International Journal of Computer and Information Technology (ISSN: 2279 – 0764)
Volume 02– Issue 05, September 2013

An Optimal Broadcast of Warning Messages in Vehicular Ad Hoc Networks

Amira Benaidja[*], Samira Moussaoui, Farid Naït-Abdesselam[#]
[a]Department of Computer Science, USTHB University
Email: [*]abenaidja {at} usthb.dz}
[#]LIPADE Laboratory, University of Paris Descartes, France

Abstract—**In vehicular ad hoc networks, multi-hop broadcast is a key technique to disseminate warning messages for safety applications. Due to the vehicle mobility and lossy wireless channel, highly reliable, scalable and fast multi-hop broadcast protocol is very challenging to design. A number of solutions have been proposed in the past few years. However, the tradeoff between reliability and efficiency in such solutions needs to be carefully considered. The scope of this paper is to present an optimal protocol for the broadcast of safety messages in VANETs. Optimality, in terms of delay and transmission count, is achieved using a broadcast strategy that exploits opposite vehicles. To carry out reliable and efficient broadcast coordination, intelligent periodic rebroadcasts, which effectively adapt our protocol to sparse and dense networks, are proposed. Simulations are conducted and results are presented to show that it has a better performance over existing competing protocols.**

Keywords-Optimal broadcast; safety applications; VANETs; warning messages

I. INTRODUCTION

Recently, communication in Vehicular Ad hoc NETworks (VANETs) has been an active research area. VANET is a multi-hop mobile network designed to provide a wide range of road applications such as safety warning [1, 2], transport efficiency or mobile infotainment [3].A multi-hop broadcast protocol works as a basis for many vehicular applications including the safety ones which are the most important applications in VANETs. For example, after two vehicles collided with each other on a highway, or traffic congestion happens because of heavy rain or snow, the upcoming vehicles need to be notified immediately. In both cases, the warning messages should be disseminated out with short delay to vehicles that are up to several kilometers away, not only to prevent more possible accidents, but also to enable the vehicles to make a detour as early as possible to avoid congestion.

Due to the high mobility, frequent partitions and varying traffic density, the design of broadcast protocol is very challenging. The core problem in multi-hop broadcasting is how to minimize the number of redundantly received messages while maintaining good latency and reachability, since rebroadcasting causes tradeoff between reachability and efficiency.

Several broadcasting schemes have been proposed in the context of MANETs [4, 5, 6, 7]. Many broadcast protocols have been proposed for vehicular ad hoc networks [8, 9, 10, 11, 12, 13, 14, 15] .However, it remains an open problem to reliably and efficiently deliver messages under different vehicular traffic densities.

This paper addresses the issue of reliably and efficiently disseminating warning messages, and introduces an Optimal multi-hop broadcast protocol (OCast) for vehicular safety. Optimality, in terms of delay and transmission count, is achieved using a broadcast strategy that exploits opposite vehicles. To carry out reliable and efficient broadcast coordination, intelligent periodic rebroadcasts, which effectively adapt OCast to sparse and dense networks, are proposed.

The rest of this paper is organized as follows. Section II presents the related work and Section III describes our protocol OCast. The simulation behavior used and obtained results are discussed in Section IV. Finally, Section V concludes the paper.

II. RELATED WORK

The simplest way to achieve broadcasting is flooding [16].In flooding, each node rebroadcasts a packet upon its first reception. Obviously, in a high-density network, flooding introduces too many redundant broadcasts and consequently incurs collisions and results in a low dissemination rate, which is known under the name of Storm Broadcast Problem [4].Several strategies have been suggested to improve the simple flooding approach where various heuristics have been proposed to coordinate the rebroadcasting of the message.

In [8], the proposed solution called RBM (Role-Based Multicast) advocates broadcasting the alert only when the vehicle comes in the transmission range of a new neighbor. However, RBM requires that each node maintains a list of all its neighbors, and the maintenance generates a significant overhead. As alarm messages are unexpected, determining the set of neighbors increases delays for rebroadcast when emergency. DDT [9] delays the rebroadcasting for a time inversely proportional to the distance from the sending vehicle in order to avoid some retransmissions. The problem with DDT is that a vehicle rebroadcasts only once. This means that DDT is unreliable in a not loaded road or when vehicles are distant (fragmentation problem). So certain vehicles cannot be informed and consequently, will present a danger in the case of emergencies. OAPB [10] proposes that a vehicle node rebroadcasts with average probability $\overline{\phi}$, which is determinate dynamically in term of the vehicle nodes density in its zone and the node obtaining the maximal density has to rebroadcast the message. However, OAPB doesn't overcome the fragmentation problem and the maintenance of neighbors generates additional overhead. An emergency message dissemination protocol for Inter-Vehicle Communications (IVC) divides the highway into virtual cells [11], which move as the vehicles move. However, the maintenance of this structure generates additional overhead. In [12], a distributed opportunistic broadcast protocol (OppCast) has been proposed. It employs opportunistic forwarding to enhance reception reliability. However, OppCast increases latency and transmission overhead especially in dense vehicular networks. A path diversity mechanism for sender-oriented broadcast protocols in VANETs has been proposed[13].It uses two paths to deliver a packet to each relay node in order to provide a high reliability and a low delay for multi-hop broadcast protocols. However, it can't ensure reliability in sparse networks and a significant broadcast overhead is generated in dense networks. ODAM [14] restricts rebroadcast to only special relays and in risk zones. It allows overcoming problems as fragmentation, reliability and neighbors' determination. To do that, it proposes periodic rebroadcasts of the alarm messages by introducing dynamic relays. These relays are designated according to the distance from the sender. However, ODAM has considered passing information only through vehicles traveling in the same direction, rather than taking advantage of traffic in opposite direction lanes. In [17], a formal model of data dissemination in VANETs is proposed to study how VANET characteristics affect the performance of data dissemination. The results show how opposite vehicles can be exploited as carriers to quickly disseminate information to the vehicles that follow. In [14], simulations show that ODAM is not reliable 100% with transmission ranges<200m because it limits rebroadcast to the members of risk zones without taking advantages of vehicles located outside these zones. Furthermore, it may happen that many periodic broadcasts cannot reach any new vehicle due to the short broadcast period $\Delta\theta$, which generates useless overhead. Also, the initiator periodic broadcasts according to this static period generate a significant overhead specifically in large scale. In [15], a system of abiding geocast (AG) is presented for disseminating warning message among mobile vehicles in VANETs. In order to overcome fragmentation, this system utilizes vehicles traveling in opposite direction as relays to reduce broadcasts and help message delivery upstream. In order to save unnecessary broadcasts while keeping the warning message in the affected area, the wait time of an individual relay vehicle is set dynamically for the next broadcast when it receives (directly or indirectly)a message from other vehicles traveling in the same direction. However, in this system, a relay vehicle is only responsible for delivering the message to vehicles traveling in the opposite direction without taking in consideration vehicles traveling in the same direction when this relay is a vehicle approaching the event. Thus, certain vehicles cannot be informed before reaching the warning line and consequently will present a danger. This reason too prevents this system from being very efficient in unidirectional roads. In order to indirectly supply relays the information of other relays with the same direction through opposite vehicles, this system uses the last opposite vehicle information which is broadcasted with the warning message and updated with the received message. Else, a relay must wait for some time without periodically broadcasting only when the new relay is traveling in the same direction. These two strategies generate additional overhead especially in dense networks. In this system, the initiator of disseminating is a vehicle leaving the event which prevents (in the case of sparse networks) vehicles entering the warning zone after its exit from receiving the alert.

In this article, we propose an Optimal multi-hop broadcast protocol for warning message dissemination in VANETs, which allows to overcome the problems presented above, namely: Broadcast storm, fragmentation and overhead while taking in consideration the temporal constraint in order to quickly disseminate warning information to every vehicle that passes through the warning zone during the lifetime of the event before it reaches the warning line and with a low broadcast overhead.

III. OCAST: OPTIMAL MULTI-HOP BROADCAST PROTOCOL FOR VEHICULAR SAFETY

In this section, we present our proposed broadcast protocol. Fig. 1 shows the system model. We assume that the VANET consists of vehicles equipped with embedded computers, GPS receivers and unidirectional radio antennas of range R. Communications between vehicles are supposed to be bidirectional, and are based on the broadcasting of messages. Each vehicle has a unique identifier nod-id in the network and circulates with a constant speed randomly chosen in the interval [Smean-ε, Smean+ε] where Smean is the speed mean and ε represents its variation. Only one initiator of disseminating, other vehicles act as relays. The warning message has the following form:

Message: <Warning information, Sender –information>.

Warning information: < Initiator-ID, topic, content, location, safety Distance, time Limit, effect Distance>.

Sender-information:<ID, direction, speed, location, send Time>

Where, Safety Distance represents the distance between the event and the safety line (warning line). It means that vehicles moving towards the event should be informed at least distance away from the event and Time limit is the validity of the warning event. Effect line is used to indicate beyond which point vehicles will become inactive and not broadcast any more, whereas effect distance is the distance between the event and the effect line. The area between these two points is called warning zone. Effect distance is set by the beginner of dissemination, and then it will be constant and delivered to other vehicles with the message.

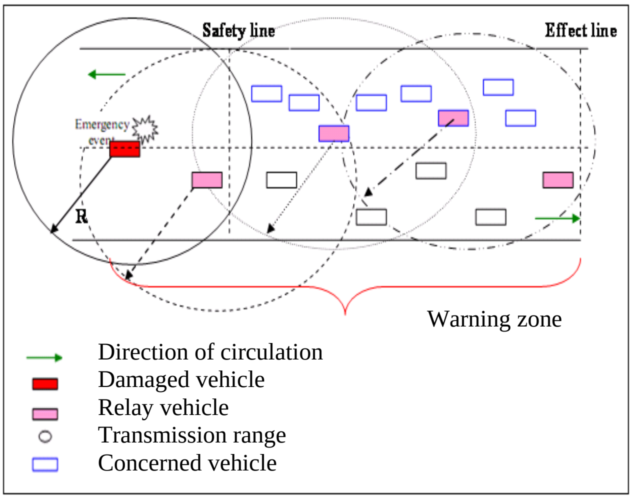

Figure 1. VANET model and overview of the broadcast scheme.

A. Broadcast strategy

As an example application of our approach, we demonstrate the equipped vehicles distributing a warning message about an accident in road traffic. When the accident occurs, the damaged vehicle which is the initiator of disseminating must broadcast a warning message to inform relevant vehicles about the danger. In each accident side, only one vehicle among all vehicles receiving this message must react to ensure its rebroadcast in order to inform other vehicles. This vehicle must be the furthest vehicle from the initiator. This relay can be a vehicle leaving or approaching the event but it must be the furthest vehicle from the sender comparing to the event in order to quickly cover the greatest geographic zone not yet covered by the sender. Once the broadcast done, it is taken by a new relay and so on. In each time, the relay is selected according to this principle (Fig. 1). We note that only the drivers of vehicles approaching the accident are alerted to avoid unnecessary and hasty reactions.

To favor the furthest vehicle from the sender to the accident to becoming relay, we propose that a vehicle receiving the warning message must first verify its relative position in report with the sender. If it is further than the sender to the accident, it starts executing the DDT algorithm [9] to see if it is the furthest vehicle from the sender or no. We have adopted the same DDT mechanism principle (wait time inversely proportional to the distance) but modified the formula used to calculate the wait time value (defertime). The value of defertime(x), computed by a vehicle(x)receiving the warning message from a sender (s)and which is candidate to retransmit it, is given by (1).

$$defertime(x) = \max\_\ defer\_time * \frac{R^{\varepsilon} - D_{sx}^{\varepsilon}}{R^{\varepsilon}} + \alpha \qquad (1)$$

$$defertime(x) = \max\_\ defer\_time * \frac{R^{\varepsilon} - D_{sx}^{\varepsilon}}{R^{\varepsilon}} \qquad (2)$$

Equation (2) is the formula used in [14] to calculate the defertime value which is in turn an improvement of the formula used in the DDT mechanism to accelerate the warning message dissemination. Where R is the transmission range, D_{sx} is the distance between (s) and(x), and ε is a positive integer. Assuming a uniform distribution of nodes over the area, the choice of ε=2 will give a uniform distribution of the various value of defertime in [0, max-defer-time].The value of max-defer-time is equal to twice the average of communication delay. This formula allows selecting the furthest vehicle. The receivers calculate the distance to the sender using the position inserted in the message. A waiting time inversely proportional to this distance is then engaged before rebroadcasting. Thus, the first rebroadcasting vehicle will be the most distant node which has the minimal value of defertime and the other vehicles cancel their retransmissions when receiving the broadcasted message.

Our contribution consists in adding a random variable α (that takes values of order ms) when calculating defertime ((1)) in order to overcome the multiple relays problem, when two (or more) vehicles equidistant to the sender designate them self as relay at the same time. The vehicle getting the smallest value of α will have the shortest waiting time and has to rebroadcast the message. This optimizes in turn our proposed broadcast scheme since it minimizes competitions and collisions by assuming vehicles different α values when they have the same distance to the sender. If a choice must be done between vehicles equidistant to the sender and having the same value of α, the vehicle which has the smallest identifier nod-id has to remain as relay.

The initiator vehicle must broadcast the warning message periodically according to a dynamic period Δθ which depends on the relays availability in the warning zone. Initially it broadcasts according to the period: Δθ=(R-Dbrake(S))/S [14], to ensure informing relevant vehicles at least with braking distance (Dbrake) away from the accident, especially in sparse networks where these vehicles cannot be informed before. When it knows that other relays are active, it stops its broadcasts until the disappearance of these relays from the warning zone and restarts after according to Δθ=(R-Dbrake(S))/S. That is in order to avoid unnecessary broadcasts while keeping the message in the alert zone. In our protocol, it's the damaged vehicle which initiates the warning message broadcast but when its embarked system is completely damaged, it's the first vehicle detecting the event which must ensure this task. Several methods can be used for the event detection. For example, when an accident occurs, the airbags activation can initiate the warning message broadcast.

B. Reliability and efficiency in OCast

In order to overcome fragmentation, in our system, the relay vehicle has to broadcast the warning message periodically according to a period Δθ which ensures informing opposite vehicles since these later are the preferred relays which allow overcoming fragmentation and disseminating the alert quickly and efficiently. This period also takes in consideration vehicles traveling in the same direction specially when the relay is a vehicle approaching the accident and separated from the safety line with a distance<R, in order to ensure informing vehicles approaching the event before they reach the safety line ,avoiding consequently dangerous situations.

The wait time of a relay vehicle for the next broadcast is set according to transmission range, its speed Sself, current location Curr-loc, location of safety line and maximum speed of vehicles with the conservative assumption that the vehicle is moving at the maximum allowable speed Smax. The wait time can be set for a relay leaving or approaching the event using (3).

$$\Delta\theta = \min((R + |Curr\_loc - Safetyline|)/S\max,\; 2*R/(S\max + Sself)) \quad (3)$$

For a leaving relay, during this time, opposite vehicles which are vehicles approaching the accident cannot travel from beyond the transmission range, pass then leave its range or cross the safety line. So, this periodicity ensures informing approaching vehicles before they reach the safety line.

For an approaching relay, this periodicity ensures that opposite vehicles are informed to overcome fragmentation and disseminate quickly the alert. During this time too, vehicles traveling in the same direction cannot travel from beyond the transmission range, pass then leave its range or cross the safety line. So, this periodicity ensures informing approaching vehicles before they reach the safety line.

In order to save unnecessary broadcasts while keeping the warning message in the alert zone, we dynamically set the wait time of the relay vehicle for the next broadcast when it receives (directly or indirectly) the message from a new relay further than him to the event. If this new relay is a vehicle approaching the accident, the relay must stop its periodic rebroadcasts definitively because the new relay will ensure this task. If this new relay is a vehicle leaving the accident, the relay must stop its periodic rebroadcasts momentarily until the new relay leaves the warning zone. In this case, the wait time is calculated with location of effect line, actual location and speed of the leaving relay.

The relays can communicate directly when the network is not fragmented; otherwise they can't. In this case and in order to avoid unnecessary broadcasts while keeping the warning message in the alert zone, we exploit intermediary vehicles (approaching or leaving) to connect them indirectly (Fig. 2) using the last leaving relay information as follows:

A vehicle(C)leaving or approaching the event, receiving the warning message from a leaving relay and receiving after the same message from another relay(approaching or leaving)nearer than the first relay to the accident before the first relay leaves the warning zone, must inform the second relay about the first by broadcasting a message, named message 'STOP'. This message contains the first relay information<ID, direction, speed, location, Send Time>which vehicle(C) has registered when receiving the message from the first relay. In our protocol, every vehicle must save the last received warning message if its sender is a vehicle leaving the event. When

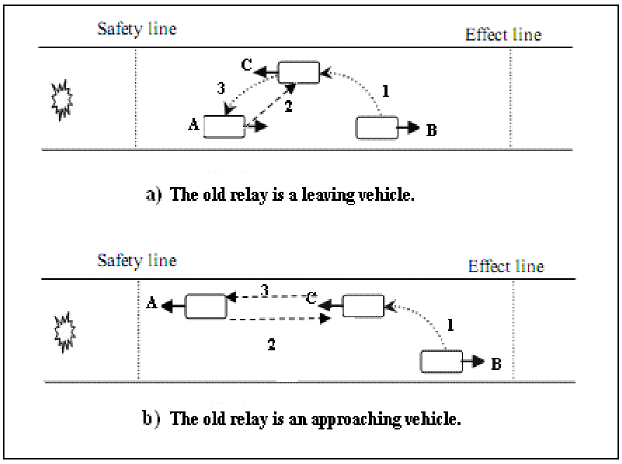

Figure 2. Example of an indirect communication between relays.

receiving the message 'STOP', the second relay must stop its rebroadcasts until the first relay leaves the warning zone.

So, we have succeed in saving unnecessary broadcasts while keeping the warning message in the warning zone using the last leaving relay information which is broadcasted only when it's necessary(fragmentation)and in a reduced message; saving consequently both time and bandwidth specially in dense networks which adapts our protocol to sparse and dense networks. Our protocol is also efficient in unidirectional roads since the periodicity of relays approaching the event takes in consideration vehicles traveling in the same direction in addition to opposite vehicles and we propose that vehicles leaving the event in these roads will not be used as relays to avoid useless broadcasts.

IV. Simulation Results

In order to evaluate the performance of OCast against ODAM and AG, we created a mobility model to simulate the vehicles behavior on the road. We carried out series of simulations using the network simulator NS2 [18]. In addition to OCast, we have simulated ODAM and AG since these two protocols are proportionally more effective than other proposed ones and from them we were inspired. The parameters of our model are listed in Table I. The vehicles are uniformly distributed on a bidirectional road consisting of two lanes at a rate of N vehicles per Kilometer per lane and run at constant speed throughout the lanes. The speed of each vehicle is randomly selected in the interval [Smean-ε, Smean+ε] and it can overtake other vehicles. For all the simulations, we fix the length of the straight road to 15Km. The location of the accident is at 0 meters, the safety distance is 200 meters, the effect distance is 6Km and the lifetime of the event is 500s. For

ODAM and OCast, the beginner of dissemination is the damaged vehicle and it is a leaving vehicle located at the safety line when the event occurs for AG. Initially, all vehicles approaching the accident are located before the safety line.

TABLE I. PARAMETERS

Description	Value
Transmission range(R)	200m
Mac layer	IEEE802.11
Data rate	2Mbps
Paquet size	64Bytes
Safety distance	200m
Effect distance	6Km
Trafic density(N)	1,3,6,9,12,15vehicles/Km/lane
Speed mean(Smean) Speed variation ε	25m/s 5m/s

A. *Message delivery ratio*

Fig. 3 compares the message delivery rate for different vehicles densities, which represents the ratio of the approaching vehicles that receive the message to the total number of approaching vehicles. We can remark that OCast and ODAM achieve 100% delivery rate for all densities. This is justified by the relays availability in dense networks and by the initiator periodic broadcasts in sparse networks. AG cannot alert all relevant vehicles in sparse networks (N=1,3vehicles/Km/lane) due to the fact that the initiator vehicle is a vehicle leaving the accident which prevents vehicles entering the alert zone after its exit from receiving the alert. Its delivery ratio increases with the traffic density which allows keeping the warning message in the alert zone and informing new approaching vehicles after the initiator exit. We can see in Fig. 4 that the three protocols ensure informing vehicles before the risk zone in sparse and dense networks. For higher traffic densities, this is justified by the relays availability which allows informing vehicles early. For sparse networks, this is justified by the periodic broadcasts of the initiator vehicle which allows informing approaching vehicles early during its traveling in AG and at least with braking distance away from the accident in OCast and ODAM. Fig. 5 shows that informed vehicles with OCast have received the alert before crossing the safety line in sparse or dense networks. For higher densities, this is due to the relays availability specially those far away from the safety line which allow informing early concerned vehicles. For weak densities, the reason is that the initiator vehicle ensures informing vehicles which have not receive the alert due to the lack of relays in the alert zone coupled whit the fact that the periodicity of relays approaching the event ensures informing vehicles traveling in the same direction before crossing the safety line. The lack of these two factors which doesn't allow 5% from vehicles informed with AG to receive the alert before reaching the safety line with the traffic density 3 vehicles/Km/lane. With a traffic density of 1 vehicle/Km/lane, informed vehicles with AG have received the alert before reaching the safety line because they have received the warning from the leaving initiator vehicle. For higher densities, informed vehicles have received the alert before crossing the safety line due to the relays availability too.

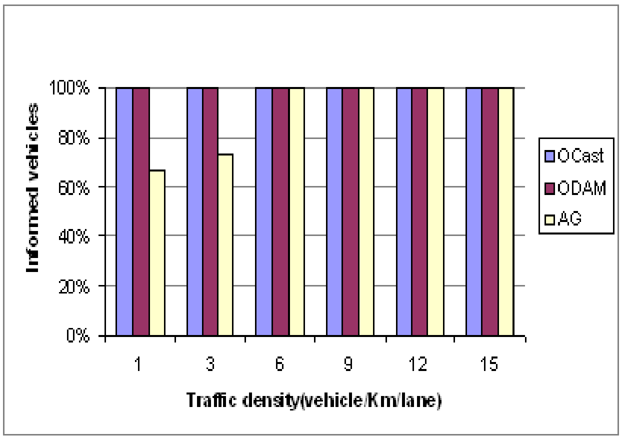

Figure 3. Message delivery ratio

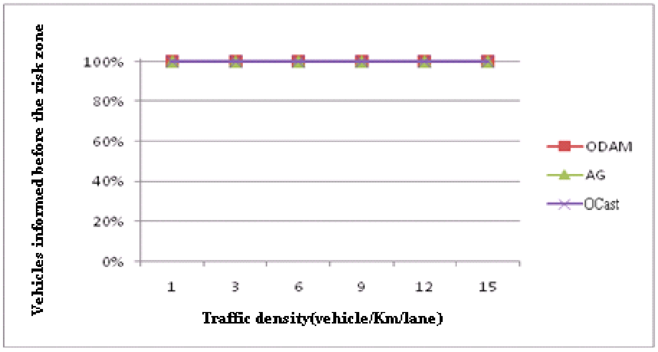

Figure 4. Ratio of vehicles informed before the risk zone.

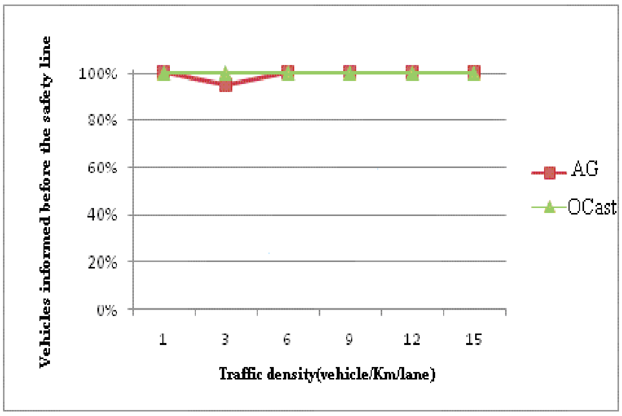

Figure 5. Ratio of vehicles informed before the safety line.

B. *Delivery average delay*

Fig. 6 compares the delivery average delay for different traffic densities, which is calculated through $(\sum_{i=1}^{A} Ti)/A$, where Ti is the time when approaching vehicle i was informed and A is the number of informed approaching vehicles. OCast shows better performance than ODAM for all densities. The fact is that OCast doesn't limit rebroadcast to approaching vehicles as ODAM does, but it uses also leaving (opposite) vehicles which allow informing earlier concerned vehicles. For higher densities, we can remark that OCast and AG have the same average delay because they use the same relay selection strategy and have the same relays periodicity when these relays are close to the effect line. For weak densities, AG has the minimal delay compared to OCast due to the fact that most informed vehicles have received the alert earlier from the leaving initiator which doesn't stop its periodic rebroadcasts until its exit. Moreover, this delay is that of informed vehicles which represent 66,66%, 73,33% from the total number of concerned vehicles. The increase of this delay between 1 and 3 vehicle/Km/lane proves this because with a higher density, the number of informed vehicles increases and consequently the delivery average delay increases. The average delay of the tree protocols decreases significantly with the traffic density (6vehicles/Km/lane) and decreases more with the density increase due to the relays availability which allows informing earlier concerned vehicles.

C. Broadcasted messages number (broadcast overhead)

Fig. 7 compares the number of broadcasted messages (broadcast overhead) during the lifetime of the emergency. OCast shows much better performance than ODAM for all traffic densities. The first reason is the static periodicity of the initiator vehicle which broadcasts the alert periodically according to the period $\Delta\theta$=1,66s during all the lifetime of the accident, contrary to OCast where the initiator set dynamically this periodicity according to the relays availability in the warning zone. Moreover, the relay periodicity in ODAM is shorter than that in OCast and ODAM doesn't use opposite vehicles which allow avoiding certain broadcasts especially in sparse networks. With the traffic density 1vehicle/Km/lane, AG has slightly better performance than OCast because the damaged vehicle doesn't broadcast the message contrary to OCast where this last one broadcasts periodically in order to alert all concerned vehicles replacing the relays lack in sparse networks. However and unfortunately, AG doesn't ensure informing all relevant vehicles which has reduced more the number of broadcasted messages. For all other densities, OCast shows much better performance than AG. The reason is that AG proposes that the relay sets dynamically its periodicity only when the new relay is traveling in the same direction in order to connect relays indirectly using the last opposite vehicle information, contrary to OCast where the relay sets dynamically its periodicity whenever the direction of the new relay and the efficient use of the reduced message 'STOP' which allows connecting relays indirectly faster and avoiding consequently many periodic broadcasts comparing to AG. The number of broadcasted messages with OCast decreases significantly with the density increase because the initiator dynamic periodicity increases with the relays availability which minimizes the number of broadcasts. Furthermore, the relays periodic broadcasts decrease with the availability of new relays.

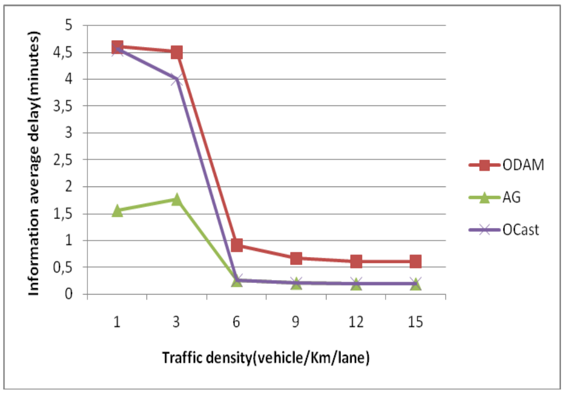

Figure 6. Delivery average delay.

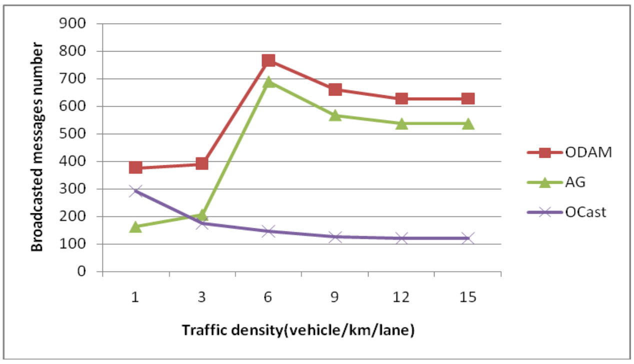

Figure 7. Broadcast overhead.

V. Conclusion

In this paper, we have proposed OCast, an Optimal multi-hop broadcast protocol for vehicular safety. Simulations show the optimality of OCast compared to similar solutions. It can ensure robustness and guarantee desirable performance of high message delivery ratio, limited latency and acceptable communication overhead under different traffic densities.

References

[1] Q. Xu, T. Mak, J. Ko, R. Sengupta, "Vehicle-to-vehicle safety messaging in dsrc", In: VANET '04, 2004, pp. 19–28.

[2] M. Torrent-Moreno, J. Mittag, P. Santi, H. Hartenstein, "Vehicle-to-vehicle communication: Fair transmit power control for safety-critical information", IEEE Transactions on Vehicular Technology 58 (7) (2009) 3684–3703.

[3] M. Li, Z. Yang, W. Lou, Codeon, "Cooperative popular content distribution for vehicular networks using symbol level network coding, selected areas in communications", IEEE Journal on 29 (1) (2011) 223–235.

[4] NI S., et al., "The Broadcast Storm Problem in Mobile Ad Hoc Network", MobiCom'99, Seattle, Washington, USA 1999, pp. 151–162.

[5] Q. Zhang and D.P. Agrawal, "Dynamic probabilistic broadcasting in MANETs", Journal of parallel and Distributed Computing, 65 (2005), pp. 220–233.

[6] Y. Tseng, S. Ni and E. Shih, "Adaptive approaches to relieving broadcast storms in a wireless multihop mobile ad hoc network", IEEE Transactions on Computer, (2003), pp. 545–557.

[7] M.B. Yassein, S.F. Nimer and A.Y. Al-Dubai., "A new dynamic counter-based broadcasting scheme for mobile ad hoc networks", Simulation Modeling Practice and Theory, (2010).

[8] L. Briesemeister and G. Hommel, "Overcoming Fragmentation in Mobile Ad Hoc Net-works", Journal of Communications and Networks. Vol. 2, N° 3, pp. 182–187, September 2000.

[9] M.-T. Sun and al., "Gps-based message broadcast for adaptive inter-vehicle communications", VTC Fall 2000.

[10] Alshaer, H. and E. Horlait, "An Optimized Adaptive Broadcast Scheme for Inter-Vehicle Communication", In Proceedings of the IEEE Vehicular Technology Conference (IEEE VTC2005-Spring),pages 2840– 2844, Stockholm, Sweden, May 2005.

[11] M. Durresi, A. Durresi and L. Barolli, "Emergency Broadcast Protocol for Inter-Vehicle Communications", In Proceedings of the 11th International Conference on Parallel and Distributed Systems (ICPADS'05), 2005, pp. 402-406.

[12] M. Li, K. Zeng, W. Lou, "Opportunistic broadcast of event-driven warning messages in vehicular ad hoc networks with lossy links", Computer Networks 55 (10) (2011) 2443-2464.

[13] C. Wu, S. Ohzahata and T. Kato, "A low latency path diversity mechanism for sender-oriented broadcast protocols in VANETs", Ad Hoc Networks(Elsevier) (2012),doi:10.1016/j.adhoc.2012..02.007.

[14] Benslimane.A, "Optimized Dissemination of Alarm Messages in Vehicular Ad-hoc Networks (VANET)", In Proceedings of the 7th IEEE International Conference, Toulouse, France, June 2004.

[15] Qiangyuan Yu and Geert Heijenk , "Abiding Geocast for Warning Message Dissemination in Vehicular Ad Hoc Networks", IEEE International Conference on Communications Workshops,2008.ICC Workshops '2008.

[16] C. Perkins, E. Royer and S. Das, "IP Flooding in Ad hoc Mobile Networks", IETF Internet Draft, draft-ietf-manet-bcast-00.txt, November 2001.

[17] T. Nadeem, P. Shankar and L. Iftode, "A Comparative Study of Data Dissemination Models for VANETs", In Proceedings of the 3rd Annual International Conference on Mobile and Ubiquitous Systems, July 2006.

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