Towards realistic vehicular network simulation models

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***Abstract*—Recently, testbed deployments using real IEEE 802.11p devices have allowed making performance measurements using this technology. The results obtained in those experiments evidence that lots of factors influence wireless communications: small obstacles like trees, small moving obstacles like cars, or large obstructions like buildings. All of them affect the transmission range, reducing the communication possibilities. Based on the insight provided by these results, in this work we propose a propagation model that attempts to replicate all these effects in simulation in order to increase the accuracy of experiments. Our solution combines (i) an attenuation model that replicates transmission range and fading behavior of real 802.11p devices, both in line-of-sight conditions and when obstructed by small obstacles, and (ii) a visibility model to deal with large architectonic obstacles, such as buildings. Our model was evaluated using the OMNeT++ platform, and results show that having the exact building positions and shapes is a critical parameter, introducing performance differences of up to 50% compared to simpler models.**

***Index Terms*—802.11p; Signal propagation; Obstacle models**

I. Introduction

Simulation tools are widely used in research to verify an idea when real testbeds are not possible to deploy, or when not enough resources are available. Despite the important benefits that simulation tools offer, there are also several drawbacks associated with the wrong use of such tools. Martinez et al. [1] have acknowledged a high number of simulation parameters in vehicular networks, showing how different simulation configurations modify the final result.

Currently, the IEEE 802.11p [2] standard for vehicular networks is being implemented by several hardware development companies [3]. This enables the research community to perform real experiments using this technology [4] [5]. By comparing simulation results with real results we are able to validate simulation tools, and to determine the configuration of simulation parameters that best matches real-life experiments.

In this paper we focus on enhancing the physical layer model of the OMNeT++ simulator [6] in order to achieve simulation results that resemble real-life behavior as much as possible. For this endeavor we will combine two independent models - visibility and attenuation - which allow addressing the specifities of urban scenarios in the most adequate manner. In particular, visibility data will rely on information about real-life buildings, as made available by the OpenStreetMap project [7], and attenuation estimations are based on real testbed results under both line-of-sight and typical urban conditions, where vehicles themselves are also accounted as signal interference sources.

II. Determining attenuation and visibility

Overall, we consider that all the classic propagation models avaliable for simulating vehicular networks ([8][9]) suffer from strong limitations when focusing on 5.9 GHz signal propagation in urban environments. Basically, all of them assume that the visibility conditions remain mostly unchanged for a fixed distance. However, in urban environments, buildings and other architectonic constructions reduce the signal propagation drastically. So, the development of a hybrid model is needed. Such model must be able to distinguish between visibility situations, where usual radio propagation is available, and non-visibility situations, where obstacles prevent signals from being received. Hence, our proposal combines an attenuation with a visibility model to increase the degree of realism. Both models are described below.

A. Attenuation model

In this work we propose combining the *Modified Free Space* model [9] and the *Nakagami* model[8], tuning their parameters to replicate the signal fading behavior measured in real deployments according to [10]. We tuned the transmission power and antenna gain according to the real experiments made and adjusted the remaining parameters.

In our proposal, the attenuation model will be adjusted to consider two different environments: the first one will be based on experimental results that consider the existence of typical urban obstacles, such as vehicles, trees, etc. [10]; this model is called *vehicle obstructions*. The second one will replicate the results of line-of-sight experiments available in [11]; this model is called *line of sight*. These adjustments are made in terms of the α parameter for the *Modified Free Space* model, and the m parameter for the Nakagami model, allowing to adjust the shape of the packet arrival pattern so as to resemble the experimental data.

B. Visibility model

In order to get a high level of realism, vehicles must move following real road topologies. However, we consider that

Table I
SUMMARY OF THE MAIN PARAMETERS CONFIGURATION.

Parameter	*Value*
Standard	802.11p
Transmission rate (Mbps)	6
Transmission power (dBm)	18
Antenna gain (dB)	5
Packet size (Byte)	36

information about existing buildings is also critical in order to account for their impact on signal propagation. In the literature, we can find few proposals of realistic obstacle modeling, being the most relevant ones proposed by Martinez et al. [12] (2009) and Sommer et al. [13] (2011). These models define the conditions for a transmission to be successful in terms of signal blocking, meaning that communication between two nodes is blocked whenever there is a large obstacle between them. However, while the former assumes synthetic buildings occupying all the terrain near a road, the latter is able to extract realistic building information from OpenStreetMap, and inject it in simulations to create a more realistic simulation environment.

In the following section we evaluate the performance differences when vehicular networks are defined without obstacles, using the building definition available in the OpenStreetMap database, and modeling all the areas near roads as buildings (synthetic buildings).

III. MODEL TUNING AND PERFORMANCE ASSESSMENT

The goal of this section is twofold: first we will adjust the signal propagation model used according to real-life experiments; then, using such model, we will assess the impact of buildings as obstacles to communications. These studies were performed using the OMNeT++ simulation platform [6], along with the INETMANET and Veins extensions; the Sumo tool [14] is also used in order to simulate realistic vehicular movements.

A. Channel model tuning

Our goal is to accurately represent real-life transmission conditions in 802.11p vehicular environments. In particular, we want to replicate experimental results by Meireles et al. [10] for the vehicle obstructed model, where channel conditions are measured in the presence of real traffic. This means that vehicles themselves will also affect the signal propagation conditions, being representative of typical urban scenarios, while not accounting for the presence of buildings, which in our model are handled separately.

In a first step we tune our model by adjusting the α parameter of *Modified Free Space* in order to replicate results from real experiments in simulation. A summary of the values used in the testbed experiments is shown in table I; these values are used to tune the simulator as well, and fairly replicate the experiments.

To determine the optimum value of the α parameter in the *Modified Free Space* propagation model, a set of tests where performed varying the value of this parameter, and comparing the radio coverage achieved against real results by focusing on the impact that distance has on the packet arrival ratio. Figure 1 shows the obtained results.

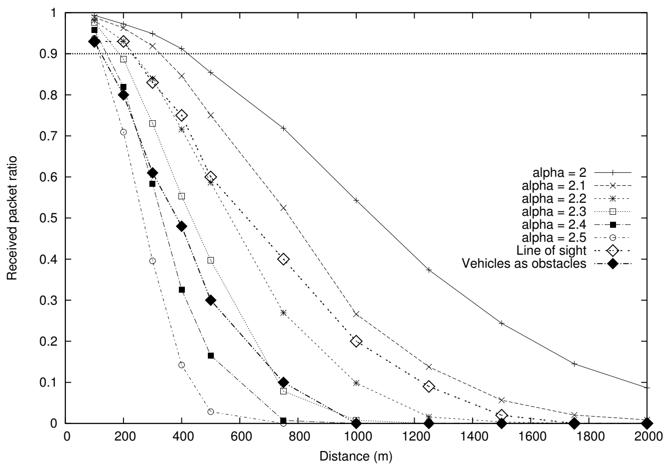

Figure 1. Effects of varying α in the proposed attenuation model

Notice that, in the figure, we have two different references value sets, tagged as “Line of sight” and “Vehicles as obstacles”. Focusing on the first set of results, which is based on the experimental values presented in [11] (line-of-sight case), we can see that an alpha value of 2.2 already offers a good degree of accuracy. For the second set of results, based on the experimental values presented in [10] (vehicles as obstacles case), we can see that an alpha value of 2.4 is the most adequate one in terms of radio coverage.

We find that a value of $m = 1$ is adequate to minimize the error.

B. Assessing the performance impact of static and mobile obstacles

After adjusting the propagation model parameters as seen in previous section, and considering either line-of-sight or vehicle obstructions for the signal propagation, we now present a new set of experiments to evaluate two main features: (i) the impact of mobile obstacles (vehicles), and (ii) the impact of static obstacles (buildings) on message delivery. To evaluate these features we used OMNeT++ combined with Sumo. We used Sumo tools to generate routes following map streets for 500 cars on a $12km^2$ area in a suburban area of Moscow.

In terms of traffic generation, all cars broadcast packets at regular intervals of 10s, and we consider two cases: (i) broadcasts are limited to one hop; and (ii) broadcasts are rebroadcasted by other vehicles (flooding).

Figure 2 shows the effectiveness of the broadcast/rebroadcast process for both signal attenuation models, and with different obstacle models. Focusing on the differences between signal attenuation models, we can see that the *Line of sight* model, as expected, is able to reach a higher number of nodes than the *Vehicle obstruction* model. In general, assuming line-of-sight communications in dense

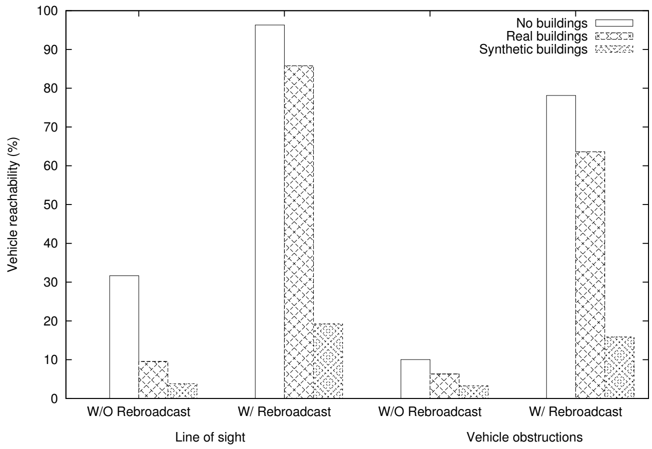

Figure 2. Vehicle reachability ratio under different conditions.

urban areas is naive because it is very difficult not to find any obstacle, such as cars or trees, when communication between two vehicular nodes takes place. This assumption would be associated with an error of up to 23% in the worst case, meaning that small mobile obstacles should be accounted for due to their impact on communications.

Focusing on the signal obstructing effects of buildings, two important issues are detected: (i) not including buildings in simulations could have a dramatic impact on results (especially in dense urban areas), showing an excessively good behavior; (ii) including synthetic buildings in areas where buildings are sparse is excessively restrictive, producing results that are much worse what they should be. In general, the degree of error produced by synthetic buildings depends on the actual building density in each area.

IV. Conclusions

In this paper we proposed a signal propagation model that is able to accurately replicate results obtained in real vehicular network environments. The model discriminates between static and dynamic obstacles through two different elements: the first one accounting for the signal attenuation behavior under line-of-sight conditions, or in the presence of small obstacles (mostly moving vehicles), and the second one accounting for signal blockage by considering the presence of buildings with different degrees of realism.

In our experiments we quantified the difference between the different propagation model combinations in terms of broadcasting effectiveness. Results have highlighted that the main factor affecting message dissemination performance is the degree of accuracy when representing buildings (up to 66%), showing that synthetic buildings can be too restrictive, while not considering buildings at all produces results that are too optimistic. Additionally, small mobile obstructions like other moving vehicles are also relevant in terms of signal propagation, also having a very significant impact on the final results (up to 23%). Overall, the results presented in this paper show that accurate vehicular simulations require a detailed physical layer model that accounts for both the presence of buildings and other vehicles on signal propagation in order to avoid too optimistic (no obstacles) or too pessimistic (synthetic buildings) results. As future work we plan for a better integration of the INET-Veins tandem with Sumo in order to optimize the obstacle retrieval process, avoiding processing building and network layouts as independent elements.

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References

[1] F. Martinez, C. Toh, J. Cano, C. Calafate, and P. Manzoni, "Determining the representative factors affecting warning message dissemination in vanets," *Wireless Personal Communications*, pp. 1–20, 2011.

[2] *802.11p-2010 IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments*, Std.

[3] http://www.savarinetworks.com/. Mobiwave - on-board equipment.

[4] http://www2.rohde schwarz.com/, "Wlan 802.11p - measurements for vehicle to vehicle (v2v) dsrc application note."

[5] A. Paier, D. Faetani, and C. Mecklenbrauker, "Performance evaluation of ieee 802.11 p physical layer infrastructure-to-vehicle real-world measurements," in *Applied Sciences in Biomedical and Communication Technologies (ISABEL), 2010 3rd International Symposium on*. IEEE, 2010, pp. 1–5.

[6] A. Varga *et al.*, "The omnet++ discrete event simulation system," in *Proceedings of the European Simulation Multiconference (ESM'2001)*, vol. 9, 2001.

[7] http://www.openstreetmap.org/. Openstreetmap.

[8] U. Charash, "Reception through nakagami fading multipath channels with random delays," *Communications, IEEE Transactions on*, vol. 27, no. 4, pp. 657–670, 1979.

[9] A. Kuntz, F. Schmidt-Eisenlohr, O. Graute, H. Hartenstein, and M. Zitterbart, "Introducing probabilistic radio propagation models in omnet++ mobility framework and cross validation check with ns-2," in *Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops*. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2008, p. 72.

[10] R. Meireles, M. Boban, P. Steenkiste, O. Tonguz, and J. Barros, "Experimental study on the impact of obstructions in vehicular ad hoc networks."

[11] D. Eckhoff, C. Sommer, and F. Dressler, "On the Necessity of Accurate IEEE 802.11p Models for IVC Protocol Simulation," in *75th IEEE Vehicular Technology Conference (VTC2012-Spring)*. Yokohama, Japan: IEEE, May 2012.

[12] F. Martinez, C. Toh, J. Cano, C. Calafate, and P. Manzoni, "Realistic radio propagation models (rpms) for vanet simulations," in *Wireless Communications and Networking Conference, 2009. WCNC 2009. IEEE*. Ieee, 2009, pp. 1–6.

[13] C. Sommer, D. Eckhoff, R. German, and F. Dressler, "A computationally inexpensive empirical model of ieee 802.11 p radio shadowing in urban environments," in *Wireless On-Demand Network Systems and Services (WONS), 2011 Eighth International Conference on*. IEEE, 2011, pp. 84–90.

[14] D. Krajzewicz, G. Hertkorn, C. Rössel, and P. Wagner, "Sumo (simulation of urban mobility)," in *Proc. of the 4th Middle East Symposium on Simulation and Modelling*, 2002, pp. 183–187.