A VANET Solution to Prevent Car Accidents

Francisco J. Martinez[1] , Juan-Carlos Cano[2] , Carlos T. Calafate[2], and Pietro Manzoni[2]

Abstract— **Vehicular Ad hoc Networks (VANETs) are regarded as the adequate solution to cooperative driving between communicating cars on the road. There are strong economical interests in this field since vehicle-to-vehicle (V2V) communication allows to improve traffic safety, to improve route planning, or to control traffic congestion.**

The 802.11p is a draft amendment to the IEEE 802.11 standard for vehicular communications. It has been adopted by Wireless Access in Vehicular Environments (WAVE), which defines an architecture to support Intelligent Transportation Systems (ITS).

In this work we present a driver warning system in which damaged vehicles send warning messages and the rest of the vehicles make the diffusion of these messages. We concentrated on diffusion of warning messages sent by damaged nodes in order to inform the rest of vehicles in the scenario in 802.11p-based VANETs. The target is to send vehicle safety messages with high reliability and low delay.

We performed a sensibility study to evaluate the impact of varying some parameters in the proposed advertisement system. We show that the propagation delay is lower when node density increases and that the percentage of blind nodes (i.e., nodes that do not receive these packets) highly depends on this factor. Finally, the results demonstrated that, to obtain the lowest possible propagation delay in our system, the best solution is that messages have different priorities depending on their characteristics.

Keywords— **vehicular ad hoc networks, performance evaluation, inter-vehicle communication.**

I. Introduction

VEHICULAR ad hoc networks (VANETs) represent a rapidly emerging research field, being a particularly challenging class of Mobile Ad Hoc Networks [1], used for communication and cooperative driving between cars on the road.

VANETs have particular features like: distributed processing and organized networking, a great number of nodes, the distribution and the speed of these nodes, a constrained but highly variable network topology, communication conditions and mobility patterns, signal transmissions blocked by buildings, frequent partition due to the high mobility, and finally there are no significant power constraints.

The development of VANETs is backed by strong economical interests since vehicle-to-vehicle (V2V) communication allows to share the wireless channel for mobile applications, to improve route planning, to control traffic congestion, or to improve traffic safety, e.g., avoiding crash situations [2]. Emerging wireless technologies for V2V and vehicle-to-roadside (V2R) communications, such as Dedicated Short Range Communications (DSRC), seem quite promising at reducing the number of fatal roadway accidents by providing early warnings [3].

In Inter-Vehicular Communication (IVC) systems, broadcast is a frequently used method. Possible applications relying on broadcast include sharing emergency, traffic, weather, road data among vehicles, as well as delivering advertisements and announcements.

The 802.11p is a draft amendment to the IEEE 802.11 standard for vehicular communications. It has been adopted by Wireless Access in Vehicular Environments (WAVE), which defines an architecture for Intelligent Transportation Systems (ITS).

In this paper, we propose a basic warning advertisement system based on the use of 802.11p standard and a flooding protocol. The target is to send vehicle safety messages with high reliability and low delay. We evaluated the performance of our proposed system, and we also concentrated on several important issues related to traffic safety such as the propagation delay of warning messages in an urban environment, the number of blind vehicles, and the total number of packets received by each vehicle. We varied some parameters of the model to study the variation of the aforementioned metrics.

This paper is organized as follows: Section II presents our proposed advertisement system in 802.11p-based VANETs. Section III presents the details of the simulation tools, the experimental environment and the methodology we followed to perform the simulations. Experimental results are described in Section IV. Section V describes the related work with regard to warning messages in VANETs. Finally, Section VI presents some concluding remarks.

II. The Warning Advertisement System

In this section we describe how the driver warning system that we proposed operates, as well as the technologies and protocols involved.

In our system, each vehicle periodically broadcasts information about itself. When a vehicle receives a broadcast message, it stores and immediately forwards it by re-broadcasting the message. Warning messages should be propagated to all neighbors up to a certain number of hops, and so a flooding-based routing protocol fits our requirements adequately. We pretend that the warning packets sent by damaged nodes can be received by all the vehicles in the nearby area, and so this protocol offers the best reliability in terms of coverage.

The purpose of 802.11p is to provide the minimum set of specifications required to ensure interoperability between wireless devices that communicate in potentially rapid changing communication envi-

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[1] F.J. Martinez is with Department of Computer and Systems Engineering, University of Zaragoza, e-mail: `f.martinez@unizar.es`.

[2] J.C. Cano, C.T. Calafate, and P. Manzoni are with Department of Computer Engineering, Technical University of Valencia, e-mail: `{jucano, calafate, pmanzoni}@disca.upv.es`.

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ronments, as well as in situations where transactions must be completed in time frames much shorter than the minimum allowed with ad hoc 802.11 networks.

For our Warning Advertisement System we picked IEEE 802.11p technology because it is expected to by widely adopted by the industry, as occured with other IEEE 802.11 standard extensions. Moreover, we consider that this technology is able to offer good performance in environments where the physical layer properties are rapidly changing and where very short-duration data exchanges are required. The data rate employed by our system is of 6 Mbps, which is the data rate used for broadcasting with IEEE 802.11p. The MAC layer is based on the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) Quality of Service (QoS) extensions [4]. Therefore, application messages are categorized into different ACs, where AC0 has the lowest and AC3 the highest priority.

The proposed warning advertisement system is composed by the damaged nodes that send warning messages periodically ($T_{warning}$) to inform about their situation to the rest of the vehicles. These messages have the highest priority (AC3). Undamaged vehicles make the diffusion of these warning packets and periodically send other messages with information such as their position, their speed, etc. These periodic messages have less priority (AC1) than warning messages and are not propagated by other vehicles. With respect to warning messages, each vehicle is only allowed to propagate them once for each sequence number, being that older messages are dropped.

III. Simulation Environment and Methodology

The overall goal of this work was to evaluate the effectiveness of the warning advertisement system presented in section II, as well as measuring and comparing the behavior of some important metrics such as the propagation delay of warning messages, the number of blind nodes and the number of packets received per node when modifying the different parameters of a VANET scenario.

Figure 1 shows an example of the advertisement system. Notice that the darker buildings area represents the downtown. Dark rectangles represent vehicles, shadowed rectangles represent vehicles stopped at semaphores, and crosses represent damaged cars sending warning packets (darker circles).

The simulation results presented in this paper were obtained using the ns-2 simulator [5]. The ns-2 is a discrete event simulator developed by the VINT project research group at the University of California at Berkeley. Our simulated system tries to follow the upcoming WAVE standard as closely as possible. Achieving this required extending the ns-2 simulator to implement IEEE 802.11p. In terms of the physical layer, the data rate used for packet broadcasting was fixed at 6 Mbit/s. The MAC layer was extended to include different priorities for channel access.

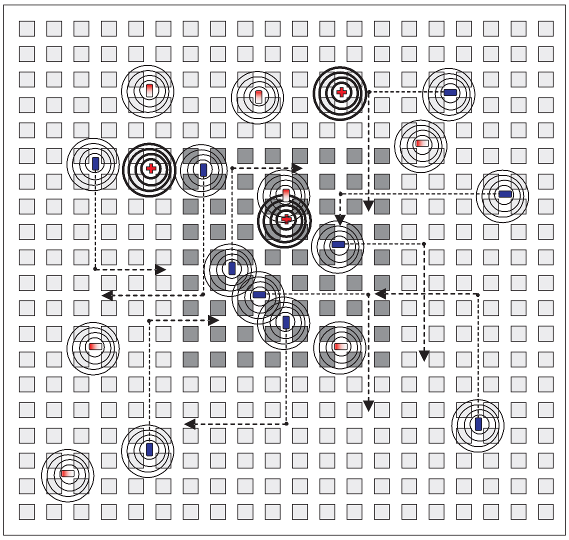


Fig. 1. Typical simulation environment using the proposed warning advertisement system in a Downtown scenario.

Our methodology relied of first selecting the most representative parameters for VANETs, then defining a reference scenario and, finally, varying the selected parameters, thereby generating and evaluating a large number of different scenarios. The selected parameters were: 1) the total number of vehicles, 2) the scenario size, 3) the size of the messages sent 4) the priority of these messages and 5) their periodicity.

Each simulation had a duration of 450 seconds. In order to achieve a stable state before gathering data traffic, we only start to collect data after the first 60 seconds.

Since the Random Waypoint Model is considered unrealistic [6], in the simulation nodes moved according to a mobility model called Downtown Model (DM) [7], a model we have proposed and validated for use in VANETs. In this model streets are be arranged in a Manhattan style grid, with a uniform block size across the simulation area. All streets are two-way, with lanes in both directions. Car movements are constrained by these lanes. Nodes will move with a random speed, lower than the maximum one defined by the user. Damaged vehicles will remain stopped during the entire simulation time. This model also simulates semaphores at random positions (not only at crossings), and with different delays. Moreover, this model adds traffic density like in a real town, where traffic is not uniformly distributed; so, there are zones with a higher vehicle density. These zones are usually in the downtown, and vehicles must move more slowly than in the outskirts. Finally, there are two types of nodes. Nodes that are damaged and send warning messages, and the rest of vehicles that propagate these messages over the whole map area.

In our experiments damaged nodes send warning packets with maximum priority (AC3) every second ($T_{warning} = 1s$) and the rest of the nodes send lower priority (AC1) packets with positioning information

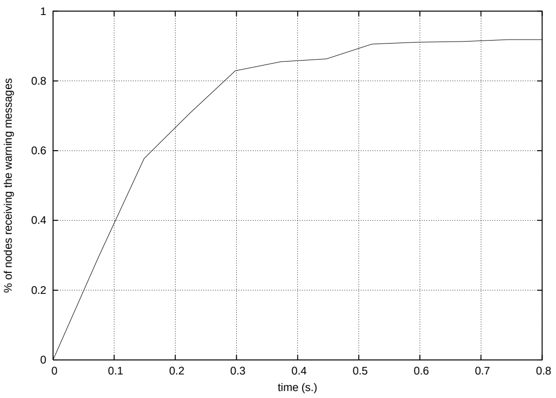


Fig. 2. Average propagation delay of warning messages in the basic scenario.

every two seconds. These nodes also make the diffusion of the warning packets.

IV. Simulation Results

In this section we first obtain reference results using the basic scenario, and then using a wide variety of scenarios by varying one of the selected parameters. As usual with VANET simulation, the number of parameters and their possible values is very large. We therefore performed a thorough evaluation.

Since the performance results are highly related with the specific scenarios used, the results shown in this section represent an average of five different executions of the simulation with different randomly generated mobility scenarios. We evaluated the following performance metrics: (a) average percentage of blind nodes, (b) propagation delay and (c) average number of packets received per node.

The percentage of blind nodes is the percentage of vehicles that do not receive the warning messages sent by the damaged nodes. These nodes can remain blind because of their position or due to collisions.

A. The basic scenario

Table I shows the parameter values used in the basic scenario. The results obtained for the measured metrics when simulating the basic scenario were: 9.07 blind nodes and 72.18 packets received per node, on average. We found blind nodes to be typically those nodes remaining isolated with respect to other nodes in terms of transmission range.

Figure 2 depicts the average propagation delay of the warning messages. As can be seen, information does not reach all nodes, but in only 0.15 seconds about 60% of the vehicles received the warning message, and in less than 0.3 seconds the information reached about 80% of the vehicles. From now on we will use as reference the time is takes to reach 80% of the vehicles (or 60%, in case there are too many blind nodes). For our basic scenario the propagation process was completed in 0.8 seconds.

B. Varying the number of nodes

Figures 3 and 4 show the simulation results when varying the number of nodes and maintaining the rest of parameters unaltered. We selected 25, 50, 100 (basic scenario), 150 and 200 nodes.

TABLE I

Parameter values for the basic scenario

Parameter	**Value**
number of nodes	100
maximum speed	23 $m./sec. \approx$ 83 km/h
map area size	$2000m \times 2000m$
distance between streets	50 $m.$
number of damaged nodes	3
downtown size	$500m \times 500m$
downtown speed (min.-max.)	$3 - 14$ $m./sec. \approx$ $11 - 50$ km/h
downtown probability	0.7
warning packet size	$256B$
normal packet size	$512B$
packets sent by damaged nodes	1 *per second*
warning message priority	$AC3$
normal message priority	$AC1$

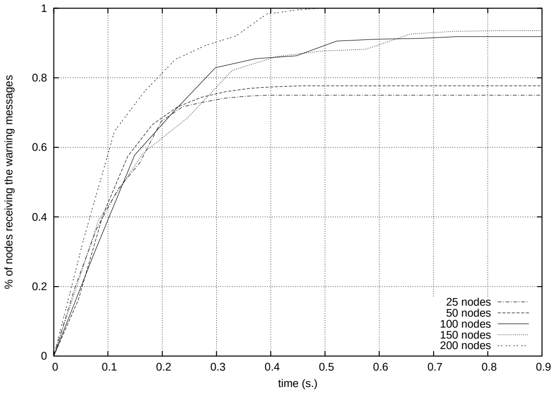


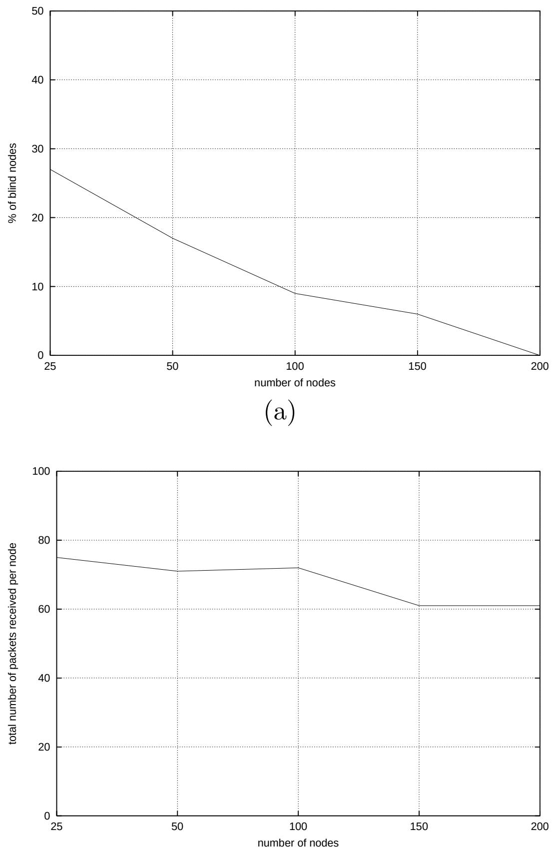
Fig. 3. Average propagation delay when varying the number of nodes.

As we expected, the propagation delay is lower when the node density increases. Information reaches about 60% of the vehicles in less than 0.2 seconds, and propagation is completed in less than 0.9 seconds. When simulating with 200 nodes, propagation was completed in only 0.5 seconds.

The behavior in terms of percentage of blind nodes highly depends on this factor. In fact, when node density is high, there are no blind nodes. This characteristic is explained because the flooding propagation of the messages works better with higher node densities. Due to collisions, the number of packets received per node slightly decreases when the number of nodes increases.

C. Varying the scenario size

In this section we show the simulation results when varying the size of the area, maintaining unaltered the density of nodes and the rest of parameters. We selected scenario areas of 1000×1000m, 1500×1500m, 2000×2000m (basic scenario), 2500×2500m and 3000×3000m. Node density



(a)

(b)

Fig. 4. Percentage of blind nodes (a) and number of received packets (b) when varying the number of nodes.

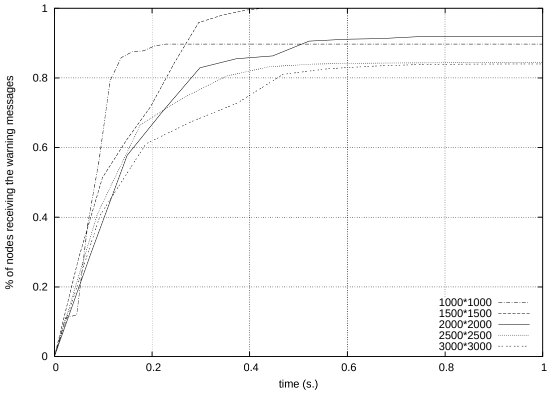
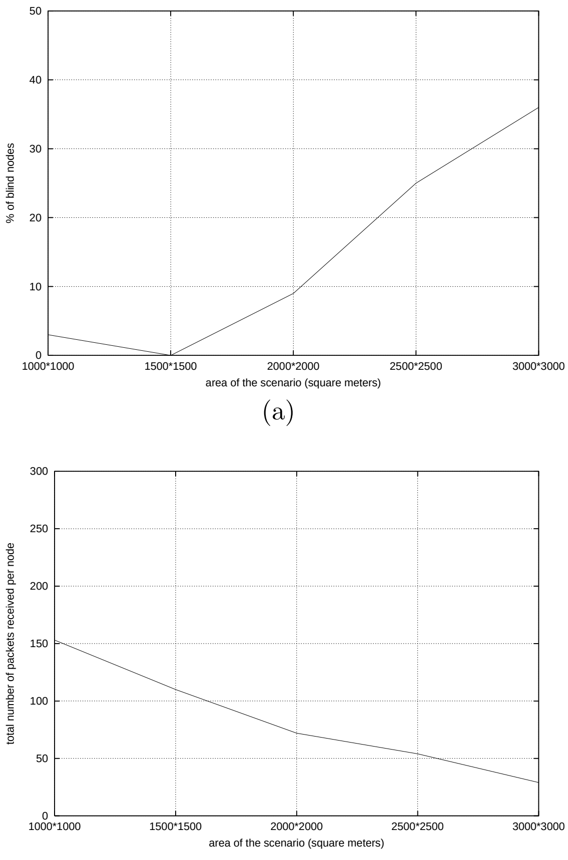


Fig. 5. Average propagation delay when varying the size of the area.

is set to 25 vehicles per square kilometer.

Figure 5 depicts the average propagation delay of the warning messages. As can be seen, when the area increases, the system needs more time to inform 80% of the vehicles (approximately 0.12, 0.25, 0.30, 0.35 and 0.45 seconds respectively).

As can be observed in Figure 6, the percentage of blind nodes highly depends on this factor. When the area is very small, the percentage of blind nodes is also very small. When the size of the area increases, the number of blind nodes also increases. Nevertheless, the number of packets received per node decreases.



(a)

(b)

Fig. 6. Percentage of blind nodes (a) and total number of packets received (b) when varying the size of the area.

D. Varying the message size

In this section we evaluate the impact of varying the size of the warning messages sent by nodes in terms of propagation delay. The selected values were: 64, 128, 256 (basic scenario), 512 and 1024 Bytes. Figure 7 show the propagation delay of the simulation.

As can be observed, the size of the messages sent does not affect the propagation delay in our system since the current degree of congestion is relatively low. The system needs less than 0.33 seconds to reach to the 80% of the vehicles. In this case, the percentage of blind nodes (9.07) and the total number of messages received (71.63) do not change.

E. Varying the message priority

In this section we vary the priority of regular (background) traffic to assess the impact in terms of warning messages' effectiveness.

Figure 8 show the simulation results when varying the priority of the messages sent by undamaged nodes, maintaining the rest of parameters unaltered. We selected AC3 (highest priority in our simulation system), AC2, AC1 (basic scenario) and AC0 (lowest priority). As can be seen, packet priority affects the propagation delay, but not to the percentage of blind nodes and the total number of messages received.

The results demonstrated that, to obtain the low-

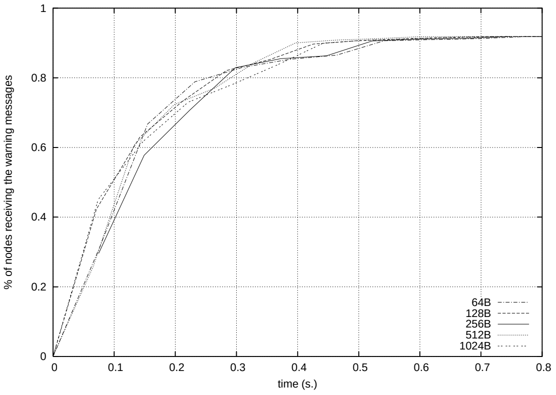


Fig. 7. Average propagation delay when varying the size of the sent packets.

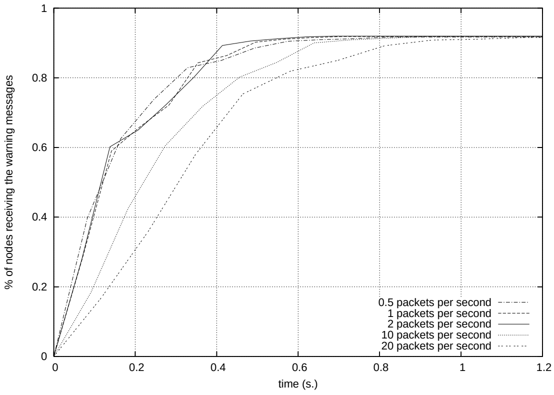


Fig. 9. Average propagation delay when varying the data rate (same priority for messages).

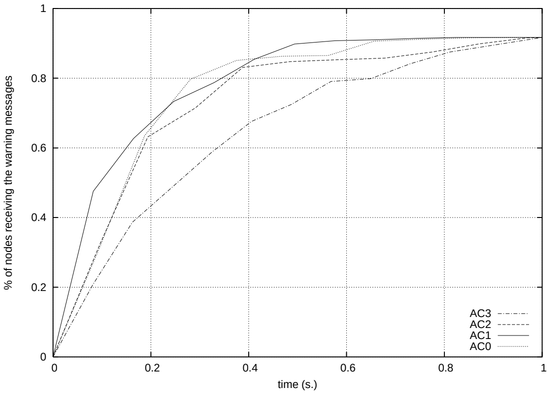


Fig. 8. Average propagation delay when varying the priority of the messages sent by the undamaged nodes.

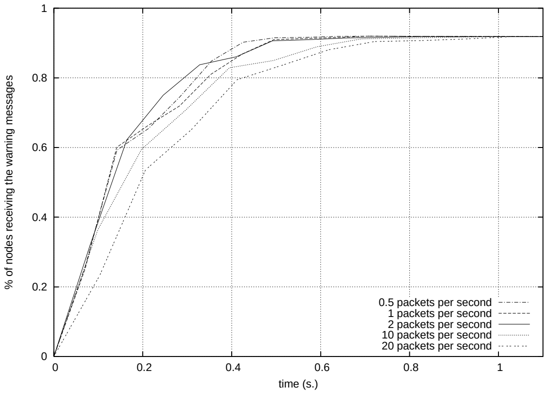


Fig. 10. Average propagation delay when varying the data rate (different priority for messages).

est possible propagation delay in our system, the best solution is to give the less priority to the background traffic, while warning messages must have the highest priority. In that case, about 80% of the nodes are informed in only 0.28 seconds. If we increment the priority of the normal messages, the system needs more time to inform 80% of the nodes (0.34 and 0.36 seconds). The worst case scenario arrives when all the messages (warning and normal) have the same priority, since the system needs 50% more time to inform 80% of the vehicles. The priority does not affect the percentage of blind nodes (9.07) and the total number of messages received (72.18).

F. Varying the periodicity of messages

In this section we studied the impact of varying the periodicity of the messages sent in two different situations: first, when the priority of all the messages is the same and second, when the priority of the normal messages is lower than the priority of the warning messages.

Figure 9 shows the propagation delay when varying the data rate considering that all the messages have the same priority. Figure 10 shows the propagation delay when varying the data rate considering that the priority of normal messages is lower than the priority of warning messages. As can be seen by comparing both figures, when the message priority differs the system's behavior is improved since it requires less time to inform 80% of the vehicles. In both cases, when the data rate increases, the system requires more time to inform the rest of vehicles. Therefore, to achieve optimum performance, was must find a trade-off between message generation intervals and system responsiveness. Besides, we must make sure that message priority is handled adequately to avoid that warning messages compete with other traffic.

V. RELATED WORK

Previous research works regarding warning messages have focused on three issues: medium access control, message dissemination protocols and collision prevention mechanisms.

In [8] authors considered a counter-based method to assign additional delays on top of the MAC backoff, and used it as a rebroadcast suppression mechanism that reduced packet collisions. They also combined a location-based method with the counter-based method to make a better choice of the next hop forwarder. Korkmaz et al. [9] proposed a new efficient IEEE 802.11 based Urban Multi-hop Broadcast protocol (UMB) which was designed to address the broadcast storm, hidden node and reliability problems of multi-hop broadcast in urban areas. They showed that this protocol had a very high success rate and efficient channel utilization.

Yang et al. [3] tried to achieve low-latency in delivering emergency warnings in various road situations. They designed an effective protocol, comprising congestion control policies, service differentiation mechanisms and methods for emergency warning dissemination. Their protocol removes unnecessary packet forwarding by checking for message duplicates in the application layer, though some authors [8] think that it also requires local neighbor knowledge and additional application processing, which is difficult to acquire and maintain for collision avoidance protocols requiring low latency. Sengupta et al. [10] focused on Cooperative Collision Warning (CCW) systems and presented experimental results showing the performance of a first prototype CCW system. The CCW concept provides warnings or situation awareness displays to drivers based on information about the motions of neighboring vehicles obtained by wireless communications from those vehicles.

To the best of our knowledge, none of the research works currently available has studied the most important parameters in a VANET when warning messages are used to improve traffic safety, including a detailed performance evaluation.

VI. CONCLUSIONS

In this paper we presented a warning advertisement system for IEEE 802.11p-based VANETs, and we made a performance analysis of inter-vehicle communication systems to improve traffic safety.

To evaluate our system we enhanced the ns-2 simulator to support the novel IEEE 802.11p technology. We selected the most representative parameters for VANETs, and then we defined and simulated a basic scenario. Finally, by varying the selected parameters, we generated and simulated more scenarios. The results obtained from the simulations allow us to draw some important conclusions:

- As we expected, the propagation delay is lower when node density increases. Besides, the percentage of blind nodes highly depends on this factor. In fact, when node density exceeds a certain threshold, there are no blind nodes. This behavior takes place since the flooding propagation of messages works better with a higher node density. Finally, the number of packets received slightly decreases when the number of nodes increases due to collisions.
- When the area increases, the system needs more time to inform the rest of the vehicles and the percentage of blind nodes highly depends on this factor, too. When the area is very small, the percentage of blind nodes is also very small. When the area increases, the number of blind nodes also increases. Nevertheless, the total number of packets received per node decreases.
- The size of the packets sent does not affect the warning advertisement system's behavior.
- When we vary the priority of the packets sent by the undamaged nodes, the propagation delay of the system changes. The results demonstrated that to obtain the lowest possible propagation delay in our system, the best solution is to give less priority to the background traffic, while the warning messages must have the highest priority. We have a worst case scenario when all the messages (warning and normal) have the same priority. However, packet priority does not affect the percentage of blind nodes nor the total number of packets received.
- The system's behavior decays when increasing the data rate of messages, especially if both warning and regular messages are assigned the same priority.

As future work we plan to increase the level of realism of the system by enhancing the physical layer model to include obstacles, improving the flooding routing protocol, and assessing the impact in terms of overall performance.

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