Reducing the Communication Required By DSRC-Based Vehicle Safety Systems

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***Abstract*— We present an adaptive communication scheme for Cooperative Active Safety System (CASS). The literature surmises CASS may need a vehicle to periodically broadcast safety-related information as often as every 100 msec. Here we present a new communication design scheme, supported by simulations, that shows CASS could be enabled by broadcasting, on average, as little as once every 500 msec.**

***Index Terms*— V2V, DSRC, Vehicle Safety Communication**

I. Introduction

Active safety systems rely on object detection and ranging sensors [1]. Equipping a vehicle with a number of object detection and ranging sensors could be very expensive. In this paper, we describe a new communication scheme for Cooperative Active Safety System (CASS). CASS aims at enhancing vehicle safety by using relatively inexpensive technology alternatives combining GPS and Dedicated Short Range Communications (DSRC). In CASS, we assume that vehicles are equipped with a GPS receiver, a DSRC transceiver, and in-vehicle sensors. The safety-related information exchanged between vehicles consists of position, speed, heading, and other vehicle kinematic and dynamic information, and this is broadcast to all neighbors within a certain communication range (or power). We built the first Wi-Fi and GPS based CASS prototype able to provide safety warnings for a variety of driving situations on sub-second time-scales [2]. Our design also resolved some of the challenges on reliably estimating vehicle position [3].

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This paper presents a new communication design intended to be used by CASS vehicles to track each other as required, and to provide driver assistance and safety. Prior communications designs for CASS have relied on periodic safety-related information broadcasts, typically every 100 msec, by each vehicle that is sometimes supplemented by event-driven safety messages. The communication design presented here is designed to be adaptive with a message every 500 msec on average per vehicle. This potential saving in the broadcast rate of safety messages is the motivation for our work. The emphasis of this paper is more on establishing the inter-vehicle messaging rate for vehicle safety communications rather than the communication performance that will result from the rate.

II. DESIGN

Fig. 1 shows the design block diagram that we propose for adaptive communication in CASS. Each vehicle in CASS has an extended Kalman filter, called the "Self Estimator" that estimates its position, speed, and heading by integrating differential GPS and in-vehicle sensors.

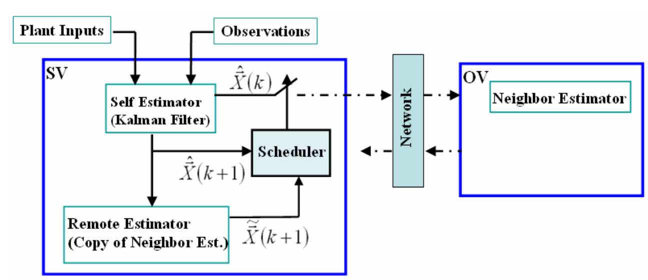

Fig. 1. Design Block Diagram

We also require each vehicle to run an estimator for each vehicle in its neighborhood. This is called the "*Neighbor Estimator*" in Fig. 1. The outputs of the vehicle Self Estimator and the Neighbor Estimators for all the neighboring vehicles should drive the CASS safety applications in the vehicle. There is a third estimator, called the "Remote Estimator" in Fig.

1. This exists solely to enable our adaptive communication design. Each vehicle has one Remote Estimator. Let the Remote Estimator of vehicle *i* be denoted by RE_i. Let the Neighbor Estimator run by neighbor *j* for vehicle *i* be denoted NE_{ji}. The purpose of RE_i is to estimate the output of all the NE_{ji}'s. It is an estimator of all the Neighbor Estimators.

A vehicle's decision to communicate or not communicate at any instant of time is taken based on the difference between the outputs of its Self Estimator and Remote Estimator. In this paper, all communications are triggered by thresholds on differences in the longitudinal and lateral positions output by the Self and Remote Estimators. The Remote and Neighbor Estimators use the same model. The Remote Estimator estimates by running the Kinematic equations.

III. Results

To evaluate the communication rates produced by this design we have incorporated our design into Ruby SHIFT [4] traffic simulator. We present simulation results for two vehicular traffic scenarios: regular freeway and freeway with a merge lane. We use 0.5 m and 0.3 m as values for the longitudinal and lateral errors thresholds, respectively, violations of which trigger communication from the vehicle. Our performance measure is the number of messages per second per meter.

Fig. 2 presents the spatial density of communication for a straight section of a freeway with our design. For this run, the average inter-vehicle distance is 40 m with maximum flow density of 55 meters per vehicle per lane. Thus, the traffic is flowing freely. If periodic communication was used at 10 Hz (i.e. without adaptive communication rate control), within a 300m distance window and 2 sec time window, the number of messages produced would be 600. Fig. 2 shows the number of messages with our communication design at all points on the freeway is less than 100 messages.

Fig. 3 shows how the average communication message time interval per vehicle is changing with varying traffic flow conditions. The average time interval between messages has a mean of 520 msec and standard deviation of 27 msec. Fig. 4 presents results for a 3 lane freeway with an added merge lane. The merge lane joins the freeway at 1000 m. The average flow is 1700 vph per lane across four lanes. If periodic communication was used at 10 Hz, within the 300m distance window and 2 sec time window, on average 645 messages would be produced. Using the new communication design we see no more than 160 messages even at the merge zone.

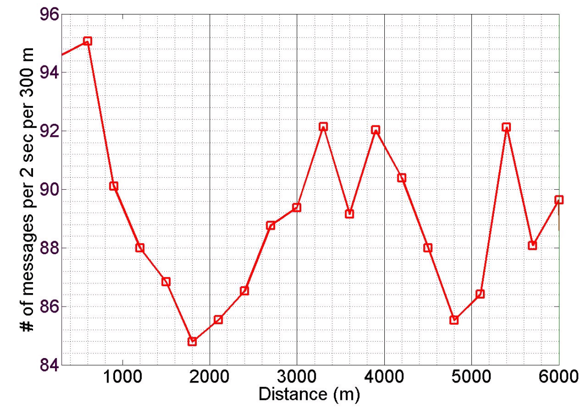

Fig. 2. Communication density in a regular 4 lane freeway

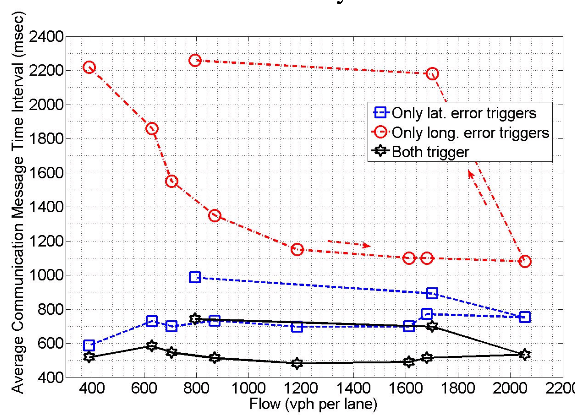

Fig. 3. Variation of the message time interval versus flow

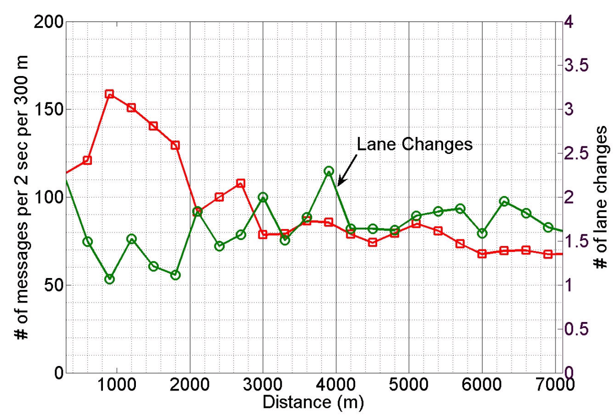

Fig. 4. Comm. density in a freeway with a merge lane

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