A Vehicle Information Transmission Method by Inter-Vehicle Communication and its Application to Traffic Jam Detection

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Abstract - Currently, car navigation systems are advancing in the field of Intelligent Transport Systems (ITS), thereby advancing traffic information systems. Further reduction of economic losses arising from traffic jams is anticipated through inclusion of traffic information systems. Vehicle Information and Communication Systems (VICS), VICS probe, and Internavi Floating Car Systems with telematics have therefore been researched and developed. This study specifically examined multi-hop inter-vehicular communication and the vehicle information acquired by it. We designed a traffic information system that improves accuracy and real-time features of the acquired traffic information without a communication-based VICS center, traffic information center, or server: each vehicle acquires other vehicles' information using real-time inter-vehicular communication. In this paper, we propose a method of vehicle information transmission using inter-vehicular communication. We also attempt to detect traffic jam situation using vehicle information that each vehicle receives.

Keywords: ITS, Car navigation system, traffic information, VICS, telematics.

1 INTRODUCTION

Currently, there are nine development fields of intelligent transport systems, among which is the field of highly advanced car navigation systems [1]. Of such systems, Vehicle Information and Communication Systems (VICS) [2] have difficulty acquiring traffic information correctly except for information related to links (roads) where sensors are emplaced. Therefore, a method that is currently under consideration is the use of a VICS probe [3] to improve the level of traffic information accuracy and traffic volume measurement by collecting probe data that the vehicle can sense using such bi-directional communication equipment as a light beacon or an electric wave beacon on roads with no sensors in place. Any such traffic information system gathers information once at an information center. It then selects and transmits necessary information to other vehicles, in which sense we can call it an infrastructure-dependent system. In contrast, infrastructure-independent systems exist, for which prior studies to utilize inter-vehicular communication methods have been made. One such system is the Advanced Safety Vehicle (ASV), which transmits vehicle location information from one vehicle to another using inter-vehicular communication. Then all available short-distant vehicle locations are displayed on the car navigation system screen to notify the driver [4]. Thereby, inter-vehicular communication is used to transmit the real-time information. It is considered useful for multi-hop communication utilizing Mobile Ad-hoc NETwork (MANET) technology [5].

Traffic View [6] is a technique for a vehicle to obtain information of all other vehicles moving on a straight road such as a highway. It transmits the collected vehicle information to trailing vehicles using one-hop communication at a constant transmission timing that is preset for all related vehicles. Another technique, RMDP [7], reduces transmission message collisions and improves transmission rates by determining every interval as to when to transmit next based on the amount of data received during past transmission intervals of the vehicle and the number of error messages caused by data collisions. From such a study of transmitting vehicle information using inter-vehicular transmission techniques, tradeoffs are understood as the most important factor to consider, the resolution of which yields the right message size of the vehicle information for every usage, the transmission interval, the transmission distance, and the real-time necessity of transmission.

One matter to note is that when VICS tries to measure the traffic flow on every link to determine possible traffic jams with information from sensors set along the road and vehicle driving times on the road, it normally, and invariably, takes some time to do so, thereby producing some discrepancies in measurement from the actual traffic situation. To avoid that situation, we proposed a traffic information system to notify drivers of traffic information on a real-time basis. The system analyzes the surrounding traffic status by allowing every vehicle to send traffic information to surrounding vehicles at a constant interval within seconds [8, 9].

In the study described above, acquisition of information related to all surrounding vehicles is done using a flooding technique [10], which is recognized as a broadcast type transmission technique. However, one problem is that a broadcast storm phenomenon [11] can be produced by transmission flooding, which results in failure of traffic information transmission. In such a storm, the transmission interval used by every vehicle becomes shorter and the amount of communication equipment that is used increases in scale. A study of Location Aided Routing (LAR) [12] has been made to efficiently construct a routing table based on location information of every mobile node, but constructing a routing table engenders difficulty because the vehicles concerned move so rapidly that communication frequently gets cut off.

In this paper, we propose a vehicle information transmission method in line with improving its transmission rate along with flooding to help improve the accuracy level of traffic flow measurement. In addition, we seek a means to evaluate a possible traffic jam situation based on information received from each vehicle, and show how it could be used in the real world. The former comprises two transmission methods, one of which is a means to delete messages to transmit the previously received vehicle information in order to reduce the transmission load. Another is a means to reduce the broadcast message transmission load by forming a group of vehicles for link-by-link messaging, sending only a representative message to every one of such link groups. The latter method judges whether a traffic jam is possibly occurring or not on every link by computing the weight level of every vehicle on the link depending on where it is located.

Section 2 proposes a vehicle information transmission method while improving the flooding technique. Section 3 presents an evaluation of such a proposed vehicle information transmission method using a simulation technique. Finally section 4 presents examination of how such a proposed method can detect a possible traffic jam situation from available vehicle information as that used in the real world.

2 VEHICLE INFORMATION TRANSMISSION BASED ON INTER-VEHICULAR COMMUNICATION

2.1 Vehicle Information Transmission

Vehicle information sent and transmitted through inter-vehicular communication includes a vehicle identification code, location, speed, acceleration, moving direction, time of sending the information, and a link identification code. Every vehicle is supposed to be equipped with a GPS receiver, a car navigation system, and a wireless inter-vehicle communication device (IEEE802.11x or similar device). Using a GPS alone, the measurement of the vehicle location can be known within several meters, but the current car navigation system uses a map-matching technique, the error can be reduced further to sub-meter-order as long as the vehicle is moving on a road. A GPS can be used not only for measuring the vehicle location; it can also synchronize the physical clock of the vehicle's computer, based on time information sent from the GPS satellite, with precision of a few microseconds. Current technology levels of the vehicle can already sense the speed, acceleration, and moving direction of a vehicle. Furthermore, when a message is broadcast, it includes information of the vehicle from which the transmission is made. That information can be useful to delete the message by the receiving vehicle, as described later. Based on the definition of these pieces of vehicle information, Table 1 presents some actual examples of vehicle information held in memory.

Each piece of vehicle information would be transmitted with a vehicle identifier (ID). Every time a message is received from any surrounding vehicle, vehicle information with the same identifier would be constantly updated to include up-to-date vehicle information.

Table 1: Examples of vehicle information

ID	speed	acceleration	direction	latitude	longitude	time	Link ID
10	30	5	2.45	25.44	136.44	120030	1732
11	45	2.5	3.43	25.43	136.45	120040	4723
15	20	-5	0.03	25.45	136.39	120115	9612

2.2 Method of Deleting Vehicle Information Messages

In our method, it is not assumed that each vehicle acquires information of any specific vehicle per se, but we basically use a broadcasting type of communication such as a flooding method to acquire surrounding vehicles' information. However, when a vehicle regularly transmits its vehicle information messages to all other vehicles using a flooding method, if the transmission intervals are short, then the associated message transmission would fail because some messages will collide. Therefore, in our study, we propose a method of deleting broadcast transmission messages while predicting other vehicle locations based on basic vehicle information such as speed, acceleration, and the moving direction. We call this the message deletion method.

The GPS receiver can not only measure its location; it can also synchronize the physical clock of the vehicle with the time the GPS satellite holds. In other words, the time difference of the messages sent and received among vehicles becomes the time spent for communication, which means that other vehicle locations can be predicted by acquiring information through inter-vehicular communication; location, speed, acceleration, moving direction, and the time that the other vehicles acquire using the installed sensor. Vehicle V_n sends its vehicle information to vehicle V_l before V_m does. Furthermore, location information, x_n, y_n, of vehicle V_n acquired from the GPS in addition to its speed, v_n [km/h], its acceleration, a_n [km/h/s], the time that message n is sent, S_n [ms], and the time R_m [ms] at which vehicle V_m receives message m. Then the moving distance l_n [m] of vehicle V_n from the perspective of vehicle V_l can be expressed as follows.

$$l_n = \frac{v_n(R_m - S_n) + \frac{1}{2} a_n \frac{(R_m - S_n)^2}{1000}}{3600} \quad (1)$$

Furthermore, with the y axis for the longitudinal line, the x axis for the latitudinal line, and θ_n [rad] for the moving direction of the vehicle V_n, the predicted location, X_n and Y_n, after moving a distance of l_n [m] can be expressed as shown below.

$$X_n = x_n + l_n \cos\theta_n \qquad (2)$$
$$Y_n = y_n + l_n \sin\theta_n$$

An important rule is that vehicle V_l does not broadcast the message it receives from vehicle V_n if the information of all vehicles meets the following conditions: information of vehicles V_n and V_m, which are within the range of one hop of each other is received and retained; the predicted location of the vehicle V_n, which has sent the broadcast message is X_n and Y_n; the predicted location of the vehicle V_m is X_m and Y_m; the current location of vehicle V_l that judges the transmission is x_l and y_l; and the communication range of the communication equipment installed in each vehicle extends as far as α [m].

$$\sqrt{(X_m - X_n)^2 + (Y_m - Y_n)^2} \le \alpha \; or \; \sqrt{(x_l - X_m)^2 + (y_l - Y_m)^2} > \alpha \cdots (3)$$

Fig. 1 portrays an actual example using vehicles V_1, V_2, and V_3. It presents a case in which, if vehicle V_2 has received messages from vehicles V_3 and V_1, then V_2 analyzes the message sent from V_1 and does not make a broadcast transmission when it can predict that V_3 will remain within the transmission range for V_1.

In addition, because no location can be available for those vehicles from which no vehicle information has been received, it is assumed that there would be no surrounding vehicles: consequently, no broadcast transmission is made.

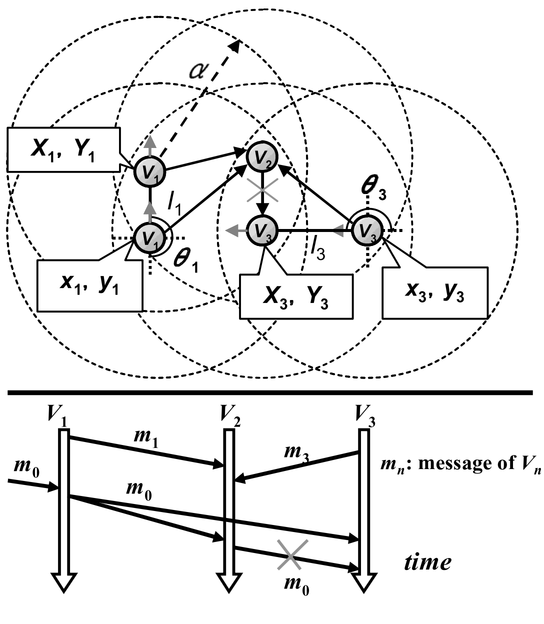

Figure 1: Example of message deletion method.

In the method we propose, the location of other vehicles is predicted based only on vehicle information that has been received already. Based on that information, whether a broadcast transmission is made or not is determined.

Salient differences between LAR and the proposed method are the following.

- The proposed method incorporates acceleration.
- LAR determines and notifies others of the area by examining locations of the sender and receiver, but the proposed method determines whether to transmit or not every time the transmission is made by examining the state of surrounding vehicles.
- LAR considers locations of the sender and receiver only, but the proposed method examines relative locations of all three vehicles.

2.3 Information Transmission using a Link Group

To improve the vehicle information transmission efficiency, we propose, in addition to the message deletion method described in section 2.2, a means to choose a representative vehicle for every link and for such a representative vehicle to send the collected vehicle information to surrounding links with its signal range expanded. Herein, we call this proposed method the link group method.

Fig. 2 presents an example of expanding the communication range around the representative vehicle for the link.

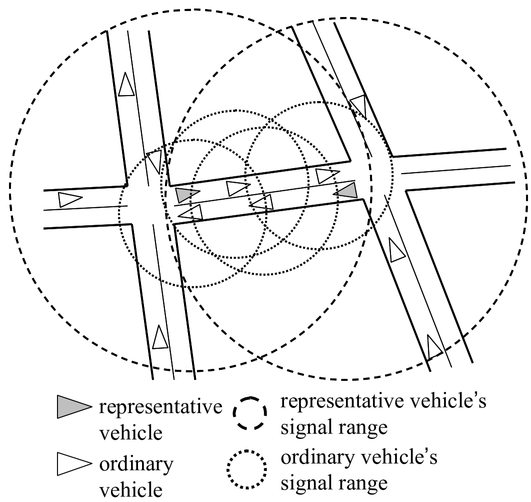

Figure 2: Example of the communication range of a representative vehicle and an ordinary vehicle

On every link, vehicles are classified into two categories––ordinary vehicles and representative vehicles. Then a representative vehicle is defined as one that has newly entered the associated link. A vehicle, when it enters the link, defines itself as a representative vehicle, and sends a message forward to vehicles ahead requesting a change of the representative vehicle role. The representative vehicle gathers vehicle information of all vehicles on the link and creates a link representative message for it. The representative vehicle sets the transmission time using variables obtained based on the identifier of each link and available information about its moving direction, and sends the link representative message regularly. The representative vehicle receives a message from any vehicle behind on the link requesting a representative role change; it then gives the right to that role to that vehicle. Additionally, the representative message is sent based on the flooding technique, and would be transmitted further from one to the next by other representative vehicles. A link is defined here as a road section from one intersection to another.

Other vehicles, when they receive messages from ordinary vehicles or the representative vehicles of other links, retain that vehicle information, but do not broadcast it. Furthermore, when a new representative vehicle sends a message forward regarding the representative vehicle change, that signal might not reach it if the link is too long. In that case it might be necessary that there be more than one representative vehicle.

3 SIMULATION OF VEHICLE INFORMATION TRANSMISSION

In this paper, we use a prototype car navigation system to simulate and evaluate the manner in which the vehicle information would be actually transmitted as we propose.

3.1 Simulation method

For simulation of vehicle information transmission, we examine a straight road on a digital map placing the moving vehicles on the road. We evaluate the transmission efficiency while changing the communication range size intentionally. The following describes all simulations.

(1) Setup of simulation for communication

- The flooding method, the message deletion method, and the link group method will be evaluated.
- The messages sent are actually broadcast ones. Therefore, no ACK process of CSMA/CA will be considered to take place. Detection of message collisions will be made on the message receiving side. We assume that it takes 1 ms to send a vehicle information message. Our model is therefore a simple one assuming that every vehicle uses 1 ms of time during communication when it receives or sends data. The time interval for each vehicle to send data is fixed at 1 s.
- For the flooding method and the message deletion method, the communication ranges from each vehicle will be varied starting from 100 m to 1000 m by 100 m steps.
- For the link group method, the communication ranges that the ordinary vehicles or representative vehicles use will be varied starting from 100 m up to 1000 m in 100 m steps. However, measurements are made only in the setup in which the communication ranges by ordinary vehicles are always smaller than those by representative vehicles.
- Measurements for each method will be made for 10 s. Measurements will be made vehicle-by-vehicle to the average number of transmitted broadcast messages, the average number of received messages, the average vehicle information transmission rate, and the average number of vehicle information updates. The number of vehicle information updates signifies the times the vehicle information received from other vehicles is saved for a new message, or updated for existing messages. The vehicle information transmission rate is the number of vehicle information updates divided by the total number of messages transmitted by all associated vehicles. No message will be destroyed irrespective of the distance from which they come, but all information of vehicles on the roads will be received and considered.

Fig. 3 presents a simulation model used for messages in sending and receiving. Each vehicle would move during each 1 ms of time, and finishes in sending a message during any one of the 1 ms intervals. The shaded area shows a message collision occurring. In the diagram, messages m_k and m_m collide, for example. Whether the messages collide or not is judged on the message receiving side, but the vehicle, when it sends a message, happening to receive a message from another vehicle at the same time would understand that a message collision had occurred.

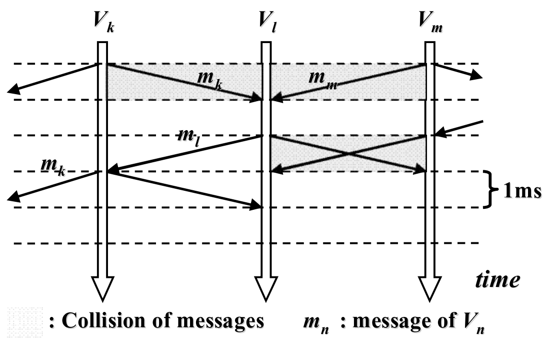

Figure 3: A simulation model used for message sending and receiving

(2) Simulation setup for vehicle movement

- The straight road we use is assumed as 1 km long having one lane in each direction. On the straight road, we place 200 vehicles randomly, making them run in both directions on the road.
- The actual digital map is assumed to be of Kawagoe city in Saitama prefecture, so the vehicles move randomly on that map. Kawagoe city is as wide as about 20 km × 20 km; that is expressed on the digital map. On it, 3000 vehicles are placed randomly.
- For both Kawagoe city and the straight road, the vehicle movement; the vehicle acceleration is expressed based on the Optimal Velocity (OV) model [13]. The maximum speed of vehicles is 60 km/h for both Kawagoe city and the straight road; the minimum is 0 km/h.

Fig. 4 portrays a screen image of this prototype car navigation system. This car navigation system runs on Linux base, and can use shape file map data [14]. At present, the map data of Saitama prefecture are put in the system. It has such functionalities as present position representation, facility location searching, map zoom in and out, and route searching. Fig. 5 shows a digital map of Kawagoe city and a chart of a vehicle positioning arrangement, both of which are products from the prototype car navigation system. This digital map includes 11,077 links.

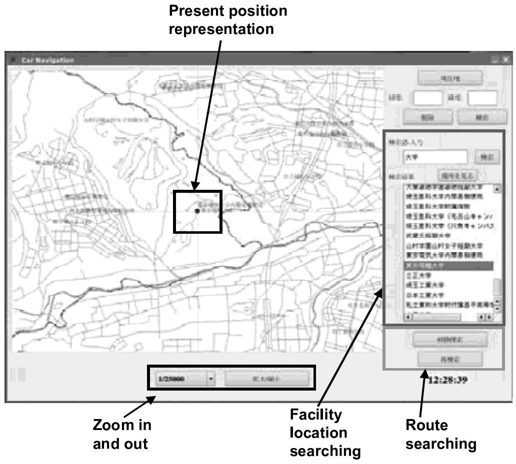

Figure 4: Execution of prototype car navigation

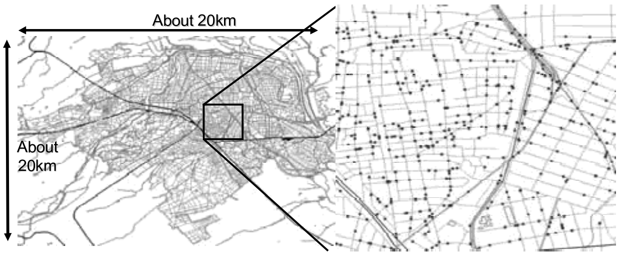

Figure 5: Digital map of Kawagoe city and a chart of a vehicle positioning arrangement

3.2 Results from Simulation

Fig. 6 shows the average number of messages sent and received in the straight road environment when the communication range size was varied from 100 m to 1000 m for the flooding method and the message deletion method. The message deletion method shows that the number of messages that are sent is decreasing, although those received increase as the size of the communication range increases.

Fig. 7 shows the average vehicle information transmission rate and the average number of vehicle information updates. The message deletion method shows that both the number of updates and the transmission rate are increasing as the communication range size grows.

Fig. 8 shows the average number of messages sent and received in Kawagoe city when the communication range size was varied from 100 m to 1000 m for the flooding method, the message deletion method, and the link group method. We find that the number of messages sent and received increases more for the link group method than for the flooding method or the message deletion method.

Fig. 9 shows the average vehicle information transmission rate and the average number of vehicle information updates. We find also that the message transmission rate and the update frequency are improved more for the link group method than for the other two methods.

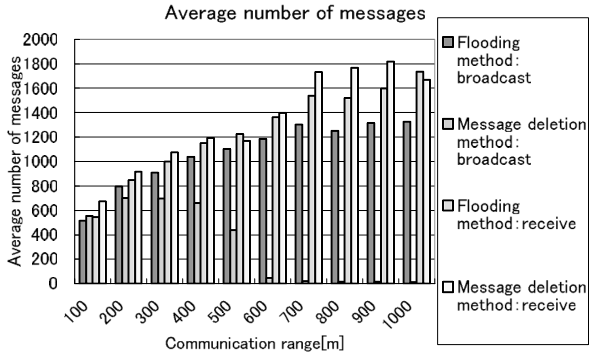

Figure 6: Average number of messages sent and received in a straight road

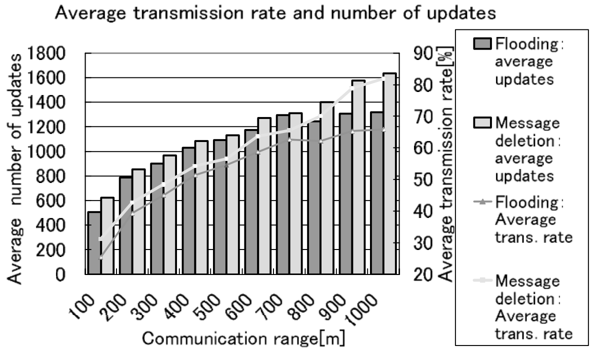

Figure 7: Diffusion ratio of messages and vehicle information update frequency in a straight road

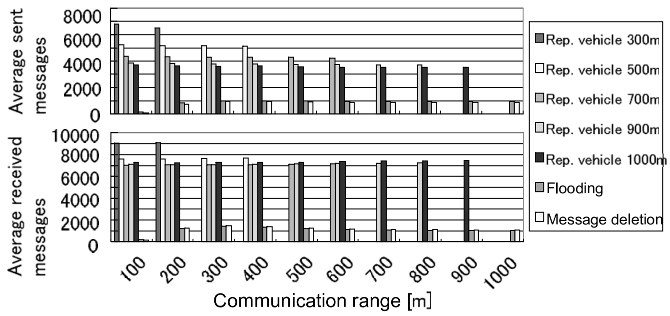

Figure 8: Number of sent and received messages in Kawagoe City

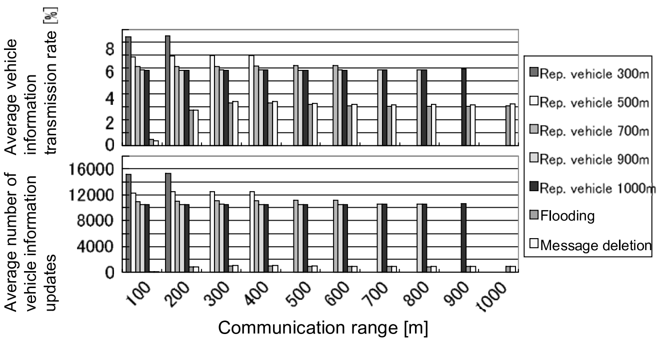

Figure 9: Average vehicle information transmission rate and the average number of vehicle information updates frequency in Kawagoe City

3.3 Considerations

We find from Fig. 6 that the number of received messages increases as the communication range increases on the 1 km straight road using the message deletion method, although the number of sent messages decreases. That is true because the range in which the multi-hop transmission had to be made became so limited as the communication range increased that the number of wasted broadcast messages decreased to a great extent in the message deletion method. This concurs with the fact that the average number of message updates was improved so that the message transmission rate improved by 5–15% more compared to the flooding method.

In the simulation for Kawagoe city, the message transmission rate improved when the message deletion method was used alone compared to that obtained when using the flooding method, but that improvement was not as great as that for the simulation using the straight road. However, when it comes to the link group method, its efficiency was certainly recognized. As Fig. 8 shows, the number of sending messages increased by 3000–5000, and the number receiving messages by 6000–7000. That improvement occurred because the number of message collisions decreased as much as the number of messages transmitted from all vehicles had decreased. As a consequence, the number of messages sent and received increased. An additional finding is that the number of sent messages decreases as the communication range covered by a representative vehicle expands, but the number of received messages does not decrease as much as the decrease for the sending ones. That is true because the message deletion method is used in parallel. A noteworthy point is that the greatest number of receiving messages was obtained with the communication range set to 200 [m] for ordinary vehicles, and 300 [m] for representative vehicles. The result was different for the case of using a straight road, in which case we had increasingly better results as the communication range was expanded.

Fig. 9 shows that the number of message updates increased even to 10 times that when flooding was used. Additionally, results show that, at maximum, the message transmission rate is more than twice as much as that for the flooding, which underscores the efficiency of the link group method.

The simulation this time showed the best results of all with the setting of the communication range of 200 [m] for ordinary vehicles and 300 [m] for representative vehicles. However, the message transmission rate for those was as low as 8.5%: the vehicle information transmission method that we propose has difficulty obtaining vehicle information in the range of 20 km × 20 km. Consequently, we would have to narrow down the simulation range to find the most efficient range size for our proposed methods.

4 APPLYING VEHICLE INFORMATION TO TRAFFIC JAM DETERMINATION

4.1 Weighted Method for Traffic Jam Determination

We next propose a means to detect and evaluate a possible traffic jam situation based on transmitted and available vehicle information. In general, the traffic flow volume increases as the vehicle density on the link increases. However, beyond a certain level of vehicle density on the link, the traffic flow volume begins to decrease. Given the ability to obtain vehicle information from all vehicles, it would be possible to measure the vehicle density on the link based on the position of every vehicle on it. Thereby, we would be able to judge whether a traffic jam is occurring or not. However, not all vehicles have inter-vehicular communication equipment installed. Moreover, obtaining all necessary information through inter-vehicular communication is difficult. We therefore propose a method to detect possible traffic jams based on vehicle information; the vehicle's speed, acceleration, direction, and position on the road obtained from vehicles with inter-vehicular communication equipment while considering other vehicles that have no such equipment.

We first define a vehicle as a traffic-jam causing element or not in the following manner. Based on traffic information, the vehicle speed in traffic jam is supposed to be 10 km/h or less. Moreover, we infer that the vehicle acceleration would decrease in a traffic jam. We therefore define the vehicle as a traffic-jam causing element when its speed is 10 km/h or less and its acceleration 5 km/h/s or less. Additionally, we consider that some vehicles are in a halted state near the link exit area, where there are normally traffic lights, and that some other vehicles are turning right or left. Considering that fact, we weight the vehicle information based on where the vehicle is located on the link. We assign less weight to those vehicles that are about to leave the link in the forward direction; we assign more weight to those near the link entrance area. Such a weighting parameter β is defined as follows.

$$\beta = -P + 1 \cdot\cdot\cdot (4)$$

$$P = \frac{Location\ \ of\ Vehicle\ \ [m]}{Length\ \ of\ \ Link\ \ [m]} \cdot\cdot\cdot (5)$$

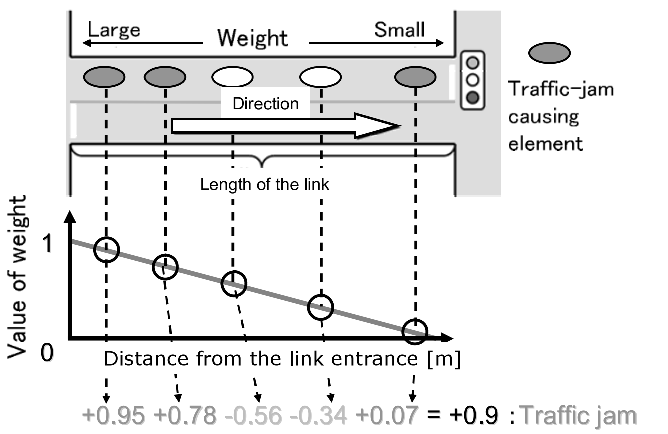

Figure 10: Example of weight according to the vehicle position in the link

We have a positive number for traffic-jam causing elements (with a maximum value of 1), and a negative number for non-traffic jam causing elements (with a minimum value of -1). Summing them up for every link, if the total is negative, we infer that a traffic jam is not occurring. In contrast, if it is positive, we infer that a traffic jam is occurring. With a positive number of summed values, if reached, we can use it to know how heavily a traffic jam is occurring. The closer it is to zero (0), the lower the probability that a traffic jam occurring. The larger it becomes, the greater the chance that we have a traffic jam. In Fig. 10, we have assigned a positive value weight to the traffic-jam causing element, and a negative value to non-traffic jam causing element. Their sum was 0.9. We therefore infer that a traffic jam is occurring on this link.

4.2 Simulation for Traffic Jam Determination

4.2.1 Simulation method

For the simulation we made to measure the traffic flow volume, we constructed a traffic flow simulator and drew a curve of traffic flow (Q) versus vehicle density (K). Using this Q–K curve, we make a comparison to elucidate the degree to which our proposed method agrees with simulation results in terms of whether a traffic jam is occurring or not.

Generally regarding the traffic flow simulator, it includes a macro model and a micro model. The individual behavior of each vehicle is examined in our proposed system described herein. Therefore, we constructed a traffic flow simulator using an OV (Optimal Velocity Model) [13] model for the micro model. The OV model defines the vehicle speed based on the distance from the leading vehicle. Using it, we made the following settings to do the simulation.

- We had 1 km length of straight road for the traffic flow to run on with 1 lane in one direction using that one lane only. Fig. 11 shows the screen image we used when we executed the simulation.
- We assumed a 17 [m] inter-vehicular distance, below which the speed of the vehicle would have to be decreased to avoid collision, in addition to using 16.7 [m/s] of maximum speed (about 60 km/h) and sensitivity of 1.0.
- We put a vehicle flow onto the road in either a 1, 2, … ,10 s interval in the straight line direction, and determined its entry interval randomly every 10 min.
- We set the traffic flow measurement location at 250 [m] from the link entrance point, and measured the number of vehicles passing during the 5-minute period in addition to the vehicle density.
- We had traffic lights at the road exit location, as normally exist on actual roads, and changed lights from red to green or oppositely every 30 s. The vehicles stopped for traffic lights.
- We continued the simulation for 100 [hr] (with 1200 samples). We made the vehicles move every 10 ms.

Fig. 12 shows the Q–K curve resulting from the simulation. Using the Q–K curve drawn based on the OV model and knowing whether we had a free flow or a congested flow, while judging whether we had a traffic jam or not using the vehicle information available at every 5-minute interval, we measured the traffic jam agreement ratio between the two. Along with the settings we made as shown above, we produced measurements with the following settings.

- Considering the number of vehicles with inter-vehicular communication equipment installed, we vary the vehicle information acquisition ratio on the link by 10% increasing it by 10% steps gradually to 100%. Then we examine the situation and measure the traffic jam detection agreement ratio when using our proposed method for every vehicle-information acquisition ratio as established above.
- We measure the traffic flow based on our proposed method using vehicle information available at every 5-min interval. Then we compare the traffic jam situation with that available from the Q–K curve.

Moreover, along with the weighted function of the proposed method, we compare it using the step function (with a fixed value of β=1) and function curve shown below.

$$\beta = \frac{(\cos(P \times \pi) + 1)}{2} \cdots (6)$$

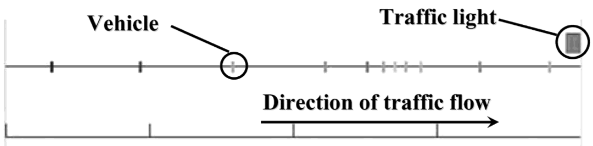

Figure 11: Screen image of simulation execution

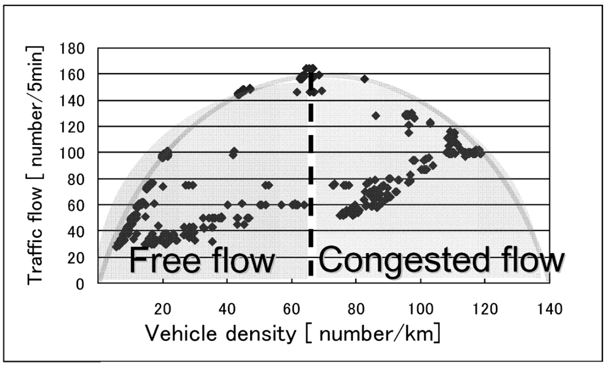

Figure 12: Q–K curve with the OV model

4.2.2 Simulation results

Fig. 13 presents evaluation results for the traffic jam detection agreement ratio obtained from the OV model that we used. Using the simulation for traffic jam detection, the results as shown in Fig. 13 reflect that measurement of the traffic flow volume based on its instantaneous state using the vehicle information available provides greater than 80% agreement, even when using a low vehicle information acquisition ratio. Furthermore, our proposed method, in which we put higher weight to the vehicles near the link entry point, yields a better agreement ratio by 5% compared to that using the step function. Moreover, results shows that more precise measurement results can be obtained when using a simple linear function rather than using a cosine function. These results show the possibility of judging whether a traffic jam was occurring or not if the vehicle information acquisition ratio was greater than 20%.

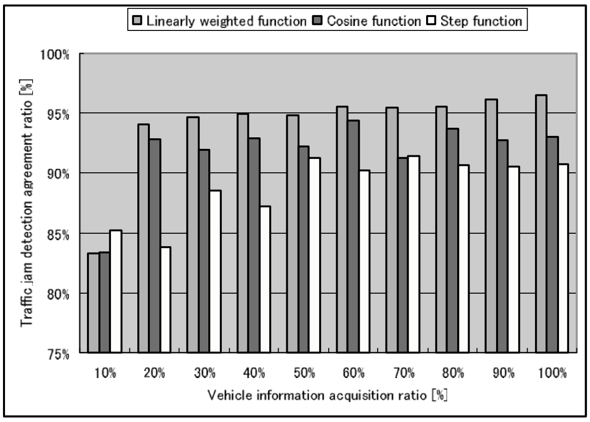

Figure 13: Traffic jam detection agreement ratio

5 CONCLUSION

In this paper, we proposed a method of using inter-vehicular communication to transmit vehicle information that every vehicle would measure. Based on the flooding method of transmitting vehicle information, we proposed a means to reduce the transmitted message volume using already received vehicle information. Moreover, we proposed a means to define a representative vehicle for every link and to send the vehicle information collected by the representative vehicle to surrounding links while the representative vehicle expands its signal range. A simulation of the vehicle information transmission method with incorporation of the vehicle movement on a digital map of the actual area revealed that the transmission rate would vary according to the communication distance, and that the message deletion method and the link group method that we proposed would contribute more to increasing the transmission rate than simple flooding would.

Furthermore, to detect a possible traffic jam, we proposed a means to use vehicle information at certain timing and to assign a weight to each vehicle depending on where it is located on the link. Then we examined possible applications. Issues that must be resolved are the need to determine, using simulation, the appropriate range for transmission, the message-sending interval, and the range at which vehicle information is given.

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