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Cut-Through Rebroadcasting using Multiple Channels for Alarm Message in Vehicular Ad Hoc Networks

Pakornsiri Akkhara, Yuji Sekiya, and Yasushi Wakahara, *Member, IAENG*

***Abstract*—At present, as a part of Intelligent Transport System (ITS), many applications in Vehicular Ad Hoc Networks (VANETs) attract a lot of research attention from academic community and industry, especially car industry. One important feature of the applications in VANETs is the ability to extend the line-of-sight of the drivers by the extensive use of on-board devices in order to improve the safety and efficiency of road traffic. However, due to mobility constraints and driver behaviors in VANETs, the broadcasting approaches used in Mobile Ad Hoc Networks (MANETs) cannot be properly applied to the applications in VANETs. Moreover, the conventional broadcasting methods for broadcasting an alarm message have a defect of long time required for the complete dissemination, which leads to the degradation in the safety of road traffic in case of emergency. This paper proposes a new broadcasting method called Cut-Through Rebroadcasting (CTR) for alarm message dissemination scenarios based on the minimization of the number of rebroadcasting vehicles and the overlap rebroadcasting by making use of multiple-channels.**

***Index Terms*—alarm message, broadcasting method, multiple channels, vehicular ad hoc network**

I. Introduction

There has been increasing interest in the application of advanced information technology to transportation systems for providing improved comfort and additional safety in driving. Existing Intelligent Transport System (ITS) deployments, e.g. Advanced Cruise-Assist Highway System (AHS) [1], mainly rely on networks in the roadside infrastructure or Road-Vehicle Communication (RVC). While such systems provide substantial benefits, their deployment is very costly, which prevents them from reaching their full potential. Due to this problem, there is a trend of equipping vehicles with the communication technology allowing the vehicles to contact with other equipped vehicles in their vicinity, which is referred to as Inter-Vehicle Communication (IVC). IVC has two key advantages: low latency due to direct communication among vehicles and broader coverage beyond areas where roadside infrastructure equipments have been deployed.

The vehicles with such IVC capability form ad hoc networks called Vehicular Ad Hoc Networks (VANETs). Their specific characteristics allow the development of *Comfort Application* and *Safety Application* [2]. Although much effort is needed in order to make these applications reality, methods to disseminate various messages seem to be one of the most important challenges. In addition, the huge social and economical cost related to road accidents makes research of proactive safety services a task of primary importance in the ITS. A fundamental application for providing this safety service is the fast and reliable propagation of an alarm or warning message to the upcoming vehicles in case of hazardous driving situations such as accidents and dangerous road surface conditions. However, the existing broadcasting methods have some serious defects such as long delay for the complete propagation and high cost due to the use of wide frequency band. Because of these serious problems, they have not yet been actually put into wide commercial use.

In order to solve such problems, this paper proposes a method that can reduce the broadcasting time required for the alarm or warning message propagation by utilizing multiple channels available e.g. in IEEE 802.11 standard as well as the Global Positioning System (GPS). This proposed method is called Cut-Through Rebroadcasting (CTR).

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Pakornsiri Akkhara, Yuji Sekiya, and Yasushi Wakahara are with the Department of Frontier Informatics, Graduate School of Frontier Sciences, The University of Tokyo, Information Technology Center 2-11-16 Yayoi Bunkyo-ku Tokyo Japan 113-8658 (email: pakornsiri@cnl.k.u-tokyo.ac.jp, sekiya@wide.ad.jp, wakahara@nc.u-tokyo.ac.jp).

II. Alarm Message Broadcasting

According to Fig. 1, when the vehicle located in the middle has an accident and recognizes itself as crashed by using some sensors that detect events like airbag ignition, this vehicle will start to broadcast the alarm message to propagate the information about its accident to nearby vehicles as shown by arrows. It will be possible for the drivers of other vehicles to take suitable actions to avoid the secondary accident by using this information. However, in order to guarantee safety, the following two factors have to be considered.

- Maximum allowed speed of the vehicle is about 100 km/hr. (according to the country regulation)
- Human reaction time is 0.3 s, but 0.1 s will be used for the acquisition of the information by various sensors and 0.1 s for processing the information. Therefore, at most only 0.1 s is left for vehicle-to-vehicle communication [1].

Based on these two factors, this alarm information is judged to have a very short useful lifetime. Thus, the information about the accident should reach the concerned vehicles with low delay and high reliability.

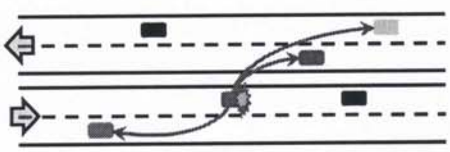

Fig. 1. Alarm message broadcasting application

III. Related Works

Among many broadcasting methods that have been proposed, *Flooding* seems to be the simplest. However, this method has some problems such as high collision or contention probability and high data redundancy because every vehicle receiving the message has an obligation to immediately rebroadcast the message to all of its neighbors. This can result in inefficiency in terms of radio resource usage, promptness of the message delivery and reliability, which has been referred to as *Broadcast Storm Problem* [2]. Consequently, a lot of broadcasting methods have been proposed in order to solve this problem and they can be taken as candidates for the alarm message broadcasting application. However, they have in practice serious problems from the viewpoint of the characteristics of VANETs as follows:

Probability Based Method [3], [4]***:*** In the probability based method, each vehicle decides to rebroadcast the message with some probability in order to decrease data redundancy and collision. Although the required average broadcasting time is rather short, this method still cannot entirely solve the redundancy problem. Moreover, its delivery ratio is generally rather low depending on the probability, which leads to the serious problem of low reliability.

Area Based Method: In this method, each vehicle decides to rebroadcast the message by considering the additional coverage area of the transmission range achieved by the rebroadcasting. In the *Distance Based Scheme* [2], [5], when a vehicle receives the message, the vehicle will not rebroadcast the message if the distance between itself and its nearest neighbor vehicle which has previously rebroadcasted the same message is smaller than a predetermined threshold because the rebroadcasting is judged redundant. The *Location Based Schemes* [5], [6], [7], [8], [9], [10] make more precise estimation of the additional coverage area by making use of the means to determine its own location, e.g. GPS.

An *Area Based Method* named *Optimized Dissemination of Alarm Message (ODAM)* [10] assigns the duty of message rebroadcasting to only furthest neighbor from the source vehicle in order to ensure the largest additional coverage area which has not yet been covered by the source vehicle. Although this method is considered efficient in terms of overhead cost and redundancy, it does not take into account a tight time delay constraint of the alarm message broadcasting application and thus its required time for the complete propagation of the message is rather long.

Cluster Based Method [11]***:*** In this method, all the related vehicles are structured into some clusters and the task for rebroadcasting the message is assigned to only the cluster head vehicle of each cluster. Although this method can work efficiently, the cost to create and maintain the cluster structure is rather high because of high speed move of the vehicles, which leads to the large traffic overload and long delay of the message propagation in general.

Topology Based Method [12], [13]***:*** *Topology based methods* are based on the complete knowledge of the network topology which is obtained by exchanging the control messages beforehand. Although this method is efficient in terms of redundancy and collision reduction, this method is not considered feasible in the VANETs because the high control traffic load is required just like cluster based method.

Cut-through Based Method [17]***:*** According to the strict delay constraint of safety application, the approaches with effectively shortened forwarding latency e.g. cut-through forwarding method are required. The cut-through forwarding method has been used in the packet switch technology to allow frame (or packet) forwarding before the frame is entirely received [16]. Unfortunately, the cut-through forwarding method has not been studied for wireless networks until recently because, in general, forwarding latency was not the primary concern for the traffic in the wireless networks. However, this is not the case for the safety application. One of the broadcasting methods that utilize cut-through forwarding has been proposed in [17]. In this broadcasting method, each vehicle that received the message has an obligation to rebroadcast the message. Thus, the Multiple Access Interference (MAI) increases in accordance with the number of simultaneously rebroadcasting vehicles. Moreover, the wide bandwidth is required for the proposed Code Division Multiple Access (CDMA).

IV. Cut-Through Rebroadcasting for Alarm Message

It should be noted that all the existing conventional broadcasting methods except the cut-through based method use only a single frequency channel and make no use of the rest channels that are actually available e.g. in IEEE 802.11 standard. However, in order to achieve the targets of safety application, we propose CTR method that utilizes multiple channels available e.g. in IEEE 802.11 standard as well as GPS function. In CTR, high priority to rebroadcast the message is given to some specific vehicles to avoid the interference problem and the multiple channels are utilized effectively to achieve overlap broadcasting.

A. The Characteristics and Assumptions for VANETs

This paper focuses on the alarm message broadcasting in the highway scenario where there are a number of vehicles moving towards both directions of the highway with possibly multiple lanes. In this scenario, the alarm message will be destined to many or all of the vehicles located away from the accident vehicle (source vehicle) and in less than some predetermined coverage distance. In other words, the position information will be used as an attribute to limit the broadcasting process. It is assumed that the highway is rectilinear and that there are no obstacles for the radio wave propagation along the highway e.g. buildings on the road.

All the vehicles are assumed to be equipped with sensing, calculation, communication capabilities and GPS so that each vehicle can sense an accident, gather information about the accident, transmit the alarm message to the nearby vehicles, and determine its own position relatively to the other vehicles. Moreover, each vehicle is equipped with at least two half-duplex transceivers based on e.g. IEEE 802.11 standard and a dedicated channel is assigned to each transceiver. With this assignment, the vehicle can transmit a message on one channel and listen to and receive a different message on the other channel at the same time. Furthermore, all the antennas are assumed non-directional.

B. *Targets to be Achieved*

Efficiency of the alarm message broadcasting method can be measured in general by whether the following targets can be achieved or not.

- According to the aforementioned human reaction time, the time required for all the vehicles located in the predetermined coverage distance to receive the alarm message completely is shorter than 0.1 s.
- Since the alarm message is broadcasted in a multi-hop manner, the number of vehicles that newly receive the alarm message in each hop should be as large as possible and thus the number of rebroadcasting vehicles should be smallest.

C. *Cut-Through Rebroadcasting*

The basic idea is to give high priority to the furthest vehicle in the transmission range from the source vehicle to rebroadcast the alarm message after recognizing it from its header. This priority control leads to the avoidance of collision of rebroadcasted alarm messages by the vehicles in the transmission range of the source vehicle by suppressing the rebroadcasting of vehicles with low priority and by making only the vehicle with high priority rebroadcast the message. Moreover, this method is characterized by utilizing cut-through-like forwarding approach or the overlap operation of alarm message transmission by some vehicles under the assumption that each vehicle is equipped with at least two transceivers and different channels are assigned to the transceivers in the individual hops to avoid the collision in broadcasting. For overlap broadcasting for more than 2 hops, at least 3 different channels are required for efficient transmission without interference.

The scenario in Fig. 2 will be used to further describe and illustrate the basic idea of CTR. In Fig. 2, *A* is assumed to have just had an accident, and *B, C* and *D, E* are assumed to be in the transmission range of the transceivers equipped on *A*

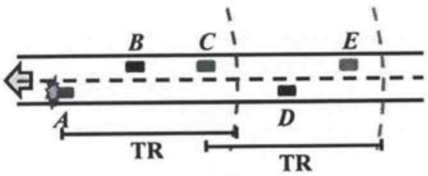

Fig. 2. Alarm message broadcasting scenario

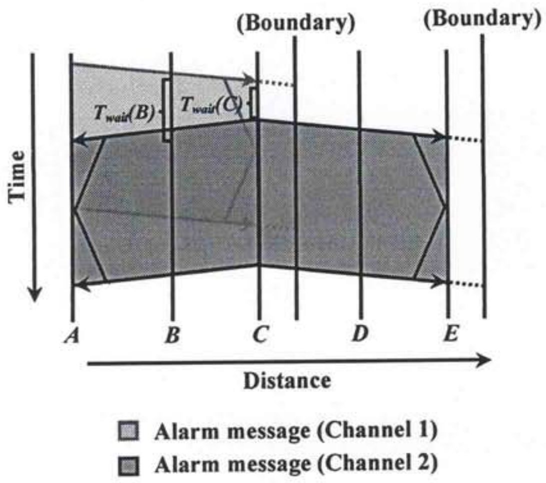

Fig. 3. Basic idea of Cut-Through Rebroadcasting

and in that of the transceivers equipped on *C* respectively. After *A* recognizes an accident event based on the information received from various sensors, *A* acts as the source vehicle and starts to broadcast an alarm message to notify nearby vehicles including *B* and *C* of the accident. After recognizing that the received message is the alarm message, *B* and *C* calculate their own waiting times $T_{wait}(B)$ and $T_{wait}(C)$, respectively. The waiting time is used by each vehicle to make decision on whether it should be responsible for rebroadcasting the alarm message in the next hop or not. It should be remarked that the waiting time is longer for vehicles that are closer to the source vehicle. The details of waiting time calculation will be described later. When a waiting time of a vehicle expires and it has not received any alarm message from any other following vehicles, it starts to rebroadcast the alarm message in the following hop. On the other hand, if a vehicle has received an alarm message from any other following vehicles before the expiration of its waiting time, then it decides not to rebroadcast the alarm message. In Fig. 3, the furthest vehicle *C* will have priority to rebroadcast the alarm message and start to rebroadcast the alarm message just after the expiration of its waiting time by utilizing a channel which differs from the one used by the source vehicle *A* in order to avoid the interference of the messages and to reduce the broadcasting time.

Then, *C* becomes a source vehicle in the next hop to rebroadcast the alarm message and then in almost the same manner, only *E* will have high priority to rebroadcast the message. Such rebroadcasting will be repeated to cover all the vehicles in the predetermined coverage distance from the original source vehicle *A*.

D. *Waiting Time Calculation*

The waiting time calculation is based on the basic idea that the header of the alarm message sent by the furthest vehicle, which should be responsible for rebroadcasting the alarm message, should arrive at the vehicles located closer to the source vehicle before the waiting time expiry of these vehicles. This basic idea can be elaborated as follows.

In Fig. 4, after an intermediate vehicle, which is located in the transmission range of *A*, recognizes that the message it has started to receive is the alarm message broadcasted by *A* from its header, the vehicle should wait for some time to be notified whether there is a further vehicle which will responsible for rebroadcasting the alarm message or not instead of immediate rebroadcasting. This notification is achieved by the recognition of the header of the alarm message rebroadcasted by the further vehicle if any. By this approach, it becomes possible to avoid the collision of the alarm message broadcasting and achieve the largest additional coverage distance. An imaginary vehicle is assumed at the boundary of the transmission range of *A*, and this vehicle is assumed to start to rebroadcast the alarm message just after recognizing the alarm message. Thus, the waiting time of intermediate vehicles should be defined so that they wait long enough to receive the alarm message header rebroadcasted by this assumed vehicle. Furthermore, in the designing of the waiting time, the time required for the transmission, propagation and processing of header of the alarm message should be taken into account and the waiting time should become longer for an intermediate vehicle closer to the source vehicle.

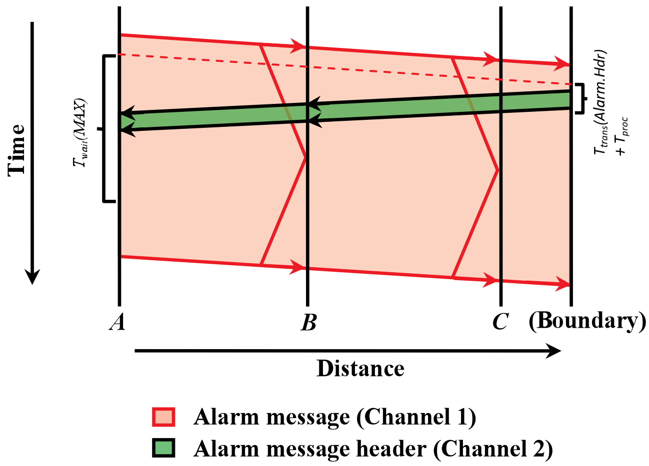

Fig. 4. Basic idea of waiting time calculation

In general, the waiting time for vehicle X located D_{SX} away from the source vehicle S can be represented by the following equations with a parameter Delta (Δ):

$$T_{wait}(X) = \frac{(TR - D_{SX})}{TR} \times T_{wait}(MAX) \quad (1)$$

$$T_{wait}(MAX) = \left[T_{trans}(Alarm.Hdr) + T_{proc} + (2 \times \frac{TR}{V_{prop}}) \right] \times (1 + \Delta) \quad (2)$$

where TR = transmission range (m)
D_{SX} = distance between vehicle X and the source vehicle S (m)
$T_{trans}(M)$ = transmission time of message M (s)
T_{proc} = processing time required for recognizing and sending the message (s)
V_{prop} = radio wave propagation speed (m/s)
Δ = predetermined constant value

By utilizing (1) and (2), the further the vehicle is located from the source vehicle, the shorter its waiting time becomes and the earlier it has a chance to access the channel to send its message. Even though it is possible to calculate the waiting time by other methods, the trade-off between the broadcasting time and the number of rebroadcasting vehicles has to be taken into account. This trade-off is discussed in section V.

After various experiments, 0.0 is chosen as the value of Delta based on the consideration about the broadcasting time required to cover the coverage distance.

V. Evaluation Results

A. Evaluation Scenario

In order to demonstrate the efficiency of CTR, the average broadcasting time and the number of rebroadcasting vehicles of CTR, ODAM, and the pure flooding method are comparatively evaluated under NS-2 simulation environment. ODAM is selected for this comparison because it is considered most efficient for the alarm message broadcasting application among the conventional broadcasting methods as described in section III.

Fig. 5 depicts the simulation scenario of a straight highway with one lane where the distance between any two consecutive vehicles is randomly chosen from the values between two predetermined distances. In this scenario, the alarm message will be rebroadcasted in the multi-hop manner

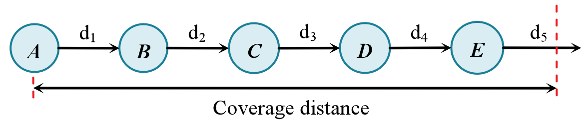

Fig. 5. Simulation topology

Table I. Simulation Parameters and Their Values in NS-2 Environment

Simulation parameters	Value
Data speed	1 Mbs
Radio propagation speed	3 x 10^8 m/s
MAC layer	CSMA/CA
Propagation model	Two-ray ground
Antenna type	Omni antenna
Alarm message size	1425 bytes
Alarm message header size	43 bytes
Transmission range	100-500 m
Distance between two consecutive vehicles	20-40 m, 40-60 m, 60-80 m
Speed of vehicle	20-27 m/s
Delta (Δ)	0.0-6.0
No. of channels	1 channel (Flooding, ODAM), 3 channels (CTR)
Coverage distance	1000 m, 3000 m
Number of lanes	1-5 lane(s)
Lane width	3.5 m
No. of repetitions for simulation	100 times

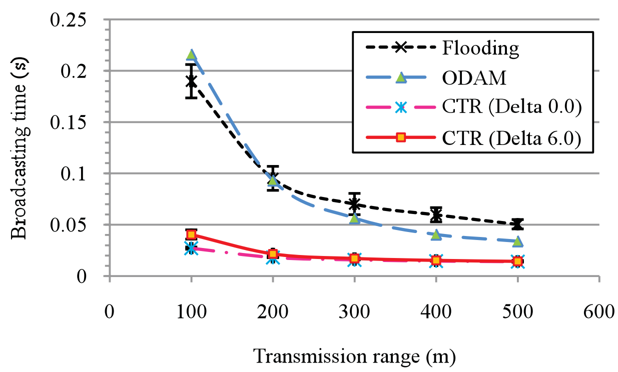

Fig. 6. Average broadcasting time required to cover the coverage distance

until it becomes possible to cover the predetermined coverage distance from the source vehicle. In addition, as mentioned in section IV, each vehicle must be equipped with at least 2 transceivers assigned with different channels. In the simulation, the time required for a vehicle which is located furthest from the source vehicle within the coverage distance to completely receive the alarm message is evaluated as the broadcasting time for various transmission range values. The simulation parameters and their values are shown in Table I.

B. Average Broadcasting Time

Fig. 6 shows the average broadcasting time of the above mentioned three methods for the case where the coverage distance is 1000 m and the distance between two consecutive vehicles is randomly chosen from the values between 20-40 m. Error bars in Fig. 6 and the following figures show the standard deviation of the results concerned. It is understood that CTR can achieve the broadcasting time shorter than the pure flooding method, by reducing the possibility of the collision in the alarm message rebroadcasting and giving high priority to rebroadcast the alarm message to the furthest vehicle in the transmission range from the source vehicle.

Compared with ODAM, CTR can achieve significantly shorter average broadcasting time by allowing the overlap in the alarm message broadcasting and rebroadcasting just after the expiration of the waiting time, while a vehicle in ODAM has to completely receive the alarm message and wait for the expiration of waiting time before they can make a decision on whether to rebroadcast the alarm message.

The average broadcasting time of CTR decreases as the transmission range increases due to the decrease in the number of hops in the alarm message rebroadcasting to cover the coverage distance. Additionally, the average broadcasting time of CTR decreases as the value of Delta decreases due to the decrease in the value of $T_{wait}(MAX)$ used in the waiting time calculation. CTR can achieve shorter than 0.1 s average broadcasting time for every transmission range in the evaluation. The average broadcasting time of CTR for the coverage distance 3000 m is about 3 times longer than the case where the coverage distance is 1000 m for each transmission range. In addition, the average broadcasting time of CTR is almost the same even when the distance between two consecutive vehicles is changed from 20-40 m to 40-60 m or 60-80 m as far as the average number of hops required to cover the coverage distance is the same, though they are not illustrated graphically in this paper. The reason for this is due to the fact that the propagation speed is extremely fast and that the propagation time of a message between two consecutive vehicles is negligibly small in comparison with other required time such as the transmission or procession time of the message. Figures in the rest of this paper have been obtained for the case where the coverage distance is 1000 m, the transmission range is 250 m and the distance between two consecutive vehicles is randomly chosen from the values between 20-40 m.

In addition to the transmission range, size of the alarm message has a large influence on the average broadcasting time of CTR. However, mobility speed, which is one of the main characteristics of VANETs, does not have a significant influence on the efficiency of CTR for the coverage distance used in the above evaluation. The influence of the alarm message size and the mobility is shown in Fig. 7 and Fig. 8, respectively.

Fig. 9 illustrates influence of the number of lanes on the average broadcasting time of CTR. As the number of lanes increases, the possibility that there is a vehicle located close to the boundary of the transmission range will increase, resulting in smaller number of hops required to cover the coverage distance and smaller waiting time in each hop as well. Consequently, the shorter average broadcasting time can be achieved.

C. *Number of Rebroadcasting Vehicles*

Fig. 10 illustrates the total number of vehicles which were located in the coverage distance 1000 m and rebroadcasted the alarm message by the above mentioned three methods and also the theoretically minimum value of the number of rebroadcasting vehicles for reference. By giving priority control in the alarm message rebroadcasting, the number of rebroadcasting vehicles of CTR is significantly smaller than those of ODAM and the pure flooding method which obliges every vehicle to rebroadcast the alarm message. The reason why the number of rebroadcasting vehicles by CTR where Delta is 6.0 is a little larger than the theoretically minimum value and is smaller than the case where Delta is 0.0 is as follows.

According to $T_{wait}(MAX)$ in (2), because propagation time of a message between two consecutive vehicles is negligibly

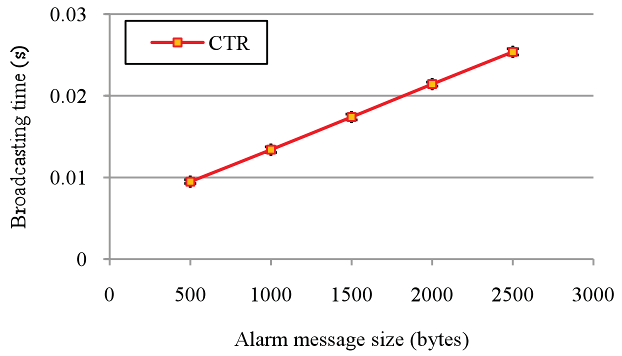

Fig. 7. Influence of the alarm message size on the average broadcasting time

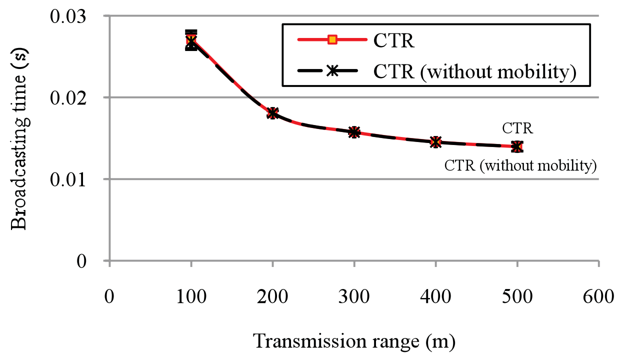

Fig. 8. Influence of mobility on the average broadcasting time

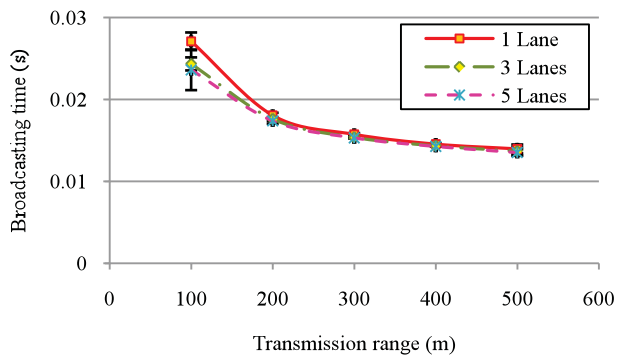

Fig. 9. Influence of the number of lanes on the average broadcasting time

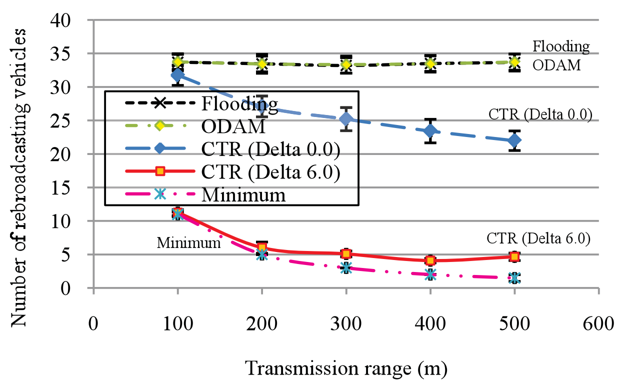

Fig. 10. Number of rebroadcasting vehicles required to cover the coverage distance

small in comparison with other required time, $T_{wait}(MAX)$ can be considered as a constant value. With the same average distance between two consecutive vehicles, the difference between the waiting times of any two consecutive vehicles, which can be calculated by (1), decreases as the transmission range increases. In addition, $T_{wait}(MAX)$ decreases as the value of Delta decreases, resulting in decrease in the difference between the waiting time of any two consecutive vehicles as well. Thus, the possibility that the leading vehicles will not receive the header of the alarm message from the rebroadcasting vehicle before the expiration of their waiting time and start to rebroadcast the alarm message will increase, resulting in larger number of rebroadcasting vehicles.

Although it is possible to increase the value of $T_{wait}(MAX)$, the average broadcasting time increases accordingly. Thus, the trade-off between the average broadcasting time and the number of rebroadcasting vehicles has to be considered in the waiting time calculation.

VI. Conclusion and Further Researches

By reducing the broadcasting time of the alarm message, the drivers of the vehicles moving toward the accident place will have more time to make a decision on the suitable action, resulting in more safety alarm message broadcasting application.

This paper has proposed a new broadcasting method in order to achieve such reduction in the broadcasting time by making use of multiple channels and GPS capability. This method is named Cut-Through Rebroadcasting (CTR). CTR can be characterized by the fact that the high priority to rebroadcast the alarm message is given to only the furthest vehicle within the transmission range. CTR can greatly reduce the broadcasting time mainly because of this priority control and the overlap rebroadcasting of the alarm messages by two or three vehicles. The resultant broadcasting time is well below the upper limit of 0.1 s even when the coverage distance is e.g. 3000 m. Moreover, CTR is able to solve the *Broadcast Storm Problem* as well. In addition, CTR may be improved for reducing the number of rebroadcasting vehicles by the cancellation of rebroadcasting the alarm message after the reception of the header of the alarm message if the rebroadcasting has not yet actually started and has been suspended by the operation like CSMA/CA in case of collision. However, more study is required to confirm and evaluate this improvement in detail. Future study is also considered important to minimize the waiting time of vehicles in order to further decrease the broadcasting time.

This paper has an assumption of rectilinear road. If the road is not rectilinear and has a shape of e.g. curve, then some vehicles in the coverage distance may not be able to receive the alarm message according to so far proposed efficient broadcasting method. Thus, our future researches will focus on the approaches to cope with such a problem.

References

[1] Advanced Cruise-Assist Highway System Research Association (AHSRA), *Development of Road-to-Vehicle Communication Systems*. Available: http://www.ahsra.or.jp/eng/c04e/index.htm

[2] Y. Tseng, S. Ni, Y. Chen, J. Sheu, "The broadcast storm problem in a mobile ad hoc network," *Wireless Networks*, vol.8, no.2/3, pp. 153-167, March-May 2002.

[3] B. Williams, T. Camp, "Comparison of broadcasting techniques for Mobile Ad Hoc Networks," *the 3rd ACM International Symposium on Mobile Ad Hoc Networking and Computing*, pp. 194-205, 2002.

[4] H. Alshaer, E. Horlait, "An optimized adaptive broadcast scheme for Inter-Vehicle Communication," *the 61st IEEE Vehicular Technology Conference 2005 (VTC 2005-Spring).*

[5] T. Osafune, L. Lin, M. Lenardi, "Multi-Hop Vehicular Broadcast (MHVB)," *the 6th International Conference on ITS Telecommunications 2006.*

[6] L. Briesemeister, G. Hommel, "Role-Based Multicast in highly mobile but sparsely connected ad hoc networks," *First Annual Workshop on Mobile Ad Hoc Networking and Computing 2000 (MobiHOC. 2000), Aug. 11, 2000*, pp. 45–50.

[7] M. Sun, W. Feng, T. Lai, K. Yamada, H. Okada, K. Fujimura, "GPS-based message broadcasting for inter-vehicle communication," *International Conference on Parallel Processing 2000*, pp. 279–286.

[8] E. Fasolo, R. Furiato, A. Zanella, "Smart Broadcast Algorithm for Inter-vehicular Communications," *IWS 2005/WPMC 2005*, Sep. 2005.

[9] E. Fasolo, A. Zanella, M. Zorzi, "An effective broadcast scheme for alert message propagation in Vehicular Ad hoc Networks," *IEEE International Conference on Communications 2006 (ICC '06).*

[10] A. Benslimane, "Optimized Dissemination of Alarm Message in Vehicular Ad-Hoc Networks (VANET)," *the 7th IEEE International Conference HSNMC 2004*, Springer Publisher, pp. 655-666.

[11] T. D.C. Little, A. Agrawal, "An information propagation scheme for VANETS," *the 8th International IEEE Conference on Intelligent Transportation Systems*, September 13-16, 2005.

[12] A. Zenella, G. Pierobon, S. Merlin, "On the limiting performance of broadcast algorithms over unidimensional ad-hoc radio networks," *WPMC'04, 2004.*

[13] P. J. Wan, K. Alzoubi, O. Frieder, "Distributed construction of connected dominating set in wireless ad hoc networks," *IEEE INFOCOM'2002, 2002.*

[14] J. P. Sign, N. Bombos, B. Srinivasan, D. Clawin, "Wireless LAN performance under varied stress condition in vehicular traffic scenarios," the *56th IEEE Vehicular Technology Conference 2002 (VTC 2002-Fall).*

[15] C. Cheng, P. Hsaio, H.T. Kung, D. Vlah, "Parallel use of multiple channels in multi-hop 802.11 wireless networks," *Military Communications Conference 2006 (MILCOM 2006).*

[16] Intel, *Switches – What are forwarding modes and how do they work?*. Available: http://support.intel.com/support/express/switches/sb/cs-014410.htm

[17] O. Shagdar, M. N. Shirazi, S. Tang, R. Suzuki, S. Obana, "Improving reliability of Cut-Through Packet Forwarding in CDMA Vehicular Network," *IEICE Technical Report, NS2007-86 (2007-10).*

[18] *The network simulator - NS-2.* Available: http://www.isi.edu/nsnam/ns/

[19] F. J. Ros, P. M. Ruiz (2004), *Implementing a new MANET Unicast Routing Protocol in NS2.*

[20] R. A. Calvo, J. P. Campo (2007), *Adding multiple interface support in NS-2*

[21] T. Kim, D.J. Lovell, "Observation of real driving behavior in car-following: preliminary results," *Vehicular Technology Conference 2005 (VTC-2005).*