Simple vehicle information delivery scheme for ITS networks

Katsuhiro Naito, Koushiro Sato, Kazuo Mori, and Hideo Kobayashi
Department of Electrical and Electronic Engineering, Mie University,
1577 Kurimamachiya, Tsu, 514-8507, Japan
Email: {naito, kmori, koba}@elec.mie-u.ac.jp, k-sato@com.elec.mie-u.ac.jp

***Abstract*— There has been significant interest and progress in the field of vehicular ad hoc networks (VANETs) in recent years. Intelligent Transport System (ITS) is the major application of VANETs. Vehicle-to-vehicle communication is an important factor for safe driving applications such as blind crossing, prevention of collisions, and control of traffic flows. These applications require exchanges of vehicle information such as vehicle position, cruising speed, direction, and steering angle. Delivery schemes of vehicle information require high delivery ratio, low latency, and high scalability. Additionally, large-size vehicles on actual road environments may interrupt communication between vehicles. Therefore, adequate vehicles should forward vehicle information to their neighbor vehicles in delivery of vehicle information. This paper proposes a new routing protocol for delivery of vehicle information to neighbor vehicles within a specified geographical region. The proposed protocol can deliver new vehicle information with short delay by performing temporal limited flooding before a route construction. Moreover, it can deliver vehicle information effectively with forwarding by adequate vehicles. As a result, our scheme can achieve the high delivery ratio of vehicle information and high scalability. Finally, we assume the different sizes of vehicles in the computer simulations. Then, we evaluate the proposed scheme in the more actual wireless environment. The numerical results show that the proposed protocol can achieve the high delivery ratio with short delay even if the communication between standard-size vehicles is interrupted by the large-size vehicle. Moreover, our protocol has the high scalability in case of increasing of vehicles.**

***Keywords*— VANET, Vehicle-to-vehicle communication, ITS networks, Routing protocol, Vehicle information**

I. Introduction

Vehicular ad hoc networks (VANETs) are new technology to integrate the capabilities of new wireless networks to vehicles. Intelligent Transport System (ITS) is the major application of VANETs [2], [3], [4]. ITS includes several applications such as blind crossing, prevention of collisions, control of traffic flows, traffic monitoring, and nearby information services. These applications can be divided into two major categories. One is called safety application, which improves vehicle safety on the roads. The other is called user application, which provides value-added services such as internet access and entertainment. As for safety applications, their specification requires low latency, high delivery ratio, scalability, etc [5], [6]. VANETs are designed to provide drivers with real-time information through vehicle-to-infrastructure communication or vehicle-to-vehicle communication.

The vehicle-to-infrastructure communication is used for delivering of traffic information, electronic payment of highway tolls, internet accesses, entertainment, etc [7]. Vehicles communicate with many base stations that are equipped along a road. Therefore, vehicles perform handover of base stations one after another. The vehicle-to-infrastructure communication is especially important technology to achieve some user applications in ITS. Meanwhile, vehicles communicate each other in the vehicle-to-vehicle communication. Main service of vehicle-to-vehicle communication is offering vehicle information for safety applications.

The vehicle-to-vehicle communication in VANETs has special attributes that differentiate it from the other types of networks such as mobile ad hoc networks (MANETs). One of the main different features between VANETs and MANETs is related to the behavior of nodes. Vehicles in VANETs are faster than nodes in conventional MANETs. Moreover, the mobility patterns of vehicles in VANETs are more restrictive due to road structures. Therefore, these characteristics are very effective in most of the previous routing protocols [8].

Finding and maintaining routes has many difficulties in the dynamic behavior of vehicles in VANETs. Routing in VANETs has been recently studied and a variety of different protocols were proposed [10]. These protocols can be classified into five categories such as pure ad-hoc routing, position-based routing, cluster-based routing, broadcast routing, and geocast routing.

VANETs and MANETs share the same principle such as self-organization, low bandwidth, and short radio transmission range. Therefore, most ad-hoc routing protocols are still applicable. Ad-hoc on-demand distance vector (AODV) [11] and dynamic source routing (DSR) [12] are well-known routing protocols for general purpose mobile ad-hoc networks. These protocols can reduce overhead in scenarios with a small number of flows. Meanwhile, VANETs differ from MANETs by their dynamic change of network topology. The conventional studies showed that most ad-hoc routing protocols suffer from highly dynamic nature of vehicle mobility and tend to have low communication throughput due to poor route management performance [13].

Vehicle movement in VANETs is usually restricted in just bidirectional movements constrained along roads and streets [14]. Position-based routing employs routing strategies that use geographical information obtained from navigation system on-board vehicles. Most position-based routing algorithms are based on forwarding decision upon location information. Some protocols exchange information of location and each vehicle's speed, and select a route with minimum link loss probability [15], [16], [17]. Additionally, greedy perimeter stateless routing (GPSR) [18] is one of the well-known protocols. It works best in a free space scenario. However, direct communication between vehicles may not exist due to buildings and large-sized vehicles. Connectivity-aware routing (CAR) protocol finds paths between a source vehicle and a destination vehicle, considering vehicle traffic and movement of vehicles [19].

In cluster-based routing, each cluster can have a cluster head, which is responsible for intra- and inter-cluster communication [20]. Vehicles in a cluster communicate with neighbor vehicles directly. Inter-cluster communication is performed via the cluster-heads. Many cluster-based routing protocols have been proposed in MANETs. However, the VANETs have different features due to constraints on mobility, high speed movement, and driver behavior. As a result, cluster-based routing protocols can achieve good scalability for large networks. But, vehicles suffer from the long delay and the overhead involved in forming and maintaining clusters in VANETs [21].

Broadcast routing is frequently used for delivering advertisements and announcements in VANETs. The simplest way to implement broadcast mechanisms is flooding, in which each vehicle re-broadcasts packets to all of its neighbors. Flooding performs relatively well for a small number of vehicles. However, it suffers from broadcast storm problems when the number of vehicle in networks increases [22]. Some schemes for the broadcast storm problems have been proposed in ad hoc networks [23], [24], [25]. However, the investigation about the broadcast storm problems is not enough to be considered in VANETs.

Geocast routing is a location-based multicast routing [26]. Therefore, packets are delivered from a source vehicle to all other vehicles with a specified geographical region. The geocast routing is benefit mechanisms in many applications of VANETs. For example, a vehicle can detect some problems in neighbor vehicles to prevent collisions. Most geocast routing schemes are based on directed flooding. In VANETs, each vehicle can obtain its own location by using global positioning system (GPS). Therefore, some researchers have proposed forwarding techniques that reduce redundant transmission by using this location information [27], [28].

However, almost all schemes do not consider intercept of communication by large-size vehicle. In the actual VANETs, sizes of vehicles are also different. Therefore, VANET routing protocols should consider the actual communication environment. Another researcher considers broadcast schemes based on IEEE 802.11 [29], [30]. In these techniques, adequate vehicles for forwarding are selected because vehicle positions

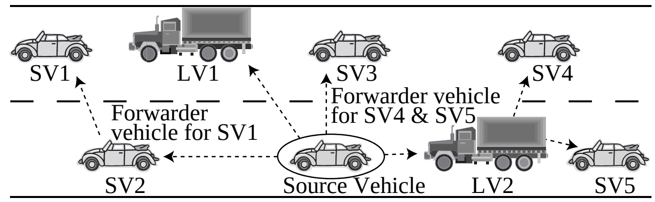

Fig. 1. Vehicle information delivery in ITS.

are exchanged via some control packets. However, actual wireless environments in ITS networks are especially severe from a practical standpoint. For examples, a standard-sized vehicle comes under an influence of blocking by large-size vehicles, and each vehicle suffers from dynamic fluctuation of signal intensity by moving so fast. In these environments, a distance can not be appropriate criteria for selection of forwarder vehicles.

We have proposed a simple delivery scheme for vehicle information [1]. In this paper, we evaluate packet delivery ratio and transmission delay. One characteristic of our scheme is utilizing vehicle information messages (VIMs) themselves for route construction. At first phase, all vehicles forward all vehicle information messages on a temporary basis. Therefore, delivery of new vehicle information can be achieved with short delay. This characteristic will be especially important to achieve blind crossing and prevention of collisions The reason for this is that almost all routing protocols require several periods to construct routes, and these route construction periods will have big overhead to reduce the delay for recognizing each vehicle. At second phase, each vehicle selects an adequate forwarder vehicle for its vehicle information forwarding. As a result, the number of forwarded vehicle information messages can be reduced to solve broadcast storm problems. This characteristic is an important factor to achieve high scalability with increasing of vehicles. Finally, our scheme utilizes vehicle information instead of hello messages to maintain routes. Consequently, our scheme can check a link status between neighbor vehicles without any control messages, and the number of control messages can be also reduced. We assume the different sizes of vehicles in the computer simulations. Then, we evaluate the proposed scheme in the more actual wireless environment. The numerical results show that the proposed scheme can achieve the high delivery ratio with short delivery delay.

II. System Model

A purpose of this paper is to achieve a vehicle-to-vehicle communication scheme, which delivers vehicle information within a specified geographical region. Figure 1 is a diagrammatic illustration of vehicle information delivery for safety applications in VANETs. We assume that each vehicle transmits its vehicle information message as a source vehicle

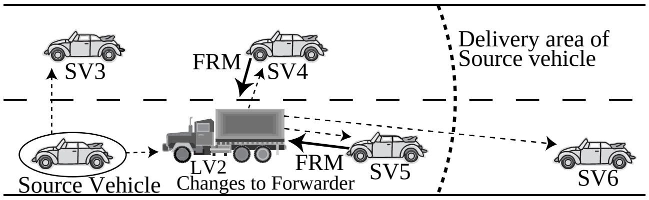

Fig. 2. Example procedure of forwarding request.

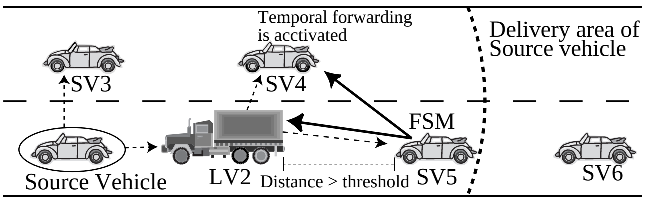

Fig. 3. Example procedure of forwarder search request.

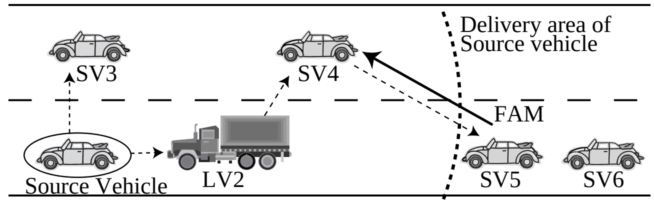

Fig. 4. Example procedure of forwarding abort request.

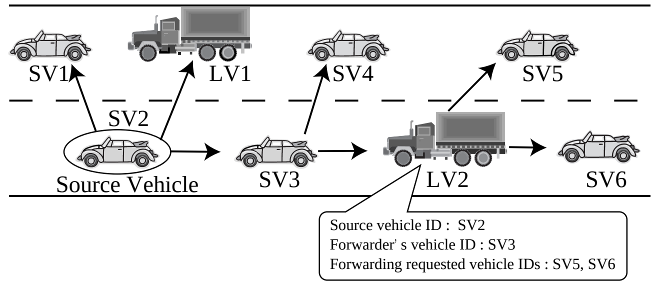

Fig. 5. Example routing information of LV2.

periodically. But, we focus our attention on routes to neighbor vehicles from a source vehicle in Fig. 1. Vehicles $SV2$ and $LV2$ are forwarder vehicles for their neighbor vehicles. Our protocol can support a mixed environment of standard-sized and large-size vehicles. A vehicle information message is delivered to some vehicles in a limited area. The limited area is defined as the delivery distance, and is determined as a fixed value beforehand. Our scheme can be implemented in a bidirectional road environment by using directional information of vehicles. However, we assume a one-way road in the explanation for simplicity.

In the proposed protocol, three types of control messages are introduced to deliver vehicle information messages; a Forwarding Request Message (FRM), a Forwarder Search Message (FSM), and a Forwarding Abort Message (FAM). The FRM is transmitted when vehicles request neighbor vehicles to activate forwarding function. The FSM is transmitted when vehicles detect link losses. The FAM is transmitted when a distance between a vehicle and its source vehicle is longer than its delivery distance. These example procedures are shown in Figures 2, 3 and 4.

Almost all routing protocols require periodic transmission of control packets because adequate routes may be changed due to moving of vehicles. On the contrary, each vehicle does not transmit the control packets periodically in the proposed protocol. In order to recognize neighbor vehicles, each vehicle uses vehicle information messages as substitutes for special control packets like hello messages. As a result, control messages are only transmitted when vehicles lose links to neighbor vehicles or change links to other neighbor vehicles. Therefore, our protocol can reduce the number of transmitted control messages.

Table I shows the components of the routing table. In the proposed scheme, the routing table in Table I is constructed for each source vehicle. In the assumed ITS networks, vehicle information is delivered in a limited area near a source vehicle. Therefore, our assumed application is one of multicast application types and the proposed protocol is one of geocast routing protocols. As a result, each source vehicle has a receiver group for vehicle information. In the proposed protocol, the source vehicle ID is used for determining the receiver group for the source vehicle. The source vehicle position is used to detect the delivery area. The final received time of vehicle information is used to remove the routing information if the vehicle does not receive the vehicle information for a long time. The forwarder's vehicle ID is used to maintain its own forwarder vehicle information. The forwarding requested vehicles IDs are an ID list of vehicles, which transmit a Forwarding Request Message to its own vehicle. If this list has some vehicle IDs, the vehicle should forward vehicle information from the source vehicle. The forwarding requested vehicle positions are lists of positions for forwarding requested vehicles. These lists are used to find vehicles that exist outside of delivery area of the source vehicle.

Figure 5 is example routing information of large-size vehicle 2. The LV2 has constructed a route to the SV3 and has been requested to forward vehicle information of the SV2 by the SV5 and the SV6. Therefore, the forwarder's vehicle ID of LV2 is the SV3, and the forwarding requested vehicles IDs are SV5 and SV6.

Figure 6 shows a flow chart of the proposed routing scheme. In this flow chart, a source vehicle S transmits a vehicle information message periodically, and a forwarder vehicle F forwards the vehicle information message from the vehicle S. Finally, a destination vehicle D receives it.

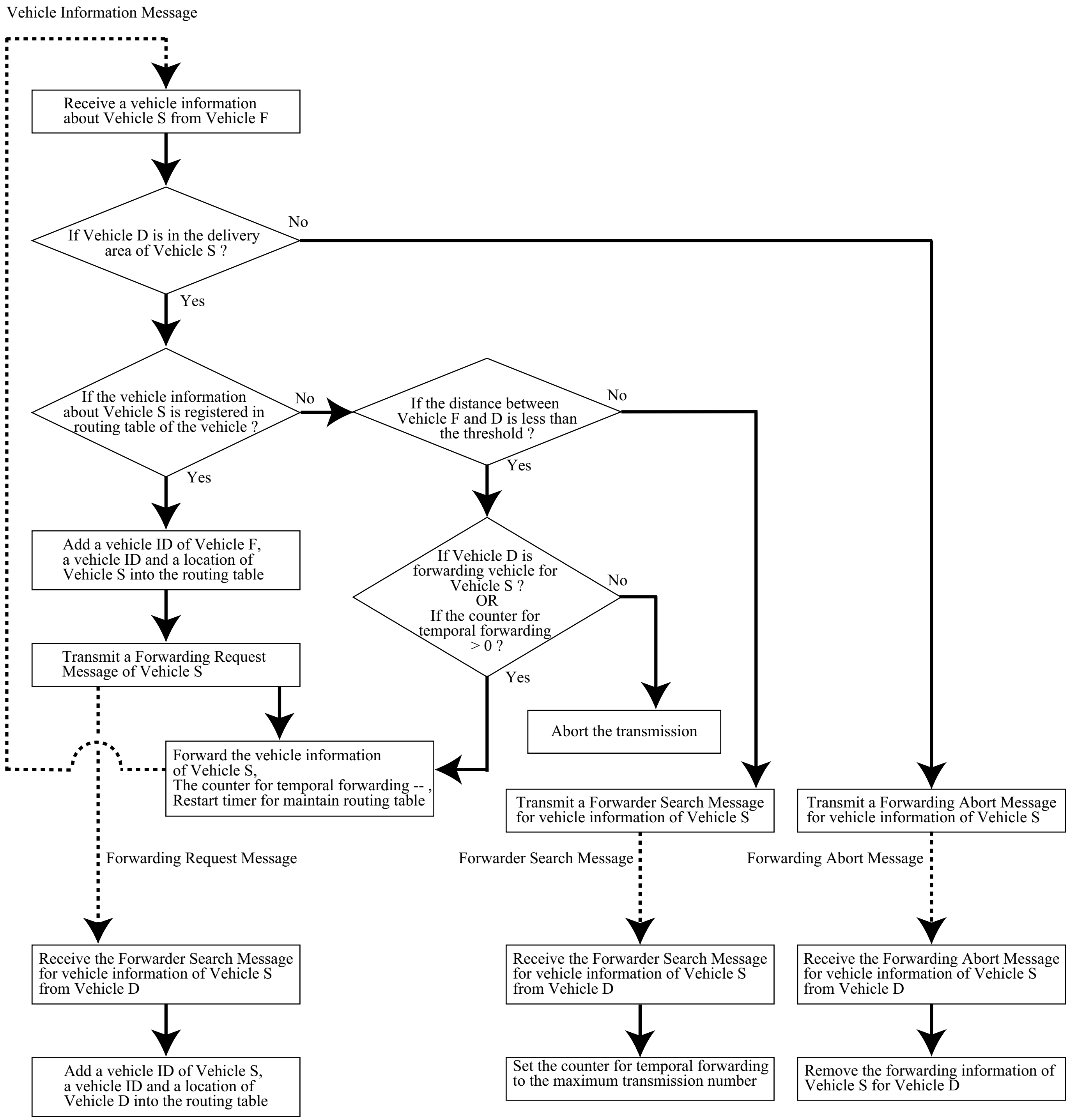

Fig. 6. Flow chart of the proposed routing protocol.

A. Forwarding Procedures

When a vehicle receives new vehicle information messages from neighbor vehicles, two procedures will be performed. The first one is forwarding procedures and the second one is forwarding request procedures. In the forwarding procedures, vehicles forward the received vehicle information message to neighbor vehicles. The procedures are described as follows.

1) The vehicle calculates a distance between a previous hop vehicle and itself.
2) The vehicle calculates a forwarding delay period according to the distance in order to set priorities of forwarding. The delay period is set to a short time when the distance is long. On the contrary, the delay period is set to a long time when the distance is short. This is because the

TABLE I
COMPONENTS OF ROUTING TABLE.

Source vehicle ID
Source vehicle position
Final received time of vehicle information from source vehicle
Forwarder's vehicle ID
Forwarding requested vehicle IDs
Forwarding requested vehicle positions

number of hops can be reduced if the distance is long. In the proposed procedures, every vehicle forward vehicle information with prioritized delay on a temporary basis. Therefore, the proposed scheme is tolerant of vehicle movement.

3) The vehicle sets a forwarding delay period that is related to the distance.
4) The vehicle forwards the received vehicle information message with this forwarding delay period.

B. Forwarding Request Procedures

In the forwarding request procedures, vehicles request to forward vehicle information messages to neighbor vehicles. Procedures are described as follows.

1) The vehicle calculates the distance between the source vehicle of the vehicle information message and itself.
2) The vehicle checks the routing table to find the source vehicle ID within the vehicle information message when the distance is shorter than the delivery distance.
3) The vehicle adds the vehicle ID and a position of the source vehicle into the routing table when the source vehicle ID cannot be found in the routing table.
4) The vehicle requests the previous hop vehicle as a forwarder vehicle for itself by transmitting a Forwarding Request Message (FRM).
5) The neighbor vehicle that receives the FRM adds a vehicle ID and a vehicle position of the requesting vehicle.
6) The neighbor vehicle starts forwarding of vehicle information messages to the requesting vehicle.

Figure 2 is an example procedure when the vehicles $SV4$ and $SV5$ transmit FRMs. In this figure, the vehicle $SV6$ does not transmit a FRM because it exists outside of delivery area of the source vehicle $SV0$. Finally, the vehicle $LV2$ starts forwarding of new vehicle information messages.

C. Forwarder Search Procedures

Following procedures are performed when the distance between a forwarder vehicle and itself becomes longer than a threshold.

1) The vehicle tries to find another vehicle as a forwarder vehicle because the current forwarder vehicle is far from itself.
2) The vehicle transmits a Forwarder Search Message (FSM) to neighbor vehicles.
3) The neighbor vehicles activate each forwarding function of vehicle information messages if each distance between the vehicle transmitting the FSM and themselves is shorter than the threshold.
4) The neighbor vehicles start forwarding their vehicle information messages for a while. The maximum retransmission time of vehicle information messages is set to a counter for the temporal forwarding.
5) The vehicle transmits a new FRM to an adequate vehicle of its neighbor vehicles when it receives a new vehicle information message from them.

Figure 3 is an example procedure when the vehicle $SV5$ transmits a FSM because the distance between the $LV2$ and the $SV5$ is longer than the threshold. In this figure, the vehicle $SV4$ activates the temporal forwarding procedures for the $SV5$. Hence, the vehicle $SV5$ will transmit a FRM to the vehicle $SV4$.

D. Forwarding Abort Procedures

Following procedures are performed when vehicles move to outside of the delivery area of their source vehicle

1) The vehicle transmits a Forwarding Abort Message (FAM) to its forwarder vehicle.
2) The forwarder vehicle removes the forwarding information for it from the routing table.

Figure 4 is an example procedure when the vehicle $SV5$ moves to outside of the delivery area, and transmits a FAM to the vehicle $SV4$. The vehicle $SV4$ will inactivate the forwarding procedures for the vehicle $SV5$.

III. EXAMPLE OPERATIONS

In the proposed scheme, each vehicle starts to construct a route by receiving a new vehicle information. In this section, we explain example operations of the proposed scheme with the vehicle layout in Fig. 7. Figure 8 shows an example of packet transmission in this situation. In the example, each vehicle is assumed to deliver vehicle information within radius R.

In Fig. 7, the vehicle V_1 is regarded as a source vehicle. The vehicles $V_2, V_3, V_4,$ and V_5 exist in the area where the vehicle information of the vehicle V_1 can be delivered. The vehicle V_1 transmits the vehicle information messages (VIMs) periodically. The neighbor vehicles V_2 and V_3 register the new vehicle V_1 by checking each routing table. Then, each vehicle calculates a forwarding delay according to relative position to the source vehicle V_1. The vehicle V_3 sets a shorter delay than the vehicle V_2 because the relative position to V_3 is longer than that of V_2. This procedure reduces the hop count for vehicle information delivery. Then, vehicles V_4 and V_5, which receive the vehicle information forwarded by

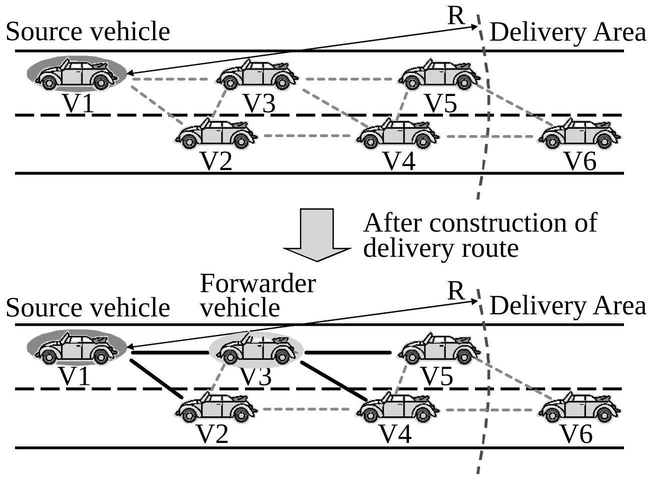

Fig. 7. New vehicle information forwarding and route construction process.

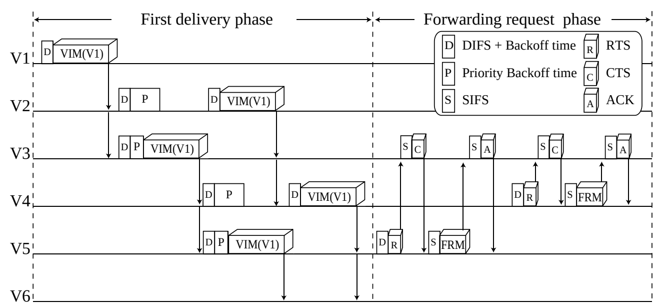

Fig. 8. Time sequence of the new route construction process.

the vehicle V_3, transmit each Forwarding Request Message to request vehicle information forwarding. The vehicle V_3 registers the forwarding requested vehicle IDs and positions when it receives the Forwarding Request Messages. Finally, the vehicle V_3 constructs a route to the vehicle V_4 and the vehicle V_5 from the vehicle V_1.

A. Route construction for new vehicles

Each vehicle transmits its own vehicle information periodically. Therefore, vehicles can find that a neighbor vehicle moves into delivery area of their souce vehicle. Figure 9 shows an example that the vehicle V_6 moves into the delivery area of the vehicle V_1. An example for packet transmission is shown in Fig. 10.

In Fig. 9, vehicles V_4 and V_5 can find the position of the vehicle V_6 because these vehicles exchange the vehicle information each other. Moreover, the vehicles V_4 and V_5 can find that the vehicle V_6 moves to the delivery are of the vehicle V_1 because they know the positions of the vehicles V_1 and V_6.

The vehicles V_4 and V_5 start to forward the vehicle information from the vehicle V_1 when they find that the vehicle V_6 moves to the delivery area of the vehicle V_1. Consequently, the vehicle V_6 will be able to receive the vehicle information

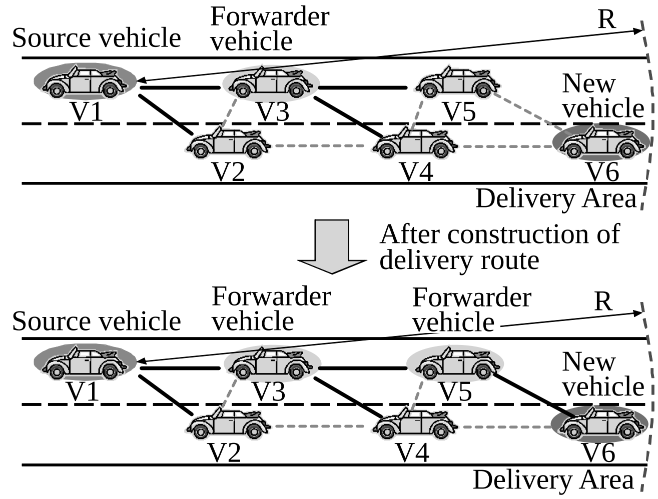

Fig. 9. Route construction for the new vehicle.

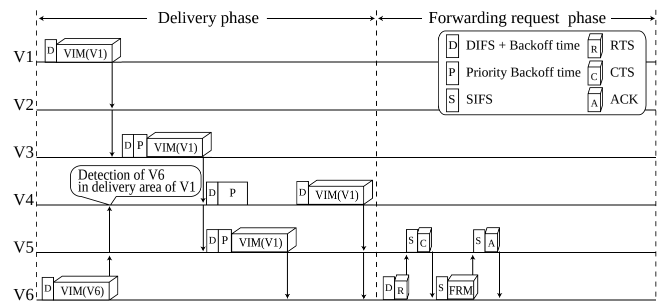

Fig. 10. Time sequence of the new route construction process for the new vehicle.

of the vehicle V_1 through the vehicles V_4 and V_5. The vehicle V_6 constructs a route by requesting vehicle information forwarding.

B. Route modification for moved vehicles

Vehicles can recognize neighbor vehicles by exchanging vehicle information each other. Therefore, a forwarding requested vehicle can start to find the next neighbor vehicles if it cannot communicate with the forwarder vehicle. Figure 11 shows that the vehicle V_5 moves to the outer area of the vehicle information delivery area of the vehicle V_3. An example for packet transmission is shown in Fig. 12.

In the Fig. 11, the vehicle V_5 finds that the route through the vehicle V_3 becomes invalid by checking the vehicle information from the vehicle V_3. Then, it broadcasts the Forwarder Search Message to neighbor vehicles. The vehicle V_4, which receives the Forwarder Search Message from the vehicle V_5, starts the temporary forwarding of the vehicle information. Finally, the vehicle V_5 can find the new route through the vehicle V_4.

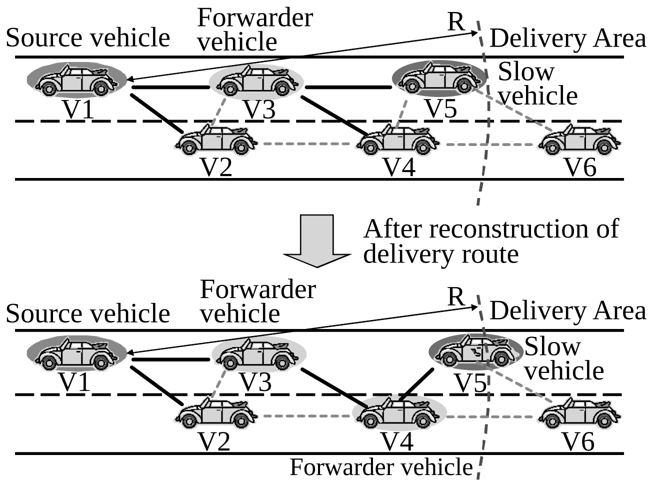

Fig. 11. Route modification process.

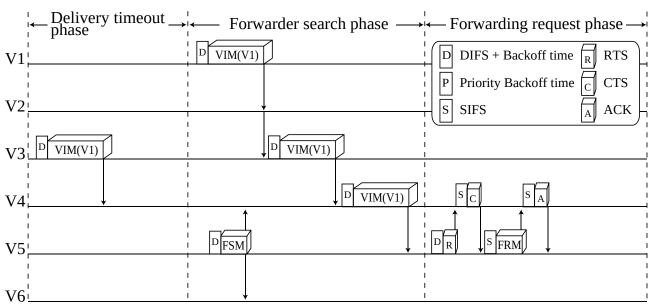

Fig. 12. Time sequence of the route modification process.

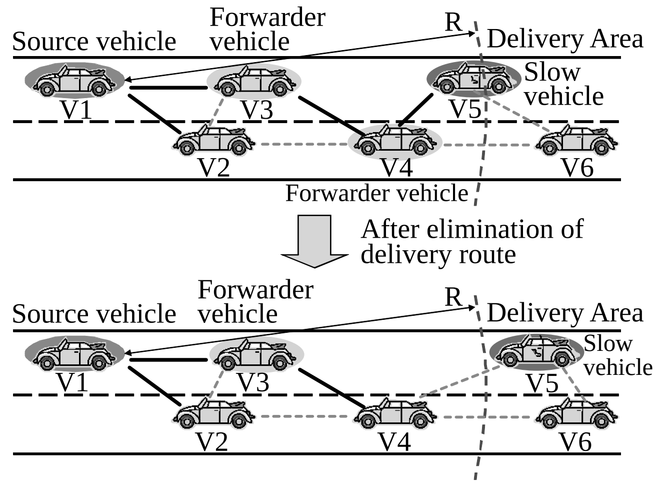

Fig. 13. Route discard process.

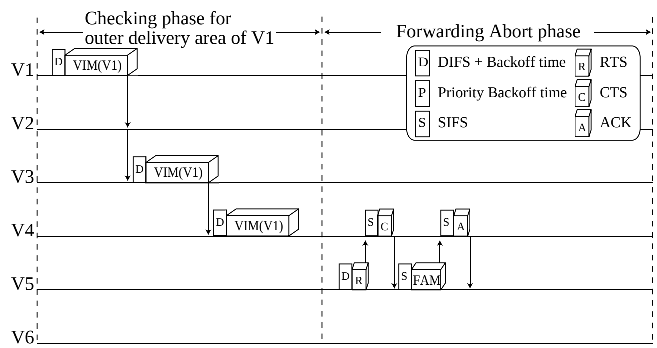

Fig. 14. Time sequence of the route discard process.

C. Route discard for moved vehicles

In the proposed scheme, two procedures for route discard are considered. The first is used in a situation that vehicles in a certain delivery area cannot receive any information of a vehicle, which were in the area, and they cannot recognize it any more. The second is used in a situation that vehicles in a certain delivery area can receive information of a vehicle and can recognize it, but it is moving out to the area. In the situations, they discards the routes in their own routing table. Figure 13 shows an example that the vehicle V_5 moves to the outer area of the vehicle information delivery area of the vehicle V_1. Figure 14 shows an example for packet transmission in this situation.

The vehicle V_5 uses the route through the vehicle V_4 in Fig. 13. It transmits a Forwarding Abort Message to the vehicle V_4 if it exists in the outer area of delivery area for a given length of time. Finally, the vehicle V_4 stops vehicle information forwarding and removes the route for the vehicle V_5.

IV. Numerical Results

In order to evaluate the feasibility of the proposed scheme, we performed computer simulations with network simulator QualNet [31]. Qualnet is the well-known wireless network simulation software that considers the more actual wireless environment. Therefore, packet errors are handled as the packet error ratio according to the received signal-to-interference and noise power ratio (SINR). Each results shows an average of 10 trials of simulation. Our proposed protocol is one of the information delivery schemes by broadcast communication. It is known that broadcast communication suffers from packet collisions when many vehicles exist in a communication area. Therefore, we considered 50 vehicles for small number of vehicles and 200 vehicles for large number of vehicles. We assumed that a road shape is a loop line with a radius equals to 1500 [m] and 2 lanes. Each vehicle is located randomly on the road, selecting the velocity between 90 [km/h] and 110 [km/h] randomly. Therefore, a distribution of vehicle velocity is uniformly between 90 [km/h] and 110 [km/h] The vehicle runs on the inside lane principally and keeps an inter-vehicular distance as 100 [m]. If there is no vehicle on the outside lane, the vehicle moves to the outside lane from the inside lane to overtake a forward vehicle. After overtaking, the vehicle moves to the inside lane if there is no vehicle on the inside lane. In the simulations, about 50 times of passing occur when

TABLE II
SIMULATION PARAMETERS.

Simulator	QualNet
Simulation time	150 [s]
Simulation trial	10 [times]
Number of vehicles	50, 200 [vehicles]
Vehicle velocity	90 – 110 [km/h]
Size of vehicle information message	100 [Byes]
Transmission interval	250 [ms]
Communication device	IEEE 802.11b
Transmission rates	11 [Mbps]
Transmission power	15 [dBm]
Antenna gain	0 [dB]
Antenna type	Omni directional
Antenna height	1.5 [m]
Propagation path loss model	Two ray
Wireless environment	AWGN
Road shape	Circle with radius = 1500 [m]
Number of lanes	2 [lanes]

the number of vehicle is 50, and about 150 times of passing occur when the number of vehicle is 200. Finally, the feature of this paper is to consider the effect of large-size vehicles. So, we define the large-size vehicle ratio that means the ratio of the large-size vehicles and the standard-size vehicles. When the large-size vehicle ratio is set to 0, all vehicles are standard-size vehicles.

As the wireless propagation model, we used a two ray propagation model. Moreover, we consider blocking effects due to large-size vehicles. So, we assumed that large-size vehicles are rectangular solids. If a rectangular solid is overlapped with the straight line between two standard-size vehicles, these two vehicles cannot communicate due to blocking.

The final purpose of this study is to fuse vehicle information delivery and communication networks for several network applications. Therefore, we employ IEEE 802.11b for a common comunication device. In the simulations, the transmission range is about 500 [m], packet errors are determined due to the received signal-to-interference and noise power ratio (SINR). Our packet error model can consider packet collisions and noises. The size of a vehicle information message is 100 [Byte], and is transmitted with 4 [packets/s]. The delivery area of vehicle information messages is assumed to be 1000 [m].

Our protocol is one of the broadcast communication methods. Therefore, we employ the probabilistic flooding scheme for comparison. The flooding probability is assumed to be 0, 25, 50, 75, 100 [%]. Simulation parameters are shown in detail in Table II.

Figure 15 shows the delivery ratio of vehicle information messages with 50 vehicles. In this study, we define that the delivery ratio is the message received ratio for vehicles in the delivery area. From results, we can find that our proposed protocol can achieve the highest delivery ratio. The delivery ratio of the probabilistic flooding scheme degrades when the

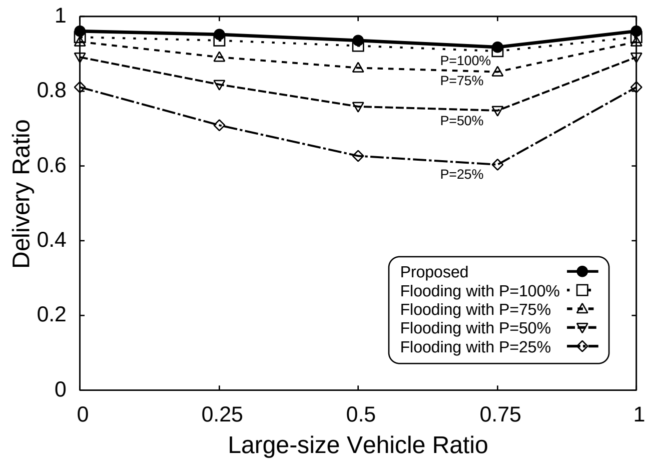

Fig. 15. Delivery ratio of vehicle information (50 vehicles).

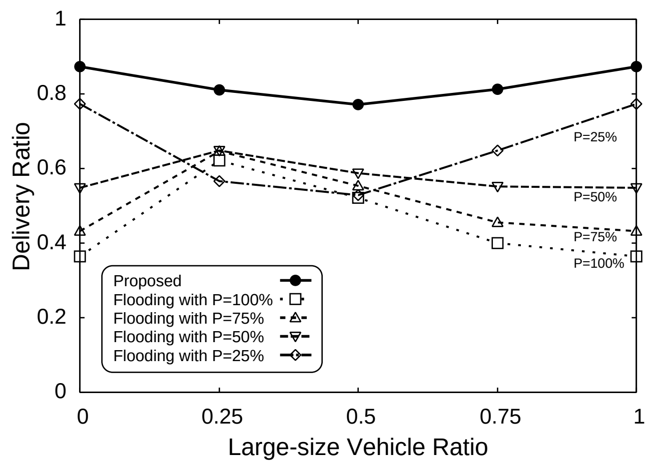

Fig. 16. Delivery ratio of vehicle information (200 vehicles).

flooding probability decreases. This is because several vehicles are required to forward vehicle information messages when there are a small number of vehicles on the road. Moreover, the delivery ratio of all schemes degrades when the large-size vehicle ratio increases. Especially, it degrades much when the value of the flooding probability is set low. The reason for this is that large-size vehicles block communications between standard-size vehicles. So, more vehicles should be required to forward vehicle information messages.

Figure 16 shows the delivery ratio of vehicle information messages with 200 vehicles. From results, our proposed protocol can keep the highest delivery ratio. But, the delivery ratio of the flooding scheme degrades. This is because the flooding schemes suffer from broadcast storm problems. We can find that some flooding schemes can achieve good delivery ratio. However, the optimum flooding probability is also changeable depending on situation change. So, it is difficult to select the optimum flooding probability in the actual system.

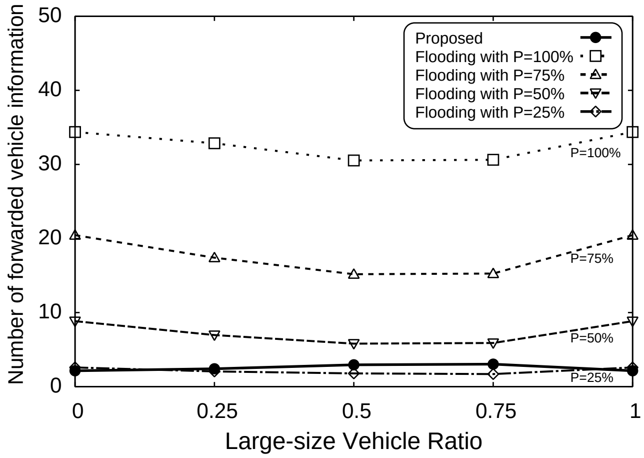

Fig. 17. Number of forwarded vehicle information (50 vehicles).

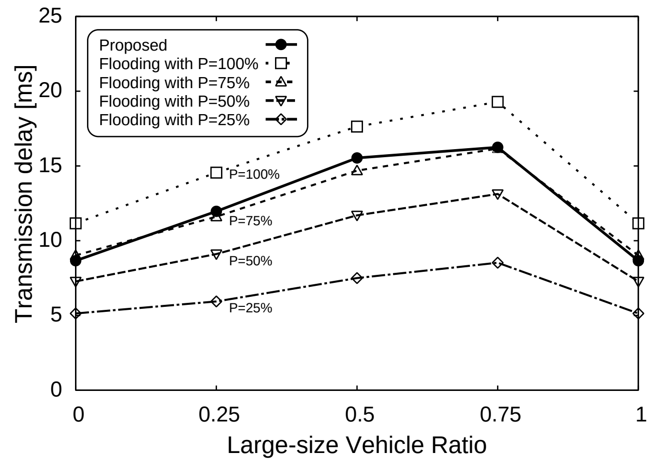

Fig. 19. Delay performance (50 vehicles).

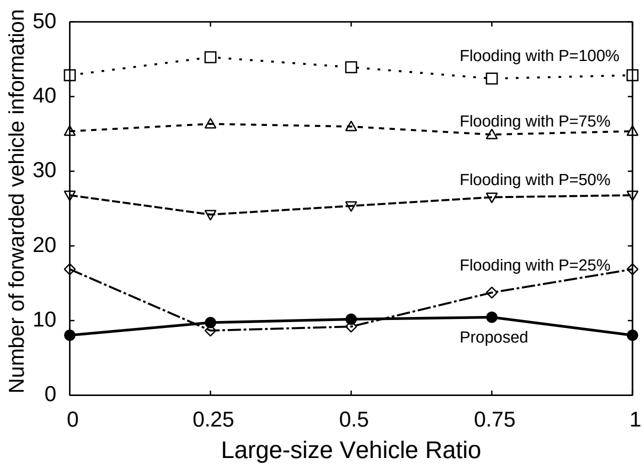

Fig. 18. Number of forwarded vehicle information (200 vehicles).

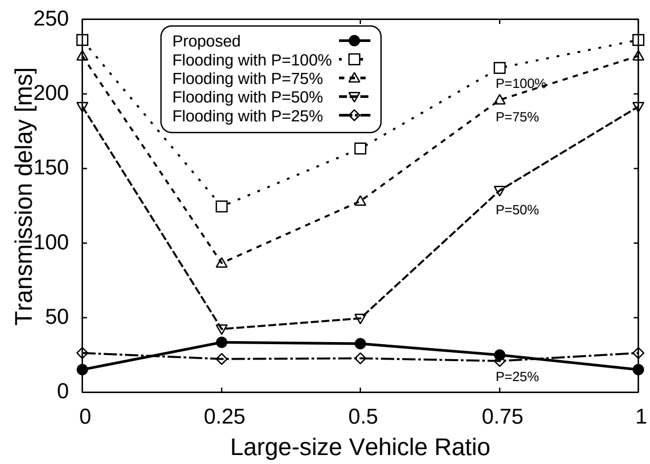

Fig. 20. Delay performance (200 vehicles).

Incidentally, the delivery ratio of the proposed protocol can achieve high performance even if the large-size vehicle ratio is changed because each vehicle selects an optimum vehicle as its forwarder vehicle in the proposed protocol. In the conventional research, the objective packet delivery ratio is assumed to be 90 [%]. In the broadcast communication, packets may be corrupted due to hidden terminal problems. Therefore, it is difficult to achieve high delivery ratio when special media access control (MAC) method is not employed. In our delivery ratio, we evaluate packet delivery ratios at all receiver vehicles. Therefore, we think that our protocol can be used for the actual environments by employing the Forward Error Correction (FEC).

Figure 17 shows the number of forwarded vehicle information in the delivery area with 50 vehicles. From results, we can find that the flooding schemes require several times of forwarding. Therefore, the flooding schemes can achieve high delivery performance. However, these excess forwarding are unreasonable from the viewpoint of the wireless resource. The probabilistic flooding can decrease the number of forwarding. But, the delivery ratio is also degraded. On the contrary, our proposed protocol requires small number of forwarding like the probabilistic flooding with 25 [%]. However, the proposed protocol can achieve the high delivery ratio like the full flooding scheme. Therefore, our protocol is a reasonable scheme from the viewpoint of wireless resources.

Figure 18 shows the number of forwarded vehicle information in the delivery area with 200 vehicles. From results, the performance of the probabilistic flooding with 25 [%] keeps small number of forwarded vehicle information messages. However, the delivery ratio of the probabilistic flooding with 25 [%] degrades due to blocking by large-size vehicles. This is because it is difficult to forward vehicle information message appropriately when the flooding probability decreases. Meanwhile, the proposed protocol can keep the smallest number of forwarded vehicle information messages. Moreover, the

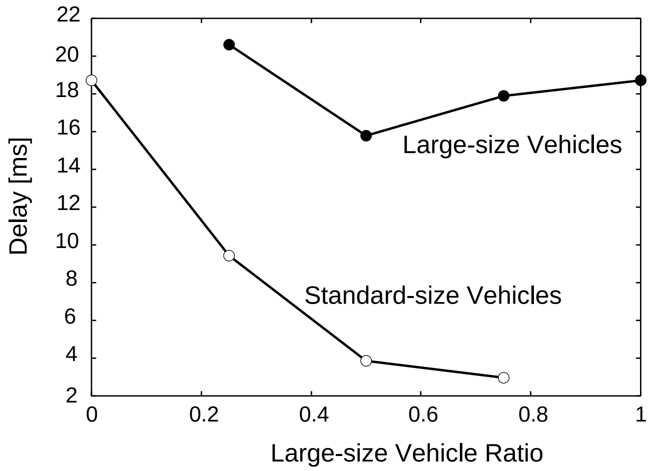

Fig. 21. Delay performance of standard and large-size vehicles.

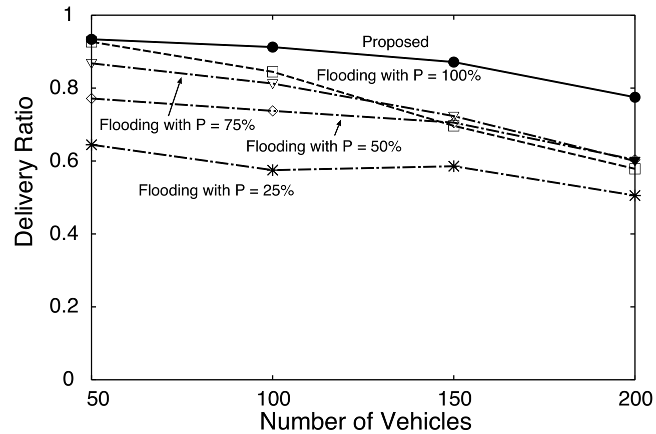

Fig. 22. Delivery ratio of vehicle information (large-size vehicle:40[%].

performance of the proposed protocol achieves a stable delivery ratio and a stable forwarding performance because each vehicle selects its forwarder vehicle by considering blocking due to large-size vehicles.

Figure 19 shows the delay performance with 50 vehicles. The delay period starts when a source vehicle transmits a vehicle information message, and ends when the vehicle information message is received at all vehicles in the delivery area. Therefore, the accurate delay of each vehicle is different due to the positions of the vehicles. So, the delay performance averages delays of all vehicles in the delivery area. From results, the delay performance of the proposed protocol is a little shorter than that of the full flooding scheme. The delay performance of all schemes increases when the large-size vehicle ratio increases. The reason for this is that blocking by the large-size vehicles causes degradation of the actual transmission range. Therefore, more forwarder vehicles are required to transmit the vehicle information messages.

Figure 20 shows the delay performance with 200 vehicles. From results, the delay performance of the proposed protocol can keep short values when the large-size vehicle ratio changes. On the contrary, the flooding schemes have especially long delay when the large-size vehicle ratio equals to 0 or 100 [%]. The actual transmission range becomes long when there is no effect of blocking due to the large-size vehicles. Therefore, broadcast storm problems occur.

Figure 21 shows the delay performance of standard-size and large-size vehicles in the proposed protocol. This kind of delay is required to transmit vehicle information in MAC layer. From results, we can find that delays of large-size vehicles decrease according to increasing of the large-size vehicle ratio because large-size vehicles block communications between standard-size vehicles and the number of vehicles in a certain communication area also decreases. Therefore, each vehicle can obtain more opportunities to transmit vehicle information. On the contrary, the delay performance of large-size vehicles is also constant. This is because large-size vehicles can communicate with standard-size vehicles and large-size vehicles. Moreover, these communication are not blocked. Then, the number of vehicles sharing the same communication is also increasing. As a result, it is difficult for large-size vehicles to obtain opportunities to transmit vehicle information.

Figure 22 shows the delivery ratio of vehicle information with a large-size vehicle ratio equals to 40 [%] and 200 vehicles. From results, the performance of the all flooding mechanisms degraded according to increasing in the number of vehicles. The reason for this is that it is difficult to select adequate forwarding vehicles in the situation the large-size vehicle ratio equals to 40 [%]. Meanwhile, the proposed protocol has good scalability performance. The scalability is one of the most important factor in ITS. This is because the proposed protocol is especially simple and only a few control messages are exchanged when a vehicle joins certain networks, it changes its forwarding vehicle and drops out the networks. Moreover, the proposed protocol can select an adequate forwarding vehicle, and improve effectiveness of channel resource.

Figure 23 shows the number of forwarded vehicle information with a large-size vehicle ratio equals to 40 [%] and 200 vehicles. From results, we can find that the proposed protocol can keep a small number of forwarded vehicle information. However, the performance of the proposed protocol is little larger than that of the probabilistic flooding with P = 25 [%] because the proposed protocol can select the forwarding vehicles. Therefore, more vehicles are selected as a forwarding vehicle when large-size vehicles blocks communication between standard-size vehicles.

Figure 24 shows the delay performance with a large-size vehicle ratio equals to 40 [%] and 200 vehicles. From results, the delay performance degrades according to increasing in the

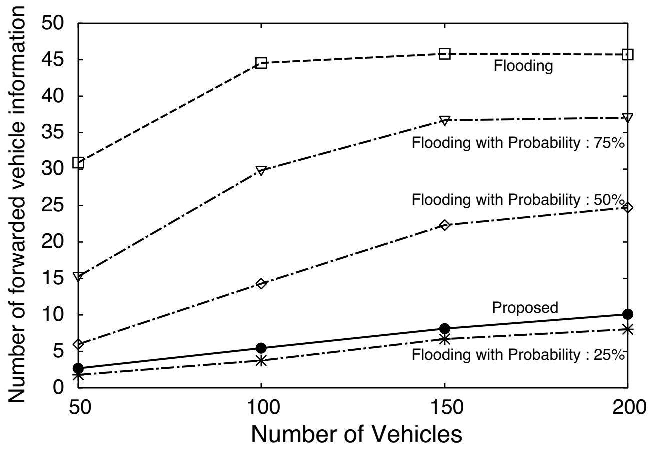

Fig. 23. Number of forwarded vehicle information (large-size vehicle:40[%].

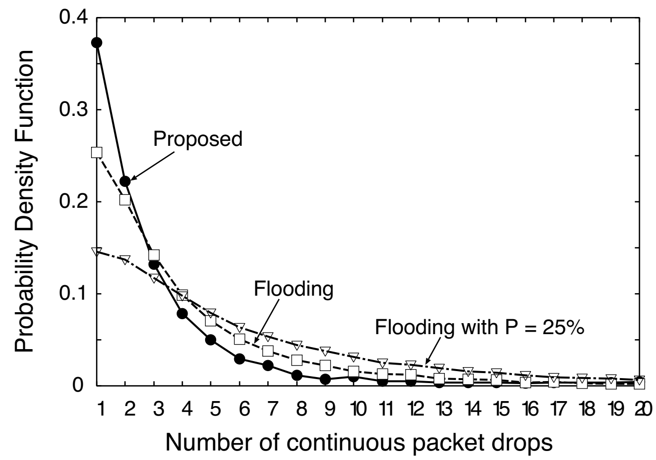

Fig. 25. Continuous drop ratio of vehicle information.

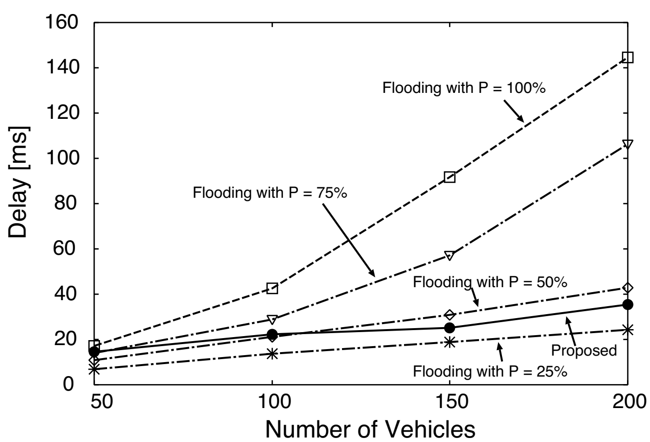

Fig. 24. Delay performance (Big size vehicle:40[%]).

flooding probability. This is because broadcast storms occur and it is difficult for almost all vehicles to transmit vehicle information. On the contrary, the proposed protocol can keep the short delay even if the number of vehicle increases.

Figure 25 shows the continuous drop ratio of vehicle information with a large-size vehicle ratio equals to 40 [%] and 200 vehicles. The continuous drop ratio means the ratio that the vehicle cannot receive the vehicle information continuously. The continuous drops of vehicle information are not suited characteristics for ITS communication because these drops cause temporal interruption of communication between neighbor vehicles. From results, we can find that the proposed protocol has good tolerance to burst packet losses.

V. Conclusion

In this paper, we have proposed a new routing protocol for delivery of vehicle information to neighbor vehicles in a specific area. The proposed protocol can deliver new vehicle information with short delay by performing temporal limited flooding before a construction of routes. Moreover, it can deliver vehicle information effectively with forwarding by an adequate vehicle. The feature of the protocol is utilizing a vehicle information message itself to detect each vehicle status. Moreover, our protocol can be extended for a bidirectional road by using directional information. As a result, our protocol does not require periodic transmission of control messages. In addition, we have evaluated an environment with the mixed factor of standard-size and large-size vehicles. In the actual environment, it is important to support this mixed factor for real safe driving systems. Finally, we can find that our protocol can achieve the high delivery ratio with short delay even if large-size vehicles influence the communication. Moreover, we can provide required quality in communications if we employ the forward error correction (FEC) to recover the packet loss. Considering all these results mentioned above, the proposed method could be one of the fundamental schemes for achieving ITS.

VI. Future work

In this paper, we evaluated the performance with two sizes of vehicles in additive white gaussian noise (AWGN) environment. Therefore, our evaluation can assume more actual vehicle conditions and wireless communication environment. However, multi-path fading is also significant degradation factor in city environment. Then, it is important to handle the dynamic fluctuation of wireless channel. Moreover, the proposed scheme was evaluated with the IEEE 802.11b system. Therefore, it is not difficult to implement on embedded system with IEEE 802.11 device. Authors has a schedule to implement the proposed scheme on a Linux router board with a mini-PCI IEEE 802.11device.

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