Demo: Visualization of Vehicular Communication: Insights into Power, Effective Range, Clustering, and Neighborhood Size

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Abstract—This demo describes how visualization can be used to gain insight into the following properties of vehicular communication on a city scale: received power, communication range, and number of directly reachable vehicles. Furthermore, the demo shows how visualization can provide useful insights for planning vehicular communication systems in urban environments (e.g., in terms of infrastructure placement, designing effective algorithms, etc.). Videos of the demo can be found at <http://vehicle2x.net/videos>.

I. INTRODUCTION

Vehicle-to-vehicle (V2V) communication is becoming a reality, with the finalization of Release 1 standardization package by ETSI and CEN/ISO following the EC mandate M/453¹ and the recent announcement by the U.S. Department of Transportation to move forward with V2V communication². To provide an account of what the future vehicular networks will look like, this demo shows visualization of realistic city-wide V2V communication simulations. Specifically, the demo shows visualization of received power, communication range, and neighborhood size (defined as the number of vehicles that the ego vehicle can communicate with directly/without multi-hop communication). Visualization also provides insight into: i) network clustering (where a cluster is defined as a group of vehicles that can communicate with each other in either single- or multi-hop fashion); and ii) evolution of network over time (by animating multiple simulation time steps) and space (by visualizing communication in different environments).

A. Generating Vehicular Mobility

To simulate vehicular traffic in different environments, we use Simulation of Urban MObility (SUMO) traffic simulator [1]. SUMO is an open source road traffic simulator that uses freely available roadway information provided by the OpenStreetMap project [2].

B. Simulating V2V Communication

City-wide vehicular communication is simulated using GEMV², a geometry-based, efficient propagation model for V2V communication [4]. GEMV² imports vehicular mobility

(a) City-wide view of vehicular communication.

(b) Street-level view of vehicular communication.

Fig. 1. Visualization of received power generated by GEMV² in the city of Cologne using NASA World Wind [3]. The transmit power of all vehicles is set to 21 dBm EIRP. The origin/destination pairs for vehicles are derived through the Travel and Activity PATterns Simulation (TAPAS) methodology. Transmitting and receiving vehicles are connected with a straight line, elevated at the receiver end. Warmer line color represents better signal at the receiver; apart from the line color, circles above receiver that are positioned higher represent better signal.

data from SUMO and building and foliage outlines from OpenStreetMap [2]. Apart from the propagation-related statistics, GEMV² allows for analysis of networking metrics such as packet delivery rate, effective transmission range, neighborhood size, etc. The demo shows simulations where all vehicles are equipped with V2V communication technology (i.e., 100% penetration rate); other penetration rates can be simulated easily. For details related to V2V simulations, including the simulation parameter settings, please refer to the GEMV² paper [4]. The source code of GEMV² is available at <http://vehicle2x.net>.

¹http://europa.eu/rapid/press-release_IP-14-141_en.htm

²<http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications>

Fig. 2. Visualization of neighborhood size generated by GEMV² in the city of Porto using Google Earth. The transmit power of all vehicles is set to 21 dBm EIRP. For each ego vehicle, the colored bar represents the number of vehicles it can communicate with directly. Warmer and taller color bars represent more neighbors.

C. Tools for Visualization

GEMV² generates the V2V simulation output in Keyhole Markup Language (KML) format. To visualize the result, we use Google Earth³ and NASA World Wind [3], though any tool for displaying three-dimensional virtual globe⁴ can be used, provided that it supports KML format. If the simulated vehicular mobility/V2V communication is composed of multiple time steps, the output of GEMV² is an animation of all time steps (sample videos are available at <http://vehicle2x.net/videos>).

II. VISUALIZING RECEIVED POWER, EFFECTIVE RANGE, CLUSTERING, AND NEIGHBORHOOD SIZE

City-wide vehicular communication shown in Fig. 1(a) gives an insight into a “moment in life” of an urban vehicular network. The combined effect of thousands of communicating vehicles generates a map containing “points of attraction” in a city: locations where most communication occurs. The effect of different surroundings, even within a city, can be seen clearly. Fig. 1(a) shows that the communication in some parts of Cologne is limited due: i) smaller number of vehicles on less significant roads; and ii) the propagation characteristics such as strong attenuation due to buildings. Furthermore, it is interesting to see the effect of river separating two parts of downtown Cologne: it clusters the communication on two ends, with the vehicles on the bridge connecting the two sides in the snapshot shown in Fig. 1(a).

Network clustering effect is particularly well suited for analysis through visualizations, since visualization gives an instant account of the network behavior in time and space; for example, spatial clustering effect is visible in Fig. 1(a), with a large central cluster covering most of the city, and several satellite clusters at the outskirts.

Similarly, the dependence of effective range on the environment where the V2V communication occurs can be analyzed effectively through visualizations. Figure 1(b) shows that vehicles communicate best over the face of the road, with

the surrounding buildings limiting the communication over the roadside.

Figure 2 shows the neighborhood size for each vehicle. The size of the neighborhood for a vehicle depends on two parameters: i) the density of the traffic, affected by the type of the road the vehicle is on (the neighborhood will likely be larger on an arterial road than on a small alley); and ii) the surroundings, which affect the propagation characteristics, thus limiting the effective range and the neighborhood size. The demo will show the evolution of the neighborhood from low density traffic scenarios (e.g., early morning hours) to high density (e.g., rush hour traffic).

The insights provided by the visualization – that the vehicular communication is channeled over the face of roads in urban areas, that certain roads have more communicating vehicles than other, that vehicles on a bridge can help relay the message between two parts of the city – can be useful for planning vehicular communication systems in urban environments (e.g., where to place roadside infrastructure to improve connectivity) and for designing effective algorithms (e.g., neighborhood size can help in designing congestion control algorithms, whereas density of communication over certain roads can be useful for routing protocol design).

For the V2V communication characteristics discussed above, the demo will show the differences arising from different surroundings (e.g., difference in received power, range, and neighborhood size in different cities as well as comparison of highway and urban V2V communication patterns), as well as the evolving of V2V communication over time.

III. CONCLUSIONS

This demo provides a visual account of what a vehicular communication network in an entire city will look like. By employing novel, computationally efficient algorithms, the behavior of thousands of connected vehicles can be simulated and visualized. Visualization can enable novel insights into the behavior of vehicular network over time and space, highlighting the differences in V2V communication performance caused by surroundings, density of vehicular traffic, and communication parameters (e.g., transmit power). All the tools and geographic data used for this demo are open source and free to use. Therefore, anyone interested in visualizing V2V communication can use the same method to visualize vehicular communication in a city of their choice.

REFERENCES

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³<http://www.google.com/earth/>

⁴http://en.wikipedia.org/wiki/Virtual_globe