensure that they have the up-to-date location information of mobile nodes in their respective regions. Consequently, location servers refresh their location information with the use of location update mechanism. However, location update frequency and the overhead of replying to the location queries are main challenges in LIM. This paper focuses on the issue of Location Information Management in VANETs.

In MANETs, there are some approaches for location information service management mentioned in the literature [3], [4]. The existing studies fall into two categories: flooding-based [10], [11], [14] and quorum-based [15], [16] location service protocols. In flooding-based approach, it requires that all mobile nodes broadcast their queries and the response of location query through the whole network. Such flooding indeed can be useful to find the location of destination but results in huge control overhead and wasting network bandwidth [5], [6]. This causes serious scalability reduction problem discussed in [6]-[9]. The quorum-based protocols is relatively more adequate, which needs to choose nodes to be location servers in the networks. The location server collects up to date location information and replies location information to location query in its radio range. Basically, our scheme also belongs to this category. However, it also needs an efficient location service management to solve the issues, such as the location server choice and the mechanism to discover location server for a target node.

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Our proposed location service management scheme is based on the concept of peer-to-peer (P2P) overlay network architecture which makes the location information lookup efficient. A Location Information Point (LIP) collects location information of end users within its radio range in the network. There are two types LIP groups, such as hotspots group and non-hotspots group, and hotspots group forms a P2P overlay network. When a mobile node sends out lookup query, local LIPs receive and flood this query message to local LIP firstly. If local LIP cannot reply to query message, it should broadcast query message to other LIPs belonging to hotspot group. LIPs of the hotspot group will flood the lookup query throughout the overlay network formed by LIP members of the hotspot group. If not found, query message will be forwarded to those LIPs of the non-hotspot group until all LIP been visited. Based on hierarchical search in P2P overlay network, our scheme can reduce traffic overhead and achieve fast response for queries of destination location lookup. Furthermore, our scheme is developed based on distributed method and hence it is more feasible.

The rest of the paper is organized as follows: Section II describes major issues in Location Information Management for VANETs. Section III describes our proposed Location Service Management scheme and our system model. In Section IV, we show the results of simulations and give the discussion in this section. Finally, Section V concludes this paper.

II. Major Issues in Location Service Management

Usually, there are two major evaluation metrics for location service management, which are costs of location querying and updating. Hence, to provide minimum location querying and update costs in a large scale urban environment is main goal while developing location service management protocols. However, in a large scale urban environment, scalability and locality awareness are related to the feasibility of location service management protocols very much. Therefore, taking cost metrics and feasibility metrics into account ensures location service management work well.

Scalability— In a large scale urban area, a large amount of vehicles location information should be processed. The goal of location updating is to make the location information up-to-date in LCS as possible. The study in [12] proposes message aggregate while location updating, which is a promising strategy to ensure scalability. In our proposed location information management scheme, we also proposed a distributed location updating strategy to ensure scalability even if the network area is getting bigger and the number of Road Side Unit (RSU) increases. Locality awareness--Effectiveness and feasibility of location service management is how to locate destination vehicle in large scale VANETs. RLSMP [12] is a region-based location service management protocol. In RLSMP, VANETs is composed of virtual cells and partitioned into several segments (clusters). Each cluster contains several cells. There must be a Cell Leader (CL) in a cell, which is responsible for collecting location information of vehicles within the coverage range of its cell. CL also aggregates location information and forwards them to CL in location service cell (LSC) which is defined as the central cell of a cluster. CL and LSC are responsible for answering location querying cooperatively. Fig.1 shows the network structure in RLSMP. There are four segments, each containing 25(5 × 5) cells.

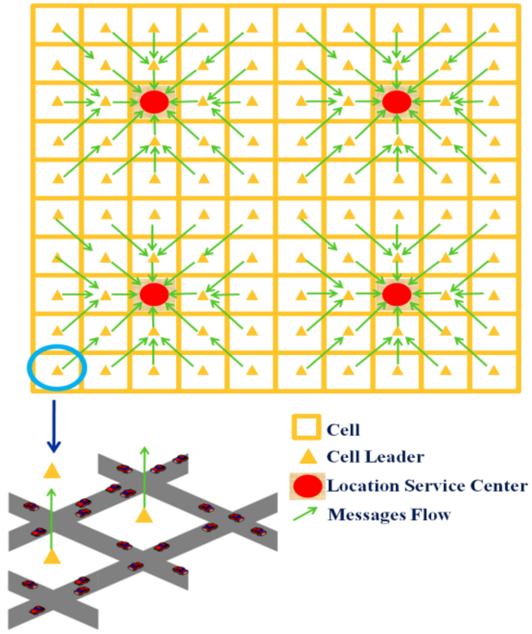

Fig. 1. The network structure in RLSMP

However, the mechanisms in [12] may lead to long delay. In our propose protocol, location information of vehicle will be store in the RSU and we proposed an efficient scheme to searching destination (vehicle) among all the RSUs deployed in city area.

TABLE I : The Parameters in Our Urban Environment

Parameters	Description
A	Size of urban area
L_A	The number of LIPs in area A
T_r	Transmission range of a LIP
V_A	Total of vehicles in the area A
V_{L_i}	The number vehicles in LIP i
S	The velocity of a vehicle
t	The average time interval staying in a LIP range
d	The vehicle density within LIP's coverage radius
N	The number of intersections in a urban area

III. System Model and Proposed Scheme

A. System Model

In our system model, we assume vehicles in VANETs traveling in urban areas and each vehicle is equipped with an On-Board Unit (OBU) consisting of wireless communication function device (IEEE 802.11p), sufficient power supply, extendable storage and processing capacities. A unique identification is given for every vehicle. Vehicles can send and receive information through OBU and they also can communication with others under inter-vehicular communications (IVC) mode.

In infrastructure-based VANET, Road Side Unit (RSU) is a low-cost infrastructure point which is equipped with multiple communication interfaces (IEEE 802.11p interface and wired connection). RSU collects and manages local location information of vehicles in VANETs within its transmission range, called it as a Location Information Point (LIP) which are stationary devices providing full coverage and connectivity on the road. Additionally, LIPs are connected via a backbone network and hence they exchange information with each other [13]. We consider an urban environment of topology size as shown in Fig. 2. Table I shows the parameters in our urban environment.

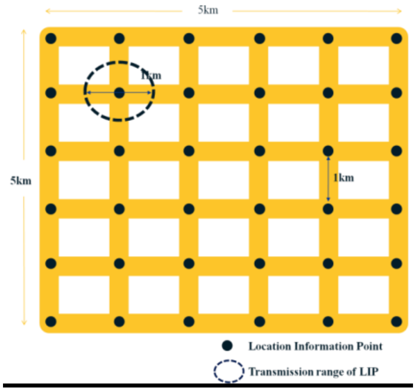

Fig. 2. System architecture in our proposed scheme

B. A Group-Based Location Service Scheme

In VANETs, two unique characteristics, large scale network area and highly dynamic changing network environment, make vehicle's location information hard to manage via a central location service scheme. Therefore, our proposed scheme is a distributed location service scheme and LIPs in VANETs play important role in our distributed scheme. The LIPs in area A store vehicles' location information within their individual coverage range for answering the query from local vehicles or other LIPs. In following three sub-sections, we describe our location service management.

1) Location information initialization and updating

First, we describe location information initialization and updating algorithm. In our VANET, each LIP keeps a vehicle table to provide the location service. Location information of the vehicles in vehicle table contains description, vehicle ID, time stamp, and status as show in Table II. This table will refresh its contexts every *p* seconds in order to make the location information of the vehicle up-to-date. The explanation of context in Table I is as follows: Description is name of vehicle; vehicle ID is a unique identification for every vehicle; time stamp is time of a vehicle joining into the LIP, and status is a value to remark that the vehicle is currently inside or outside of LIP coverage. Here, we give following statement for two statuses of a vehicle in vehicle table. While the status is 1, it means that a given vehicle is still within T_r, and LIP, therefore, can send to and receive messages from this given vehicle. When status is 0, that means a given vehicle being outside of T_r and this vehicle's location information can be discovered by one-hop neighbors of local LIP. The location of the vehicles with status =0 in vehicle table is optional information in our proposed scheme and we also call it as historical data. The vehicle's location information will be flushed from the table after 2t seconds since that vehicle leaves T_r, which means vehicle has travelled to the LIP two-hop away from local LIP.

TABLE. II: DESCRIPTION OF LOCATION INFORMATION TABLE

vehicle table	
Description	Name
Vehicle ID	Unique ID for vehicle on the road
Timestamp	Time joining into LIP's coverage range
status	Status of vehicle (0 or 1)

2) Location information overlay network

In our VANET, LIPs communicate with each other through wired broadband network to gain internet access and exchange information among LIPs. The cooperation of LIPs can deal with location information queries from the vehicles. This is an infrastructure-based P2P system providing a decentralized location information management service. However, an efficient cooperation mechanism among LIPs is the key point of a scalable and feasible location service scheme. This paper develops a location information overlay network to facilitate efficient communication among LIPs. In the following, we describe the architecture of overlay network and LIPs communication over such overlay network.

In our VANET, density information, which means the vehicle density within the transmission range, is important information to construct overlay network. Using density information of the LIP, a LIP can determine whether it is a hotspot point or non-hotspot point. The density of the LIP higher than a threshold means that the LIP should be a hotspot point and the threshold value can be set according to the historical density of the daily or monthly traffic record. The hotspot LIP points have higher probability to answer location information query and this paper lets those hotspot LIP points construct one P2P overlay network. Here, we take an example for explanation of determining whether a LIP is a hotspot or not. Here, we assume hotspot threshold value is 1000 cars/hr within the transmission rage of a LIP. Based on hourly traffic record in a LIP, and LIP can be classified as hotspot LIP if current car density is higher than hotspot threshold value. The rest of LIPs in area *A is* classified as a non-hotspot LIPs group. After classifying LIP group type as hotspot or non-hotspot groups, a list of LIP groups, including hotspot and non-hotspot, should be maintained in each LIP. In order to keep this list up-to-date, each LIP should broadcast its group type to other LIPs while it discovers the change of its group type. Finally, each LIP learns the architecture of a hotspot LIPs overlay network shown in Fig. 3 via a list of LIP groups.

Using Hotspot LIPs overlay network can facilitate the searching of vehicle location because the success rate of searching vehicle location in hotspot LIPs overlay network should be higher. Hence, in our VANET, if local LIP cannot find the target vehicle out, searching on hotspot LIPs overlay network should start. While searching target vehicle over hotspot LIPs overlay network still cannot succeed, non-hotspot LIPs take searching work over then via broadcasting queries to them. Based on the above description of the queries of vehicle location information, in our VANET, the query can be categorized into local and global query. Hence, in the following context, we explain the mechanisms of both query types in detail.

3) Local query retrieval

When a vehicle (source) tries to communicate with another one, it will forward the query message to local LIP, which will be marked as source LIP (sLIP). Each LIP contains the location information of the local vehicles in its own territories.

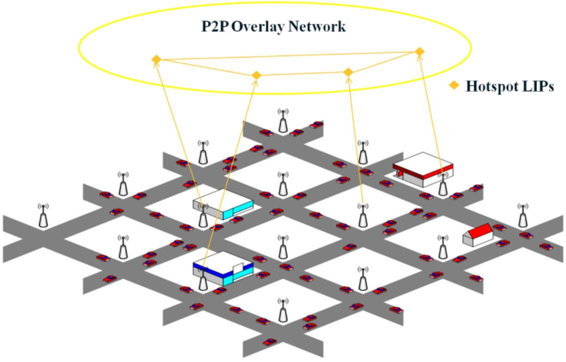

Fig. 3. Location information overlay network.

While sLIP receives query messages, sLIP looks the target vehicle up in the vehicle table. If destination identification (Dst_ID) is found in the vehicle table, sLIP can reply the query directly. We call this kind of query messages as local query. Basically, a sLIP will take the following two actions while Dst_ID is found in local LIP.

Action 1: If location status of the target vehicle in vehicle table is equal to 1, it means that vehicle (destination) is registered in the local LIP. LIP generates a reply message to vehicle (source). When the source vehicle receives replying message, the source can communicate with the target vehicle destination through the local LIP.

Action 2: If location status of the target vehicle in vehicle table is equal to 0 (This location of the vehicle with status = 0 in vehicle table is historical data and it is optional information), it is possible that the target vehicle has traveled to next one-hop neighbor LIPs. Therefore sLIP will broadcast the query message to one-hop neighbor with TTL = 1. Here, we assume the location information of the vehicle must be found in one-hop neighbor LIP's vehicle table in this case for simplicity.

4) *Global query retrieval*

While the query messages cannot be replied by local LIP, it means the source and the destination vehicles locate in different LIPs, which is called as global query. In this case, the first task is to find target LIP (tLIP) containing the location information of target vehicle. sLIP has to forward the lookup query to visit all LIPs in the network until it finds tLIP. A flooding-based lookup scheme can be employed, but it causes VANET network full of redundant query message and heavy overhead in VANET. Therefore, we use hotspot LIPs overlay network as communication platform. When a query is defined as a global query, sLIP should forward this query to hotspot LIPs overlay network we mentioned before. The LIPs in hotspot overlay network performs lookup mechanism to search Dst_ID. The global query message will be flooded in hotspot overlay network until every LIP in such network receives the query message or the packet's TTL is expired. If searching time has been exceeded s second or the searching in hotspot overlay network fails, sLIP does not receive reply message from tLIP, the query message will be forwarded to non-hotspot group until all non-hotspot LIPs have been visited. This P2P overlay network flooding can reduce query overhead much and delay time on replying during the process of searching destination vehicle.

IV. Evaluation

We use several simulations to evaluate the performance of our proposed location service management scheme and understand the comparison between previous famous location service schemes(GSM,RLSMP[12]) and our proposed scheme. In the simulations, there are two types of our proposed schemes: one is proposed scheme (without the location information of the vehicles with status =0) and the other one is proposed scheme with historical data(with the location information of the vehicles with status =0).

A. *Network scenario*

The simulation environment is a large scale squared urban area. A number of vehicles randomly travel within the VANET. The road topology is a 5km x 5km grid road network, each road segment is 1km with one lane in each direction shown in Fig. 4. LIPs are deployed on road intersection to form a full coverage in the network. The maximum velocity V of a vehicle in urban area is set as 13.9 m/s (50km/h). The vehicle density, δ, varies from 1.8~80 vehicles/km, and the total vehicles N in the network varies between 2000 ~ 3000. We use the random-walk model as the mobility pattern of vehicles. Assume the target vehicle is randomly chosen in the topology in the simulations. Each simulation lasts for t_s (300s) seconds and we assume 15% of LIPs are hotspot points. Most vehicles will be within the coverage of this 15% of LIPs. That's mean we have high probability to find the destination vehicle in those hotspot LIPs. 10% of vehicles in the network are randomly chosen as source of query. In this paper we consider several simulation scenarios by varying the network size and LIPs number.

B. *Simulation Results and Discussion*

Fig. 5(a) shows the comparison of the overhead of all schemes in different network size. 10% of total vehicles in the network randomly produce query message in simulation time. The overhead includes Location update overhead, query overhead. We observe that GSM system gets the smallest communication overhead because the base station of GSM system has a bigger coverage range than other two schemes. So, in the GSM systems, it uses the expensive infrastructure to provide huge range coverage and gets a better performance. Although the query message overhead in our scheme is higher than RLSMP, we have less location update cost comparing to RLSMP. As a result, our proposed scheme total communication overhead is similar to RLSMP.

In Fig. 5(b), it shows the success rate of lookup schemes in different network size which is varied from 25 km^2 to 625 km^2. We assume the target is random chosen and the location information of destination is unknown. We can see that the success rate of GSM is up to around 90%, because of the powerful coverage of base station. RLSMP has to aggregate the location information for increasing the success rate but it will come with heavy traffic load on the channel. Even that RLSMP can achieve high lookup success rate above 60%. Our proposed scheme produces total communication overhead less than RLSMP but success rate can reach around 80%. Our scheme with historical data outperforms our original scheme and that proves historical data is helpful to find the location of target vehicle. In Fig. 5(c), it shows the delay time of replying to query messages and we observe our scheme quickly reply query messages.

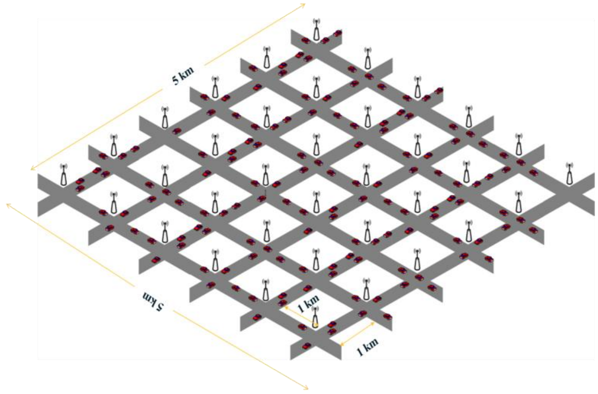

Fig. 4. Urban area environment (5km × 5km)

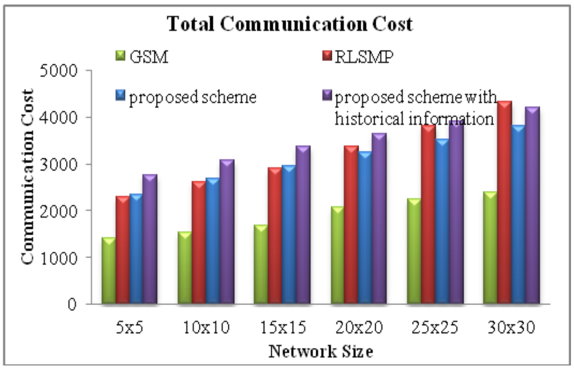

Fig. 5(a). Communications overhead in different network size

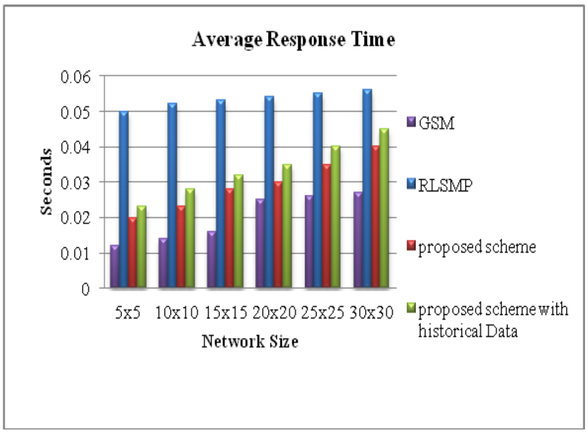

Fig. 5(b). Success rate when the destination found

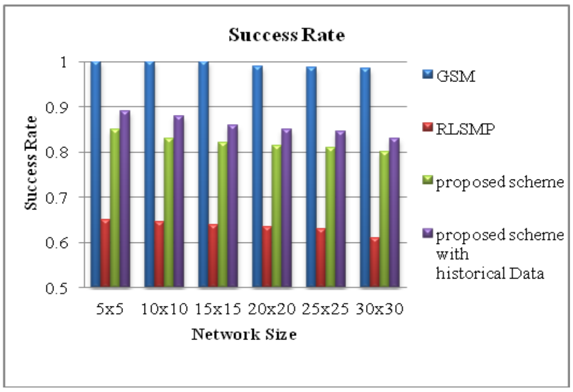

Fig. 5(c). Average delay time on response the query

V. Conclusion

Vehicular Ad-hoc Networks (VANETs) characterize a rapidly emerging and challenging class of Mobile Ad hoc Networks (MANETs). Vehicles construct a decentralized communication network via wireless multi-hop routing. Many applications can be developed in VANETs. To support the different types of applications, the network must be able to efficiently locate the vehicle (mobile node). We proposed a location information service scheme to update the location information of vehicle on the road and location retrieval when query messages are occurs. In our scheme, we propose a P2P overlay network which is formed by hotspot LIPs group. A new location management protocol is employed to reply to lookup queries in the network. Location Information Points record vehicles (mobile nodes) location information distributed in own transmission range and keep a group list to construct a hotspot overlay network. Usually, most vehicles will locate in hotspot LIPs, hotspot LIPs group can increase success rate of replying lookup queries in short time period. Even our proposed scheme also need much total communication overhead as RLSMP, but we have shorter delay time and higher success rate than RLSMP. Hence, our proposed scheme should perform well in VANETs.

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