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Typhoon: Resource Sharing Protocol for Metropolitan Vehicular Ad hoc Networks

Guey Yun Cahng*, Jang-Ping Sheu†, and Jyun-Hua Wu*

*Department of Computer Science and Information Engineering

National Central University, Jhongli, Taiwan, R.O.C.

†Department of Computer Science

National Tsing Hua University, Hsinchu, Taiwan, R.O.C.

Abstract

In this paper, we propose a realistic resource sharing protocol for VANET. The main idea of our protocol comes from typhoons. Typhoons move according to their eyes' mobility, i.e., quorums which are responsible for a given resource holder/requester "moves" according to the resource holder's/ requester's mobility. Our protocol exploits spatial locality between requesters and resource holders. When resource requesters get their desired resources, they are able to be new resource holders. For hot-resources, requesters are so numerous that the spatial locality is much enhanced over time. Besides, lots of applications (*e.g., available parking slot information*) *in VANET are location-aware which have spatial locality between requesters and resource holders. By the aid of the spatial locality, resource holders/requesters share/query sources in their vicinity in our protocol. Simulation results show that our protocol has lower search latency and well scalability comparing to the previous work. Besides, due to that the spatial locality is enhanced over time, successful rate increases over time.*

Keywords: *resource sharing, vehicular ad hoc network, distributed.*

I. INTRODUCTION

In VANET, resource sharing is an important issue cause of the reusability of comfortable driving services, such as traffic information, available parking slots, advertisements, and video stream sharing, etc. The major challenge in resource sharing is to find out a resource holder (i.e., vehicle which holds the resource), called *lookup problem*. In [7, 11, 12], road side units (RSUs) are used to play the role of directory server. Resource holders (vehicles which have the resources) leave their location information in RSUs. Requesters (i.e., drivers who are interested in specific resource) send their queries to corresponding RSUs, and then RSU would reply the location of a resource holder. However, RSUs usually become the bottleneck in the network especially when there are high traffic volumes. Besides the cost of deploying RSUs is very expensive [1] especially in metropolitan regions. Due to the drawback of RSU deployment, flooding-based approaches are developed [2, 4]. Requesters flood their requests to the whole network until a resource holder being met. Flooding-based approaches are impractical in VANET due to their extremely high cost. In [3, 5, 6, 8, 9, 10, 13], quorum-based approaches are proposed. Quorums are locations responsible for storing/replying information of resource holders. For a specific resource, it's corresponding quorums are usually one or several fixed locations which are far from requesters. Since high mobility of vehicle frequently results in regular/sudden disconnection, the transmission between requesters and quorums has rather low successful query rate, high query cost and high search latency. The detail could be found in Section II.

In most comfortable driving services, there is spatial locality between requesters and resource holders. When resource requesters get their desired resource, they are able to be new resource holders. For hot-resources, requesters are so numerous that there are substantial increases in the number of resource holders over time, i.e., the spatial locality is much enhanced over time. On the other hand, lots of services in VANET are location-aware (e.g., available parking slot information, traffic information, etc). Requesters are usually near the resources holders and tend to be clustered. Once a vehicle references a specific resource, it is highly likely that nearby vehicles will reference the same resource. And hence the locality of requesters and resource holders are enhanced over time.

As a result, we propose a realistic resource sharing protocol. Resources are shared with requesters in resource holders' vicinity.

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Simulation results show that our protocol have lower cost, lower search latency, and well scalability comparing with the other previous work. Even though our initial successful query rate is less than other works, our successful query rate is as good as previous works after a short period due to that spatial locality is enhanced over time.

The remainder of this paper is organized as following. Section II reviews the related work in this field. The scheme of our resource sharing protocol is described in Section III. In Section IV, we evaluate the performance of our protocol using network simulators. Finally, we conclude the paper in Section V.

II. Related works

In quorum-based approaches, location information of resource holders are stored in real/virtual coordinates which are determined by hash functions. According to whether quorums are dependent on the location of resource holders/requesters, quorum-based approaches can further divided into location-invariant and location-variant.

Most of quorum approaches are location- invariant. However, this kind of approaches has poor scalability, long search latency and high cost. In [13], a location-invariant approach, called GHT, is introduced. The map is divided into grids and quorums are grids which are computed by a specific hash function. Intersection location service (ILS) [3] is an approach for location service. In ILS, only road intersections are chosen as quorums. In [9], an infrastructure-based traffic information system is introduced. A virtual two-dimensional space is developed for determining quorums. In [6], PAV develops a chord ring structure for determining quorums. In [5], VITP considers location-aware resources, i.e., available parking slots. Quorums are chosen to be vicinity of target areas, i.e., parking areas.

In [10], a location-variant approach for location service, called Region-Based Location Service Management Protocol (RLSMP) [10], is proposed. The quorum corresponding to a specific resource holder (or requester) is the cluster which it currently belongs to. If the desired vehicle's location information is not available in a requester' quorum, then the requester sent its request to other cluster in spiral around current cluster until it finds out the desired vehicle's location information. In fact, RLSMP is *semi-location-variant*. Since clusters are predefined in RLSMP, quorums corresponding to two close resource holders may be distinct, while quorums corresponding to two far apart resource holders may be the same one. In [8], GLS is introduced to track the location of mobile nodes in MANET.

Our protocol is completely location-variant. The main idea of our protocol comes from typhoons. Typhoons move according to their eyes' mobility. In our protocol, quorums corresponding to a given resource holder (or requester) is completely dependent on the location of the resource holder (or requester).

III. Resources sharing scheme

According to spatial locality between requesters and resource holders, resource search in a requester's vicinity is sufficient. Besides, due to regular/sudden disconnection in VANETs, large research area would result in higher communication overhead and incomplete transmission with high possibility. Hence, it is reasonable that quorums corresponding to a resource holder is near the resource holder.

3.1 Assumption

Before introducing our protocol, we have some assumptions. We assume that each vehicle is equipped with GPS and navigation software which is installed a digital map. We assume that the navigation software has traffic information computing from the historical data. The driver could know his current position or any specific location's position by the digital map. We divide the digital map into uniform sized grids. Each grid has its own unique *global coordinate* (X, Y) produced by longitude and latitude. We also define that *local coordinate* of a grid (X, Y) to be $\langle X \bmod L, Y \bmod L \rangle$, where L is the tolerable updating distance (due to regular/sudden disconnection in VANETS, long updating distance results in high update failure rate and high update cost. So, updating distance should not be too long). Clearly, more than one grid has the same local coordinate. In Fig. 3.1, nine dark gray grids have the same local coordinates when L=4.

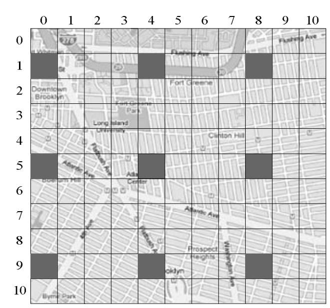


Fig. 3.1 Dark gray grids have the same local coordinates ⟨1,0⟩.

For ease of the following discussion, we let S be the holder of resource R, while Q is a requester which queries R. Define the *update area* of resource holder S to be the area which quorums responsible for storing S's information belong to. We also define the *query area* of requester Q to be the area which quorums responsible for replying Q's request belong to.

3.2 Resource sharing schemes

The main idea of our protocol comes from typhoons. Typhoons move according to their eyes' mobility. In our protocol, update area of resource holder is centered at *S* and moves according to *S*'s mobility. Similar, query area of requester *Q* is centered at *Q* and moves according to *Q*'s mobility.

We assume that there exists a hash function which can map each resource name to a local coordinate. For simplicity, we call grids to be *buddies* if their local coordinates are the same to the local coordinate that the queried resource is mapped to. Suppose that queried resource *R* is mapped to a local coordinate (i.e., $\langle 0,0\rangle$ to $\langle L-1, L-1\rangle$), say $\langle 1,0\rangle$. For example, nine dark gray grids in Fig. 3.1 are buddies for resource *R*. In our protocol, each resource holder stores its location information in buddies in its update area, and each requester sends its query to buddies in its query area to obtain resource holders' location information. Clearly, large update/query area results in high successful query rate but also leads to high cost. There is a trade-off between improving successful query rate and reducing cost

In this paper, we introduce two resource sharing mechanisms, *nearest storing finite search* (*NSFS*) resource lookup protocol and *buddy grid referencing* (*BGR*) resource lookup protocol, for query cost critical applications and update cost critical applications, respectively.

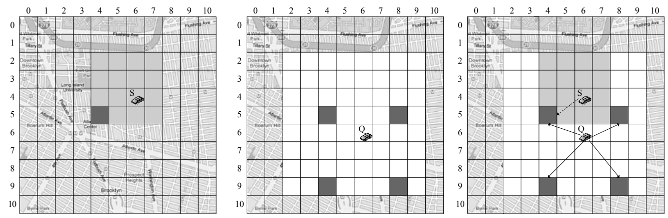
A. Nearest Storage Finite Search (NSFS)

Consider the case that the number of updates is much more than the number of query. In order to reduce the communication cost, we reduce update cost by reducing the size of update area.

In NSFS, an update area is a small square with side length *L* that there is only one buddy in it. That is, for each update, there is a quorum responsible for resource holder *S* (i.e., the only one buddy in S's update area). For example, in Figure 3.2(a), car *S* is located in grid (4, 6) and the light gray area from grid (2, 4) to grid (5, 7) is *S*'s update area. Since resource *R* is hashed to local coordinate $\langle 1,0\rangle$, *S* stores its resource information (i.e., resource name, *S*'s location information, and etc) to the only one buddy (i.e., grid (5, 4)), in its update area. Notice that no matter where the buddy is, update distance is smaller than *L* since *S* is located at the center of *S*'s update area.

In order to improve the successful query rate, *query area* is a larger square with side length 2*L* (i.e., twice of update area's side length). Notice that there are four buddies in an NSFS's query area. For each query, requester send its query to the four buddies in its query area for searching resource holders' information. As Figure 3.2(b) illustrated, car *Q*'s query area is composed of white grids from (2, 2) to (9, 9). And Q sends its query to the four dark gray grids for obtaining information of holders of resource *R*.

In NSFS, resource holder *S* stores its information in only one buddy in *S*'s update area, while requester *Q* sends queries sequentially to four buddies in *Q*'s query area (see Figure 3.2(c)). Since the number of updates is much more than that of queries, NSFS has lower total cost in this case.



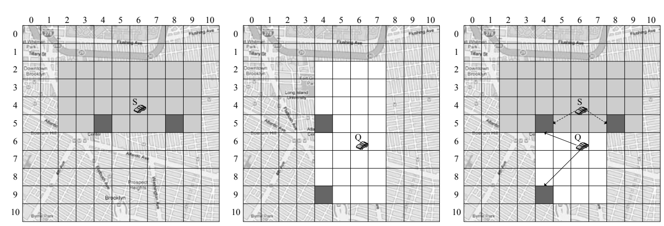
(a) (b) (c)

Figure 3.2: NSFS scheme. (a) An update area. Gray area is *S*'s update area if *L*=4. Grid (5, 4) is the buddy. (b) A query area. Q's query area is composed of white grids. Four dark grids are buddies. (c) An example of NSFS scheme.

On the contrary, when the number of queries is much more than the number of updates. In order to reduce the communication cost, we reduce update cost by reducing the size of query area. We can choose the query area to be a square with side length *L* and the update area to be a square with side length 2*L*.

B. Buddy grid Reference (*BGR*)

We propose another lookup protocol called *Buddy grid Reference* (*BGR*) for the case that the number of updates is not much higher/lower than the number of queries. In BGR, query area's size is the same to that of update area. The update area in BGR is a *L*×2*L* rectangle, while query area in BGR is a 2*L*×*L* rectangle (see Figure 3.3(a) and Figure 3.3(b)). Clearly, there are two buddies in an update/query area. Each resource holder *S* stores its information to two buddies in its update area, while requester *Q* sends its query to two buddies in its query area for querying resource *R* (see Figure 3.3(c)).



(a) (b) (c)

Figure 3.3: BGR scheme. (a) An update area. Gray area is *S*'s update area. Grids (5, 4) and (5, 8) are buddies. (b) A query area. White area is *Q*'s query area. Grids (5, 4) and (9, 4) are buddies. (c) An example of BGR scheme.

IV. Performance Evaluation

In this Section, we compare the performance of BGR, NSFS, RLSMP [10], flooding based and GHT [13].

We use ns-2 and VANETMobiSim to simulate the performance of aforementioned protocols. We use VANETMobiSim to simulate the moving behavior of vehicles on the roads. There are seven vertical roads and seven horizontal roads and 400 vehicles in every 4000 meters × 4000 meters area. Vehicles have speed varied from 0 to 60 km/hr and random destinations. Traffic lights change every 30 seconds. We use ns-2 to simulate the wireless networks, and the communication range is 250 meters. The moving information of each node is provided by VANETMobiSim. There are ten requesters per minute. If the requester are fail to get resource, they would request again in next minute. The network is divided into uniform sized grids. Each grid has side length 500 meters × 500 meters. There are three kinds of network sizes, small, medium, and large (see Table 4.1).

Four performance measures: successful query rate, average hop counts of lookup resource, average hop counts of querying data, total number of update and total hop counts of update, are considered. In RLSMP, the cluster size is equal to the query area in each scenario.

Table 4.1: The detail in each scenario

	Small	medium	Large
Network size (m^2)	4000×4000	8000×8000	12000×12000
Update area (grid)	4×4	8×8	12×12

4.1 Successful query rate

Figure 4.1 shows that flooding protocol with 80 hops, RLSMP, and GHT have nearly 100% successful query rate. Although flooding with 20 hops, NSFS, and BGR have lower successful query rate initially (because only vicinity of requesters are searched), they have near the same successful query rate with the other two protocols after 3 minutes. This is because the number of resource holders increases over time (i.e., requesters which successful get the resources become resource holders), which enhances the spatial locality between the requesters and resource holders. BGR has higher successful query rate than NSFS in first 3 minutes because more locations are used to store the information of resource holders in BGR.

4.2 Query cost

Figure 4.2 shows the simulation result of obtaining the information of resource holders. 80-hop flooding has highest cost because request packets are always transmitted 80 hops no matter they have or have not met resource holders. GHT has second highest query cost because resource holders information are stored in a fixed grid corresponding to resources' name. Although in RLSMP, BGR, and NSFS, resource holders' information are stored in resource holders' vicinity, RLSMP have higher cost than that of BGR and NSFS. RLSMP has lower successful query rate in requesters' cluster, and hence request packets have to be forwarded to other clusters, which leads to higher cost.

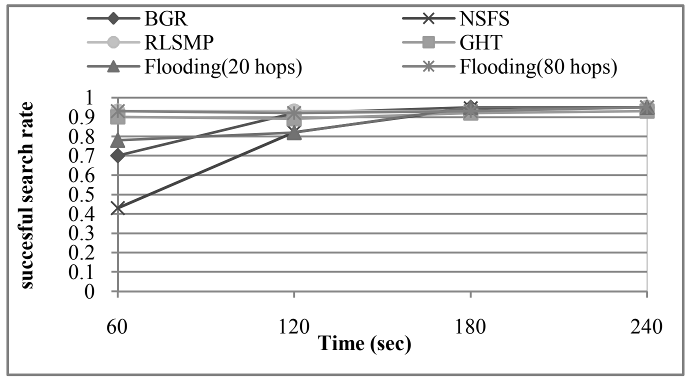


Figure 4.1: Successful query rate.

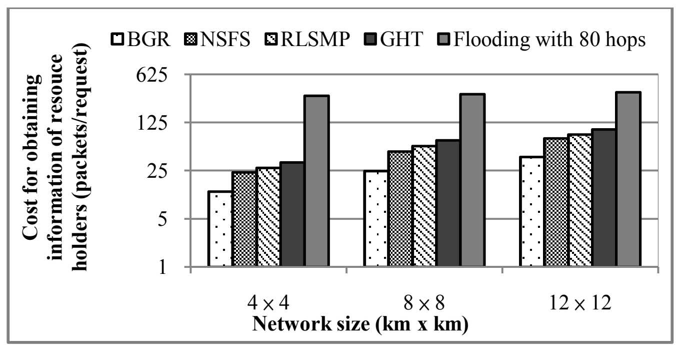


Figure 4.2: Average hop counts of request.

In Figure 4.3, we present the average hop counts of querying a resource, including the hop counts for finding the information of resource holders and the hop counts for finding a resource holder. Flooding protocol has lowest hop counts because requesters could always find out a resource holder by a shortest path (since the request packet is transmitted to the whole network) and there is no need to find information of resource holders. GHT protocol has the largest hop counts because the location for storing the information of resource holders is independent of the locations of requesters and resource holders, i.e., they may be far from each other two. RLSMP has more hop counts that BGR and NSFS because RLSMP spends more hop count in finding the information of resource holders.

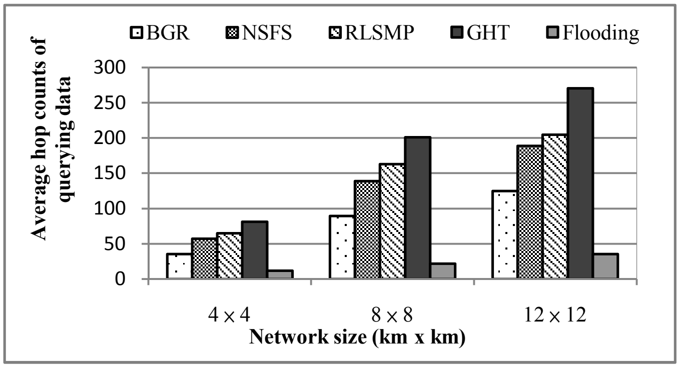


Figure 4.3: Average hop counts of querying data.

4.3 Update cost

Figure 4.4 shows the simulation results of update cost. NSFS has the lowest update cost because resource holders only store their information in their vicinity. BGR's update cost is higher than both NSFS's and RLSMP's because there are two grids responsible for storing a resource holder's information in BGR while there is only one such grid in NSFS and RLSMP. BGR store each resource holder's information in two grids (i.e., buddy grids) for increasing the successful query rate. GHT has the highest hop counts of update, because resource holders need to update their resource information to fix grids. The difference between our protocols and GHT would be large especially when the network size is large, because the size of query area could change as the change of environment.

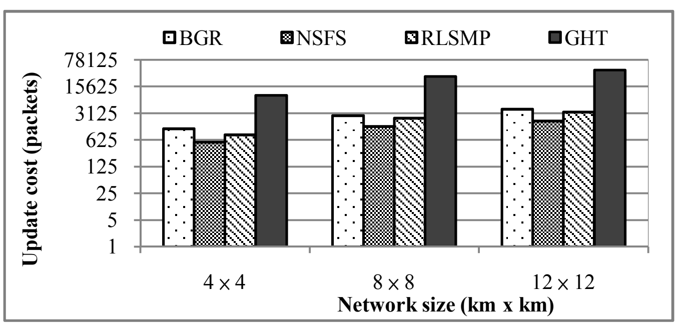


Figure 4.4 Total hop counts of update.

V. CONCLUSION

In this paper, we propose the concept of locality for the resource sharing in VANET. We also analyze the successful query rate, update latency and search latency. We could adjust our mechanism according to our analysis result in the different scale of environment. According to the simulation results, our protocol has lower search cost and lower update cost than GHT and RLSMP. The successful query rate would be the same as GHT and RLSMP after some duration.

REFERENCES

[1] ASTM E2213-03, "Standard specification for telecommunications and information exchange between roadside and vehicle systems — 5 GHz band dedicated short range communications medium access control and physical layer specifications," *ASTM Int'l.,* 2003.

[2] M. Abuelela and S. Olariu, "ZIPPER: a zero-infrastructure peer-to-peer system for VANET," *Proceedings of the ACM Workshop on Wireless Multimedia Networking and Performance Modeling*, 2007.

[3] Y. J. Chang and S. Y. Wu, "Intersection location service for vehicular ad hoc networks with cars in Manhattan style movement patterns," *Proceedings of the IEEE Conference on Ubiquitous Intelligence and Computing*, 2008.

[4] Y. C. Chen and J. P. Sheu, "Interest-based lookup protocols for mobile ad hoc networks," *The Journal of Information Science and Engineering*, 2006.

[5] M. D. Dikaiakos, A. Florides, T. Nadeem and L. Iftode, "Location-aware resources over vehicular ad hoc networks using car-to-car communication," *The IEEE Journal on Selected Areas in Communication*, 2007.

[6] S. Haibin, M. Qi and M. Aidong, "P2P Computing in design of VANET routing protocol," *Proceedings of the International Conference on Networking and Mobile Computing*, 2007.

[7] I. Leontiadis, "Publish/subscribe notification middleware for vehicular networks," *Proceedings of the International Conference on Middleware Doctoral Symposium*, 2007.

[8] J. Y. Li, J. Jannotti, D. S. J. D. Couto, D. R. Karger and R. Morris, "A scalable location resource for geographic ad hoc routing," *Proceedings of the International Conference on Mobile Computing and Networking*, 2000.

[9] J. Rybicki, B. Scheuermann, W. Kiess, C. Lochert, P. Fallahi and M. Mauve, "Challenge: peers on wheels – a road to new traffic information systems," *Proceedings of the ACM International Conference on Mobile Computing and Networking*, 2007.

[10] H. Saleet, R. Langar, O. Basir and R. Boutaba, "Proposal and analysis of region-based location service management protocol for VANETs," *Proceedings of the IEEE Conference on Global Telecommunications, 2008*.

[11] B. Shrestha, D. Niyato, Z. Han, and E. Hossain, "Wireless access in vehicular environments using bitTorrent and bargaining," *Proceedings of the IEEE Global Telecommunications Conference*, 2008

[12] S. Wan, J. Tang, R. S. Wolff, "Reliable routing for roadside to vehicle communications in rural areas," *ICC*, 2008.

[13] C. Wewetzer, M. Caliskan, A. Luebke and M. Mauve, "The feasibility of a search engine for metropolitan vehicular ad hoc networks," *Proceedings of the IEEE Global Communication Workshops*, 2007.