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.

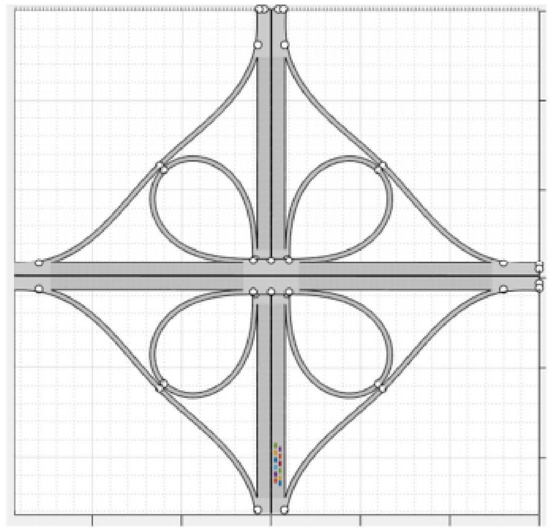
Introduction (cont’d)

- 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

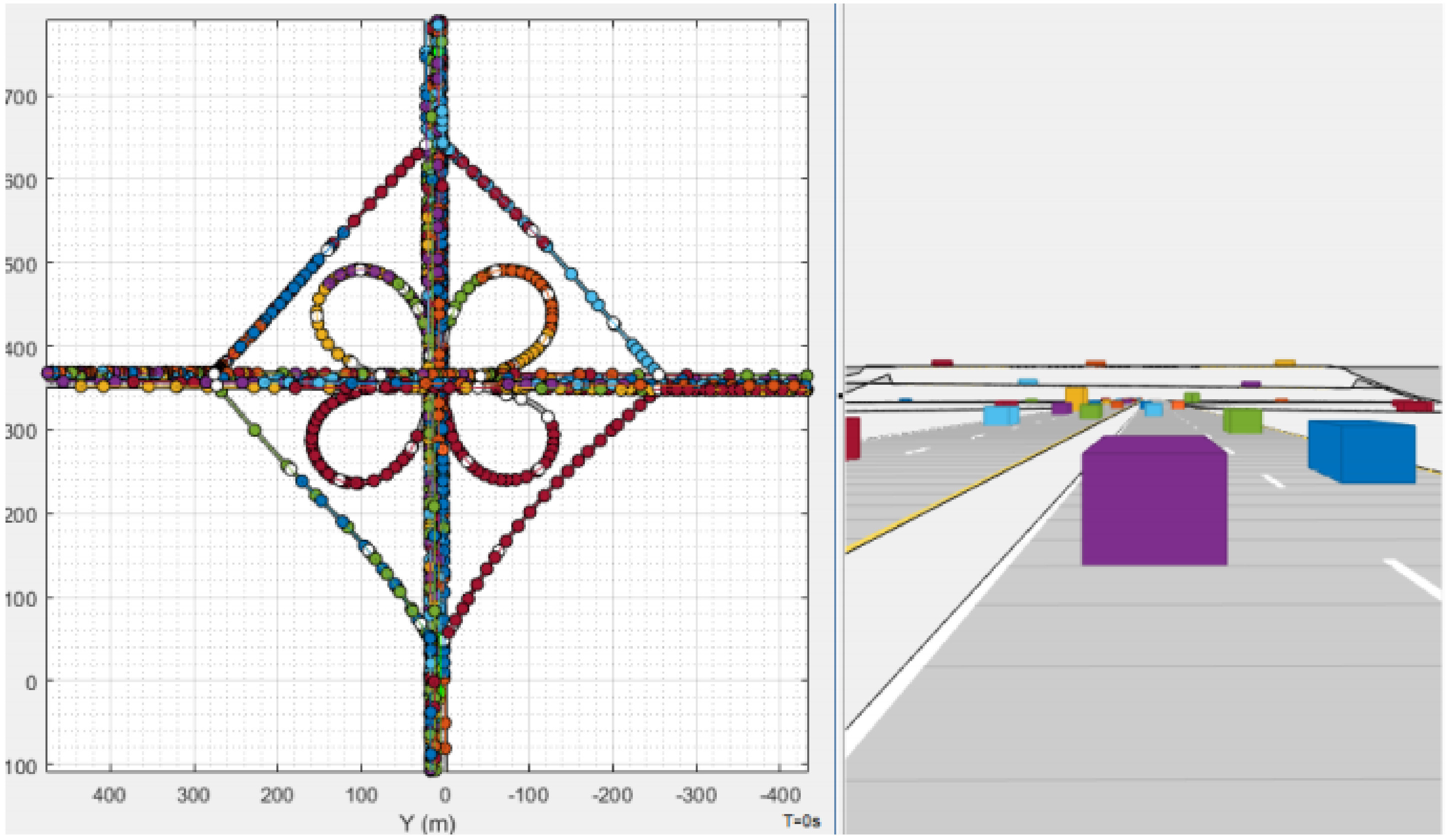
- To capture the unique characteristics of a suburban geometry, this paper adopts a Rural Macrocell (RMa) environment that is defined in the channel model by the 3rd Generation Partnership Project (3GPP) [3].
  - Path loss
    - The key characteristics of this scenario are continuous wide area coverage 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)

```
scenario = drivingScenario;

%HIGHWAY JUNCTION

% % Highways
road(scenario, [-300 -8 0; 300 -8 0], 15); % north
road(scenario, [-300  8 0; 300  8 0], 15); % south
road(scenario, [-8 -300 8; -8 300 8], 15); % east
road(scenario, [ 8 -300 8;  8 300 8], 15); % west
%Adding vehicles
 egoVehicle = vehicle(scenario,'ClassID',1, ...
                    'Position',[-232 -10 15]);
 egoVehicle2 = vehicle(scenario,'ClassID',2, ...
                    'Position',[-229 -5 20]);
 egoVehicle3 = vehicle(scenario,'ClassID',1, ...
                    'Position',[-226 -10 15]);
 egoVehicle4 = vehicle(scenario,'ClassID',2, ...
                    'Position',[-222 -5 20]);
 egoVehicle5 = vehicle(scenario,'ClassID',1, ...
```



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 km2 is attributed to the dimension of the geometry as shown



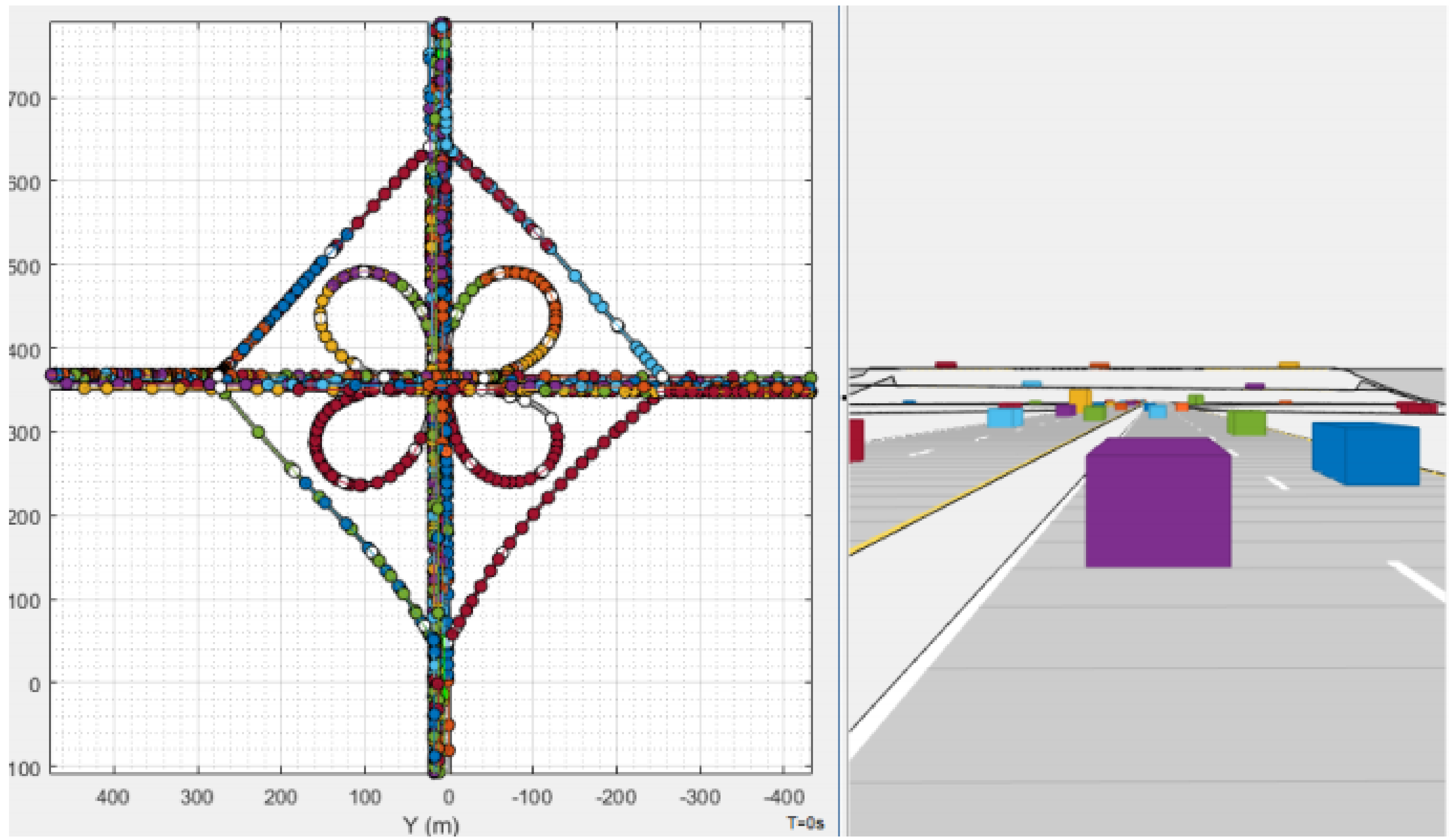
Simulations Methodology

- 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 in efficient 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.

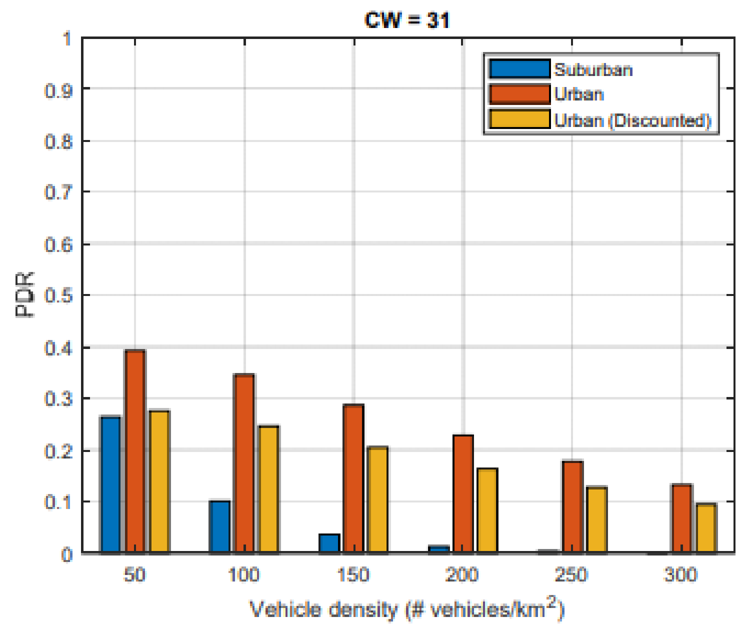


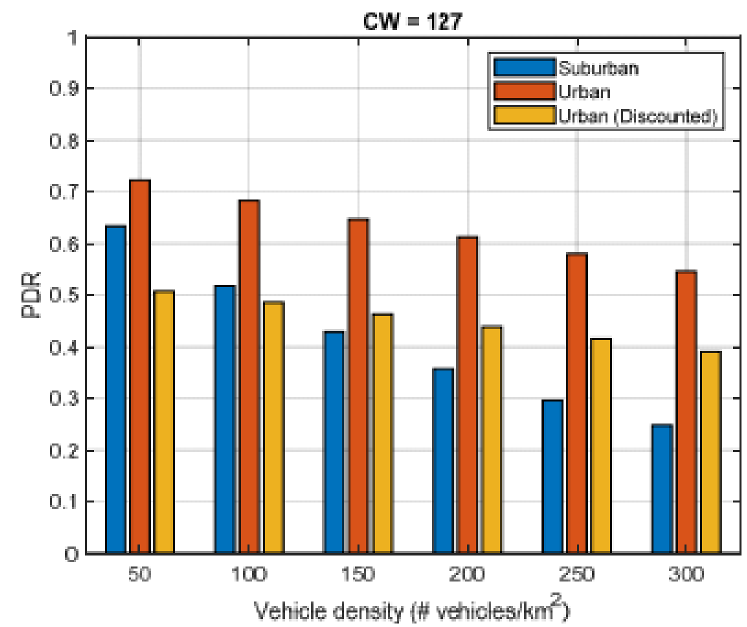
Results

- 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

[1] U.S. FCC, “Use of the 5.850-5.925 GHz band,” FCC-20-164A1 Rcd , Nov. 2020.

[2] Y. S. Song and S. K. Lee, “Analysis of periodic broadcast message for DSRC systems under high-density vehicle environments,” in Proc. IEEE International Conference on Information and Communication Technology Convergence (ICTC) 2017 .

[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.

[4] A. Singh, T. Das, P. Maniatis, P. Druschel, and T. Roscoe, “BFT protocols under fire,” in Proc. USENIX NSDI 2008 .