Poster: Investigating Doppler Effects on Vehicle-to-Vehicle Communication: An Experimental Study

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Poster: Investigating Doppler Effects on Vehicle-to-Vehicle Communication: An Experimental Study*

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ABSTRACT

Doppler effects on vehicular communication have been theoretically modeled by many researchers. However, very limited experimental studies have been conducted to investigate the impact of Doppler shift on the vehicle-to-vehicle (V2V) communication range and reliability with high speed mobility. The current work-in-progress research aims to quantify the impact of Doppler effects on V2V communication reliability, range, and reachability using single-hop Dedicated Short Range communications (DSRC) between two opposite traffic. We conducted our experiments by mounting the after-market DSRC on-board units on the dashboard of two vehicles that cross each other from opposite directions with constant relative speeds on a real interstate freeway. Our preliminary results indicate that the communication time and range drop to approximately 70% and 40% after the two vehicles cross and start moving away from each other with the average relative speeds of 110 and 140 mph, respectively. Similarly, the packet delivery ratio is also drastically reduced after the vehicles start moving away from each other. Apparently, these results indicate that there might be a strong effect of Doppler phenomena on the transmission range, packet delivery rate and the duration of the communication.

CCS CONCEPTS

• **Networks** → **Network reliability**; • **Computer systems organization** → *Embedded systems*;

KEYWORDS

Doppler effect, V2V, DSRC, OBU, Packet delivery ratio

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1 INTRODUCTION

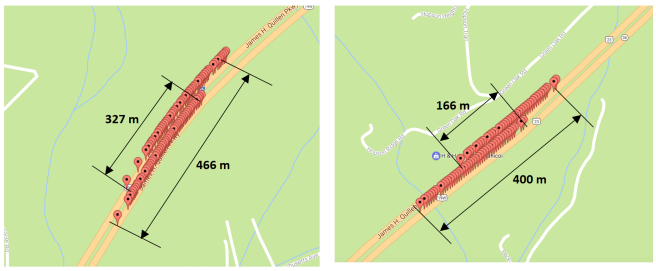
Doppler shifts can negatively impact the reliability of V2V communication when a vehicle's speed is above 50 km/h [3]. Several researchers experimentally measured the impact of Doppler shift on channel characteristics [1, 2, 4]. In [2], the researchers use a measurement system to characterize V2V 5.9 GHz wireless communication channels. Experiments were conducted in suburban areas and established some understanding with the impact of speed and separation distance on the Doppler spectrum. A correlation was observed between speed and separation, and have interpreted this in terms of driver behavior. The Speed-Separation diagram introduced in this study found that the Doppler spread is proportional to effective speed and can be used to predict how Doppler spread and coherence time depend on the separation between the vehicles. RMS Doppler spread was measured by Bernado et. al. [1] for various driving environments. However, none of the existing experiments investigated the impact of this Doppler shift on packet delivery ratio for two vehicles crossing each other from opposite direction at a high relative speed (up to 230 km/h or 140 mph).

2 EXPERIMENTAL SETUP

Our current experiment focused on investigating the detrimental effect of Doppler shift on the reliability of V2V communication. The empirical data was collected by driving two vehicles, equipped with after-market DSRC devices, from opposite directions on the interstate-26 freeway near Johnson City, TN. The OBUs were equipped with omnidirectional antennas, which means that if the vehicles were static, the communication range should be equal in all directions. The OBUs broadcast Wave Short Message packets through the channel 172 in every fifth of a second. Figure 1(a) shows the experimental setup inside the vehicle. We conducted the first experiment with a relative velocity of 110 mph by crossing each other at a constant speed of 55 mph. The second experiment was conducted at a relative speed of 140 mph by crossing at 70 mph. Each device kept logs of both transmitted and received packets,

(a) Experimental Setup (b) Change of packet delivery ratio

Figure 1: (a) OBU inside the vehicle (b) Packet delivery ratio at 55 mph



(a) 55 MPH (b) 70 MPH

Figure 2: Change of communication ranges before and after crossing each other for 55 and 70 Mph speeds

where each packet contained information about the speed, direction, lat-lon coordinates, altitude, and GPS time stamp. The Haversine formula was used to accurately determine the greater circle distance between two vehicles at every fifth of a second using the GPS coordinates.

3 RESULTS

Figure 2 shows the successful reception packets indicated by markers on the highway map. As seen in Figure 2(a), while vehicles were approaching each other from opposite direction at a constant speed of 55 mph, the first instance of successful communication between the cars happened at a distance of 466 meters. As the two cars passed each other, they kept communicating among themselves up to a distance of 327 meters and after that, they were no longer able to communicate. This indicates a 30% reduction of the communication range in the reverse direction compared to the forward direction. Figure 1(b) indicates that while vehicles approach each other at a speed of 55 Mph, the packet delivery rate is as high as 84% within 350m away from each other. This rate suddenly drops to 50% after the vehicles cross each other. In the case of 70 mph, as observed in Figure 2(b), the forward communication range was 400 meters and the reverse range was 166 meters, which implies that 60% of the communication range is reduced in the reverse direction. From Figure 3, it can be observed that at 55 mph speed, the total

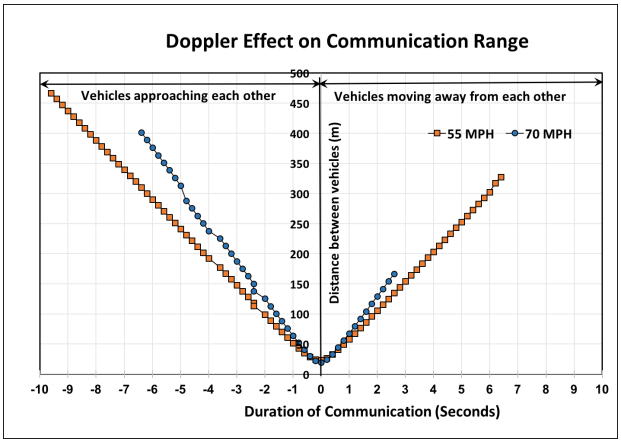


Figure 3: The Doppler effect on V2V communication range and duration of contact

active communication duration between two vehicles was about 16 seconds, while the 70 mph scenario had a total 9-second long communication. Each marker on the plot indicates the distance between the vehicles at the corresponding time.

The initial results of this experiment can be deemed as the effect of Doppler shift. The transmission frequency was 5.86 GHz (center frequency of channel 172). The amount of frequency shift between before and after crossing each other was calculated to be around 2563 Hz for 70 mph. This could be the primary reason for the drastic reduction of communication range after the cars passed each other.

4 CONCLUSIONS AND FUTURE WORK

The results of this experiment motivated us to examine the effects of interior obstructions of a vehicle in DSRC signal transmission, since the range is reduced toward reverse direction. To minimize the impact of interior obstacles on the signal strength through the rear end of a vehicle, we are conducting experiments mounting the DSRC OBUs on the roofs of the vehicle. Early results from the later experiments suggest that interior obstacles contribute to the signal attenuation and thus reduce the communication range in the reverse direction. However, further experiments are required to quantify the extent of impact from the two factors—interior obstacles and Doppler shift—on the reliability of V2V communication.

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