On the Performance of a Method for Efficient Aggregation of Demands Distribution for Location-Dependent Information Using Soft-State Sketch in VANET

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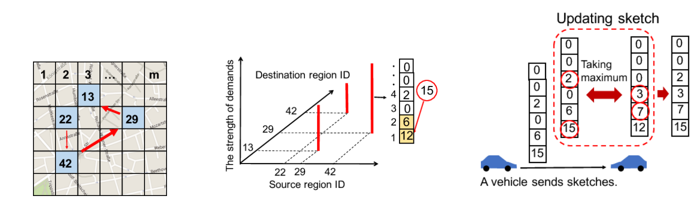
I. Introduction

When we drive a car, we often want information of the location where we will go. Ishihara et al. proposed a VANET based information sharing system that a vehicle obtains a picture of the driver's Point of Interest (POI) via a VANET and show it to the driver when he/she inputs his/her POI[1]. If vehicles broadcast picture data of POI to disseminate the data to all vehicles when taking the picture, pictures that are not required can be sent, and the network load will be high. Therefore, to disseminate Location-Dependent Information (LDI), e.g. a picture of a POI, to as many vehicles that want it as possible with small traffic, a data dissemination scheme based on a Demand map (Dmap) is proposed[1]. In the scheme, each vehicle has a Dmap, a data set describing geographical distribution of strength of demands for LDI, and it exchanges partial data of its Dmap (Dmap Information: DMI) with other vehicles via a VANET. Each vehicle preferentially sends strongly demanded LDI to vehicles on routes to areas that contain many vehicles that want the LDI. Frequency of sending DMI and the size of DMI that vehicles send at a time affect the network load and how accurately a Dmap on each vehicle reflects the geographical distribution of recent actual demands. In this paper, we propose a method for determining which vehicles send DMI and when vehicles send DMI, and a method for selecting DMI to be sent. In addition, we evaluate the effect of the proposed methods on the accuracy of Dmaps.

II. Methods for sending DMI

A. Data dissemination scheme based on Dmap

If a vehicle that has LDI knows where vehicles that want the LDI are and how strong they want it, the vehicle may be able to send the LDI via the optimal route so that many vehicles that want the LDI can receive the LDI. A Dmap represents geographical distribution of strength of demands for LDIs. To represent a Dmap, we divide the roads into multiple regions and give an ID to each region (Fig. 1. (a)). We call a region where a vehicle requesting LDI exists a source region s, and call a region whose LDI is requested by a vehicle a destination region d. An entry of a Dmap represents the strength of demands from each s to each d (Fig. 1 (b)).

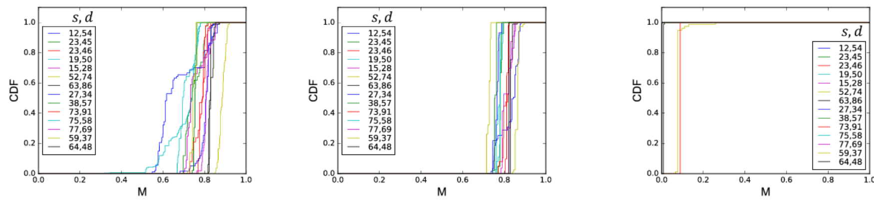


(a)Regions in Dmap (b)Concept of Dmap (c)Updating sketches

Fig. 1. Dmap and how to use sketches in Dmap

The simplest way to create a Dmap is to collect all log data concerning demands from all vehicles in the area covered by the Dmap. However, if vehicles follow this way, they need to manage large data. Therefore, we represent a Dmap using soft-state sketch[3], a data structure to stochastically estimate the number of unique data. Each vehicle has k ($k \geq 1$) sketches (sets of sketches: SS), arrays of non-negative integers per pair of s and d (Fig. 1 (b)). When a vehicle in a region j demands LDI of a region r, it randomly selects one of sketches for a pair of the source region j and the destination region r, and puts the initial TTL (Time To Live) value for the demand into i-th element of the sketch with probability $1/2^i$. Each vehicle sends SSs with a beacon that it sends periodically. When a vehicle receives an SS from other vehicles, it merges the received SS with its SS for a pair of the source and destination is the same as received one by selecting a larger value in values of each element of its SS, and the received SS and setting the value as a new value to each element (Fig. 1 (c)). A vehicle estimates the number of demands based on the run lengths of non-zero value from element with index 0 in sketches in an SS.

Fig. 3. LDI transfer zone $A_{s,d}$



(a) With random method (b) With HPRU&P method (c) With HPFU + HPRU&P method

Fig. 4. CDF of accuracy of Dmap (M) at 900 seconds

B. Proposed methods for sending DMI

1) High priority to frequent sketches updater (HPFU) method: If vehicles exchange DMI (SS) frequently, accuracy of their Dmaps will become high because soft-state sketch is a data structure to stochastically estimate the number of unique data and large number of samples will improve the accuracy of estimation. However, if vehicles frequently exchange SSs, the network load becomes high. Therefore, vehicles should adjust the frequency to send SSs. Vehicles that frequently update sketches may gather SSs from many vehicles and their sketches may be more accurate than sketches held by vehicles that rarely update sketches. Therefore, in our method, vehicles that frequently update sketches send SSs preferentially. To this end, each vehicle sends the Total Count of Updating Sketches (TCUS) during a past certain period with a beacon. When each vehicle sends a beacon, it compares the TCUSes of vehicles in the vicinity and its TCUS. Then, if its TCUS is in top h of them, the vehicle selects some SSs and give high priority to recently updated SSs considering the vehicle's position as described below, then sends them with a beacon.

2) High priority to recently updated sketches and considering vehicle's position (HPRU&P) method: To decrease the network load when vehicles send SSs, vehicles need to select SSs that are appropriate to increase the accuracy of their Dmaps. SSs that are more recently updated should have high priority. In addition, vehicles that are on the route for delivering data from a destination region d to a source region s (We call a region that contain this route an LDI transfer zone) should grasp actual demands from s to d because they will be involved in delivery of LDI of d. To this end, each vehicle selects SSs that it sends as shown below.

At first, a vehicle v that sends SSs selects top-k recently updated SSs from its SSs and regards them as a set $\boldsymbol{L}_v$. Second, the vehicle regards a rectangular region that consists of a diagonal whose ends are s and d as an LDI transfer zone $A_{s,d}$ (Fig. 3). It selects SSs $S_{v,s,d}$ whose pair of s and d satisfies $P \in A_{s,d}$ from $\boldsymbol{L}_v$, where P is v's current region, and regards them as a set $\boldsymbol{L}'_v$. If v sends only recently updated SSs, the same SSs may be sent from multiple vehicles and updated frequently. Then, the accuracy of Dmaps of the vehicle will be degraded. Therefore, v randomly selects n SSs from $\boldsymbol{L}'_v$.

III. Evaluation of proposed methods

To evaluate the accuracy of Dmaps in case of using the proposed two methods, we conducted simulation using *Scenargie*[4], a network simulator. In our scenario, there are seven double lane 2km-roads in the simulation square area. We divided this area into small regions that have 200m per side and gave an ID to each region. Vehicles in regions which are predefined demand LDI of regions which are predefined.

We use the ratio of coincidence between the actual number of demands and the estimated number, M, as a performance metric to evaluate the accuracy of a Dmap. M is defined as follows.

$$M = 1 - \min\{1, |R - D|/R\}. \tag{1}$$

D is the number of demands estimated from a Dmap. We evaluate M for (s, d) of only vehicles that are in region $A_{s,d}$ at the time point of analysis because vehicles in LDI transfer zone should grasp actual demands for (s, d) to deliver LDI.

CDF of M at 900 seconds in the simulation are shown in Fig. 4. As shown in Fig. 4. (a) and (b), the great part of vehicles have large M values in a case (b) where vehicles select SSs according to HPRU&P method and send them with every beacon compared with a case (a) where vehicles randomly select SSs and send them with every beacon. Additionally, as shown in Fig. 4. (c), almost all of vehicles have low M values when they determine whether they send SSs according to HPFU method and select SSs according to HPRU&P method. The reason of this is that demands are overestimated. Since in this case, vehicles that update SSs frequently send recently updated SSs, then the remaining TTLs of sketch elements after receiving the SSs are hard to become zero, while TTLs of sketch elements of other SSs easily become zero.

IV. Conclusion

In this paper, we proposed methods for efficiently exchanging data of Dmap, information of graphical distribution of the strength of demands for LDI in a VANET. The simulation results show that HPRU&P method improves accuracy of Dmaps and decreases communication traffic. Designing an improved method for selecting vehicles that send Dmap data to increase the accuracy of Dmaps is remained for future work.

References

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