Encourage for VANET Based Traffic Information Sharing System on BRTS

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Abstract—In this paper, I propose a process which proficiently accumulate, maintains and proliferate traffic information using inter-vehicle communication with “Message Shipping” technique used in vehicular ad hoc network (VANET). In the proposed process, we use buses (Bus Route Transit System) as message shipping which travel along regular routes. In that instruct to develop information proliferate proficiently in low-density areas, buses accumulate as much traffic information as possible from four wheeler in their propinquity, and regularly broadcast the gathered information to nearest four wheeler. I have to implement the proposed system on the traffic simulator NETSTREAM / SUMO and compared information proliferate proficiency between my proposed process and a procedure which uses inter-vehicle communication amid only normal four wheeler. In the simulation, the proposed process improved the proficiency up to 45%.

I. INTRODUCTION

In recent times, the research of wireless communication technologies, Intelligent Transport Systems (ITS) [1] have been attracting public attention. ITS is expected to resolve the traffic’s critical problems as well as traffic accidents and traffic jams by unauthorize traffic information amid corridor and four wheeler by wireless communication. Recently, in Japan, China several services are already available, such as ETC (Electric Toll Collection System) [2] and VICS (Vehicle Information and Communication System) [3]. ETC allows drivers to pass tollbooths without stopping for payment. VICS granting information of traffic jams and road construction places to drivers by Radio Channel broadcast and optical signal on the roadside so that their four wheeler steering systems can display congested areas/roads on the map and routing them avoiding those areas. Even though VICS is valuable, there could be some time interval between the scattered information and the live situation, because it gathered all traffic congestion information from the electronic device on roadside to central place (e.g., a central server), and broadcast it after dispensation. Moreover, VICS desires many electronic devices installed on the roadside for supervise traffic conditions, and consequently it is pricey to cover every where in a city.

To focus on these problems, many researches about inter-vehicle communication have been proposed to realize fast and efficient dissemination of traffic information [4]-[9]. Our previously proposed method [4] divides a target geographical region into fixed sub-regions called areas. Each car measures time to pass an area, and generates traffic information statistics from the information received from cars with inter-vehicle Communication. Each car retains information of only current Area and its neighboring areas (hereinafter, we call it responsible areas). Consequently, it becomes a problem that traffic information statistics may be propagated to only a few cars or may be lost when a density of cars becomes temporarily low.

In this paper, we use the message ferrying technique [10] to address the above problem. It uses routine-run vehicles as ferries to relay information between cars which cannot converse directly. We propose a new method using buses as the ferries for traffic information sharing among cars using only inter-vehicle communication. Buses generally go predetermined circular routes on time. Thus it is expected to avoid losing traffic information statistics of areas which buses go along. In the proposed method, we suppose that buses have larger storage than other vehicles and hold traffic information statistics of all areas received from neighboring vehicles. We also make buses measure time to pass each area by them in order to provide traffic information on areas with only a few cars. Moreover, we let cars exchange control packets with buses in advance to get required information efficiently with limited wireless bandwidth. The control packet indicates what kind of information the car needs.

We implemented above mechanisms to the traffic flow simulator NETSTREM / SUMO [11], [12] and evaluated information propagation efficiency between our proposed method and our previous method without ferries. As a result, we have confirmed that the proposed method can collect and maintain about 50% more traffic information.
II. RELATED WORK

Recently, application utilizing inter-vehicle communication has been paid attention thanks to popularization of wireless LAN devices. Using car navigation systems with wireless LAN I/F, cars can exchange traffic information with other cars through ad-hoc communication. Sun et al. have proposed a QoS routing protocol for vehicular ad hoc networks which establishes stable routes of communication considering a vehicular mobility in order to communicate with small delay and low packet loss probability [5]. Nadeem et al. have proposed a scalable traffic monitoring system for inter-vehicle communication considering road conditions [6], and Xu et al. have proposed a protocol for inter-vehicle communication according to time and distance [7]. Saito et al. have proposed a protocol for inter-vehicle communication with high information arrival rate [8], [9]. This protocol adjusts communication timings depending on traffic flows. In the research, a protocol has been designed to improve efficiency of information exchange taking into account packet collision probability. These existing protocols are designed to propagate simple information to relatively close range, and it is difficult for these protocols to accurately estimate traffic jams of wide area and the arrival time at a destination. In our previous work [4], we proposed a method to allow cars to autonomously collect and share traffic information (i.e., area passage time) using only inter-vehicle communication. In this method, a target geographical region is divided into fixed sub-regions called areas. Each car measures time to pass an area with respect to each pair of roads entering to/exiting from the area, and generates traffic information statistics based on the information received from cars which passed the same pair of roads. Four wheeler exchange and aggregate traffic information of each area using inter-vehicle communication. Most of existing researches including our previous work have been studied under the assumption that a density of cars is large enough. Therefore traffic information statistics tends to be lost in areas with low car density.

A. Message Shipping

The message shipping technique aims to achieve proficient data propagation in disconnected ad hoc networks [10]. In ad hoc networks, communications are often unstable due to the limitation of wireless range and node mobility. The ship relays messages between nodes which cannot communicate directly. In this technique, all nodes are classified into regular nodes and message ships. Here, regular nodes move freely, but ships move regularly along the predetermined routes. Regular nodes send messages to ship or receive messages from ships. Ships gathered messages from regular nodes, move to other disconnected portion of ad hoc networks, and send the gathered messages there.

III. PROPOSED PROCESS

In this section, we propose a process to gather and share traffic information proficiently by using buses going predator-mined circular routes on time.

A. A Process for Sharing Traffic Information using Inter-Vehicle Communication among only Four Wheeler

We aim to gather information using short range wireless communication, GPS and small computer on each four wheeler, without using fixed infrastructure on the ground. Similarly, in this paper, we assume that each car has an onboard computer with the following functionalities.

- IEEE 802.11 compliant wireless LAN device
- GPS receiver Device
- Hard disk drive to store traffic information
- Road map data (on HDD)
- Computer system with sufficient power for instantly processing Received information

We amid assume that a given road map can be treated as a graph where each node and each link correspond to an intersection and a road between intersections, respectively.

1) Measuring Area Passage Time: In the proposed process, the target geographical region is divided into square areas with sides of several hundred meters length as shown in Fig. 1. This is to keep away from significantly increasing the amount of traffic information and to manage it efficiently. We assume that each area is assigned a unique ID number and that onboard computer on each car has information regarding to locations of areas and their IDs. We also assume that the size of areas can be changed according to a road density and road shapes.
In the proposed method, when the number of area passage records for a link pair retained in a car reaches a predetermined threshold C (which is 3 to 5, typically), the values of these records are averaged by creating a statistics data called area passage statistics, and the original area passage records are removed. The area passage statistics include the following information (it can contain multiple records for different link pairs) (AreaID, inlinkID, outlinkID, AAPT, MakeTime, hash,)

Here, AAPT denotes the average area passage time of C four wheeler. hash, is calculated from hash values hash, of the original area passage records, and used to avoid redundantly counting the same statistics. Each car regularly broadcasts area passage records and statistics data which it reserves. When a four wheeler receives area passage statistics data from another four wheeler, it compares the hash value of each statistics data which it retains, and stores the received data if it is not already retained. Area passage statistics data have expiration time, and they are discarded after the time elapses from their generation.

3) Data Maintenance and Discard in Inter-Vehicle Communication:

It is not reasonable for each normal vehicle to retain information of all areas for the following reason: Wireless bandwidth of the inter-vehicle communication is limited; storage size of computer equipped at each car is also limited; and information of the areas which are far from current area may not be needed because it is usually old when it is received in current area. In order to address this problem, in our previous work [4], each car retains information of only responsible areas (current area and its neighboring areas). However, in this method, traffic information statistics may be propagated to a few cars or may be lost when a density of four-wheeler is low. For example, after a vehicle passes through area A and generates an area passage record, if there are no vehicle in wireless communication range of the four-wheeler while it goes through the responsible areas of A, that record is discarded without being received by other cars. Moreover, a four wheeler cannot get information of distant areas since each vehicle remains information of only the responsible areas of the current area. In this paper, we focus on the message shipping technique to address this problem.

B. Proposed Process using Buses as Message Ships

The method discussed above assumes that all four wheeler have same equipment and are operated on a same protocol to share traffic information by using inter-vehicle communication. But there are actually various kinds of vehicles. Buses are, especially, routine-run vehicles and they travel predetermined routes.
Therefore, we introduce the message ferrying technique to the above method in order to improve information broadcast proficiency. In the proposed process, we suppose that cars are regular nodes and buses are shipping.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Difference Between Normal Four Wheeler And Buses</th>
</tr>
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<tbody>
<tr>
<td>Normal 4 Wheel</td>
<td>BRTS and Other Buses</td>
</tr>
<tr>
<td>Device</td>
<td></td>
</tr>
<tr>
<td>• IEEE802.11g compliant wireless LAN</td>
<td>• GPS receiver Electronics Device</td>
</tr>
<tr>
<td>• HDD includes Road Map data</td>
<td>• Computerize System with sufficient power</td>
</tr>
<tr>
<td>(HDD capacity)</td>
<td>about 50GB Bigger than Four Wheeler</td>
</tr>
<tr>
<td>Performance</td>
<td>depend on travel with predetermined routes regularly</td>
</tr>
<tr>
<td>Prototype</td>
<td>driver’s</td>
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</tbody>
</table>

We suppose that buses also have devices described in Sec. III-A, similarly to normal four wheeler, but the buses have HDDs with larger capacity. We show the difference between regular cars and buses in Tab. I. In this method, we assume that both the size of an area passage record and an area passage statistics data need several dozen bytes where an element of these data is expressed as a 32bit-integer number. The method needs only several dozen mega bytes for each car even if there are several dozen incoming/outgoing links in each area and there are several thousands of cars on the whole service region.

The proposed method makes four wheeler and buses communicate with each other in order that buses can gather as many information from nearest four wheeler as possible. Then, buses broadcast their reserve information regularly so that the nearby four wheeler can get traffic information. Normal Four wheeler gathered traffic information, reserve it, and exchange it with other four wheeler as described in III-A. Besides, in this proposed method, the regular cars also communicate with buses in the proximity. In order to efficiently exchange information within limited wireless bandwidth, control packets which contain kinds of demanded information are first exchanged between cars and busses, and then they exchange the main information.

1) Data Aggregation by Buses: In order to efficiently collect information not owned yet, buses first propagate control packets which contain link pairs whose information is already retained by the bus, and then, cars in the proximity send their information which is not listed in the control packets. The control packets are also used to notify the cars of knowing that the bus is in their proximity. Here, we call control packets sent from buses bus packets. A bus packet contains lists of link pairs which the bus retains. An element of the list is a set of the following 3-tuples.

(Area ID, In link ID, Out link ID)

When a four wheeler receives a bus packet, the four wheeler inspects the contents of the bus packet and then the car sends its information which is not owned by the bus to the bus.

2) Data Collection by Regular Four Wheelers: In the proposed method, normal four wheeler can obtain more information than our previous method [4] by requesting the bus to send important information. As described in Sec. III-B1, cars and buses exchange control packets before they communicate. Hereafter, we call the control packets sent from regular cars car packets.

A four wheeler packet includes lists of the area which the car needs information of. An element of the list is a set of the following 2-tuples.

(Area ID, Priority)

Here, Priority denotes a priority for the area. When a bus Receives a control packet from a car, the bus sends information of the required areas to the four wheeler according to the priority in the packet. According to the received control packets, the bus sends information in order of the amount of requests. In case where it is impossible to send all information, the bus chooses information to send, and schedules when to send each information. There can be several ways to specify priority in the request packets: number of responsible area, the most congested region, etc.

3) Information Maintenance and Throw a Way of Buses: A bus also measures area passage time, and generates area passage records and area passage statistics data. Therefore, buses always provide the latest traffic data of the bus routes. In our method, normal four wheeler only retain information of their responsible areas to reduce the amount of retained traffic information, but we do not make buses dispose information according to their position. Instead, each set of data is expired after a predetermined duration.

IV. TENTATIVE VALIDATION

In order to evaluate the proposed method with realistic traffic flows on a realistic road system, we have implemented the method on the traffic flow simulator NETSTREAM [11], [12]. Then we have conducted simulation to confirm if the proposed method can collect and retain traffic information more efficiently than our previous work without buses.
A. Simulation of Inter-Vehicle Communication

We implemented the simulation of inter-vehicle communication as follows. The implemented modules and NET-STREAM / SUMO can communicate with each other every second in simulation time scale, and those modules can get position of each car.

Configuration of Inter-Vehicle Communication: We assume that the direct communication range of each vehicle (four wheels or bus) is 100 meters. When many cars in their communication ranges each other send data packets simultaneously, packet collisions may occur to lead to congestion of communication. In order to simulate this phenomenon, we divide one second into 100 time slots with 10 milliseconds lengths and assume that each packet occupies one time slot when it is broadcasted. If two and more packets try to be broadcasted simultaneously, we suppose that they are collided with one another and they cannot be received. This simulation is executed by time slot. Total simulation time is 60 seconds (i.e., 360,000 time slots). The size of each packet is assumed to be 1500 bytes. It is known that radio field intensity is inversely proportional to the square of distance from a transmitter station. However, a probability of successful packet reception is not simply proportional to radio field intensity. Thus, we adopt a Nakagami m-distribution fast fading model as described in Ref. [13], and approximate the probability of successful packet reception \( P \) by following formula.

\[
P = 0.98 \left(1 - \frac{x}{100}\right)
\]

We assume that all vehicle and all buses are equipped with a system which carries out generation and broadcast of area passage records as well as reception, update and re-broadcast of area passage statistics data for each link pair.

**Configuration of Road Map:** We used a general road map consisting of two main roads crossing at the center and several byroads as shown in Fig. 1. The map has 1.2km sides, and 29 nodes (intersections) and 39 bidirectional links (roads). Main roads are represented by thick lines in Fig. 1, and They have two lanes each way. The other roads are byroads which have one lane each way. Intersections with a signal are represented by circles of thick line. In an intersection of two main roads, the green signal for each road takes 60 seconds. In the intersection of a main road and a byroad, the green signal for the main road takes 60 seconds and the green signal for the byroad takes 30 seconds.

NETSTREAM / SUMO can simulate realistic traffic flow, including a car recurrence interval, based on a configuration like the maximum car density and the number of lanes of roads and the number of cars on the map.

Thus the density of each road is not fixed value but it is changed over time. The maximum speed of each car and bus is 60km per hour. In this experiment, we configured parameters of NETSTREAM / SUMO to make the following two situations and evaluated our proposed method. Those parameter values are obtained by an exploratory experiment.

- **Low car density:** minimum car density where each car can communicate by using inter-vehicle communication (a car per 94m road-length).
- **Very low car density:** car density where each car may not communicate by using inter-vehicle communication in some cases (a vehicle per 313m road-length).

Two bus routes a and b are shown in Fig. 1. Buses travel along the route a every five minutes and the other buses travel along the route b every seven minutes. We assume that this map is a suburban area where several bus routes are provided and about four buses travel along them every hour. NETSTREAM / SUMO used in this paper can simulate the behavior of a bus by specifying the track of the bus. We give a timetable to NETSTREAM / SUMO in order to consider bus stops. It indicates when a bus goes through each intersection. We assume that when the bus arrives at an intersection regarded as a bus stop ahead of schedule, the bus has to stop at the intersection until scheduled time. On the other hand, when the bus arrives at the intersection behind schedule, the bus has to stop at the intersection for 15 seconds.

**Configuration of Area Passage Statistics:** As threshold \( C \) for generating area passage statistics data, we used \( C = 5 \). We assume that a car throw a way area passage statistics data after a lapse of 10 minutes since the data generated.

**Configuration of Control Packet and Transmission Interval:** We assume that a bus wheel broadcasts area passage records five times at random timings for five seconds after it generated them. A four wheeler also broadcasts some retained area passage records and area passage statistics data at a random timing every five seconds. A bus broadcasts a bus (control) packet at a random timing every two seconds. A four wheeler which received a bus packet has to reply within one second, and it sends a four wheeler packet to require specific information to the bus at the same time. Similarly, a bus which received a four wheeler packet has to reply within one second. In this paper, we assume that Area ID of a car packet is one of its responsible areas, and Priority is assigned a random value for simplicity.
B. Tentative Results

In order to appraise our proposed method, we examine the brunt of buses on the number of four wheeler which retains area passage statistics data of a specific link-pair under the two four wheeler-densities. To achieve fairness, we assume that there is the same number of vehicles on the map whether the method uses buses. We have run a simulation 100 times. As a result, we have obtained the number of cars which have the area passage statistics data of the specific link pair, and estimated the area passage time from that data. We used Linkpair (C-I, L-N) of Area A5, Linkpair (V-A, B-C) of Area A8 and Linkpair (J-K, K-L) of Area A9 in Fig. 1 as the target link pairs. Linkpair (C-I, L-I) of Area A5 and Linkpair (V-A, B-C) of Area A8 are on the bus route a and b respectively. Linkpair (J-K, K-L) is a link pair of Area A9 which does not include bus routes. We evaluated information propagation ratios on those three link pairs under the two car-densities and show the results in Figs. 2-4, respectively.

Result under Low Four Wheeler Density: We show the simulation result under the low four wheeler-densities in Fig. 2. We find out that our method with buses increases the number of four wheeler which have area passage statistics data according to Fig. 2 (a)-(c). According to Fig. 2 (a)-(b), especially, we find out that area passage statistics data are widely disseminated in the areas which include bus routes. We also find out that the number of cars which have area passage statistics data in our method becomes 1.5 to 2 times larger than the method without buses as shown in Fig. 2 (b). However, our method has little effect in the areas which do not include bus routes as shown in Fig. 2 (c). This is attributed to the fact that four wheeler in the area without bus routes could not communicate with buses.

Result under Very Low four wheeler Density: We show the simulation result under the very low car-density in Figs. 3 and 4. We find out that our method with buses increases the number of four wheeler which have area passage statistics data according to Fig. 3 too. Especially, according to Fig. 3 (b), the method without buses caused the situation where the minimum number of four wheeler which have statistics data \( n_{\min} \) can be 0 at all time frames. But our method with buses has achieved the situation where the \( n_{\min} \) is not less than 1 at all time frames. Furthermore, in time frame 30 of Fig. 3 (b), the method without buses could never retain statistics data in 100 simulations because the statistics data are completely lost at least once in all situations. In contrast, our method with buses can retain one or more statistics data in all situations.

Next we compare the area passage estimation time of our method to the method without buses as shown in process without buses results in large standard deviation of area passage estimation time and bad estimate accuracy in the time frame when there are few cars having statistics data. Consequently, the estimation accuracy of the area passage estimation time becomes worse when the number of cars which have statistics data is small. Four wheeler in our method can retain relatively many statistics data. Consequently it can achieve good estimation accuracy.

C. Discussion on Tentative Results

We confirmed that our proposed method with buses allows four wheeler to retain statistics data more stably, compared with the method using only four wheeler. Additionally, our method can retain some data even if the method using only four wheeler loses data under the very low four wheeler density such that there are few four wheelers in the communication range of each four wheeler. However, the advantage of our method is not so big in the areas which do not include bus routes, because four wheeler in those areas cannot get information through buses. In the future, it is necessary to disperse control packets by multi hop communication in order to widely retain data amid four wheeler in the areas which do not include bus routes. In addition, the results show that packet collisions are hardly occurred because the car density is low. Next, we compare the area passage estimation time with the actual area passage time. A ratio of actual area passage estimation time of an area in Fig. 4 is defined as the estimated area passage time of the area divided by the actual passage time of the area. The result shows that the estimation error is within 10% in the time frames when there are five and more cars which have area passage statistics data. In these experimental results, the difference of estimation accuracy between the method with buses and without buses is not so big, but this difference can be big when the amount of generated information is quite small. Especially, as shown in Fig. 3(b), the method without buses lost statistics data in some time frames, but the method with buses retained statistics in all time frames.
V. CONCLUSION

In this paper, we proposed the process which proficiently gathered hold and propagate traffic information using inter-vehicle communication by introducing buses into the traffic information sharing system. In the proposed process, buses gathered as much traffic information as possible from four wheeler in their proximity and at regular intervals disseminate the collected information to neighboring four wheeler. It follows that the method can improve information propagation efficiency in low-density areas.

We have implemented the proposed system on the traffic simulator NETSTREAM / SUMO and compared information propagation efficiency between our proposed method and the method only using inter-vehicle communication amid four wheeler. As a result, we have confirmed that our method can propagate traffic information approximately 50% more effectively in the low four wheeler-density areas, compared with the existing method. As the future work, we will consider the ways that cars in the area without bus routes also can get traffic information Proficiently by multi hop communication and that cars and buses exchange control packet depending on the density of nearest four wheeler.

Fig. 2. Number of Cars which have Area Passage Statistics (Low Car-Density) (a) LinkPair (C-L-L-N) of Area A5 on Bus Route a  

(b) LinkPair (V-A,B-C) of Area A8 on Bus Route b
Fig. 3. Number of Cars which have Area Passage Statistics (Very Low Car-Density) (a) LinkPair (C-I,L-N) of Area A5 on Bus Route a

(b) LinkPair (V-A,B-C) of Area A8 on Bus Route b

(c) LinkPair (J-K,K-L) of Area A9 not on Bus Routes
Fig. 4. Area Passage Estimation Time (Very Low Four Wheeler-Density) (a) LinkPair (C-L,L-N) of Area A5 on Bus Route a

(b) LinkPair (V-A,B-C) of Area A8 on Bus Route b
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