Demo: Freeway Merge Assistance System using DSRC*

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ABSTRACT

This paper presents the development of a novel decentralized freeway merge assistance system using the Dedicated Short Range Communication (DSRC) technology. The system provides visual advisories on a Google map through a smart phone application. To the best of our knowledge, this is the first implementation of a DSRC-based freeway merging assistance system—integrated with smart phone application via Bluetooth—that has been tested in real-world on an interstate highway in an uncontrolled environment. Results from field operational tests indicate that this system can successfully advise drivers towards a collaborative and smooth merging experience on typical "Diamond" interchanges.

CCS CONCEPTS

• **Networks** → **Network protocol design**; • **Computer systems organization** → **Embedded software**;

KEYWORDS

Connected Vehicle, DSRC, Merge Assistance System, Freeway, Ramps, Advisory, Decentralized System, Merge Control Algorithms.

1 INTRODUCTION

Road safety and congestion have become growing concerns over the past few years. Researchers and automotive companies have begun working on vehicles that include DSRC On-Board Units (OBUs) to increase road safety and provide assistive services to drivers. Developers around the world are developing various applications for CV environments and uploading the applications into the Open Source Application Development Portal (OSADP) [6] of the U.S. Department of Transportation. In this paper, we utilize the DSRC technology to implement a freeway merge assistance system that uses a three-way handshaking communication protocol to provide advisory information to drivers.

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2 RELATED WORK

Researchers have been working on freeway merge control algorithms considering centralized or decentralized frameworks. For example, Wang et al. discussed a proactive and decentralized merging control algorithm that makes the advisory decisions at some point before the actual merging point [8]. Some researchers focused on providing lane changing advisory [7]. Researchers also consider the human factors involved in designing a freeway merge assistance system. For example, Hayat et al. analyzed the driver reactions to the advisory messages in different roadway scenarios and traffic conditions [2].

Almost all the merge control algorithms in [3–5, 8] were based on the position, gap, speed, acceleration, and time to reach the merging point (the time to reach the merging point is also known as *time to merge* or *ttm*). Most of the researchers evaluated the performance of their algorithms using simulation tools due to the unavailability of DSRC enabled OBU in the market. Very few researchers attempted to use roads in a very controlled environment (typically inside a test bed facility). To the best of our knowledge, most of the performance testing in merging control to date has been done on roads under very controlled environment.

3 SYSTEM DEVELOPMENT

The assistance system uses the DSRC enabled OBUs to communicate between vehicles and an Android device to display the advisory information to drivers.

3.1 Data Collection

To analyze the parameters of the merge assistance system, we collected BSM data. To collect the data, we conducted experiments on Interstate-26 and US Highway-321. A total of six hundred and twenty-seven error-checked BSM packets were collected. From the data, we determined that the speed of a freeway vehicle fluctuates when the driver of that vehicle sees any vehicle on the entrance ramp. The fluctuation in the speed potentially leads to merge conflicts.

3.2 Communication Protocol

The merge assistance system uses a single hop communication protocol (described in [1]) for transmitting and receiving wireless packets. The system also uses a 3-way handshaking protocol (Figure 1) to synchronize the merging order of the ramp and freeway vehicles.

4 WORK-FLOW OF THE SYSTEM

The freeway merge assistance system goes through the following steps before providing advisories to drivers.

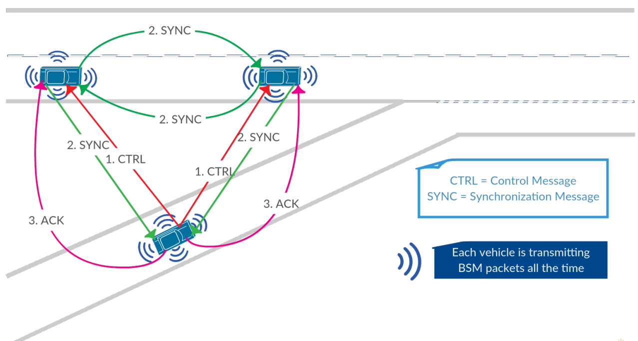

Figure 1: 3-way handshaking protocol

(1) ***Transmission and reception of BSM packets.*** The system transmits and receives the BSM packets with the customized payload fields including but not limited to device ID, GPS positions (latitude, longitude, altitude), GPS time, speed, direction, etc.
(2) ***Observation of vehicular trajectories.*** If the system detects any vehicle entering an entrance ramp, it visually notifies all the drivers involved in the merging scenario about the presence of the ramp vehicle using an alert message. Once the ramp vehicle achieves a constant acceleration, the merge assistance system of the ramp vehicle triggers the core algorithm and starts approximating the merging point.
(3) ***Generation of advisory messages.*** Once the system finds the final merging point, the ramp vehicle determines the *ttm* for each vehicle. The system synchronizes the merging orders between vehicles using CTRL, SYNC, and ACK messages based on the ttm. Then the system generates the appropriate advisory messages using the *ttm* (Figure 2).

5 EXPERIMENTAL RESULTS

To evaluate our system, we conducted field experiments on freeway ramps 27, 32, 34, and 36 on interstate I-26. Before the experiment, we trained three drivers about how the system works and how to interpret the alert and advisory messages. Among the three drivers, two drove on the freeway and one drove in the ramp. The three drivers drove in a way so that the merge assistance system could detect a potential merge conflict. Four different merging scenarios—as described in Table 1—were tested in the field evaluation. Figure 2 illustrates the visual display of the advisory messages that the drivers received through the Android device, captured as screen shots during actual experiment. The blue marker indicates native vehicle while the red markers indicate neighboring vehicles.

6 CONCLUSIONS

Progress in CV technology has created opportunities for researchers and automakers to develop safety and assistive applications. In this paper, we demonstrated the importance of the connected vehicle technology for detecting and avoiding merge conflicts on freeways. We also described the technical details of our freeway merge assistance system and evaluated the system for eight exits along the interstate I-26. Evaluation results demonstrate that the system can provide accurate advisory information for "diamond interchanges".

Table 1: Advisory scenarios

Scenario 1	The system suggests the ramp vehicle to merge in front of the freeway lead vehicle.
Scenario 2	The system suggests the ramp vehicle merge behind the freeway lead vehicle.
Scenario 3	The assistance system suggests the ramp vehicle merge behind the freeway lag vehicle.
Scenario 4	The assistance system suggests the lag vehicle to slow down for the ramp vehicle.

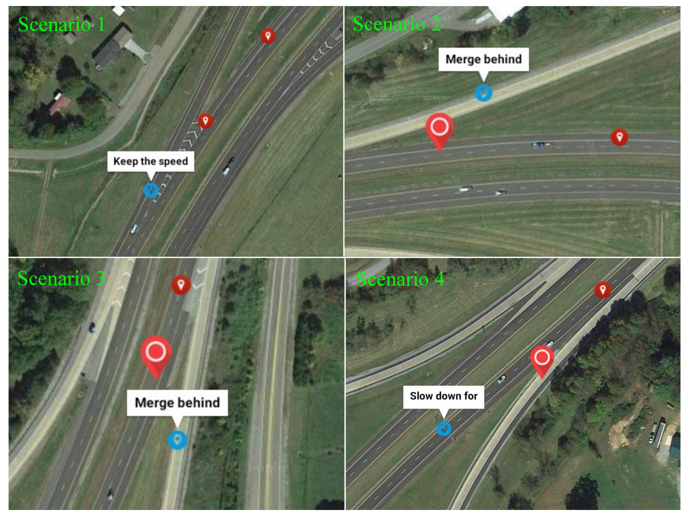

Figure 2: Screen shots of advisory messages

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