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Inter-Vehicle Communications: Assessing Information Dissemination under Safety Constraints

Marc Torrent-Moreno
Institute of Telematics, University of Karlsruhe, Germany
torrent@tm.uni-karlsruhe.de

Abstract— **The main goal of inter-vehicle communication technologies is to provide each vehicle with the required information about its surrounding in order to assist the driver avoiding potential dangers. The required information level, or awareness, can be achieved by the exchange of periodic status messages (beacons) among neighboring vehicles together with the quick dissemination of information about potential hazards. In previous work, we proposed an algorithm (D-FPAV) to control the beaconing load on the medium by adjusting the transmission power in a fair and distributed fashion. In this paper, we adapt a promising position-based message forwarding strategy in order to disseminate time-critical safety information. Moreover, we evaluate its performance when making use of D-FPAV, i.e., limiting the beaconing load on the medium, in a realistic highway environment with probabilistic radio propagation characteristics.**

I. INTRODUCTION

Nowadays, road safety is one of the main concerns of the public opinion in developed countries. Indeed, it is estimated that road traffic accidents cause 43.000 fatalities and more than 1.2 million injuries every year in the 25 European Union states. Several efforts have been started with the goal to improve road safety by means of intelligent systems, such as the European eSafety [1] which aims to reduce road's fatalities by a 50% until 2010.

Wireless technologies, and more specifically IEEE 802.11, are considered a promising candidate to be part of future vehicle safety systems due to their increased reliability and price reduction experienced during the last decade. To encourage their development the Federal Communications Commission of the USA (FCC) allocated, in 1999, 75 MHz of licensed bandwidth (divided in seven 10 MHz channels and a 5 MHz guard band) in the 5.9 GHz range for the improvement of highway safety and efficiency. Currently, the task group IEEE 802.11p [2] is developing a standard that defines the channel access strategy and the physical specifications tailored to vehicular environments.

Wireless communication technologies can support road safety by two means: by the periodic exchange of 'status' messages and by the dissemination of emergency messages. The first type of messages, also called beacons, will contain vehicles' status information such as position and speed vector. Upon reception of beacons issued by neighboring vehicles, a safety system is aware of its surrounding and is able to detect potential dangerous situations. The second type of messages, also called event-driven, will quickly disseminate emergency information to make possible to alert other drivers of an existing danger.

The exchange of safety related information will take place in one shared channel, known as Control Channel [2], among all vehicles on the road. Clearly, strategies to control the channel load and to make an efficient use of the limited resources are needed in order to achieve safety when experiencing high penetration rates in dense vehicular traffic situations. Consequently, the design of information dissemination strategies has to consider the presence of background traffic, i.e., frequent and periodic status messages.

In a previous work [3], we motivated the need to limit the channel load resulting from beacons in order to avoid the saturation of the Control Channel. Furthermore, we proposed a distributed strategy able to adjust beacons' transmission power based on the concept of fairness, D-FPAV: Distributed Fair Power Adjustment for Vehicular environments. D-FPAV achieved to restrict the beaconing load and to reduce the packet collisions on the medium while *i)* increasing the probability of reception of one-hop emergency messages and *ii)* not decreasing beacons' reception rates at close distances from the sender. The price to pay with the beacon's power reduction is, on the other hand, lower reception rates at further distances from the transmitter.

In this paper, we present our current work on time-critical emergency information dissemination. Our goal is first to outline how information dissemination can be performed in vehicular scenarios with wireless background traffic. Second, we intend to demonstrate that with an appropriate dissemination strategy, the use of D-FPAV can have a positive impact on the dissemination process even though it compromises the information accuracy from further neighbors. For this purpose we make use of the contention-based message forwarding strategy described in [4] and adjust it in order to disseminate emergency information within a geographical area. The resulting protocol is evaluated in the presence of beaconing load on the medium utilizing the ns-2 [5] simulator. The selected scenario consists of a highway environment with realistic traffic patterns and probabilistic radio propagation phenomena following the Nakagami fading model [6].

The rest of the paper is organized as follows. Section II discusses related work relevant to our study. Section III briefly outlines the mechanism to control the beaconing load and describes the emergency information dissemination strategy. In Section IV, the results of the simulation study are reported.

Finally, Section V presents concluding remarks and outlines future work.

II. RELATED WORK

Following the high interest and potential of inter-vehicle communications, several strategies for information dissemination tailored to vehicular environments have been suggested that improve simple flooding. Most of them assume that nodes are aware of their own location since positioning systems such as GPS will probably be present in the majority of vehicles in a near future. One of the first approaches to use location information was presented in [7] and proposes to select the furthest node to the own location in the direction of the road in order to retransmit a message. The positions of neighboring vehicles are exchanged on demand.

Later, other approaches appeared addressing different types of applications and environments, which are designed according to different criteria. Examples of dissemination of non-safety information are [8], [9], [10], [11] and [12], where information is destined to very large distances, i.e., from several kilometers to complete cities, and some nodes are required to store the information due to temporally partitioned networks. An example of non-safety information dissemination in a limited area is [13], which proposes a protocol designed for cooperative driving.

The following strategies focus on the dissemination of emergency information. A hierarchical structure to efficiently disseminate information with low delay for cars driving in the same direction is designed in [14]. However, it is not addressed how to manage highly dynamic topologies, e.g., with cars entering or leaving the road.

The authors in [15] propose to use a contention based strategy based on the number of neighbors that each vehicle has without evaluating the delay introduced. Although the use of a contention based approach can lead to satisfactory results (see Section IV), basing the forwarding decision on a road topology is better suited to vehicular environments.

The authors of [16] also propose their strategy to disseminate emergency information within local areas, i.e., one mile. They suggest the use of a propagation function in order to route messages which assigns higher weights to preferable locations inside of the intended destination area, and evaluate two probabilistic schemes. Further study is required before concluding that a probabilistic scheme is a valid approach for emergency information dissemination though. The probability that a message is not forwarded in a sparse but connected network as well as the probability that several neighboring nodes simultaneously retransmit a message in more dense situations should be evaluated.

A common characteristic of the above studies is that a deterministic radio propagation model was utilized for design and evaluation. Their results, therefore, may significantly vary when assuming a probabilistic radio model as suggested from empirical studies such as [17]. Moreover, none of the studies considered the wireless medium conditions depicted in Section I, i.e., the existence of background traffic.

III. SAFETY RELATED COMMUNICATION STRATEGIES

We intend to disseminate emergency information with high reliability and short delay in vehicular environments. The utilized channel is the Control Channel, where safety-related communications are allocated, and we assume the existence of wireless background traffic generated by the periodic exchange of one-hop broadcast status messages. Additionally, we show how the use of D-FPAV can have a positive impact with an appropriate dissemination strategy. Although restricting the transmission power of the periodic messages decreases their reception rates at far distances, the resulting lower load on the channel can be beneficial for dissemination schemes.

Due to the road-bounded topology of vehicular networks, common ad hoc routing/forwarding strategies are well suited for data dissemination with minimal modifications. It is a reasonable assumption that the intended communication range of an emergency message is larger than the road's width. Therefore, a message following the direction of a road will cover all its area up to destination. This mechanism could be extended in case of scenarios with road junctions, which is left to future work.

In a former study [4], we evaluated two forwarding algorithms that made use of the geographical position of the nodes, PBF (Position-Based Forwarding) and CBF (Contention-Based Forwarding). The main difference between the mechanisms is that PBF forwards messages in a unicast fashion, i.e., to a single node, in every hop and CBF makes use of broadcast messages until reaching destination.

Both PBF and CBF presented promising results in terms of packet delivery ratio for short to medium distances, e.g., up to 3 km for the selected highway scenario. However, the contention-based approach of CBF demonstrated to be more robust against 'uncertainties', i.e., dynamic topologies and probabilistic properties of the radio propagation model, achieving a better performance in terms of overhead and latency. Based on these results, we propose to use the main principles of CBF in order to disseminate emergency information in the presence of background traffic in vehicular environments.

In the following, we provide the description of the dissemination protocol, called CBD (Contention Based Dissemination), preceeded by an overview of the D-FPAV mechanism for completeness.

A. D-FPAV: Limiting the Beaconing Load

In our scenario, we assume that each vehicle will periodically transmit status information messages (beacons) and keep a neighbor table with the information acquired. Depending on the status of each vehicle, e.g., speed, the utilized transmission power and packet generation rate might change in order to satisfy safety applications requirements.

D-FPAV is a distributed algorithm used to reduce the beaconing load on the channel in case of saturation. It extends the information contained in some beacons with the positions of the nodes acquired via the wireless medium (up to a certain range) and a power value computed by these vehicles. The power value identifies the maximum transmission power level

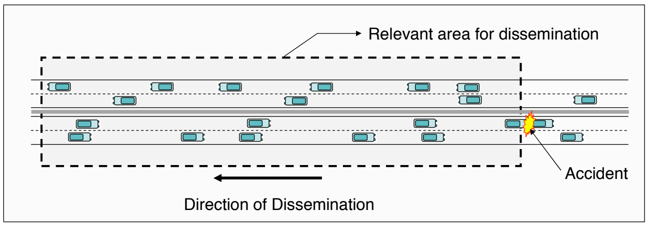

Fig. 1. Relevant area for dissemination of emergency information after an accident detection in a highway. Cars in the opposite direction are included since they can support the information dissemination process.

that nodes in the local area should use to issue their beacons in order to keep the load below a threshold, called maximum beaconing load (MBL). The MBL value is fixed in order to reduce the packet collisions on the medium in 'heavy' vehicular traffic conditions.

Before sending a new beacon, each node adjusts its transmission power to the minimum of the values suggested by its neighbors. The algorithm is theoretically proven to achieve fairness, what, from our opinion, is an essential property for safety protocols. Note that a node without a fair assignment of the resources can become a potential danger for its neighboring vehicles. For a detailed description and evaluation of the D-FPAV mechanism we refer the reader to [3].

B. CBD: Dissemination of Event-Driven Messages

The basic modification required to CBF in order to disseminate information is to adjust the addressing method. Now, instead of a single node, or position, the destination of a message is a geographical area.

We assume that a vehicle detecting a danger will issue an event-driven message. Also, the originating node will specify the relevant area, or destination area, where the information should be distributed according to the correspondent safety application. Due to the topology of our scenario, which models a straight highway (see Section IV), the relevant area could be defined, for example, by a rectangle covering the width of the road. In our case, the rectangle will contain the piece of road starting from the originator's position up to 2 km back, i.e., contrary to the driving direction, see Fig. 1. The relevant area and the direction of dissemination will be included in each event-driven message.

In order to cover the destination area, some intermediate nodes (forwarders) will be selected by the contention mechanism to forward the message in the direction of dissemination. As commented above, due to the road-bounded topology of vehicular scenarios it is a realistic assumption to consider that if the message reaches the back end of the relevant area the complete piece of road has been covered by the different forwarders' transmissions. However, it must be noted that covering the whole area does not guarantee that all vehicles inside it have successfully received a message due to potential collisions and fading effects.

A node forwarding a message by the CBD mechanism only needs to send the message in a broadcast fashion; the nodes receiving the message located in the direction of dissemination will decide, by means of a contention period, which one must re-forward the packet. Each node receiving a message that has to be forwarded will contend for a specific period of time, or not contend at all, according to the following rules:

$$\begin{cases} \text{no contention} & , P > r_{CA} \\ t(P) = T \cdot (1 - \frac{P}{r_{CA}}) & , r_{CA} \geq P \geq 0\,m \\ \text{no contention} & , P < 0\,m \end{cases}$$

where $t(P)$ is the waiting time a node will be assigned; P is the progress (in meters) in the direction of dissemination with respect to the actual sender; T is the maximum waiting time; and r_{CA} fixes the radius of the area where potential forwarders must be located, i.e., the *contention area*, see Fig. 2. Therefore, the node offering the largest progress within the contention area will select the shortest contention time. Upon reception of the re-forwarded message, nodes which are still contending will cancel the process. Finally, nodes located outside of the relevant area for dissemination will not forward the message.

The choice of r_{CA} deserves some discussion since a tradeoff between reliability, overhead and traveled distance should be considered in our environment. According to the results obtained in [18] the probability of receiving one message (without being retransmitted) decreases with the traveled distance and can be quite low close to the intended transmission range, e.g., below 20% in a similar set up than the one used in Section IV. Letting the closest node to destination select the shortest contention time can be a suboptimal choice in terms of reliability and message duplicates. Note that it is very important that all nodes in the road receive the message with high reliability, being more relevant the ones closer to the originator for obvious reasons. The purpose of selecting an r_{CA} shorter than the intended communication range aims to favor the reliability of the scheme, in terms of vehicles receiving the emergency information, at the expense of a longer dissemination delay, i.e., more hops up to destination. Additionally, this restriction reduces the probability that duplicates collide due to the incoordination present with probabilistic propagation models [19]. The study to find the optimal radius of the contention area is out of scope of this document and it is left to future work. Also, the maximum waiting time T should be adjusted with respect to the r_{CA}, as well as the average channel access time. Notice that while a larger value of T provides a longer time to suppress potential duplicates among neighboring nodes, it also increases the average dissemination delay.

IV. EVALUATION

In this section, we discuss the simulation results obtained by CBD and evaluate the effect of utilizing the D-FPAV algorithm with respect to information dissemination. First though, we describe the simulation setup, including the scenario utilized, and the communication strategies' configuration.

A. Simulation Setup

We utilized the network simulator ns-2.28, which was extended as described in [18] in order to model vehicular

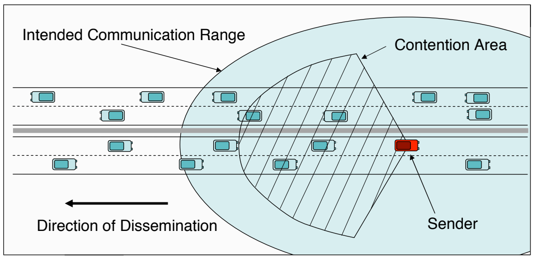

Fig. 2. Highway scenario visualization of the contention area depicted by CBD to select the next forwarding node. Nodes outside the contention area are not considered as potential next hop to re-forward the message in the direction of dissemination.

networks utilizing IEEE 802.11p technology. The selected scenario as well as the beaconing and the D-FPAV configuration are as suggested in [3] and summarized in Table I.

Our scenario models a straight 12 km long bidirectional highway with 3 lanes per direction. The representative case for this analysis consists of an average density of 11 vehicles per kilometer in each lane. The average speed of the vehicles in this set up is 121.86 km/h, corresponding to a fast-moving 'heavy' traffic German Highway.

The propagation models used are the Nakagami model (suggested and implemented in [17]), and the two ray ground model, implemented in the standard distribution of ns-2.28. The probabilistic Nakagami propagation model is configured with a fading intensity of m=3 and follows the same path loss exponent than two ray ground. The two ray ground model is deterministic, i.e., it provides a disk-range model with radius commonly known as communication range. In the following, we will refer to the radius of the disk-range computed with the two ray ground model for a specific transmission power as 'intended communication range'. The results obtained with two ray ground model are not included in Section IV-B since they did not provide valuable insight.

Each vehicle is configured to send 10 beacons/s of 500 Bytes each with an initial transmission power[1] of -1.1 dBm. The data rate utilized is 3 Mbps due to the robustness of the BPSK modulation scheme: it requires the lowest SINR (signal to interference-plus-noise ratio) to successfully receive a message, namely 4 dB.

The maximum beaconing load (MBL) for the D-FPAV algorithm is set to 1.5 Mbps, which provided a reasonable balance between increase of event-messages reception rates and the reduction of beacon's transmission power [3]. In the following, we will call D-FPAV-On in case D-FPAV is used and D-FPAV-Off otherwise.

With respect to the dissemination strategy CBD, we will take a conservative approach according to the expected reception rates shown in [18]. Assuming an intended communication range of 500m, we will not consider potential next forwarding nodes vehicles further than 300m. The maximum waiting time T is configured to 50 ms, which is longer than in [4] due to larger channel access time experienced in our selected scenario. Additionally, emergency messages will be sent with a higher priority than beacons. A wireless interface will issue emergency messages before beacons in case messages of both types exist on the interface queue.

Each simulation will run 3 s of real time. During this time a car driving in the middle of the highway, is configured to send 4 emergency event-driven messages to all cars driving behind it up to a distance of 2 km. The time between event-driven messages, 0.5 s starting at 1 s, is long enough so no retransmissions corresponding to the previous messages are being transmitted to the medium, or scheduled, at the time the actual one is issued.

Each configuration is simulated in eight different scenarios with 40 random seeds each. The complete configuration details are listed in Table I. For a more detailed justification of the chosen values see [3].

TABLE I
CONFIGURATION PARAMETERS

PARAMETER	VALUE
802.11p data rate	3 Mbps
Beacons generation rate	10 packets/s
Beacon size	500 Bytes
Intended comm. range	500 m
Radio propagation model	Nakagami
Number of lanes	3 × direction
Vehicle density	11 cars/(km· lane)
Average speed	121.86 km/h
D-FPAV	On, Off
D-FPAV MBL	1.5 Mbps
Dissemination Strategy	CBD
Relevant Area	2 km
CBD max. waiting time T	50 ms
CBD cont. area radius r_{CA}	300 m

B. Simulation Results

In the following, we present and discuss the performance results of CBD in the scenario just described above. First though, we describe the impact that D-FPAV has on the medium load and its consequences on the probability of reception of one-hop broadcast messages over the distance. This information provides valuable insight on the basis of the effect that D-FPAV has on the CBD performance metrics. The most relevant metrics' obtained values are reported in Table II.

Single broadcast, one hop

As mentioned above, all vehicles on the road are configured to send one 'status' message (beacon) every 100 ms announcing their position, speed, and so on. When making use of the D-FPAV strategy, the transmission power of each beacon will be adjusted if needed. On the other hand, whether D-FPAV is used or not, event-driven (emergency) messages will be sent without power restrictions, i.e., always with an intended communication range of 500m.

D-FPAV achieves its goal of adjusting in a fair manner the transmission power (TxPower) assigned to each beacon. With maximum beaconing load (MBL) of 1.5 Mbps, the resulting average channel busy time ratio experienced by the nodes

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[1] A transmission power of -1.1 dB corresponds to a communication range of 500 m assuming two ray ground with the modeled wireless interfaces.

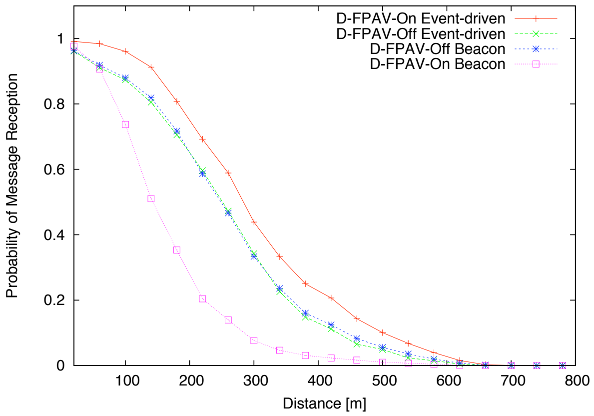

Fig. 3. Probability of successful reception of beacons and one hop event-driven messages (without retransmission) with D-FPAV-On and D-FPAV-Off with respect to the distance to the transmitter.

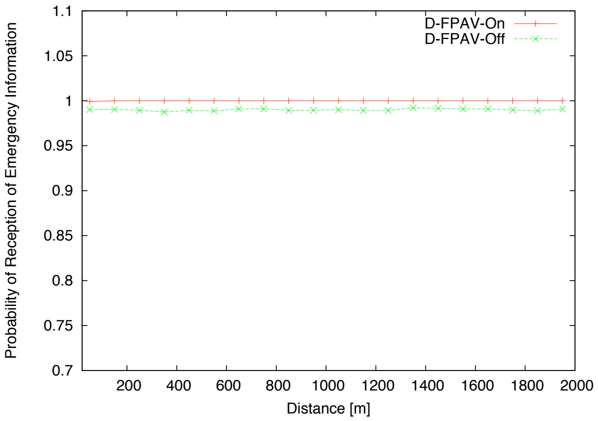

Fig. 4. Probability of information delivery inside the relevant area for dissemination with respect to the distance from the message originator (with multi-hop retransmissions).

in the network falls from a 69.8% to a 51.8%. The average beacons' TxPower is reduced to a 36%, which results in an intended communication range of 300 m (TxPower=-5.6 dBm).

Fig. 3 presents the probability of successful reception with respect to the distance of a single broadcast message, event-driven and periodic, with D-FPAV-On and D-FPAV-Off in our scenario. Note how the one-hop reception rates of event-driven messages are increased at all distances when using D-FPAV. For example, we obtain a 24.1% increase, from 49.3% to 61.2%, at a distance of 250 m, half of the intended communication range. On the other hand, we can also observe the price to pay, i.e., the reception rates for beaconing messages decrease for distances further than 70 m. However, the probability of successful reception of beaconing messages does not decrease for close distances to the sender, i.e., up to a distance of 70 m. The latter behavior was one of our design principles of D-FPAV according to the higher value of beaconing messages at close distances from the sender.

Dissemination over the distance, multi-hop

In this section we analyze the suitability of CBD for disseminating information on the presence of background traffic, and evaluate its performance when utilizing the D-FPAV mechanism.

Fig. 4 presents the probability of successful reception of emergency information over the distance inside the relevant area. In this case, distances further than the communication range, 500 m, are reached with the retransmissions from nodes winning the contention. In both cases, when using D-FPAV or not, high reception rates are achieved, 100% in case of D-FPAV-On and an average of 99.0% with D-FPAV-Off.

From a communication perspective, we can point out that the high reception rates achieved when not utilizing D-FPAV are the result of a an increased number of messages duplicates. Note that each event-driven message (without being retransmitted) has a lower probability of being received with D-FPAV-Off according to the curves in Fig. 3. However, the amount of emergency messages transmitted inside the relevant area is significantly higher with respect to D-FPAV-On. Indeed, the average amount of retransmissions sent to the medium during the dissemination of one emergency message is in average 27 packets in case of D-FPAV-On and 40 packets for D-FPAV-Off. A higher load on the medium experiences a higher amount of collisions and a decreased coordination among nodes, see [19], which results in a less efficient dissemination. The higher amount of message duplicates, however, allows CBD to reach a 99.0% of message reception on a highly saturated wireless medium, i.e., with D-FPAV-Off.

Last, we evaluate the information delivery delay experienced by vehicles located inside the relevant area for dissemination. We can observe in Fig. 5 a lower average delay in the case of combining CBD with D-FPAV. This difference, e.g., around 15 ms at a 1 km distance, is the direct impact of the reduced load and channel busy time described above. Indeed, the difference among both curves is already noticeable at close distances to the sender. At 5 m from the transmitter, the average delay experienced when using D-FPAV is 8.1 ms shorter, what directly reflects the shorter channel access time existing at each hop. More relevant in terms of safety is the maximum delay experienced by the information to be delivered to all vehicles in the relevant area. We report in Table II the maximum time that a node located at 2 km of the originator, i.e., at the other edge of the relevant area, had to wait until receiving the emergency information. In this case, the maximum delay experienced is reduced 91.8 ms in case D-FPAV is used, from 163.8 ms to 72.0 ms. We recall that it is responsibility of application designers, to evaluate the relevance of a 91.8 ms difference in terms of improved safety.

TABLE II
PERFORMANCE PARAMETERS

PARAMETER	with D-FPAV	w/o D-FPAV
Average beacon TxPower	-5.6 dBm	-1.1 dBm
Avg. beacon intended com. range	300 m	500 m
Avg. channel busy time ratio	51.8	69.8
Avg. reception rates in relevant area	100%	99.0%
Maximum dissemination delay at 2 km	72.0 ms	163.8 ms
Avg. number of retransmissions	27 pckts	40 pckts

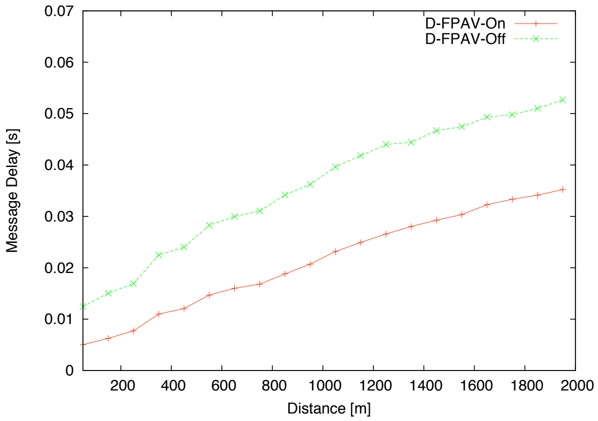

Fig. 5. Reception delay of the emergency information inside the relevant area for dissemination with respect to the distance from the message originator.

V. SUMMARY AND OUTLOOK

In this paper we adjusted a promising position based routing strategy in order to disseminate emergency information in vehicular environments. The main characteristics of the resulting scheme, called CBD, are: *i)* a forwarding mechanism based on a contention approach, and *ii)* a contention area delimited according to the safety application's reliability requirements. Indeed, the contention area, where potential forwarders are located, has to be selected taking into account the message's progress in the direction of dissemination and the probability of successful reception of the message at that distance.

We evaluated the performance of CBD in a vehicular environment with safety background traffic as well as the effect of the beacons' transmission power adjustment strategy D-FPAV. We demonstrated that in our chosen scenario, with realistic highway movement patterns and probabilistic propagation phenomena, CBD is a suitable 'time-critical' information dissemination strategy. CBD presented high reception rates, close to 100%, inside the intended dissemination area under saturated wireless channel conditions resulting from safety beaconing. Furthermore, we have shown how the use of D-FPAV for a fair congestion control additionally improved CBD's performance in terms of dissemination delay and amount of message retransmissions.

Still, many questions remain open before such a strategy can be deployed in a real environment. In the future, we plan to analyze the existing trade-off when adjusting the radius of the contention area in terms of reliability, propagation delay and overhead in order to find the optimal point of operation.

Additionally, we plan to extend the CBD protocol in order to address different situations, such as non-straight road topologies, dissemination in multiple-directions (e.g., intersections), and multiple sources cases (i.e., when more than one vehicle detects the hazard and creates an own event-driven message).

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REFERENCES

[1] "Europe's Information Society - eSafety website," http://europa.eu.int/information_society/activities/esafety.

[2] "IEEE P802.11p/D0.21, Draft Amendment for Wireless Access in Vehicular Environments (WAVE)," January 2006.

[3] M. Torrent-Moreno, P. Santi, and H. Hartenstein, "Distributed Fair Transmit Power Assignment for Vehicular Ad Hoc Networks," in *Proc. of the IEEE Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON), Reston, VA, USA*, September 2006.

[4] M. Torrent-Moreno, F. Schmidt-Eisenlohr, H. Füßler, and H. Hartenstein, "Effects of a Realistic Channel Model on Packet Forwarding in Vehicular Ad Hoc Networks," in *Proc. of the IEEE Wireless Communication and Networking Conference (WCNC), Las Vegas, NV, USA*, April 2006.

[5] "Network Simulator ns-2," http://www.isi.edu/nsnam/ns/.

[6] M. Nakagami, "The m-distribution, a General Formula of Intensity Distribution of the Rapid Fading," Statistical Methods in Radio Wave Propagation, W.C. Hoffman, Ed. Oxford, England: Pergamon, 1960.

[7] M. Sun, W. Feng, T. Lai, K. Yamada, and H. Okada, "GPS-Based Message Broadcasting for Inter-vehicle Communication," in *Proc. of International Conference on Parallel Processing (ICPP), Toronto, Canada*, August 2000.

[8] H. Wu, R. Fujimoto, R. Guensler, and M. Hunter, "MDDV: a Mobility-Centric Data Dissemination Algorithm for Vehicular Networks," in *Proc. of the ACM International Workshop on Vehicular Ad Hoc Networks (VANET), Philadelphia, PA, USA*, October 2004.

[9] T. Little and A. Agarwal, "An Information Propagation Scheme for VANETs," in *Proc. of the International IEEE Intelligent Transportation Systems Conference (ITSC), Vienna, Austria*, September 2005.

[10] L. Wischhof, A. Ebner, and H. Rohling, "Information Dissemination in Self-Organizing Intervehicle Networks," *IEEE Transactions on Intelligent Transportation Systems*, March 2005.

[11] T. Nadeem, P. Shankar, and L. Iftode, "A Comparative Study of Data Dissemination Models for VANETs," in *Proc. of the International Conference on Mobile and Ubiquitous Systems (MOBIQUITOUS), San Jose, CA, USA*, July 2006.

[12] M. Caliskan, D. Graupner, and M. Mauve, "Decentralized Discovery of Free Parking Places," in *Proc. of the ACM International Workshop on Vehicular Ad Hoc Networks (VANET), Los Angeles, CA, USA*, September 2006.

[13] K. Tokuda, M. Akiyama, and H. Fuji, "DOLPHIN for Inter-Vehicle Communications System," in *Proc. of the IEEE Intelligent Vehicles Symposium (IVS), Dearborn, MI, USA*, October 2000.

[14] M. Durresi, A. Durresi, and L. Barolli, "Emergency Broadcast Protocol for Inter-Vehicle Communications," in *Proc. of the International Conference on Parallel and Distributed Systems (ICPADS), Fukuoka, Japan*, July 2005.

[15] L. Briesemeister, L. Schers, and G. Hommel, "Disseminating Messages among Highly Mobile Hosts based on Inter-Vehicle Communication," in *Proc. of the IEEE Intelligent Vehicles Symposium (IVS), Dearborn, MI, USA*, October 2000.

[16] D. Sormani, G. Turconi, P. Costa, D. Frey, M. Migliavacca, and L. Mottola, "Towards Lightweight Information Dissemination in Inter-Vehicular Networks," in *Proc. of the ACM International Workshop on Vehicular Ad Hoc Networks (VANET), Los Angeles, CA, USA*, Sep. 2006.

[17] V. Taliwal, D. Jiang, H. Mangold, C. Chen, and R. Sengupta, "Empirical Determination of Channel Characteristics for DSRC Vehicle-to-vehicle Communication," in *Proc. of the ACM International Workshop on Vehicular Ad Hoc Networks (VANET), Philadelphia, PA, USA*, October 2004.

[18] F. Schmidt-Eisenlohr, M. Torrent-Moreno, J. Mittag, and H. Hartenstein, "Simulation Platform for Inter-Vehicle Communications and Analysis of Periodic Information Exchange," in *Proc. of the Conference on Wireless On demand Network Systems and Services (WONS), Obergurgl, Austria*, January 2007.

[19] M. Torrent-Moreno, S. Corroy, F. Schmidt-Eisenlohr, and H. Hartenstein, "IEEE 802.11-Based One-Hop Broadcast Communications: Understanding Transmission Success and Failure under Different Radio Propagation Environments," in *Proc. of the ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM), Torremolinos, Spain*, October 2006.