Simulations for Stochastic Geometry on the Performance of V2X Communications in Rural Macrocell Environment

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Introduction

- This paper aims to evaluate the performance of v2x communications in a suburban highway environment.

- What is v2x?
  - Stands for vehicle to everything communications. It involves communication between vehicle to vehicle, vehicle, vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), and vehicle to network (V2N).

- V2X communications are at the most critical moment in its history
  - the federal government’s movement that favors the Wi-Fi as an effort to meet the burgeoning bandwidth demand. This affects v2x because it shares a spectrum with Wi-Fi.
    - The spectrum bandwidth for V2X has been reduced from 75 MHz (5.850-5.925 GHz) to 30 MHz (5.895- 5.925 GHz) while granting the remainder of the 5.9 GHz to Wi-Fi.
A V2X communications system has been found to be interference-constrained mainly due to a large communications range for each vehicle. Through further analysis we discovered that a suburban geometry yielded a higher level of interference because of the openness in signal exchange among vehicles.

The framework of this research paper aims to serve as a conceptual basis for further study based on the stochastic geometry, which will more precisely assess the performance of V2X communications in safety-critical use cases.
System Model

- To capture the unique characteristics of a suburban geometry, this paper adopts a Rural Macrocell (RMa) environment that is defined in the channel model by the 3rd Generation Partnership Project (3GPP) [3].
  - Path loss
    - The key characteristics of this scenario are continuous wide area coverage supporting high speed vehicles
      - Distribution of nodes: Uniform
      - Indoor/Outdoor: 50% indoor and 50% outdoor
      - LOS/NLOS: Both LOS/NLOS (Line of sight/Non-Line of Sight)
  - Geometry
    - we create a suburban environment where two highway segments cross, which forms a 4-way junction. (as shown in the pictures)
System Model (cont’d)

- On the created geometry, we move on to distribute vehicles at the density of 100 vehicles per km$^2$.
- The normalization by km$^2$ is attributed to the dimension of the geometry as shown.
Simulations Methodology

- We found that simulation would accomplish the best efficiency as the main method to evaluate the performance of the proposed mechanism.

- The parameters defining and operating the proposed study are quite diverse in types and values, which makes it challenging to explore the parameters’ dynamic orchestration in concert.

- A simulation provides a relatively easier control over such a large space composed of various parameters with wide ranges of values.
  - It enable computations without being caught up with restrictions or errors caused by computing environmental factors including hardware, compiler, language, etc.
Simulation Methodology

- In the early stages of the project, the attempt to construct the highways in MATLAB programmatically proved to be inefficient for the goal in mind.

- Instead of creating the roads programmatically, they were constructed using the Automated driving toolbox. Through use of the automated driving toolbox, the highways were constructed, and the moving vehicles were able to be simulated.
Results

- By comparing the urban and suburban geometries, we calculate the performance of a V2X network in terms of the packet delivery rate.

- With CW of 31 and 127, a vehicle can achieve a higher PDR in an urban scenario:
  - In an urban scenario, the receivability among the Rx vehicles not undergoing blockage is higher compared to a suburban setting.
  - However, this does not mean that an urban setting is more advantageous in the performance of exchanging signals.

- The physical coverage of a message broadcast must be suppressed in an urban setting compared to a suburban scenario where no blockage exists.
Conclusion & Future Work

- This paper has presented a simulation framework that provides an analytical capability based on the stochastic geometry.
  - A particular focus was placed on the suburban geometry, in consideration of a higher interference caused by lack of blockage of signals among vehicles.
- The result indicated that a higher PDR could be achieved in an urban setting, but a discount must be applied because the higher performance was achieved only among a certain subset of vehicles due to the blockage.
References


[3] 3GPP, “5G; Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901 version 16.1.0 Release 16),” ETSI TR 138 901 , v16.0.0, Nov. 2020.