Multi-Hop Vehicular Broadcast (MHVB)

Tatsuaki Osafune, Lan Lin, Massimiliano Lenardi
Hitachi Europe, Sophia Antipolis Laboratory
1503 Route des Dolines, F-06560 Valbonne, France
Email: tatsuaki.osafune@hitachi-eu.com

***Abstract*— Inter-Vehicular Communications (IVCs) are now considered as a way to realize active safety, for example, by providing the position information of each other or the potential danger warning by wireless communications.**

We have worked on a flooding protocol over vehicular ad hoc networks (VANETs) to efficiently disseminate the information for the sake of active safety applications, such as the positions and the velocities of the vehicles. We propose a flooding protocol with *(i)* Congestion Detection algorithm which suppresses unnecessary packets due to vehicular congested traffic and *(ii)* Backfire algorithm which efficiently forwards the packet through the network by selecting the adequate receiver node based on the distance from the original node.

In this paper, we show simulation results over NS2 (Network Simulator 2). They show that the proposed flooding protocol significantly improves the performance of data dissemination over VANETS.

I. Introduction

Intelligent transport systems (ITS) services based on the infrastructures, such as vehicle information and communication system (VICS) and electronic toll collection (ETC), have been already implemented and deployed for practical services. Recently, Inter-Vehicular Communications (IVCs) are highlighted as a way to increase the road safety by utilizing the information exchanged among vehicles. Nowadays there are many governmental projects and industrial consortiums (C2CCC, ASV, VSC) working worldwide over these topics.

Some active safety applications are based on a decentralized way of communications, namely Vehicle-to-vehicle (V2V) communications without using any infrastructure. By exchanging their position and the velocity of vehicles, the potential dangers such as intersection collisions or accident ahead can be detected. V2V communications are regarded suitable for active safety applications because of their nature to be available anywhere, to require the strict latencies and to cover localized communications. Taking Intersection Collision Avoidance as an example, listed in the document issued by US DOT (Department of Transportation) [1], the allowable latency to obtain the necessary information is defined as 0.1 second. Also, the application requires the communication coverage up to 300 meters. An article of Tony et al. [2] says that the allowable latency for various V2V applications is typically defined between 100 - 500 ms, while the communication coverage is between 50 - 300 meters, and some requires up to 1000 meters.

In this paper, our technical target is:

- to form a localized vehicular ad hoc network using the short range communication devices with Carrier Sensing Multiple Access (CSMA) at the Medium Access Control (MAC) layer such as 802.11 or dedicated short range communication (DSRC)
- to develop a protocol able to satisfy the required communication coverage and the allowable latency by periodically sending the broadcast messages, taking into account the limited bandwidth defined by the aforementioned wireless communication technologies.

This paper is organized as follows. In Section 2, we overview the related works. In Section 3, the details of the proposed protocol are described. The simulation parameters are explained in Section 4 and the simulation results appear in Section 5, respectively. Finally we conclude this paper and the future works are stated in Section 6.

II. Related works

Flooding protocols for ad hoc networks are extensively summarized in [3]. It classifies the broadcast techniques for Mobile Ad Hoc NETworks (MANET) largely into four kinds. The first is *(i)* simple flooding, in which all the nodes receiving the broadcast message rebroadcast the packet exactly one time and these rebroadcasts are repeated until all the nodes receive the packet. The second is *(ii)* probability based methods, which is similar to simple flooding except that the node rebroadcast with a predetermined probability. The third is *(iii)* area based methods. In order to cover as wide area as possible, the node which can cover larger additional area is chosen as a rebroadcast node. Namely, the farther nodes from the sender preferentially rebroadcast the packet. The fourth broadcast technique is *(iv)* neighbor knowledge methods. Ideally, Minimum Connected Dominating Set (MCDS) is the set of nodes able to rebroadcast the packet with the least number of packets. However, since the problem of MCDS is known to be NP-hard for general graphs, these methods aim to disseminate the information with as less packet as possible by calculating the localized sub-optimal solution based on the knowledge of neighbors.

There are some works proposed as the flooding protocols dedicated for IVC. In [4], a flooding protocol for IVC is proposed. This protocol belongs to *(iii)* area based methods with two specific functions, Directional Broadcast and Intersection Broadcast. In Directional Broadcast functions, the authors propose a variant of RTS/CTS applied for broadcasts, so that the the broadcast messages could be sent reliably.

In [5], two are proposed, which are categorized in *(iv)* neighbor knowledge methods. In both of them, a vehicle which want to transmit a packet to the whole network select the re-transmitter based on the position information after transmitting a position request packet by one hop and aquiring the position inforamtion of neighbors as the reply.

Our approach shown in this paper belongs to *(iii)* area based methods. The reason why this approach is chosen is that we assume that the location device, such as Global Positioning System (GPS) devices, will be available in the ITS context in near-future and that the protocol can then exploit their position information. On the contrary, The simple flooding *(i)*, which the receiver nodes simply re-broadcast the messages once it is received, is too redundant and needs much network resources when there are many vehicles like in traffic jam. The probability methods are less effective if the location device is available. They are more suitable for the situation when the location devices are not available. Neighbor knowledge methods *(iv)*, although this category can be the best in terms of the network resources by efficiently rebroadcasting the messages based on the local topology, do not necessarily work well in highly mobile situations like in the targeted vehicular scenario, because the high mobility makes it difficult for the protocol to be coherent with the current neighbor topology.

III. Algorithm of MHVB

The purpose of this protocol is disseminate the information to other vehicles, and let them store it in the local database so that the application can utilize it for safety use. The main challenge of this work is to cover the required communication range, while keeping the delay time within the requirement of safety applications. In this paper, we examine how long the communication coverage can reach within 300 ms while the nodes periodically transmit the packets which include safety-related messages such as the position and the velocity. Since multi-hop would be needed to expand the communication coverage, the main target is how to flood the information efficiently. For this purpose, the proposed protocol, MHVB, has two main characteristics.

A. Backfire algorithm

The first is its efficient way of flooding based on the distance between the sender and the receiver.

The algorithm is illustrated in Fig. 1, where the radio wave is supposed to reach to around 200 meters as well as normal 802.11 device. Supposing that a packet from A should reach node D, apparently it is not node C, but node B which can retransmit the packet more efficiently. Additionally, it is also clear that there would be smaller coverage gain (shadow part in Fig. 1), if node C retransmit the packet. In MHVB, in order to make node B retransmit the packet, the following steps are processed on each receiver.

1) Store the information in the local database.
2) Calculate the distance between the originator (the original sender of the packet) and itself. If its position from the originator of the packet is further than the threshold D_{max}, the vehicle does not perform the following procedures.

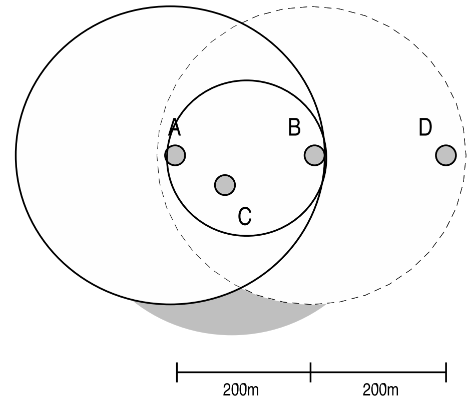

Fig. 1. Flooding

3) Calculate the distance between the sender and itself.
4) The waiting time before retransmission is calculated based on the distance from the source of the received packet. Consequently, a further node waits less time and retransmits the packet sooner than the nodes closer to the source node.
5) If the node receives the same packet more than once, it calculates the relative positions of senders against itself. If the node locates in the circle formed by the sender and the re-transmitter, like node C in Fig. 1, it cancels the retransmission of the packet.

B. Traffic Congestion Detection algorithm

The second function is based on a specific application requirement of vehicular active safety that the vehicles in the middle of traffic congestion should be generally detected by short-range sensors, and consequently the information by V2V communications is not necessary.

This condition helps MHVB work more efficiently. By counting the number of vehicles surrounding a concerned node, MHVB detects whether the vehicle locates in the middle of traffic congestion. If it is the case, it expands the interval of transmitting his own information. The conditions used to judge whether it locates in the middle of traffic congestion are:

1) If the number of vehicles detected by the packet are more than the threshold N_{max}.
2) If the number of vehicles both forward and backward are more than the threshold N_{fb}.
3) If the speed of itself is less than the threshold V_{max}.

When all the conditions are satisfied, MHVB changes the period of re-transmitting packets from the default interval T_{def}, to the new value inverse-proportional to the number of vehicles around.

IV. Description of Simulations

All the simulations have been done over NS-2 network simulator. The nodes mobility scenarios were created by a micro traffic simulator, which calculates the movement of the vehicles according to a certain formula depending on the

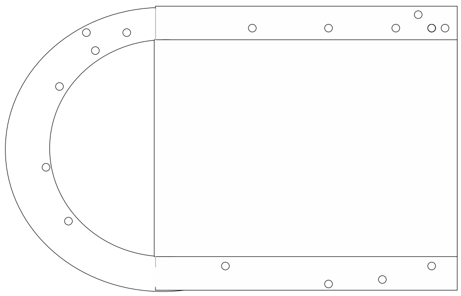

Fig. 2. The schematic figure of mobility scenario.

Simulation Parameter	Value
Simulator	NS2 (2.28)
Network Area	600 x 300 meters
Maximum Node Speed	80 km/h
Data Packet Size	80 Bytes
Simulation Time	100 seconds

TABLE I

SIMULATION PARAMETERS

distance from the vehicle ahead, which uses intelligent driver model and lane change model [6] in a two-lane roads. to simulate the vehicular movement in a certain traffic situation. In this scenario, 80 km/h is chosen as the speed under free traffic situation.

The size of the simulated space is 600x300 meters. Fig. 2 shows the mobility scenario, and the parameters used for the simulation appear in Table. I.

V. SIMULATION RESULTS

The simulation was performed for variable number of nodes, 10, 20, 30, 40, 50, 100. The MHVB parameters are set as $D_{max} = 400m$, $N_{max} = 10$, $N_{fb} = 2$, $V_{max} = 20km/h$ and T_{def}, respectively.

In order to evaluate the performance of MHVB, the simulation process outputs every one second all the records of vehicle databases where the information contained in the packets are stored, such as the positions and velocities of the surrounding nodes. Each record contains the following fields: its own ID, ID of original sender, the distance between these two nodes and timestamp of Record Creation, so that we can know if the data is received satisfying active safety application requirements.

Fig. 3 shows the graph for 10 nodes, with and without Congestion Detection algorithm, although these two results overlap with each other in this scenario. The x-axis is the distance between any pairs of vehicles. That means that we look in log file for all the pairs of vehicles with a certain distance range. The y-axis indicates the success rate, which is the rate of the data received within 300 ms after original transmission in all the pair of vehicles with x distance. We notice from Fig. 3 that there is no difference between with and without Congestion Detection Algorithm. This means that none of the nodes detect the traffic congestion. This result is

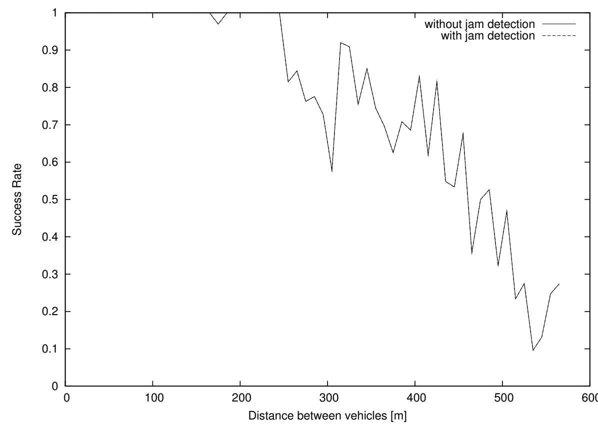

Fig. 3. Simulation results with 10 nodes.

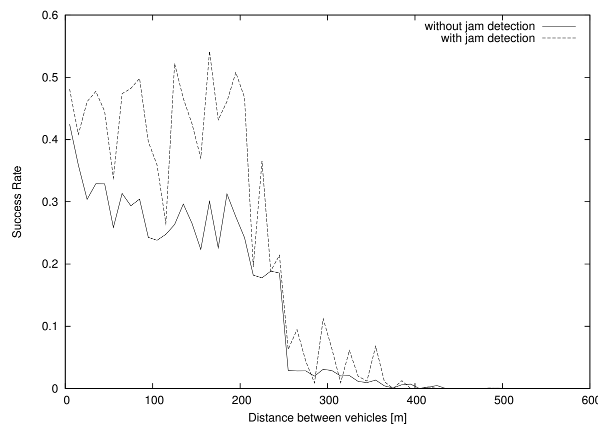

Fig. 4. Simulation results with 50 nodes.

conceivable after considering that the number of the vehicles in this simulation is equal to N_{max}. In the range between [0 - 250] meters, almost 100% of the data are successfully received, while after 250 meters, the success rate gradually decrease according to the increasing distance.

The reason can be explained by the fact that the multi-hop communications are necessary to send the information further than 250 meters. In this case, there must be an intermediate node between the originator and the receiver, which must be in the radio range of both of them. Since the density of nodes in this simulation is low, the probability of the intermediate node positioning in the right place is also low.

Fig. 4 shows the result with 50 nodes. As well as Fig. 3, line graphs both with and without Congestion Detection algorithm are plotted. With jam detection, the success rate is calculated as the reception rate of the packet within 300 ms from the nodes not in the traffic congestion.

Different from the one with 10 nodes, these two graphs have about 10% difference from the range from 0 to 200 meters. This is considered as the effect of efficient Congestion Detection, which reduces the number of the redundant transmitted packets and therefore, bandwidth is efficiently used with less collisions to obtain the data of other vehicles.

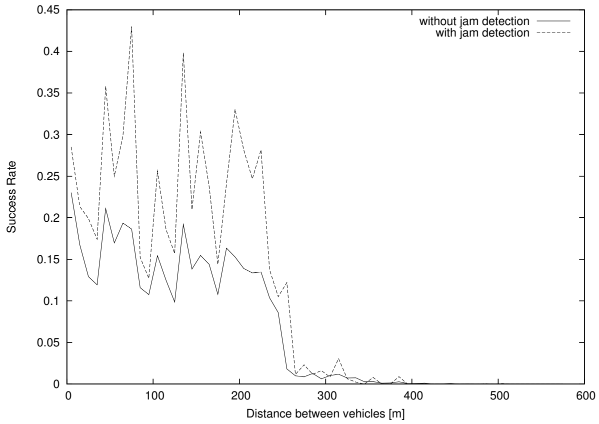

Fig. 5. Simulation results with 100 nodes.

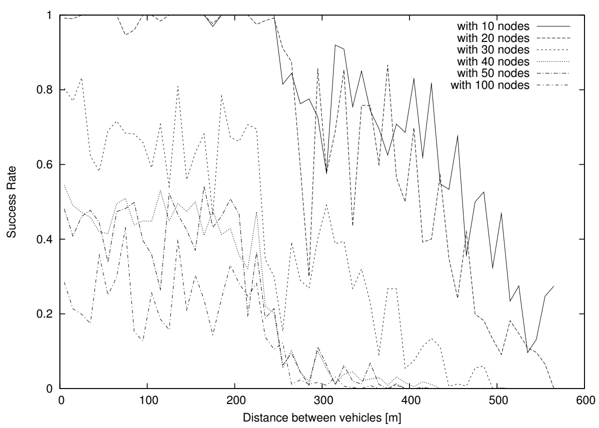

Fig. 6. Simulation results with various number of nodes.

Fig. 5 shows the results with 100 nodes. Because of too many packets sent by 100 nodes and the consequent collisions, the success rate is much lower than the Fig. 3 and Fig. 4 even in the short distance range.

Notice that the success ratio shows the significant difference of about 10 % between with and without jam detection in all the distance of both Fig. 4 and Fig. 5.

The Fig. 6 shows the success rate dependency on the number of nodes in the case of network with Congestion Detection algorithm. For 10 and 20 nodes, the success rate up to 200 meters stay almost 100%, while it decreases according to the increasing number of nodes. This implies that the bandwidth is not used up if the number is less than 20 nodes. This is also shown in the Table. II. The drastic difference between the collision rate of 20 nodes and 30 nodes are regarded as too much utilization of bandwidth with 30 nodes, while the collision rate when we have 10 or 20 nodes is the effect of hidden node problem.

Number of nodes	Collision rate
10	0.442906%
20	1.19713%
30	17.4765%
40	33.8647%
50	40.4808%
100	58.6526%

TABLE II

COLLISION RATE FOR VARIOUS NUMBER OF NODES

VI. CONCLUSIONS

In this paper, we proposed MHVB (Multi-Hop), a protocol for information dissemination in vehicular ad hoc network, which efficiently floods the packets among vehicles based on their position information. Based on the requirements of ITS active safety applications, we introduced a mechanism to detect the traffic congestion and a method to suppress the number of unnecessary packets for improving the bandwidth utilization.

The mechanism was implemented as a simulation code over NS2, and the performance was shown. By introducing our congestion detection technique, we clarify that it has a significant impact to improve the performance of flooding protocols in the ITS context. However, the scalability of our protocol is not satisfactory because too many packets transmitted by many nodes lead the packet collision and the consequent packet loss.

We are currently trying to improve the performance of MHVB by performing simulations trying with various parameters. Our target is to clarify which parameters have the big effect for the results, and to create the flooding protocol which satisfies the requirement to be used in the real world.

REFERENCES

[1] D. H. . 859, "Vehicle safety communications project task 3 final report," DOT," Annual Report, Mar. 2005. [Online]. Available: http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/CAMP3/pages/index.html

[2] R. S. Tony K. Mac, Kenneth P. Laberteaux, "A multi-channel vanet providing concurrent safety and commercial services," in *MobiCom VANET*, Cologne, Germany, 2005.

[3] T. C. Brad Williams, "Comparison of broadcasting techniques for mobile ad hoc networks," in *MobiHoc*, EPFL, Lausanne, Switzerland, 2002.

[4] e. a. Gokhan Korkmaz, "Urban multi-hop broadcast protocol for inter-vehicle communications systems," in *VANET*, Philadelphia, 2004.

[5] e. a. Min-te Sun, "Gps-based message broadcasting for inter-vehicle communications," in *ICPP'00*, 2000.

[6] D. H. M. Treiber, "Congested traffic states in empirical observeations and microscopic simulations," *Phys Rev. E 62, 1805*, 2000.