

DSRC Rebroadcasting

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ABSTRACT

Dedicated Short Range Communications (DSRC) for vehicle-to-vehicle (V2V) cooperative applications for advanced safety is becoming a reality. Many automotive manufactures are entering advanced research phases or even planning deployments of such applications in the near future. However, the success of most V2V applications requires full or near-full deployment of the DSRC devices in new and existing vehicles, which will take many years to accomplish. In the meantime, use of autonomous sensors in combination with V2V can augment this deployment transitional period. In this paper we propose a hybrid approach that uses autonomous sensors to rebroadcast information about unequipped neighboring vehicles. In addition to messages that a host vehicle sends about its own state (such as position, speed, and direction), additional sensing capabilities also allow sending information about neighboring vehicles. This information can be obtained from radars, cameras and other autonomous sensors. This paper presents an actual implementation and analysis of rebroadcasting information about the surrounding vehicles.

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INTRODUCTION

In the near future, the U.S. government may mandate or encourage passenger and commercial vehicles to be equipped with 5.9 GHz DSRC transponders [1]. According to a market penetration study for V2V safety applications, if only new vehicles are equipped with DSRC, it will take up to 40 years to reach significant, close to 100%, market penetration [3]. For successful cooperative safety applications, high market penetration is critical. One way to increase the number of transponders on the road is to include aftermarket and retrofit devices to existing vehicles. Another way to artificially increase the number of transponders is to leverage highly capable vehicles. Vehicles equipped with radars and vision-based ranging systems can detect non-DSRC vehicles and send additional information about those neighboring vehicles over the air. This paper presents the concept of DSRC rebroadcasting and compares position estimates of radar-based DSRC rebroadcasting to the classical DSRC-equipped vehicle with an automotive grade Global Positioning System (GPS) receiver.

PROBLEM STATEMENT

DSRC has the advantage that it functions non-line-of-sight, around corners, around other vehicles and buildings as seen in [4], a function that radar, camera or lidar simply cannot do. It offers the ability to provide drivers added situational awareness not possible with line-of-sight sensors alone. DSRC is not the perfect standalone system. Relying strictly on DSRC for an application like Adaptive Cruise Control (ACC) produces at best an inconsistent feel and at worst a rough inappropriate vehicle response. In addition relying

strictly on DSRC provides no awareness of non-DSRC vehicles in the vehicle proximity. A coupling, or fusing, of DSRC with other sensors offers both redundancy and error-checking capability. For example consider the Electronic Emergency Brake Light (EEBL) scenario, as shown in the Figure 1, leading Vehicle V1 is a non-DSRC vehicle, following Vehicle V2 is DSRC equipped and has forward looking radar and the trailing Vehicle V3 is DSRC equipped. If Vehicle V1 suddenly brakes, Vehicle V2 will be able to track that and respond using its own radar. Vehicle V2 also can broadcast Vehicle V1 braking and position information to the other vehicles--in this case Vehicle V3. Vehicle V3 then can act to warn the driver of a sudden brake of the vehicle that is not in direct line of sight.

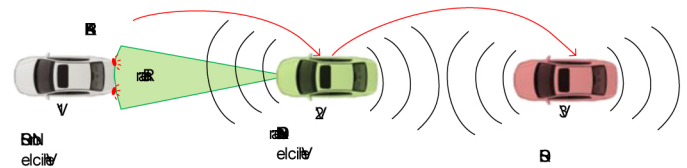


Figure 1. EEBL: example use case for DSRC rebroadcasting

Low Initial DSRC Penetration

The single biggest problem with DSRC is low initial market penetration. There simply are not enough other vehicles with DSRC to do V2V communication and cooperative applications. It serves no purpose to have the only DSRC-equipped vehicle in town. Supplementation of DSRC through autonomous sensors may be one way to overcome this obstacle.

Global Positioning System (GPS) Inaccuracy and Availability

DSRC communicates a Basic Safety Message (BSM) in which vehicles share information such as GPS position, heading, velocity, acceleration, brake and throttle status, etc. Current BSM data elements are defined in Society of Automotive Engineers (SAE) J2735 standard [2]. Automotive grade GPS receivers can achieve lane level accuracy most of the time. However, at times even with a clear view of the sky, GPS solution can drift several meters. When driving in tree cover or in urban canyons these errors can be far greater (or GPS may not function at all). While these position errors are reasonably acceptable for navigation it is far from ideal for vehicle-to-vehicle based hazard detection. Autonomous sensors (radar, lidar, camera, etc.), although limited by range and line of sight, are far more accurate for measuring near field Lane-Level distances than GPS.

DSRC latency in congested environments

Depending on DSRC radio congestion, inter packet gap (IPG) can range from 100ms at best to in excess of a second. If the DSRC message is simply informative this delay is potentially acceptable. If the BSM is intended for V2V controls, responding to where a vehicle was say 500ms ago can produce position errors of several meters at highway speeds. In ACC-like applications this leads to obvious issues. For these types of controls the use of radar (and/or other supplemental sensors) is often required because GPS position may vary so much that the system may become inadequate.

SYSTEM SETUP

Our data collection system is described next. Figure 2 shows an overview of the system. In the Host Vehicle (HV), vehicle information is supplied to the MicroAutobox and DSRC radio via internal Controller Area Network (CAN) bus. The purpose of the MicroAutobox in the HV is to interpret the data from the radar and GPS receiver and provide an estimate position of the RV. The GPS receiver feeds MicroAutobox and the DSRC radio with GPS solution every 100ms. The radar module sends target data to MicroAutobox via CAN. We define phantom data to be the data derived from the radar and transmitted over the air. Phantom data is computed in the MicroAutobox and sent to the DSRC radio for rebroadcasting via wired LAN connection and User Datagram Protocol (UDP). When DSRC radio in HV wirelessly receives the BSM from the Remote Vehicle (RV) the radio sends RV data to the MicroAutobox via wired LAN. HV transmits original and phantom BSMs and it receives RV BSMs. On the RV side there is no MicroAutobox and no radar unit; other connections are the same as in the HV. Additionally, RV logs received and transmitted BSMs in time-stamped fashion and in a comma-separated value format file for easy processing. This file is then used for the data analysis in the Results Section of the paper.

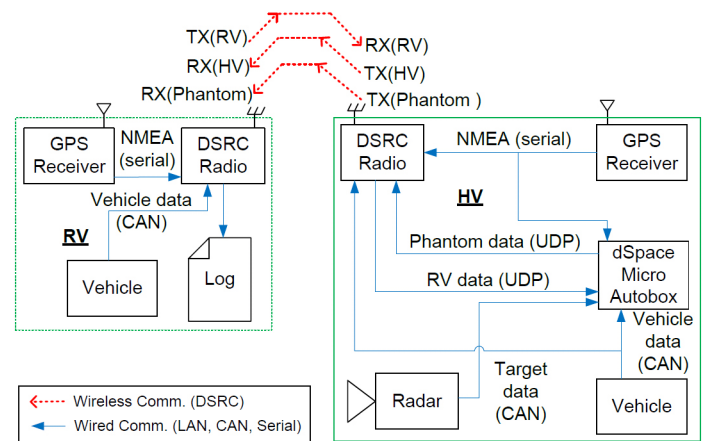


Figure 2. Host Vehicle (HV) and Remote Vehicle (RV) system overview

System Design

Our prototype DSRC rebroadcasting system was modeled with Matlab Simulink and tested in vehicles using dSpace MicroAutobox II. Below are three screen shots of the model and basic descriptions of subsystem function. Figure 3 represents the top level of the model. Figure 4 depicts the subsystem that brings in the data as UDP data from the DSRC radio and also from the vehicle and radar CAN buses for fusion. Figure 5 shows a subsystem that takes raw input from the radar and outputs a smoothed signal. It also prepares data that are sent to the radio for rebroadcasting of the phantom vehicle.

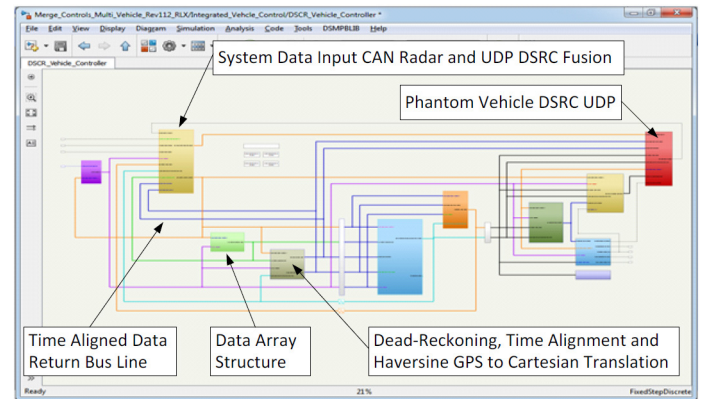


Figure 3. Top level of the model for estimating phantom vehicle data

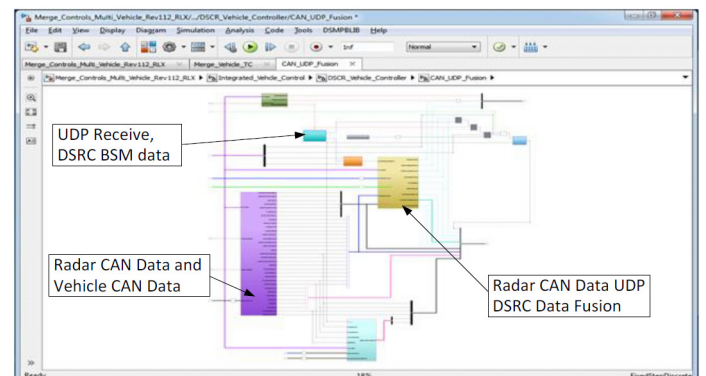


Figure 4. Subsystem that brings in the data from the DSRC radio and performs vehicle and radar CAN data fusion