Title: Vehicle-to-Vehicle Communications in Mixed Passenger-Freight Convoys

PIs: Andreas Molisch and Olivier Renaudin
Coauthors: Rui Wang and He Zeng
Ming Hsieh Department of Electrical Engineering
Viterbi School of Engineering - University of Southern California
Los Angeles, CA 90089-2565
Email: molisch@usc.edu, renaudin@usc.edu, wang78@usc.edu, hezeng@usc.edu

Project Objective

Freight traffic in California depends, to a large degree, on trucks, due to their flexibility in visiting warehouses, distribution centers, and terminals. However, trucks pose major challenges to traffic and road safety. Accidents involving trucks are more deadly, and traffic congestion is more likely in general when the flow of trucks is high. As a result, truck convoy emerges as a good solution that can reduce the probability of both accidents and traffic congestion. A key requirement for convoy formation is automated control of the distance between the participants. Communication systems that can convey information between them are essential to ensure safety. Recently the WAVE (IEEE 802.11p) standard has emerged for the communication between vehicles. However there has neither been a large-scale field test with actual IEEE 802.11p compliant devices, nor a detailed model for the propagation channel between the participating vehicles under various circumstances. The overall purpose of this project is to investigate the performance of IEEE 802.11p systems for interactions of convoys with mixed truck/car situations, and assess the impact on convoy formation.

Problem Statement

To study a propagation channel, we first need to develop a fully functional real-time MIMO measurement platform for vehicle-to-vehicle propagation channels, which enables a rapid and synchronous recording of the raw channel impulse response. The multiple antenna elements, when carefully designed and calibrated, help resolve multi-path components further in the angular domain. We also need to perform extensive measurement campaigns for various scenarios when both trucks and passenger cars are on the road.

To fully characterize the inter-vehicular propagation channel, we need to develop and parameterize a channel model based on the measured data. Hence together with the created simulation platform for the 802.11p standard, we can assess the performance of IEEE 802.11p compliant communication systems based on both measured channel impulse responses and those reproduced by the parameterized channel model. The results can provide a great insight into not only the probability of successful communication between vehicles, but also the latencies and reliabilities of the wireless links, which will provide a critical input for the design of control systems, and even for the development of policies and technologies for convoy formation.

Research Methodology

We construct and calibrate a real-time continuous MIMO channel sounder that is based on NI-USRP RIO software defined radio platforms, which operates around 5.9 GHz. We have also designed, simulated and calibrated two 8-element uniform circular arrays (UCA) for the transmitter (TX) and receiver (RX). A server rack that stores various pieces of equipment is placed inside the test vehicle, while the antenna array is mounted on the top of the vehicle. The test vehicle is either a mid-size SUV or a 16' box truck depending on the measurement scenario.

Using this setup we have collected a large dataset of channel impulse responses for various vehicle configurations in different environments. For example, we have measured propagation channels between adjacent trucks in a convoy, between trucks separated by other trucks, between passenger cars separated by trucks, between a truck and a passenger car in a highway acceleration lane. The measured environments can be categorized as urban, suburban, freeway, intersection, and tunnel.

We developed and implemented an extended version of RiMAX algorithm to extract parameters of MPCs from the V2V channel data. The estimates are fed into a separate path-tracking algorithm to produce some key statistics that help parameterize a Geometry-based Stochastic Channel Model (GSCM). We have created a simulation platform for the IEEE 802.11p standard, and evaluate the system performance based on the measured data.

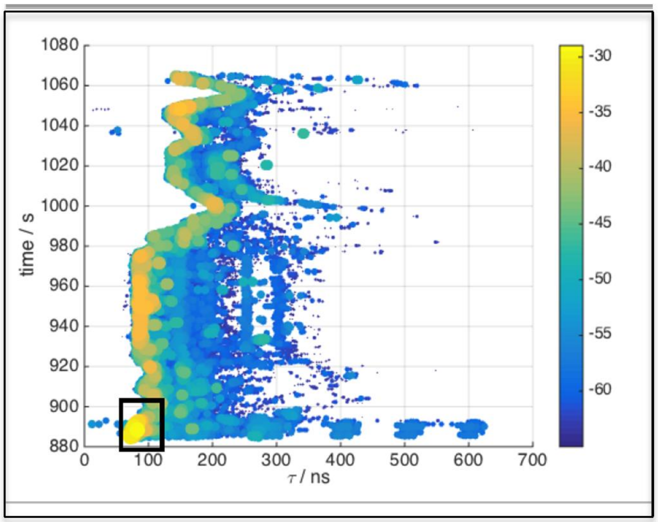

Figure 1

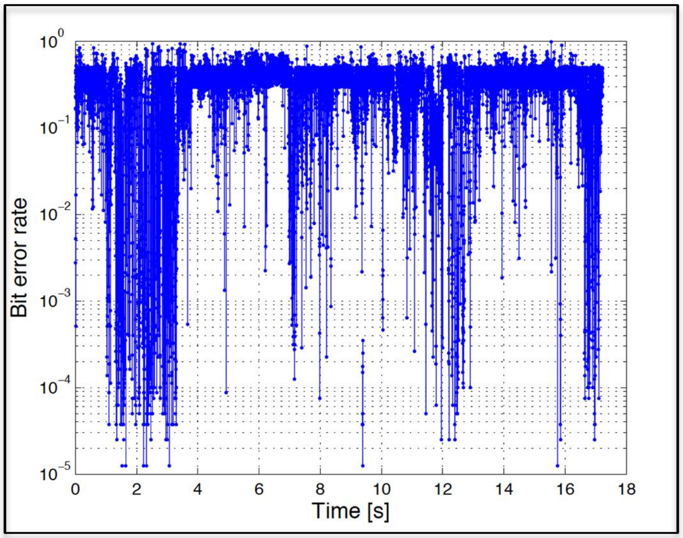

Figure 2

Numerical Results

Figure 1 shows the time-varying power delay profile (PDP) of extracted path estimates from the experiment of the car-to-car obstructed by a truck in-between. The delays of strong paths match well with the distance between the TX and RX. Figure 2 shows the time-varying behavior of the BER for the truck-to-truck obstructed by a third truck. The BER in general increases when the line-of-sight path (LOS) is obstructed, and reduces when it is only partially obstructed.