On the applicability of ray-tracing propagation models to V2V-intersection environments

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***Abstract*—In this work, we analyze the applicability of a geometric-based stochastic (GBS) model based on ray-tracing techniques to vehicular-to-vehicular (V2V) intersections. The accuracy and usefulness of the proposed model is analyzed using simulated results and narrowband channel measurements at 5.9 GHz. The results show that these type of models can be a good choice to evaluate communications protocols and system performance of future vehicular networks.**

I. Introduction

Due to the introduction of the intelligent transportation system (ITS) concept, vehicular communications are receiving considerable attention to enable smart and intelligent driving technologies based on wireless systems. The special features of both safety and non-safety applications require the development and implementation of new communications technologies, where one of the main challenges to be addressed is the characterization and modeling of the vehicular propagation channel [1], [2].

Geometric-based stochastic (GBS) models based on ray-tracing techniques, also known as map-based models, are recognized in the literature by their accuracy [3], but they have the disadvantage of being numerically intensive and therefore difficult to apply for system-level simulations [4]. However, the introduction of ray-tracing techniques plays a greater role to fulfill the numerous data needed to parameterize the GBS models, whose achievement based only on experimental measurements is very costly in both time and expenses. In the context of vehicular networks, where the propagation channel exhibits great time variability with severe small-scale fading, GBS models permit us to take into account the environment-specific information and the motion effect of scatterers surrounding the transmitter (Tx) and receiver (Rx) vehicle terminals, improving the overall realism and suitability of simulated channels [4].

In this conference contribution, we present a comparison between measurements and simulations at two different street intersections in the city of Valencia, Spain. Street intersections are typical scenarios have special characteristics to evaluate the feasibility of vehicular communications, e.g. the propagation link passes from Line-Of-Sight (LOS) to Non-LOS (NLOS) conditions making the main parameters of the channel change very quickly. The main objective of the present contribution is to analyze the applicability of GBS models based on ray-tracing techniques in these particular environments, quantifying their accuracy and usefulness, as well as to assess the impact of the road traffic and parked vehicles.

II. V2V Measurement Campaign

The measurements used in this work are part of a more extensive V2V measurement campaigns carried out in the city of Valencia, Spain. Fig. 1 shows a simplified representation of the urban area under study. Narrowband channel measurements were performed in two street intersections with specific and complex characteristics. The first one, denoted as north-south (N-S) path representing the direction followed by the Rx vehicle, is an asymmetric crossing, where corner 1 is clearly sharp (see Fig. 1), while corner 2 is formed by three successive edges, producing a smoother transition between LOS and NLOS positions. The other one, south-north (S-N) path, also shows a marked asymmetry (corners 3 and 4) increased by the difference between parked vehicles on both sides of the street. The different positions of the Tx vehicle (stopped) are also shown in Fig. 1 in red dots. The measurements were collected at 5.9 GHz, in the digital short-range communications (DSRC) band assigned to ITS applications. Details about the channel sounder used in the measurements, omitted here due to space restrictions to 2 pages, can be found in [2].

III. Ray-tracing Approach

The propagation model used to perform the simulations is a GBS model based on ray-tracing approach. This model is an adaptation of the model implemented in CINDOOR, an indoor and outdoor coverage prediction tool based on 3D ray-tracing using geometrical optics (GO) and uniform theory of diffraction (UTD) approximation techniques, developed by some of the authors [5], [6].

In the simplified representation or the urban area shown in Fig. 1, the contour of buildings is represented by flat faces obtained with software developed in house from the information provided by Google Earth. The electromagnetic

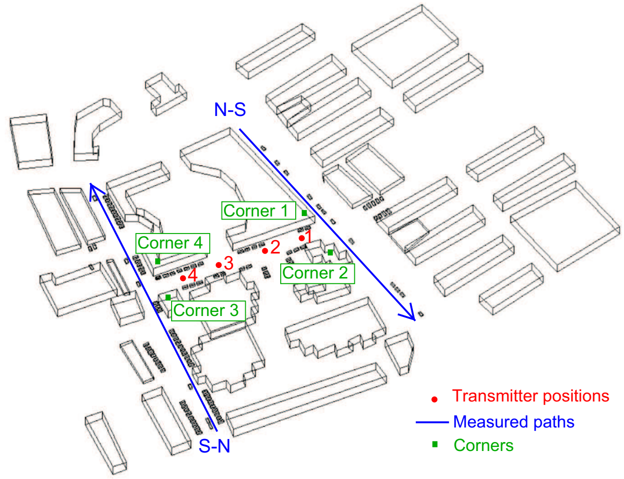

Fig. 1. Layout of the urban environment used in the simulations. The measured paths are depicted by blue, the four Tx positions are depicted by red dots and the corners involved in the simulations are numbered by green.

characteristics of building walls considered in the simulations are: a relative permittivity equal to 15, a conductivity of 5 S/m, and a surface roughness equal to 2 mm.

IV. Results

From the simulation results, we have observed that the road traffic density and parked vehicles strongly influence the propagation conditions due to their heights are similar to those of the Tx and Rx, with the antennas mounted in the roof of the vehicles. The vehicles have been modeled by rectangular boxes, whose dimensions vary randomly over predetermined realistic values. Although the vehicles were considered perfect conductors, finite losses were also introduced allowing some signal transmission to take into account the crystal effect. Also, the number and distribution of parked vehicles were randomly considered in the simulations.

A total of 4 Tx positions were considered in the simulations. For each Tx position, five simulations of the power level were performed along the both paths. Notice that the Tx location ranges from a position close to the street-crossing to other more distant ones. The mean error between measured and simulated power levels along the N-S path ranges from -2.7 to -1.3 dB, and its standard deviation ranges from 6.4 to 8.9 dB; whereas the mean error on S-N path ranges from 1.1 to 4.7 dB, with a standard deviation ranging from 7.4 to 9.3 dB. These values show a good agreement between simulated and measured data, taking into account that information on road traffic density and other interacting objects (e.g., parked vehicles) at the moment when the measurements were carried out is not available.

Minimum and maximum values of the simulated power levels when the Tx is located in position 2 and for the Rx moving on N-S path are depicted in Fig. 2. Measured data have also been depicted for comparison. It can be observed that in the majority of Rx positions along the path, the measurements are inside the margin defined by the minimum and maximum

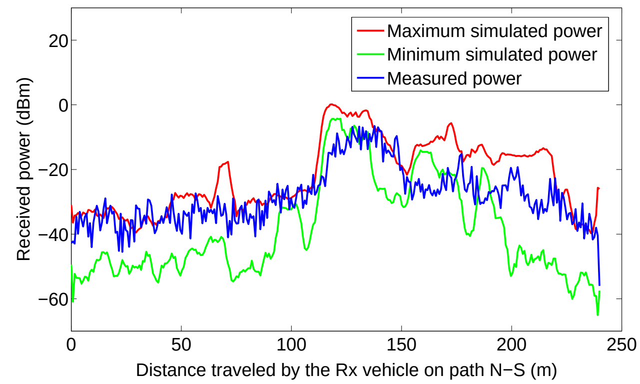

Fig. 2. Simulared and measured power levels when the Rx is moving on N-S path and the Tx is located in position 2.

simulated values. It is worth noting that a similar trend is observed in the other Tx positions on both paths. Note that this margin represents the local mean power variability that could be expected according to traffic conditions. In this sense, this margin can be useful in the evaluation of communications protocols in order to achieve the required system performance, specially in safety-critical applications.

V. Conclusion

In this conference contribution, we have analyzed the applicability of a GBS model based on ray-tracing techniques to V2V-intersection environments. The accuracy and usefulness of the proposed model have been analyzed using simulation results and narrowband channel measurements at 5.9 GHz. Simulation results have taken into account the impact of the road traffic and parked vehicle density in statistical sense. The good agreement between simulated and measured results shows that this propagation model can be used to describe the dynamic link transitions and small-scale variations, as well as the space-time structure of vehicular channels in order to investigate the introduction of multiple-input multiple-output (MIMO) and beamforming techniques.

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