A Vehicle Ad-Hoc Network for Traffic Information System

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***Abstract*— We propose a vehicle ad-hoc network for traffic information service. It allows collecting and analyzing traffic status of large areas without any infrastructure, e.g., probe cars, road side unit, and server. The proposed scheme uses multi-channel and broadcasting technique. Vehicle terminal simply needs the existing navigation systems in vehicles and wireless communication devices for vehicle-to-vehicle communication. Communication and networking algorithm is given and experimented on the testbed. It effectively collects accurate traffic information, and is able to provide real-time traffic information propagation by using only vehicle-to-vehicle(V2V) communications without infrastructure.**

Keywords-VANET; Traffic Information Service; Driver Assistance; Navigation.

I. INTRODUCTION

Recently, many researchers have been studying on the active vehicle-safety services based on inter-vehicle communication to improve drivers' safety [1]. This safety service aims at collision warning, collision avoidance, providing traffic information, etc. For instance, G. Held [1] discussed the traffic information service that assists drivers with the information of driving paths detouring accident zones or traffic jams in real-time manner.

The traffic information service roughly divides into Intelligent Road and Vehicle Ad-hoc Network (VANET) in terms of inter-vehicle communication [2-4]. In Intelligent Road, the traffic information is wirelessly collected from vehicles to access points which are deployed along the roads, sent to the information center, processed, and then broadcasted to drivers on the roads. An example of this scheme is Traffic and Travel Information via Transport Protocol Expert Group (TPEG) service. However, it has several disadvantages, e.g., it costs a lot to incorporate facilities for the service along the roads. In addition, even though a number of information providers including taxis and buses participate in TPEG, real-time service is not easy to offer due to the time delay of more than 5 minutes for updating the information. Moreover, the traffic information provided by the agencies is not free of charge. In VANET, on the other hand, the traffic information is delivered directly from vehicle to vehicle. It can be delivered to the vehicle following in the same lane or to the vehicles, so called messengers, running in the opposite lane. However, VANET typically relies on broadcasting which may cause the channel collision that degrades communication efficiency or generate too many messages overloading the systems.

In this paper, we propose a traffic information service based on vehicle ad-hoc network. The proposed scheme collects, processes, and distributes traffic information without establishing a specific infrastructure, e.g., server or separated monitoring systems. We design communication and networking algorithm. It utilizes three wireless channels. It only allows the last vehicle in a traffic jam to communicate with the vehicles in the opposite lane. This multichannel communication scheme minimizes the probability of message collision and simultaneously enables accurate and reliable data delivery.

In Section II, a concept of traffic information service for traffic congestion avoidance is proposed. In Section III, method of channel operation for efficient use of resources is presented and Finally, in Section IV, conclusion of this study and description of future work are provided.

II. TRAFFIC INFORMATION SERVICE CONCEPT

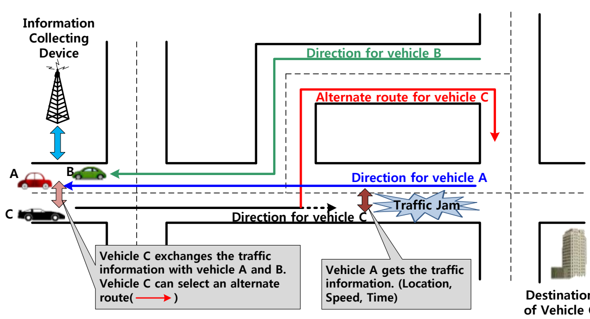

Figure 1. Traffic Information Service Concept

Figure 1 shows how the vehicle C avoids the traffic jam and arrives to the destination. Vehicle A, B, and C generate the traffic information based on location data supported by Global Positioning System (GPS). The collecting devices transfer and retrieve various information including vehicle speeds, traffic environment, etc. through the wireless network. The destination is where the vehicle C goes toward and the traffic jam is where the heavy traffic occurs.

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The service scenario is as follows: (1) Vehicle C is on the way to the destination; (2) Vehicle A has been moving in “the direction of vehicle A” as shown in Figure 1. Since vehicle A went through the jammed area, it has obtained the traffic information, e.g., speed change of vehicles over the passed locations including the jammed area; (3) Vehicle B has been moving in “the direction of vehicle B” as shown in Figure 1. The traffic information that vehicle B has obtained is likely to be normal since it did not pass through the jammed area; (4) Vehicle A, B, and C regularly transmit the traffic information on their respective paths; (5) If information collecting devices are incorporated on the road, they can serve to retrieve, process, and regularly transmit the traffic information to users; (6) Based on the delivered information from vehicle A and B, vehicle C can be aware of the traffic jam on the path of vehicle A in advance; and thus, (7) Vehicle C can choose the right path avoiding the heavy traffic.

In summary, when vehicle C does not have a priori knowledge on the traffic ahead, it has possibility to meet the jammed area before it arrives to the destination. On the opposite lane, vehicle A has come from the jammed area and vehicle B has come without suffering any traffic jam. Since vehicle C receives traffic information from vehicle A and B on two possible paths in advance, it can choose its preferred path to the destination avoiding traffic jam.

III. Service Methods

A. Channel Operation Scheme

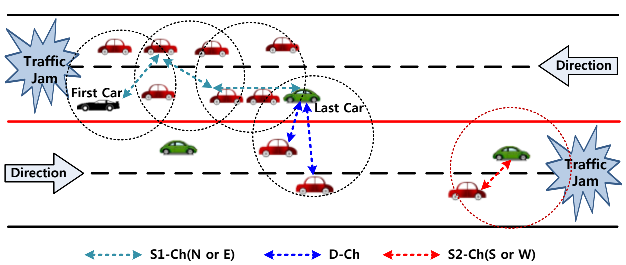


Figure 2. An Example of Wireless Communication Channels

Figure 2 shows the wireless communication channels of vehicles running on roads near traffic jammed areas. The vehicle’s terminal operates with three wireless communication chanels. The first channel (S1-Ch) is for communicating with the vehicles driving in north or east directions. The second channel (S2-Ch) is for communicating with vehicles driving in south or west directions. The third channel, called D-Ch, is for communicating with the vehicles driving in the opposite direction.

B. Message Format

The header and trailer are determined by the adopted PHY/MAC protocol. Note that all messages are broadcasted without any join and association procedure between vehicles.

We define four types of messages that are classified by the value in Msg_Type field as follows.

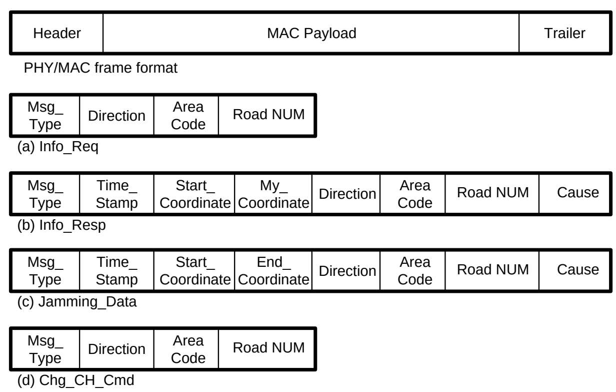
① Info_Req indicates that the message is a request for the vehicle ahead to send the traffic information through S-Ch.

② Info_Resp indicates that the message contains traffic information and is sent to the rear car through S-Ch.

③ Jamming _Data indicates that the message contains traffic information about jammed area and is sent to the cars on the other lane through D-Ch.

④Chg_CH_Cmd indicates that the message is a request for the last car to change the communication channel from D-Ch to S-Ch. This message is issued by a newly joining car to collect traffic information when it overhears the messages about jammed areas that the last car is sending through D-Ch.

These messages assist driving vehicles with spatiotemporal traffic information contained in various message fields. For example, Start_Coordinate, Time_Stamp, Cause fields contain starting points, starting time, cause of traffic jam, respectively. The length and route of traffic jam can be derived from Start_Coordinate with End_Coordinate and Area_Code with Road_NUM, respectively.



Msg_Type (1byte): message type
Time_Stamp (2bytes): current time(ddhhmmss)
Start_Coordinate (8bytes): latitude/longitude coordinate of the first car
End_Coordinate (8bytes): latitude/longitude coordinate of the last car
Direction (1byte): East->0, West->1, South->2, North->3
Area_Code (2bytes): area code managed by nation
Road_NUM (2bytes): road number managed by nation
Cause (1byte): cause of the traffic jam

Figure 3. Frame and Message Format

C. Communication & Networking Algorithm

Figure 4 shows the vehicle states, channel operations, communication algorithm in several situations. The five states of vehicles are defined as follows.

- NOR is the state of the normal car that drives faster than its predetermined speed.

- FST is the state of the first car at the starting point of jammed area, which generates the traffic information including location, time, and cause of the traffic jam.

- LST is the state of the last car at the last point of jammed area, which delivers traffic information to the vehicles on the opposite lane.

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- FWD is the state of the vehicles in the middle of jammed area, which forwards information in Broadcast Mitigation Technique(BSMT) procedure for a multi-hop broadcast-based communication. Since FWD is temporary, it eventually switches into LST or MDL.

- MDL is the state of the vehicles in the middle of jammed area. In BSMT procedure, the vehicles that are not selected to be on FWD become MDL.

In Figure 4, if a vehicle on NOR drives slower than the predetermined speed owing to traffic jam, it checks on a Jamming_data message reception to see whether there has already been a vehicle on LST.

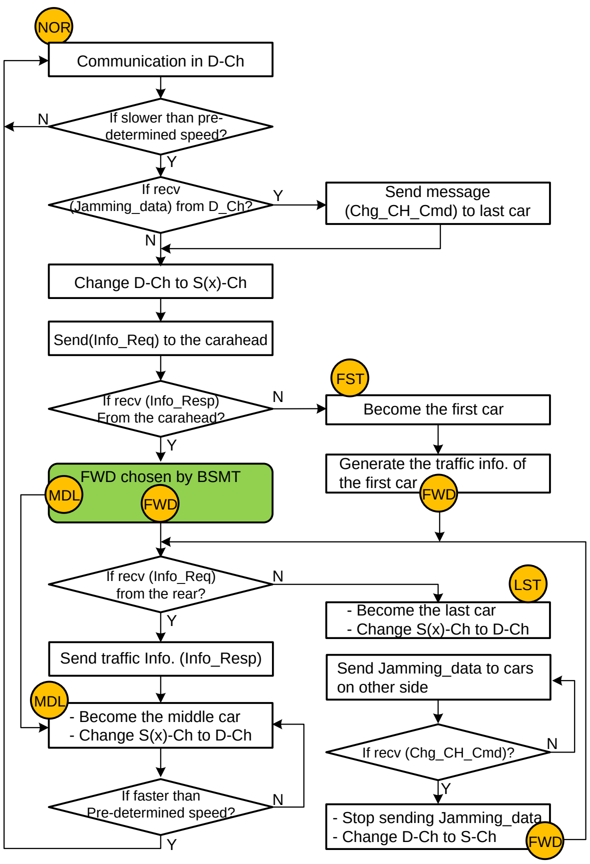

Figure 4. The Channel-Operating and Networking Algorithm

If it receives Jamming_Data through D-Ch, it sends Chg_CH_Cmd message to the car ahead on LST for requesting channel change from D-Ch to S(x)-Ch, where x is 1 or 2. Then, it also changes its own channel to S(x)-Ch and transmits Info_Req message requesting traffic information ahead, and waits for Info_Resp.

On the other hand, if it receives no Jamming_data message, it changes its channel to S(x)-Ch and transmits Info_Req message requesting traffic information ahead, and waits for Info_Resp.

If it does not receive Info_Resp for the time interval, T_d, defined by (3), it goes into FST and starts generating traffic information including its GPS location, cause of the traffic jam. And then it starts operating as the car on FWD. If it does receive Info_Resp, BSMT procedure determines whether it goes into MDL or FWD.

If it is determined to be on MDL, it changes its channel to D-Ch. On the other hand, if it is determined to be on FWD, it checks whether it receives Info_Req. If it does, it sends Info_Resp containing traffic information coming from the vehicle on FST to the vehicle in the rear and it changes its state into MDL

However, if it does not receive Info_Req, it goes into LST, changes its channel to D-Ch, and start to periodically send Jamming_Data built with traffic information from itself and the vehicle on FST to the car on the opposite lane. The transmission period is given by (10) below.

When the car on LST receives Chg_CH_Cmd while periodically sending Jamming_data, it stops sending Jamming_data, changes its channel to S(x)-Ch, and starts operating as the car on FWD.

And if all vehicles drive faster than the predetermined speed, they go into NOR.

D. Broadcasting by Broadcast Storm Mitigation Technique

The multi-channels as with S(x)-Ch and D-Ch in this paper, generally show higher performance than the single-channel since it can mitigate collision and interference. In our scheme, the traffic information from the first car should be broadcasted to the cars in the rear through S(x)-Ch or sometimes it should be propagated to the cars in the middle of traffic jam through multi-hop communication. Note that the broadcast-based scheme may cause serious problems, e.g., broadcast storm, which results in severe performance degradation. To address this problem, we utilize Slotted 1-Persistence Broadcasting Rule [5]. We briefly introduce the rule for understanding.

Upon receiving a packet, a node checks the packet ID and rebroadcasts with the pre-determined probability 1 at the assigned time slot TS_{ij}, as expressed by Eq. 1, if it receives the packet for the first time and has not received any duplicates before its assigned time slot. Given the relative distance between nodes i and j, D_{ij}, the average radio range of a wireless link, R, and the predetermined number of slots N_S, TS_{ij} can be calculated as

$$TS_{ij} = S_{ij} \cdot \tau \qquad (1)$$

where τ is the estimated one-hop delay, which includes the medium access delay and propagation delay, and S_{ij} is the assigned slot number, which can be expressed as

$$S_{ij} = N_s \left\{ 1 - \left\lceil \frac{min(D_{ij}, R)}{R} \right\rceil \right\} \qquad (2)$$

In BSTM procedure, each car becomes on MDL if it receives Info_Resp within its own waiting time derived from (1). Otherwise, it becomes on FWD and retransmits Info_Resp. After retransmitting, if it receives Info_Resp from the rear within T_d, it goes into MDL since it is a forwarder in the middle of the multi-hop message path. Otherwise, it goes into FWD since it is the last forwarder in the multi-hop message path.

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Here, the waiting time for which the car should wait to determine if it is the last on FWD after sending Info_Resp is as follows.

$$T_d = N_s \cdot \tau \qquad (3)$$

E. Broadcast Rate Control based on the car speed

In this section, we consider the broadcast rate (B_R) of traffic information through D-Ch. If the broadcast rate increases, the probability of message collision increases due to increasing interference and traffic load within radio range. However, if the broadcast rate decreases, it becomes increasingly possible that the cars driving fast may have no chance to communicate each other. Thus, the broadcast rate should be carefully determined by vehicle speed, radio range, message length, transmission speed of media.

For example, if the vehicle speed is high, the broadcast rate, B_R, of each vehicle should be high because the vehicle density in coverage range probabilistically decreases. On the other hand, if the vehicle speed is low, the broadcast rate of each vehicle should be low because the vehicle density in coverage range probabilistically increases. In other words, it is desirable to keep the network within a stable range of the total network load by adjusting the broadcast rate. Additionally, when the vehicle speed becomes lower, the cars stay longer in communication range and thus have the increasing communication success rate even with low broadcast rate. On the other hand, if the vehicle speed is higher, the cars stay shorter in communication range and the high broadcast rate is desirable to increase the communication success rate.

Therefore, B_R of D-Ch is determined by (10) under assumption that the maximum (maxS_v) and minimum of the vehicle speed is 200km/h and 0km/h, respectively.

S denotes the transmission speed of a wireless link. L_f means the length of frame. The transmission time of one frame, T_p, is as follows.

$$T_p = \frac{L_f}{S} \qquad (4)$$

The time interval, time measure of two cars on the opposite lanes staying in the successful communication range, is given as follows.

$$T_h = \frac{R}{2 \cdot S_v} \qquad (5)$$

The maximum number of transmittable packets during T_h is determined as (6).

$$N_B = \frac{T_h}{T_p} \qquad (6)$$

The maximum transmission rate, λ_{max}, is the maximum number of transmittable packets per second as (7).

$$\lambda_{max} = \frac{1}{T_p} = \frac{S}{L_f} = \frac{N_B}{T_h} \qquad (7)$$

Given λ as the sum of all broadcast rates within a communication range, the offered load, ρ, is as follows.

$$\rho = \lambda \cdot T_p \qquad (8)$$

$$\rho_{max} = \lambda_{max} \cdot T_p \qquad (9)$$

In A. Tanenbaum [6], CSMA-based wireless networks show high performance under low offered load, where $\rho <$ 0.1 ρ_{max}. Thus, B_R of D-Ch is given as (10).

$$B_R = 0.09\lambda_{max} \cdot \frac{S_v}{\max S_v} + 0.01\lambda_{max} \qquad (10)$$

F. Experimental System and Test

Figure 5 shows our experimental setup comprised of a main module and a communication module for vehicle-to-vehicle communication. The main module adopts S5PX100 with ARM Cortex-A8 Core. The peripheral includes a TFT LCD, a General Camera Interface, and a GPS. It also includes USB host/client, IEEE802.11a/b/g, UART for interfacing with external devices.

Android is used as the operating systems for the main module. Several functions are established on the main module including user interface, navigation/GPS showing the jammed area by the proposed algorithm, message transmitting and receiving blocks.

We use ATmega1281 MCU and CC2520 supporting IEEE802.15.4 for the communication module. It also supports UART communication to cooperate with the main module. The proposed vehicle-to-vehicle communication is based on IEEE802.15.4 but modified to rely on broadcast while excluding Join and Association procedures.

Figure 5. Experimental Setup

We conducted experiments where S and L_f are set to 250kbps and 54bytes, respectively. R is approximately 200m. Considering GPS accuracy, N_s is set to 5. The car speed, S_v, was selected randomly from 30 to 70 km/h at the start coordinate of latitude 36.385216 and longitude 127.359576. We monitored communication messages by using cc2420EB packet sniffer.

Our monitoring results showed that the vehicle speed of 50km/h causes no packet error and no packet loss although it slightly affects Link Quality Indicator calculated by RSS(LQI). As the vehicle speed becomes higher, the packet error and the packet loss occur more frequently because of wireless signal fading, which is a unique feature of

IEEE802.15.4. Therefore, IEEE802.11p is considerable for communication between vehicles driving at high speed.

IV. CONCLUSIONS

We proposed a traffic information service simply relying on the existing Navigation/GPS systems in vehicles and wireless communication devices for vehicle-to-vehicle communication, rather than on a separately established server. The proposed scheme collects traffic information over inter-vehicle networks, processes it to minimize the size, and transmits it to the destinations. This scheme uses three wireless communication channels and only a single selected last-vehicle is allowed to transmit the traffic information to the opposite lanes, which reduces the probability of wireless communication collision and mitigates the broadcast storm. Compared to the existing TPEG service, it has more advantages that it provides traffic information in timely manner and it can offer no charge service as well. We tested using IEEE802.15.4 based Wireless Sensor Network (WSN) platform. For future work, we will apply the algorithm to IEEE802.11p based Wireless Access in Vehicular Environment(WAVE) platform.

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