Characterization of radio propagation channel in Urban Vehicle to Infrastructure environments to support WSNs

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Abstract: Vehicular ad hoc Networks (VANETs) enable vehicles to communicate with each other as well with roadside units (RSUs). Although there is a significant research effort in radio channel modelling focused in vehicle to vehicle (V2V), not much work has been done for vehicle to infrastructure (V2I) using 3D ray-tracing tools. This work evaluates some important characteristics of a V2I wireless channel link such as Received Power, Power Delay Profile, Delay Spread and Coherence Bandwidth, in an urban scenario using a deterministic simulation model based on an in-house 3D Ray-Launching algorithm.

Analysis using Wireless Sensor Networks (WSNs) at 868MHz, 2.4 and 5.9 GHz are presented. Results shown the highly impact of the distance, link frequency, location of RSUs and obstacles in the LoS (Line of Sight) have in V2I channel propagation. These results constitute the start point in the deployment of radio-planning in V2I environments.

Keywords: Wireless Sensor Networks (WSN), 3D Ray Launching, Vehicular Ad-Hoc Networks (VANET), Vehicle-to-Infrastructure communication (V2I)

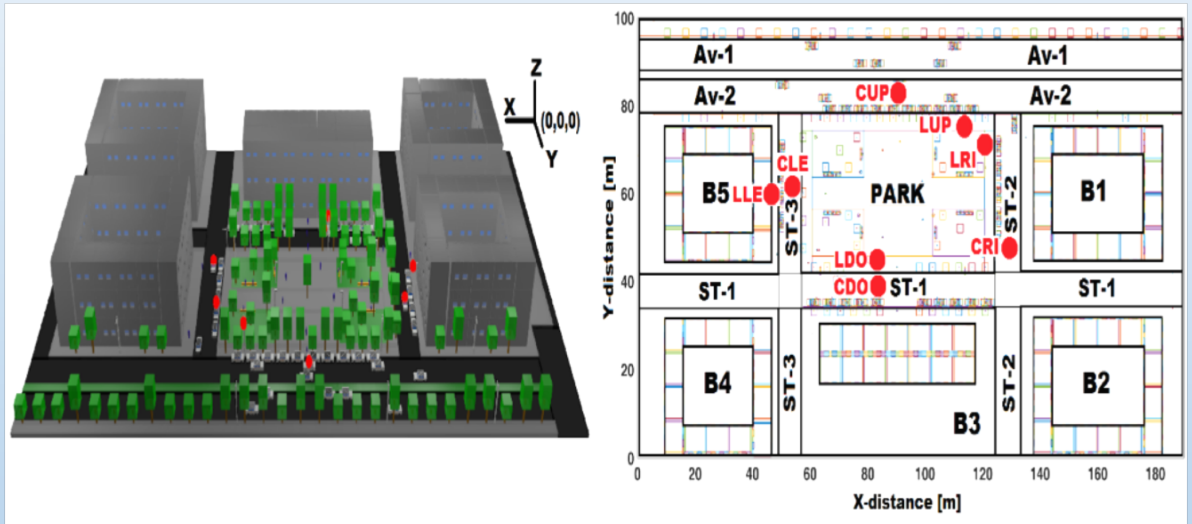
1. Introduction

- The area of Intelligent Transportation System (ITS) includes three major approaches to communication: Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I) and Vehicle to Pedestrian (V2P). The V2I Communications is the bi-directional wireless exchange of information between vehicles and Road Side Units (RSUs).

- There are few scientific work for V2I propagation analysis, even less using deterministic tools for urban environments. In this work, a deterministic method has been used, specifically an in-house 3D Ray Launching (RL) algorithm, based on Geometrical Optics (GO) and Geometrical Theory of Diffraction (GTD).

- The paper are arranged as follow: characterization and scenery simulation (section2). Results of the analysis: Received Power (RP), Power delay Profile (PDP), Root-Mean-Square Delay Spread (RMS delay spread) and Coherence Bandwidth (CB) (Section 3). Conclusions and future work (Section 4)

2. Simulation Urban Scenario



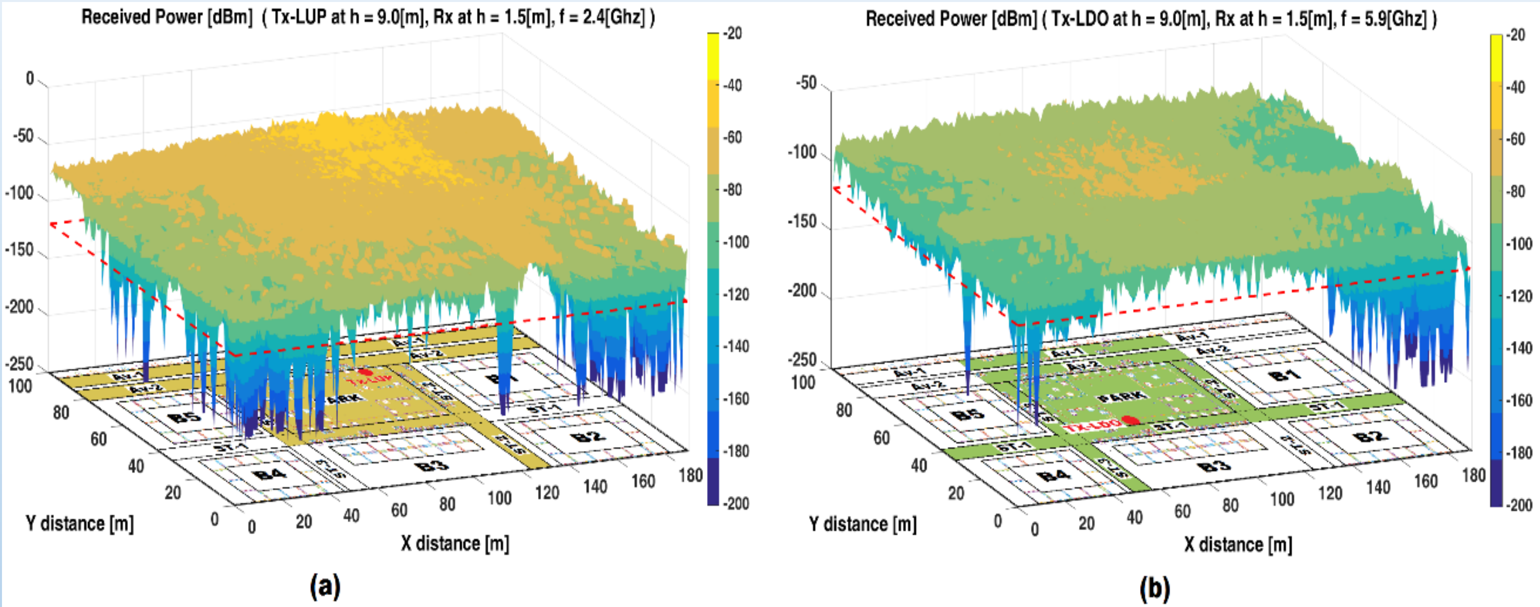
(a) (b)

Table 1. Identification of different points of interest.

Description	Abbreviation	Coordinates (x, y, z) [m]
Main Avenues: L1 / L2	Av-1 / Av-2	(x, 93, 0) / (x, 82, 0)
Streets: S1 / S2 / S3	ST-1 / ST-2 / ST-3	(x, 39, 0)/ (54, y, 0)/ (130, y,0)
Lamppost antennas: Up/ Right / Down/ Left	LUP / LRI / LDO / LLE	(114, 78, 9) / (126, 73, 9) / (83, 43, 9) / (49, 62, 9)
Car antennas: Up/ Right / Down/ Left	CUP / CRI / CDO / CLE	(91, 82, 1.5) / (130, 50, 1.5) / (84, 38, 1.5) / (54, 62, 1.5)
Builds	B1, B2, B3, B4, B5	Not applicable.

The area encompasses 380.000m^3 (190m x 100m x 20m) of scenario. The analysis was carried out for frequencies at: 868MHz, 2.4GHz and 5.9GHz. The height of the transmitter (Tx) and receiver (Rx) antennas was defined at 1.5m for cars and 9m for lampposts. The transmitted power was considered at 0dBm and the power reference level (sensitivity) was considered at -120dBm.

3. Received Power



- Surf plot of RP at Z-plane of 1.5m when: (a) the frequency of the transmitter, situated at Tx-LUP is 2.4GHz and (b) the frequency of the transmitter, situated at LDO (Tx-LDO) is 5.9GHz.
- 2D map where zone1(colored) is above to -120 dBm, and zone2(uncolored) is below to -120 dBm.
- Buildings impacts dramatically the RP. Power loss is higher at 5.9 GHz. It is required at least 2 RSU for optimal wireless coverage.

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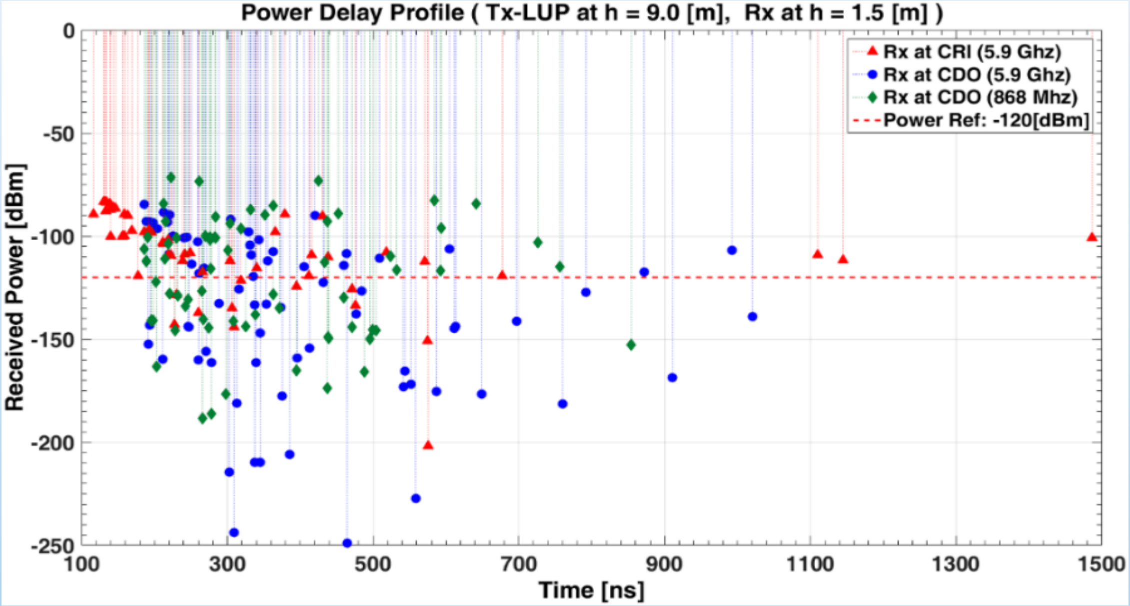
3. Time dispersive parameters

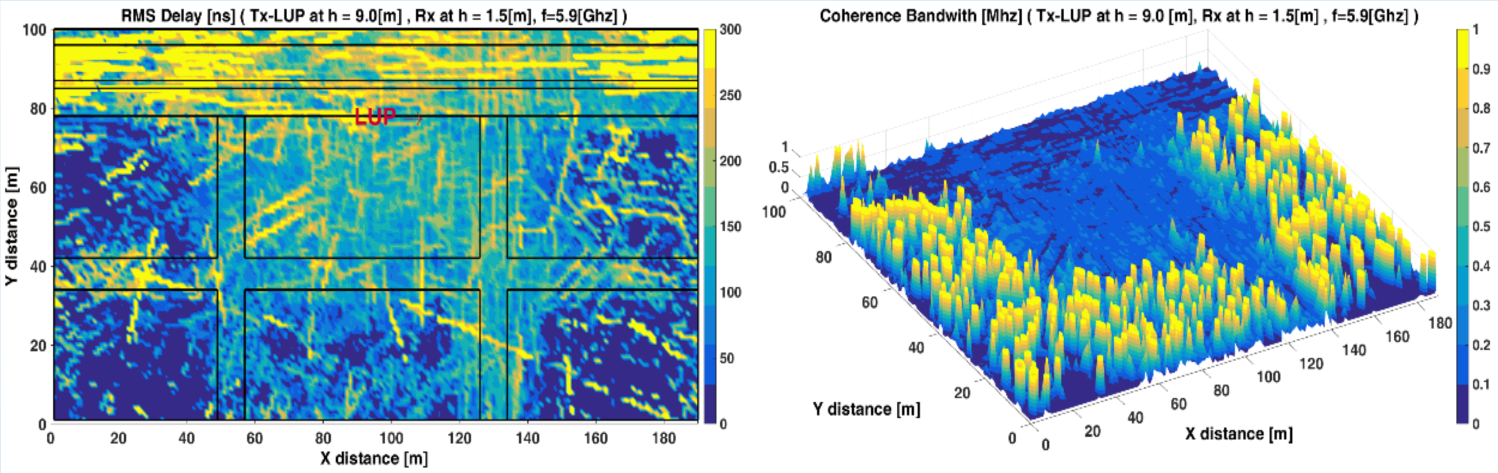
3.1 Power Delay Profile



- PDP for Tx-LUP and Rx- CRI at 5.9GHz and Rx-CDO at 868MHz and 5.9GHz.
- The time dispersive effects are more notorious for 5.9GHz
- Conversely, the average of RP is less for 5.9GHz versus 868MHz for CDO.
- The density of the received rays is higher in the vicinity of the Tx-LUP due to the multipath propagation

3. Time dispersive parameters

3.1 RMS delay spread and CB



(a) (b)

- Figure (a) and (c) show RMS delay spread and CB respectively at Tx-LUP and Rx at vehicles level(1.5m).
- RMS delay spread exhibit its highest values at zone1 and CB at Zone2. Areas closer to the antenna Tx have the higher RMS delay spread.
- Highest values of CB correspond to areas with channel availability, however, the RPs values below the sensitivity level, means the wireless communication will be unable.

4. Conclusions and future work.

4.1. A 3D in-house ray-launching tool has been used, which enables an accurate evaluation of RP, PDP, RMS delay spread and CB in the context of V2I environments, using WSNs at frequencies of 868Mhz, 2.4GHz and 5.9GHz.

4.2 Factors such as distance from Tx, link frequency, location of RSUs and, obstacles in the LoS will have profound impact in the V2I channel propagation. It is observed lower RP and higher dispersion signal levels at 5.9GHz.

4.3 The higher the obstacles in the LoS, the higher the power loss: the buildings yield the more significant power loss, however, they induce the well-known phenomenon of waveguide effect along the streets, which should be taking into account in the deployment of RSUs at intersections.

4.4 At least 2 RSUs located at specific street intersections are needed to provide optimal V2I wireless communication in terms of coverage.

4.5 As a future work, a measurement campaign should be considered for the urban scenery in order to contrast the 3D RL simulation results, with test-field measurements. The identification and characterization of significant areas could lead us to the proposal of an empirical or statistical propagation model. Geographical area (zone2) with high CB and low RP levels where the V2I communication is unable, could be of special interest in research fields as cognitive radio, V2P, etc.

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Conflicts of Interest: The authors declare no conflict of interest. The statements made herein are solely the responsibility of the authors.

4. References

1. Kochanek, K. D.; Xu, J.; Murphy, S. L.; Minino, A. M.; Kung, H.-C. National Vital Statistics Reports Deaths: Final Data for 2009. *Natl. Cent. Health Stat.* **2012**, Volume *60*, pp. 1–117.
2. Fukushima, M. The latest trend of v2x driver assistance systems in Japan. *Comput. Netw.* **2011**, Volume *55*, pp. 3134–3141.
3. Instituto Nacional de Estadística y Geografía. Accidentes de tránsito terrestre en zonas urbanas y suburbanas. http://www.inegi.org.mx (accessed Nov 5, 2016).
4. IEEE 802.11p-2010 Amendment to IEEE Std 802.11-2007: Wireless Access in Vehicular Environments (WAVE) 2010.
5. Viriyasitavat, W.; Boban, M.; Tsai, H. M.; Vasilakos, A. Vehicular communications: Survey and challenges of channel and propagation models. *IEEE Veh. Technol. Mag.* **2015**, Volume *10*, pp. 55–66.
6. ITU-R. ITU-R P.1411-8 Recommendation: Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300MHz to 100GHz.; Pseries: Radiowave propagation; International Telecommunication Union: Geneva, 2015; p. 49.
7. Matolak, D. W. Modeling the vehicle-to-vehicle propagation channel: A review. *Radio Sci.* **2014**, Volume *49*, pp. 721–736.
8. Azpilicueta, L.; Rawat, M.; Rawat, K.; Ghannouchi, F.; Falcone, F. Convergence analysis in deterministic 3D ray launching radio channel estimation in complex environments. *Appl. Comput. Electromagn. Soc. J.* **2014**, Volume *29*, pp. 256–271.
9. Azpilicueta, L.; Vargas-Rosales, C.; Falcone, F. Deterministic Propagation Prediction in Transportation Systems. *IEEE Veh. Technol. Mag.* **2016**, Volume 11, pp. 29–37.
10. Hassan, K.; Rahman, T. A. The Mathematical Relationship Between Maximum Access Delay and the R.M.S Delay Spread. In the seventh international conference on wireless and mobile communications; 2011; pp. 18–23.
11. Rappaport, T. *Wireless communications: Principles and Practice.*; Pearson, Ed.; Communications Engineering and Emerging Technologies Series.; 2nd ed.; Prentice Hall PTR: United States, 2002.