# Vehicular Communications at Intersections in the 5 GHz Band

Seilendria A. Hadiwardoyo, Andrés Tomás, Enrique Hernández Orallo, Carlos T. Calafate, Juan-Carlos Cano, Pietro Manzoni

Networking Research Group (GRC),Department of Computer Engineering (DISCA), Universitat Politècnica de València

## Abstract

We study the problem of 5 GHz vehicular communications at intersections, in which interferences are present depending on the intersection types. Real scenario experiments are done in each type of intersection to obtain the packet delivery ratio depending on distances. Obtained results show that intersection-related communications depend on the distances to the intersection and line-of-sight (LOS) conditions.

## Background

Vehicular communications are part of the Intelligent Transportation Systems (ITS) effort to provide advanced solutions for traffic.

A remarkable issue in ITS is its capability of providing safety applications. In fact, ITS solutions can conveniently provide warning notifications in emergency situations. Event warnings are among the most important safety applications whereby critical messages are sent out.

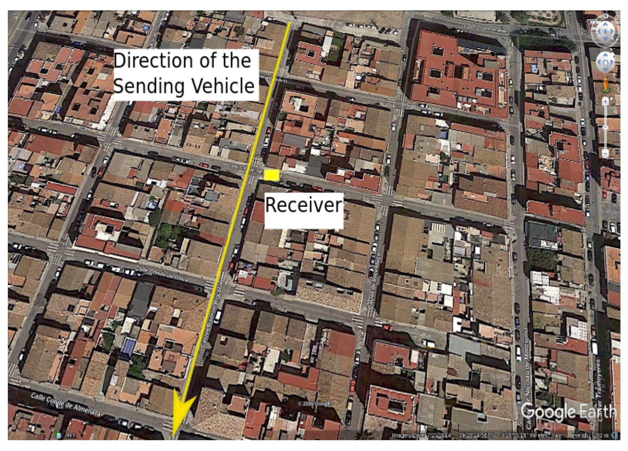
The delivery of these messages should be reliable and experience a low delay. One of the main challenges to address when delivering notifications to nearby vehicles in urban environments is intersection management. Since buildings will severely hinder signals in the 5 GHz band, it becomes necessary to transmit at the exact moment a vehicle is at the center of an intersection to maximize delivery chances.

Having critical communications, message dissemination should be as effective as possible. Taking as reference the survey on this topic by Sanguesa et al. [1], we find that most of the dissemination schemes consider the handling of intersections to maximize the dissemination, being intersection awareness critical to achieve this purpose.

## Methodology

Inside View

Outside View




Satellite View

Two devices were used in the experiments. The first one is the GRCBox [2], which is our on board unit providing fully funcitonal V2V communications.

Packet transmission tests using this device will consider two alternative positions for the antenna (on the dashboard of the vehicle, and on its rooftop)

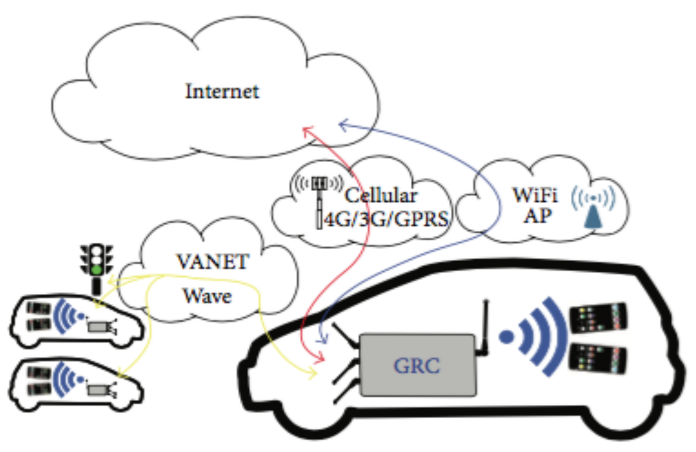
Another device is an Android mobile phone. This phone is equipped with a custom application that generates messages resembling to DENM [3].

Real moving vehicles are deployed: one acting as data sender, and the other one as a data receiver.
The receiver will be static and stopped a few meters away from the center of the intersection, while the sender will be moving along a different street, crossing a common intersection.

The receiver will record the location of both the sender and the receiver vehicles as the sender is moving.

Our data analysis consists of calculating the packet delivery ratio along with the distance between the sender and the receiver.

The experiment considers particular types of intersections, where we have selected three with different characteristics (based on different degrees of obstructions):
1. Intersection 1 (Open Scenario), minimum level of obstruction in an open space
2. Intersection 2 (Building Scenario), maximum level of obstruction in an urban canyon full of buildings
3. Intersection 3 (Trees Scenario), moderate level of obstruction in a residential area with LOS blocked by either buildings or trees.



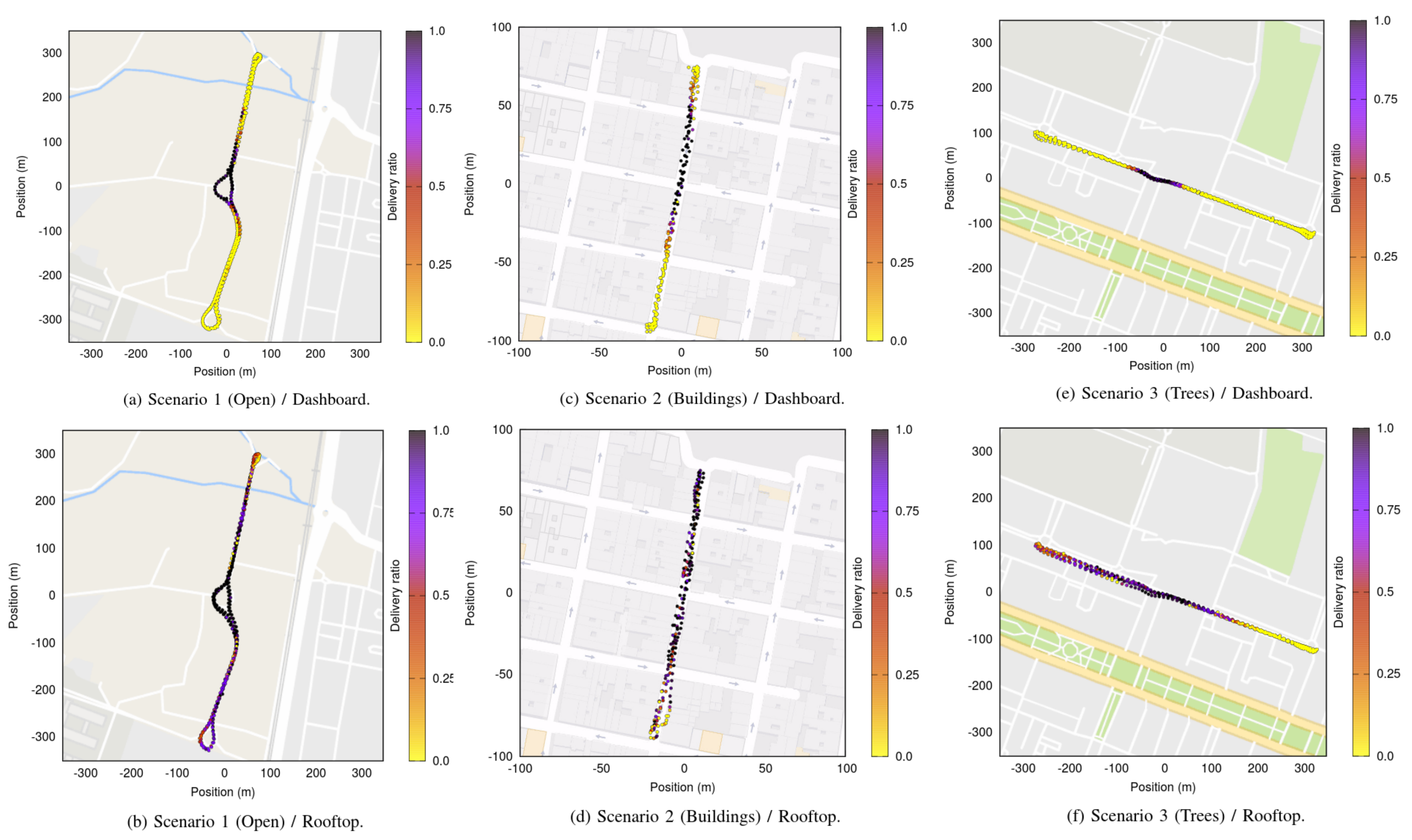

GRCBOx with VANET environment

## References

[1] J. A. Sanguesa, M. Fogue, P. Garrido, F. J. Martinez, J.-C. Cano, and C. T. Calafate, "A survey and comparative study of broadcast warning message dissemination schemes for vanets", Mobile Information Systems, vol. 2016, 2016.
[2] S. M. Tornell, S. Patra, C. T. Calafate, J.-C. Cano, and P. Manzoni, "Grcbox: extending smartphone connectivity in vehicular networks", International Journal of Distributed Sensor Networks, vol. 2015, p. 5,2015.
[3] ETSI,Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specification of decentralized environmental notification basic service, TS 102 637-3, 2010.

## Experimental Results

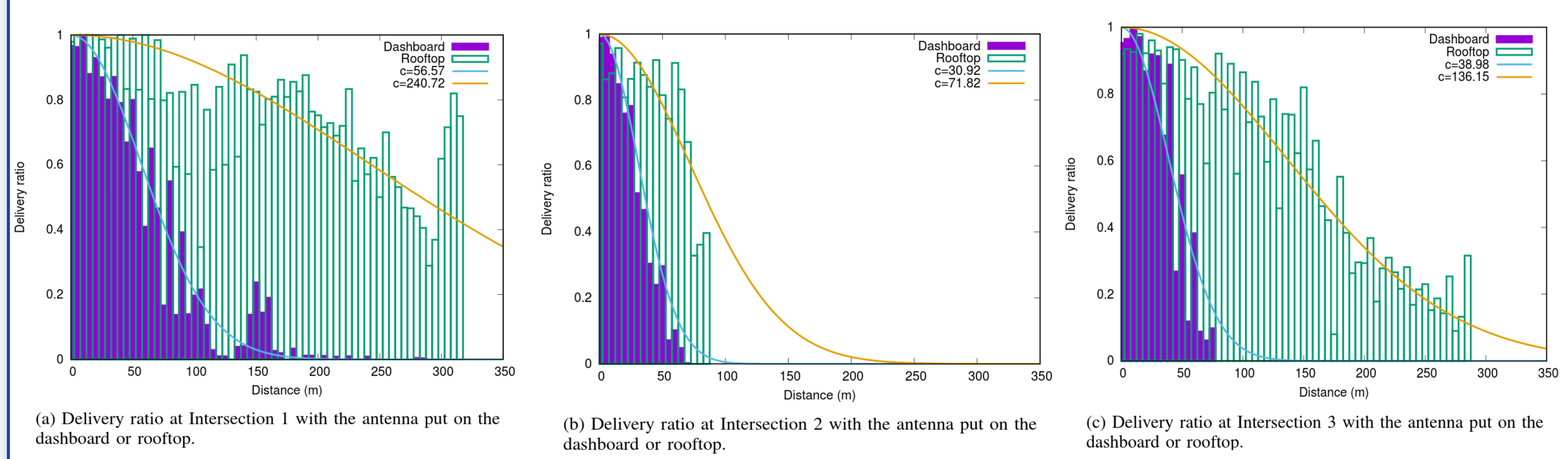
**Heat Maps of different Scenarios. Each plot shows the packet delivery ratio depending on the sender position, scenario (open, building and trees) and antenna location (dashboard, rooftop)**




(a) Scenario 1 (Open) / Dashboard. (c) Scenario 2 (Buildings) / Dashboard. (e) Scenario 3 (Trees) / Dashboard.
(b) Scenario 1 (Open) / Rooftop. (d) Scenario 2 (Buildings) / Rooftop. (f) Scenario 3 (Trees) / Rooftop.

The figures show the percentage of messages received.
The first scenario (figure a and b) is under ideal conditions since experiments were done in an area with minimum levels of obstruction.
The second scenario (figure c and d) represents a worst-case condition, being done in an area with maximum levels of obstruction.
In a moderate scenario (figure e and f), the results in terms of radio range is in between the first and the second scenarios.

## Intersection Modeling




(a) Delivery ratio at Intersection 1 with the antenna put on the dashboard or rooftop. (b) Delivery ratio at Intersection 2 with the antenna put on the dashboard or rooftop. (c) Delivery ratio at Intersection 3 with the antenna put on the dashboard or rooftop.

Different intersections were modeled based on the experimental results fittings (see figures above). Our purpose is to obtain a generic model that allows integrating the different behaviors observed in simulation tools, as well as analytically studying the effectiveness of event-related message delivery at intersections.
After evaluating several fitting functions (polynomial, power) for the different types of intersections and antenna locations, the best fitting was obtained using a modified Gaussian function:

$$f(x) = e^{-\frac{x^2}{2c^2}}$$

Note that this exponential function computes the delivery ratio for a particular distance $x$. As the distance grows, this probability asymptotically becomes 0. The value of the constant $c$ will depend on the scenario and antenna position. The parameter $c$, or the standard deviation of the Gaussian function, and the fitting error (expressed as $\chi$), can be defined by the table below following the scenario condition:

| | Antenna on dashboard | | Antenna on rooftop | |
|---|---|---|---|---|
| | $c$ | $\chi^2$ | $c$ | $\chi^2$ |
| **Intersection 1** | 56.57 | 15.35 | 240.72 | 30.15 |
| **Intersection 2** | 30.92 | 12.84 | 71.82 | 21.67 |
| **Intersection 3** | 38.98 | 6.18 | 136.15 | 20.14 |

## Conclusions and Future Works

- The impact of the intersection type is significant, as differences of up to 150 meters in transmission range were detected.
- Having a rooftop antenna is also a critical factor, allowing to extend the transmission range between 100 and 250 meters, which may represent more than a 100% increase in some cases.
- A Gaussian function offers adequate fits for all cases by just varying one parameter.
- Future works will consist in translating the results to a simulation platform in order to achieve a more realistic simulation model able to better resemble real-life experiments.

This work was partially supported by the "Ministerio de Economía y Competividad, Programa Estatal de Investigación, Desarollo e Innovación Orientada a los Retos de la Sociedad, Proyectos I+D+I 2014", Spain, under Grants TEC2014-52690-R and BES-2015-075988 under Smart@CarPhone Project.

SMART@CarPhone

GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD