Develop and Test Connected Vehicle Freeway Speed Harmonization Systems

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Introduction

The objective of speed harmonization is to dynamically adjust and coordinate maximum appropriate vehicle speeds in response to downstream congestion, incidents, and weather or roadway surface conditions to reduce vehicle crashes and maximize traffic throughput. Research and experimental evidence have consistently demonstrated that by reducing speed variability among vehicles, especially in near-onset flow breakdown conditions, traffic throughput is improved, flow breakdown formation is delayed or even eliminated, and collisions and severity of collisions are reduced.

A dynamic speed harmonization system will be successful at managing upstream traffic flow by being able to:

1. Reliably detect the location, type, and intensity of downstream congestion (or other relevant) conditions,
2. Formulate an appropriate response plan (i.e., vehicle speed and/or lane recommendations) for approaching vehicles, and
3. Disseminate such information to upstream vehicles and in a manner that achieves an effective rate of compliance.

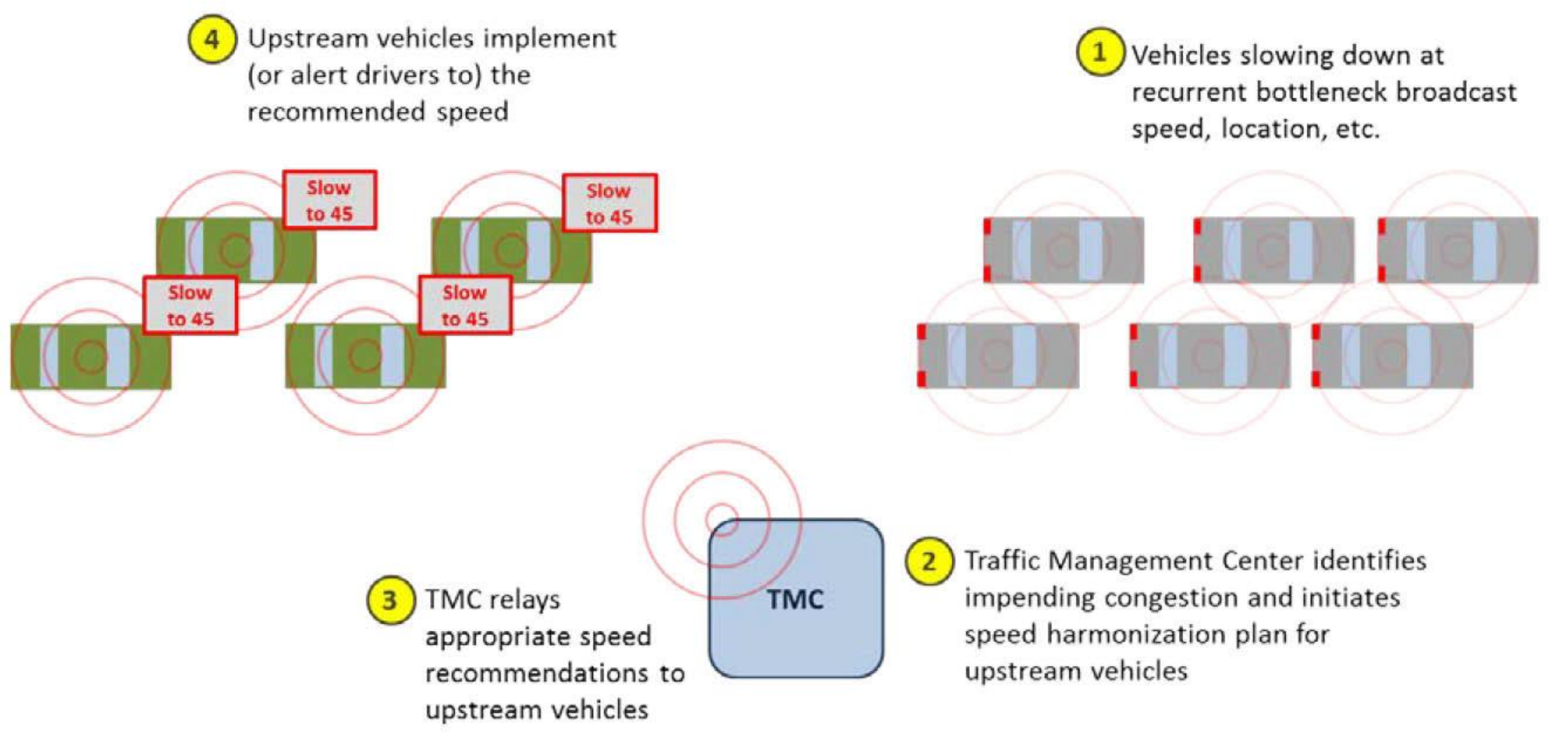
Current speed harmonization implementations are fundamentally limited by their exclusive reliance upon infrastructure-based detection and alerting. This imposes a number of limitations on the system, impacting its ability to:

1. Target appropriate speed recommendations to specific portions of the facility,
2. Ensure that generated speed recommendations are received by drivers,
3. Obtain sufficient traffic and road weather data to be able to produce accurate speed recommendations, and
4. Operate for sufficient periods in the day to provide speed guidance whenever the need may arise.

A connected vehicle-enabled dynamic speed harmonization system has the potential to address each of these limitations.

Research Objectives

The goal of this research effort is to develop a dynamic speed harmonization application (SPD-HARM) that makes use of the frequently collected and rapidly disseminated multi-source data drawn from connected travelers, roadside sensors, and infrastructure, as depicted in the image below. The application may be a vehicle-integrated device (e.g., a vehicle manufacturer-installed or aftermarket integrated device), a personal wireless application (e.g., a smartphone or other handheld device), or another application capable of collecting, receiving, and disseminating movement and locational information. The goal of SPD-HARM would be to improve the nature, accuracy, precision, and speed of dynamic decision making by both system managers and system users.



Connected Vehicle SPD-HARM Framework

Methodology

SPD-HARM is implemented to reduce the intensity of shockwaves by allowing vehicles to adjust their speeds in a dynamic fashion. A key component of the system entails predicting the onset of shockwaves before they occur so that speed recommendations can be provided to approaching vehicles in order to reduce the intensity and speed of these shockwaves.

It should be pointed out that two main differences exist between the proposed SPD-HARM and existing variable speed limit (VSL) systems. Firstly, the proposed approach is based on predicted traffic conditions as opposed to the real-time or short past traffic status. Assuming that the downstream state involves no congestion, a recommendation to adjust the speed will not be made in existing VSL systems. Consequently, the upstream vehicles may still experience sudden decelerations while approaching downstream congestion, which would result in more fuel consumption levels or may be even cause an accident. Comparatively, the proposed approach can fully utilize the prediction result of future congestion and then provide an optimized speed recommendation to reduce congestion and save fuel consumption. Secondly, the use of a dynamic and continuous data collection and dissemination system can be achieved in the proposed SPD-HARM architecture. State-of-the-art VSL systems use stationary sensors to monitor traffic states and fixed VSL structures to deliver the information to the drivers. Consequently existing systems are based on discrete location systems, which limit the full potential of the speed harmonization concept. However, with the introduction of CV systems it is possible to dynamically detect congestion at any location and to display the information to vehicles continuously.

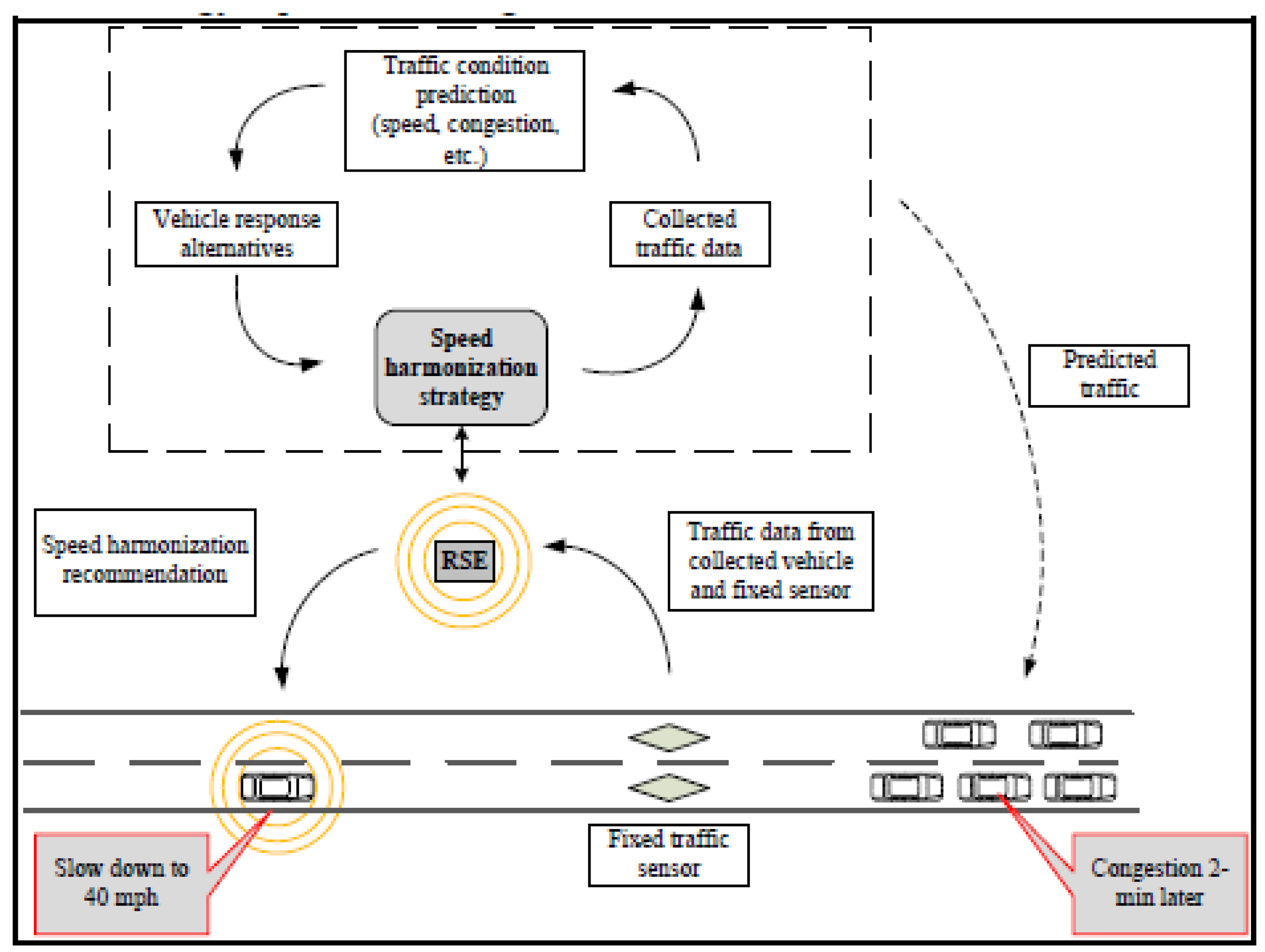


Illustration of Speed Harmonization Methodology

Experimental Scenarios

Test on Traffic Prediction Algorithm

Initial simulation tests conducted by the researchers submitting this proposal showed that the traffic speed prediction error is in the range of 3.0 to 4.5 km/h for a 5-minute prediction horizon, and the spatial-temporal propagation of shockwaves are accurately predicted. However, further testing and validation of the algorithm is needed considering different levels of congestion, different shockwave propagations, and refining and calibrating the various system input parameters.

Connected vehicle probe vehicle trajectory data and data from roadway sensors will be collected along the I-66 corridor for different days in order to test the traffic state prediction algorithm for different traffic conditions at different levels of recurrent and non-recurrent congestion. The traffic state prediction algorithm will be tested using the collected dataset and modifications will be made to the algorithm accordingly to increase its prediction accuracy.

Test on Driver Response on SPD-HARM Recommendation

This test will gather field data of driver response to speed recommendations within a CV environment. The speed recommendations from the speed harmonization algorithm will be provided to the drivers through the communication between RSE units and CV vehicles. Traffic data will be collected to evaluate the response of drivers to these speed recommendations. A model of driver response will be developed for use in the simulation analysis that is described next.

Test on SPD-HARM Algorithm

Using the validated traffic state prediction algorithm, the speed harmonization approach can be developed and the performance should be validated with respect to maximizing traffic throughput, reducing vehicle crashes, congestion and fuel consumption. A simulation test should be conducted before the field testing of SPD-HARM approach on the Northern Virginia Connected Vehicle test-bed.

A simulation environment is anticipated to be constructed based on the connected vehicle environment on Northern Virginia test-bed. The predicted shockwaves will be used to develop speed recommendations to approaching connected vehicles in order to reduce the intensity and speed of these shockwaves. The speed recommendations will be provided to drivers through CV communication and the driver response will be generated based on the developed model from the previous test. Consequently, the system-wide traffic data can be acquired in the simulation environment implemented with SPD-HARM algorithm and the benefits of the system will be quantified in terms of the following measures: system delay, vehicle fuel consumption and emission levels using the VT-CPFM model, and crash risk using a microscopic crash prediction model developed by members of the research team.

Anticipated Results and Benefits

Speed harmonization techniques have been deployed to achieve a variety of different objectives, depending on the end goal of the deployment agency or authority. Main objectives include: (a) speed management and safety, (b) delay breakdown and throughput improvement, (c) speed control under inclement weather, (d) incident management, (e) tunnel and bridge safety, and (f) flow and safety control along work zones.

1. Reduce crashes, whether due to speeding, poor visibility, inclement weather, or construction activities. Improved safety results, in terms of reduced crash rates and less severe crashes, have shown to be the most significant and consistent achievements across the deployments examined.
2. Although not the primary goal for most U.S. and international speed harmonization deployments, improvements in throughput, though modest, have sometimes been achieved.
3. Speed harmonization implementations have been shown to have a moderately positive impact on travel time reliability, likely due to the resulting more uniform traffic flow.

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