A Technique for Information Sharing using Inter-Vehicle Communication with Message Ferrying

Takashi Shinkawa, Takashi Terauchi, Tomoya Kitani, Naoki Shibata†,
Keiichi Yasumoto, Minoru Ito, and Teruo Higashino††

Graduate School of Information Science, Nara Institute of Science and Technology
Ikoma, Nara 630-0192, Japan {taka-shi,takash-t,t-kitani,yasumoto,ito}@is.naist.jp
†*Department of Information Processing and Management, Shiga University*
Hikone, Shiga 522-8522, Japan shibata@biwako.shiga-u.ac.jp
††*Graduate School of Information Science and Technology, Osaka University*
Suita, Osaka 565-0871, Japan higashino@ist.osaka-u.ac.jp

Abstract

In this paper, we propose a method to realize traffic information sharing among cars using inter-vehicle communication. When traffic information on a target area is retained by ordinary cars near the area, the information may be lost when the density of cars becomes low. In our method, we use the message ferrying technique together with the neighboring broadcast to mitigate this problem. We use buses which travel through regular routes as ferries. We let buses maintain the traffic information statistics in each area received from its neighboring cars. We implemented the proposed system, and conducted performance evaluation using traffic simulator NETSTREAM. As a result, we have confirmed that the proposed method can achieve better performance than using only neighboring broadcast.

1 Introduction

In these days, the traffic jam in urban areas is becoming a big problem in many countries [1]. In Japan, as one of traffic information dissemination systems, VICS (Vehicle Information and Communication System) is widely used [2]. VICS provides latest traffic information to cars via FM broadcast and various types of beacons. However, in VICS, all of traffic information must be gathered to one place to be processed and formatted before broadcast. Thus, a little time lag could be introduced between received information and current situation. Moreover, special devices are required to collect traffic information. So, VICS provides traffic information mainly on highways or trunk roads.

Recently, inter-vehicle communication protocols have been proposed, where cars exchange information with each other in real time using multi hop communication of wireless LANs [3, 4]. Refs.[5, 6] have proposed inter-vehicle protocols with higher information arrival rate for realistic environments by adjusting communication timings depending on traffic flows generated by traffic simulator NETSTREAM [7]. Those protocols aim to propagate simple information among cars in a relatively narrow area.

In our previous work [8], we have proposed a method for traffic information sharing among cars using inter-vehicle communication. This method divides a target road system to fixed sub-regions called *area*s. Each car measures time to pass an area for each pair of roads entering/exiting the area, and generates traffic information statistics from the information received from cars which passed the same pair of roads. Cars exchange and aggregate traffic information of each area using inter-vehicle communication. In this method, each car holds statistics information of only current area and its neighborhood areas. Consequently, it becomes a problem that traffic information statistics may be lost when a density of cars becomes temporarily low.

To mitigate this problem, in this paper, we use the message ferrying technique [9]. We use buses which travel through regular routes, as message ferries. We suppose that buses have larger storage than other vehicles, and hold traffic information statistics of all areas received from neighboring vehicles. Thereby, we attempt to avoid losing traffic information statistics. We also let buses measure time to pass each area by themselves in order to provide traffic information on areas with few cars.

We implemented above mechanisms to traffic flow simulator NETSTREM and evaluated usefulness of our proposed method. As a result, we have confirmed that the proposed method can maintain traffic information more stably than our previous work without ferries.

2 Traffic Information Collection by Inter-Vehicle Communication

In this section, we briefly explain about our previous work for collecting traffic information by inter-vehicle communication [8]. Then, we identify problems in our previous work.

2.1 Overview of our previous work

Our purpose is to allow cars to autonomously collect traffic information and estimate the arrival times at their destinations, without special infrastructures such as VICS system [2], which consists of special devices and servers.

Our previous work only requires each car to equip with wireless LAN device (such as IEEE802.11b), GPS device and car computer with small amount of memory and hard disk drive which stores road map. Latest car navigation systems equip with most of the above devices.

We assume that road map is given as a graph consisting of *node*s and *link*s, where nodes represent intersections and links do roads between two neighboring intersections.

In order to collect traffic information efficiently, we adopted the following policy.

- We divide the road map into rectangular regions (with several hundreds meter sides) called *area*s. A unique ID is assigned to each area. We assume that all car computers have the border information with the road map.
- We let each car autonomously measure the time (called *area passing time*) to pass each area using GPS device. In order to consider the influence of traffic lights and turns at intersections, the area passing time is accumulated and averaged over samples with the same pair of incoming link and outgoing link. This pair is called *linkpair*, hereafter.
- We let each car broadcast a data including area passing time and the car ID so that neighboring cars receive it and calculate statistics information (i.e., average area passing time) for each linkpair. The statistics information is also exchanged between cars by broadcast.

2.1.1 Measurement of area passing time

For example, in Fig. 1, suppose that dotted lines show area border. In Fig. 1, there are five links $\alpha, \beta, \gamma, \delta$ and ϵ which stride over the area border in the center area. In this area, there are $5 \times 4 = 20$ linkpairs. So, for this area, the statistics information for these 20 linkpairs is generated by inter-vehicle communication.

The measurement of area passing time is carried out as follows: (1) when a car notices by GPS that it crosses area border and enters a new area A, it records the area ID of A, the ID of the link (il) on which the car is running as incoming link, and the current time T; (2) When the car crosses the area border again, it records the ID of the link (ol) on which it is running as outgoing link, and the elapsed time from T as the area passing time of linkpair (il, ol). Then, it repeats the procedure from (1).

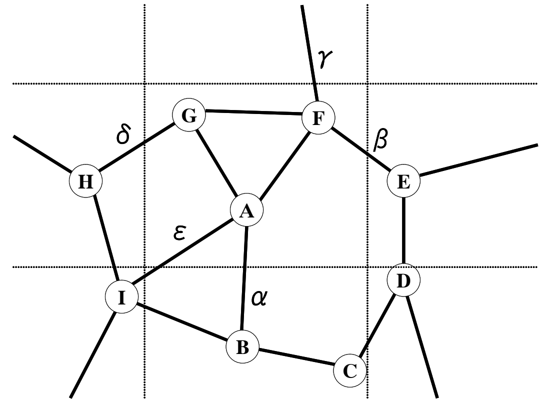

Figure 1. The example of the area passage

When each car generates the area passing time, it broadcasts the data to its radio range. Other cars generate the statistics information from bunch of received data including area passing times and propagate the statistics data by inter-vehicle communication.

2.1.2 Treatment of Statistics Information

If the number of received data items of area passing times increases, cars may not be able to exchange the data items with other cars by broadcast, because the available bandwidth is limited. So, we introduce a threshold C to denote the maximum number of data items on area passing time. Each car can hold C data items on area passing time per linkpair for the maximum. When the number of data items exceeds C, statistics information is generated by averaging over C area passing times. In order to avoid duplicated count of statistics data, a hash value calculated by car IDs contained in data items on area passing times is attached to each statistics data.

Each car broadcasts both data items on area passing time and statistics data which it holds. When other cars receive statistics data on a linkpair, it compares its hash value with that of the statistics data on the same linkpair. If two hash values are identical, the received statistics data is discarded.

Each car retains the data generated for a set of areas called *responsible areas*. The responsible areas of each car contain the area where the car is running and its neighboring areas. When each car crosses the area border, the data outside its responsible areas are discarded.

2.2 Problems

As explained in the previous section, in our previous work, traffic information on an area is retained by cars whose responsible areas contain the area. So, when density of cars in an area decreases temporarily, the collected traffic information may be lost completely.

In this paper, we try to mitigate this problem using the message ferrying technique proposed in [9]. The purpose of message ferrying is to achieve efficient data propagation in disconnected ad hoc networks. In this technique, all nodes are classified into regular nodes and message ferries. Here, regular nodes move freely, but ferries move regularly along the known routes. Regular nodes send messages to ferries or receive messages from ferries. Ferries can collect messages from regular nodes, move to other disconnected portion of ad hoc networks, and send the collected messages there.

Our basic idea is to use buses as ferries in our traffic information collection system.

3 Proposed Method

We use buses as message ferries to improve efficiency of message propagation for the following two cases.

case1: Traffic information of an area is lost when car density of the area becomes low temporarily.

case2: Cars cannot obtain traffic information of an area when there is no other car with the latest traffic information on the area.

We suppose that buses equip with devices described in Sect. 2, similarly to normal cars, where the buses have HDDs with larger capacities.

For case1, we let buses keep statistics information received from other normal cars or buses on all areas and disseminate the information to normal cars periodically to mitigate information loss on areas with low car density.

For case2, we let buses disseminate statistics information collected in the past (e.g., the information received when the bus passed the area) and the area passing time which they measured by themselves.

Amount of statistical information which each bus retains increases as time passes, if the bus does not discard any information. Also, the bus may not be able to disseminate all of information stored in its HDD due to limitation of available bandwidth of the wireless network. So, we let buses disseminate statistical information of the current area and its neighboring areas. If the bus has multiple versions of statistical information on the same area, only the latest information is sent.

4 Experimental Results

In order to investigate the impact of our proposed method on information propagation efficiency, we have implemented our method and conducted simulation with traffic flow simulator NETSTREAM [7] developed by Toyota Central R&D Labs.

4.1 Simulation of Inter-Vehicle Communication

We implemented a network simulator which communicates with NETSTREAM every second. Our simulator simulates inter-vehicle communication as follows.

Radio ranges of buses and normal cars were set to 100 meters. When multiple cars including buses broadcast traffic information at the same time in a radio range, packet collisions may occur. So, we divide one second to 100 time slots with 10ms, and give each car which wants to send data a timeslot decided by generating a random value between 0 and 99. When multiple cars with the same value are in a radio range, we consider that packet collision occurred between those cars.

In order to limit the maximum available bandwidth in the simulation within actually available bandwidth of IEEE 802.11b, we divided each area into several sub-areas called *communication area*s with 200 meter sides, and only 150 Kbytes of packets can be broadcast per second in each communication area. We approximate the ratio P of each car's successful packet reception depending on the distance between the sender and the receiver by the following formula.

$$P = 0.98\left(1 - \frac{x}{D}\right) \tag{1}$$

Here, x is the distance between two cars, and D is the maximum distance capable of communication (i.e., radius of a radio range).

4.2 Simulation Configuration

For simulation, we used the following road system as shown in Fig. 2: the field size is about 1.2km $\times$ 1.2km, the size of each area is 300m $\times$ 300m, the size of communication area is 200m $\times$ 200m, the number of *node*s (intersections) is 19, the number of *link*s is 78, and the legal speed limit of each link is 16.6m/s (60km/h). We assume that all cars equip with car computers which execute our method.

We let each car broadcast the area passing time as soon as it is measured, and broadcast the traffic information statistics which the car retains every 5 seconds. Radius of the radio range is 100 meters for both buses and normal cars, the maximum amount of broadcast packet is 150Kbytes per second in each communication area. We kept the car density somewhat low by regulating the number of cars in the simulation to 70 (0.007 cars/m^2) for the maximum.

We specified two different routes a and b in the road system as shown in Fig. 2, and let buses follow routes a and b every 5 minutes and 7 minutes, respectively. The movement

Table 1. Number of Cars Retaining Traffic Information

	Route $C-D-E$ on bus route a				Route $A-G-J$ on bus route b				Route $M-N-R$ not on bus route			
time	without buses		with buses		without buses		with buses		without buses		with buses	
(min)	cars	all cars	cars	all cars	cars	all cars	cars	all cars	cars	all cars	cars	all cars
10	3	25	4	27	2	11	6	10	0	17	0	18
20	0	40	0	43	10	16	15	18	8	18	9	18
30	0	52	0	53	2	17	16	18	0	33	0	31
40	0	38	19	39	6	10	10	10	6	27	5	30
50	1	37	5	36	1	11	10	11	4	17	4	17
60	8	18	8	18	2	6	0	5	3	9	3	9

of normal cars is specified by adjusting traffic of the routes configured with NETSTREAM. Here, we considered routes $C-I-L-N-R$ and $F-L-K-J$ to be the main road and specified that the car density on the roads becomes higher than other links.

Using the above configuration, we conducted the simulation for 60 minutes.

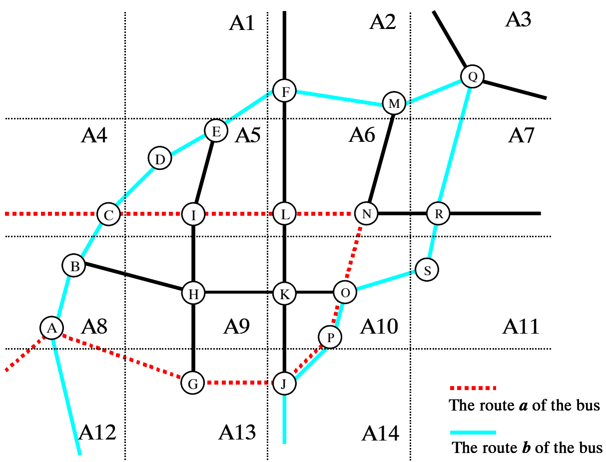

Figure 2. Bus Routes

4.3 Experimental Results and Consideration

We compared the numbers of cars which retain traffic information statistics between two cases: with and without buses. We focused on the following three routes: $C-D-E$ in area $A5$, $A-G-J$ in area $A13$, and $M-N-R$ in area $A6$. Here, route $C-D-E$ and $A-G-J$ are on bus routes a and b, respectively. On the other hand, route $M-N-R$ is not on any bus routes. We show the results for these three routes in Table 1. Here, *time* shows the time elapsed since simulation started, and *cars* and *all cars* represent the number of cars where statistics information can be obtaind by each car through our method and the number of cars which actually passed the route, respectively.

For routes $C-D-E$ and $A-G-J$, we see that there are more cars which keep traffic information when we use buses than the case without buses. Especially on route $A-G-J$, the impact of using buses is prominent. At time 20 and 30 for route $C-D-E$, there is no improvement by buses. This is because there were no cars in the radio ranges of the bus during this time interval. For route $M-N-R$, we see that there is almost no effect by buses since the cars following this route can hardly communicate with buses.

From the above result, we believe that our proposed method makes it possible to maintain traffic information to a certain extent even when car density becomes low temporarily.

5 Conclusion

In this paper, we proposed an extension of our previous work to improve efficiency of traffic information sharing using inter-vehicle communication. We implemented the proposed method and experimented with traffic simulator NETSTREAM. As a result, we have confirmed that our method based on the message ferrying technique improves the efficiency to a certain extent. As part of future work, we enhance our method to utilize ferries more aggressively to further improve efficiency of traffic information sharing.

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References

[1] Ministry of Land Infrastructure and Transport, "The traffic jam conditions of the Japanese whole country", http://www.mlit.go.jp/road/ir/data/jutai/index-d.html

[2] Ministry of Land Infrastructure and Transport, "The system outline of VICS", http://www.its.go.jp/etcvics/vics/

[3] B. Xu, and O. Wolfson, “Opportunistic Resource Exchange in Inter-vehicle Ad-hoc Networks”, *Proc. of 2004 IEEE Int’l Conf. on Mobile Data Management (MDM 2004)*, pp.4–12 , Jan. 2004.

[4] T. Nadeem, S. Dashtinezhad, and C. Liao, “Traffic view: A Scalable Traffic Monitoring System”, *Proc. of 2004 IEEE Int’l Conf. on Mobile Data Management (MDM 2004)*, pp.13–21 , Jan. 2004.

[5] M. Saito, M. Funai, T. Umedu, and T. Higashino, “Inter-vehicle Ad-hoc Communication Protocol for Acquiring Local Traffic Information”, *Proc. of 11th World Congress on ITS*, CD-ROM 4066.pdf, Nov. 2004.

[6] M. Saito, J. Tsukamoto, T. Umedu, and T. Higashino, “Evaluation of Inter-Vehicle Ad-hoc Communication Protocol”, *Proc. of 19th Int’l Conf. on Advanced Information Networking and Applications (AINA2005)*, pp.78–83 , Mar. 2005.

[7] E. Teramoto, M. Baba, H. Mori, H. Kitaoka, I.Tanahashi, Y. Nishimura, et. al., “Prediction of Traffic Conditions for the Nagano Olympic Winter Games Using Traffic Simulator : NETSTREAM”, *Proc. of 5th World Congress on Intelligent Transport Systems*, Vol.4, pp.1801–1806, Oct. 1998.

[8] T. Terauchi, N. Shibata, K. Yasumoto, T. Higashino, and M. Ito, “A Propagation Method of Congestion Information Using Inter-vehicle Communication for Alleviation of Traffic Jam”, *IPSJ SIG Technical Reports*, 2005-ITS-22, pp.71–76, Sep. 2005. (in Japanese)

[9] W. Zhao, and M. H.Ammar, “Message Ferrying: Proactive Routing in Highly-partitioned Wireless Ad Hoc Networks”, *Proc. of 9th IEEE Workshop on Future Trends of Distributed Computing Systems (FT-DCS 2003)*, pp.308–3014, May 2003.