V2V SYSTEM CONGESTION CONTROL VALIDATION AND PERFORMANCE

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ABSTRACT:

Major international automakers have considered the deployment of the 5.9 GHz Dedicated Short- Range Communications (DSRC) on their vehicle fleets for wireless connectivity. DSRC- enabled Vehicle-to-Vehicle (V2V) communication through broadcast of Basic Safety Messages (BSMs) enables safety applications for crash warning and avoidance. However, in dense traffic conditions as the V2V deployment scales up, the resultant channel load increases and leads to channel congestion and may adversely affect the performance of the safety Applications Specifically, it provides a Congestion Control protocol for transmission rate and power adaptations to achieve robust performance in dense vehicular networks. The primary contribution of this paper is that using a congestion generation test bed that emulates channel congestion including a large number of Remote Vehicles (RVs), we can validate and test any V2V equipped vehicle for compliance .

Keywords: Dedicated Short Range Communications; V2V Scalability; Vehicular Ad Hoc Network; Vehicular Safety Communication.

1.INTRODUCTION:

Such safety applications are based on V2V safety commu- nication that includes broadcast of vehicle status information through Basic Safety Messages (BSMs). The BSMs include core state information such as Global Navigation Satellite System (GNSS) location, speed, acceleration, brake status, and path history with communication ranges of 400-500 meters, or more. In particular, detailed performance requirements are specified to ensure the accuracy of GNSS position, speed, heading, acceleration, and rate among other factors with respect to ground truth. In a high traffic environment, where there is a high number of vehicles (transmitters), the channel suffers congestion due to rising interference and channel contention .

When it comes to channel capacity, presented some fundamental limits especially as a wireless network scales. The conventional approach to handle interference in the IEEE 802.11p standard is to use Carrier-Sense Multiple Access with Collision Avoidance (CSMA/CA) as the medium access protocol. In CSMA/CA, when a node (or vehicle) has a packet to transmit it first listens to the channel. In a message rate control based approach is proposed to adapt the BSM transmission rate (frequency) based on a binary comparison between measured channel load and a target threshold. Binary message rate control is also the subject of in which the authors propose using an Additive Increase Multiplicative Decrease (AIMD) message rate update mechanism for DSRC vehicular safety communication.

They present results from prototype radio tests and computer simulations that illustrate effective message rate control for hundreds of emulated or simulated vehicles. The authors in present simulation of two popular rate algorithms and compare the performance with different metrics. In the authors propose an algorithm to minimize the average system information age in a congested environment. Through the simulations, they also show that simple contention window size adaptations (i.e. increasing or decreasing the window size) are unsuitable for reducing the information age. All these factors and considerations have been merged in the SAE J2945/1 standard which provides a congestion control protocol that adapts the transmit power and rate control of V2V BSM transmissions in order to achieve satisfactory safety performance. The CC protocol executes

distributed on each DSRC- equipped On-board Equipment (OBE) installed in a vehicle and adapts its radiated (transmit) power and the Inter-Transmit Time (ITT) based on the channel congestion levels the OBE experiences locally. The underlying algorithm is designed to be opportunistic to ensure channel utilization remains below the saturation level while V2V safety applications can have a good performance. The authors in review the CC protocol presented in the J2945/1 standard and propose

2. TEST SETUP:

(i) No obstruction within 5o above the mask. (ii) At least 7 healthy satellites used. (iii) With Horizontal and Vertical Dilution of Precision (HDOP/VDOP) reported at less than or equal to

1.5 and 3, respectively. The complete set of equipment is shown in Fig: 1.

where all devices were mounted on the HV except for the RT base station.

HV unit (OBE): The DSRC device of the HV unit broadcasts BSMs using inputs from its local GNSS for basic positioning (i.e., Coordinated Universal Time (UTC),latitude,longitude, and the vehicle's. Controller Area Network (CAN) bus for additional inputs such as speed, longitudinal acceleration and yaw rate. The broadcast BSMs are secure BSMs as they are signed with certificate digests. Furthermore, in the absence of any congestion, the nominal (i.e., baseline) settings for the transmission frequency and the transmit power are 10 Hz (i.e., ITT of 100ms) and 20 dBm respectively. With congestion control, the HV unit can detect the radio environment and adapt these parameters accordingly.

Ground Truth Equipment (GTE):

The HV is also equipped with an Oxford System RT-3003 high precision localization and logging unit. This tool is able to capture highly accurate position and motion data of the HV in real-time at 100 Hz. Furthermore, the RT-3003 unit receives radio- based Real-Time Kinematic (RTK) corrections from an on- site surveyed GNSS RT base station. With these differential corrections, the ground truth position has a centimeter level accuracy.

DSRC Sniffer:

The Sniffer is a DSRC receiver operating on channel 172 that captures BSMs from the HV unit and creates a log of CBP and the received packets.

Congestion Generation Tool (CGT):

This tool has several co-located

GNSS/DSRC devices that can collectively transmit a large enough number of signed BSM and WSM packets on channel 172 to emulate multiple RVs and channel congestion in a repeatable manner. Since the CGT is mounted on the HV, all the virtual RVs appear within a designated range of the HV as it moves.

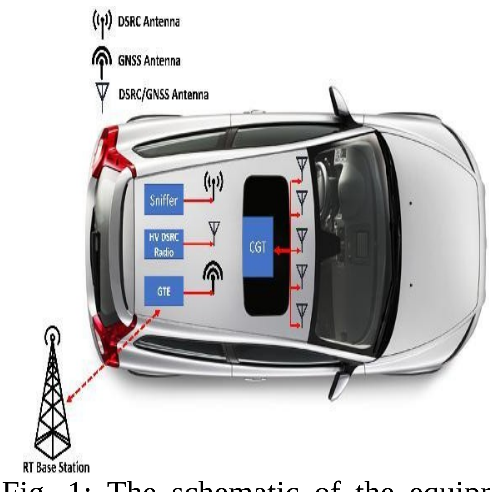


Fig. 1: The schematic of the equipment for validating the SAE J2945/1 congestion control protocol

3. TRACKING ERROR AND ITS CHALLENGES IN CSMA/CA CHANNEL:

In V2V safety communication, each vehicle continuously broadcasts its own status (e.g., position, speed, and heading) in BSMs. Each vehicle also tracks the movements of neighboring vehicles based on BSMs received from them. In intervals between BSMs from a moving vehicle, its current location has to be estimated. The accuracy of the vehicle's estimated position is measured in terms of distance from the ground truth. This displacement or distance error is a key consideration in crash avoidance applications.

A. Position Error vs. Tracking Error:

The position error represents the distance error from the ground truth and the HV's local GNSS position contained in a BSM. At the time instance that

the HV's BSM is generated, the position error e(t) is defined as,

qe(t) = (xh(t) xg(t))2 + (yh(t) yg(t))2 Where the Cartesian

coordinates (xh(t); yh(t)) and (xg(t); yg(t)) are the vehicle's GNSS position (sent in BSM) and ground truth position (reported by GTE) at time.

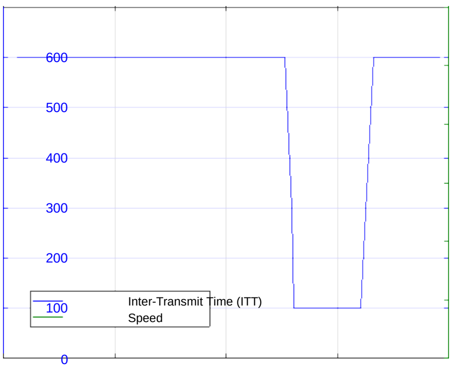
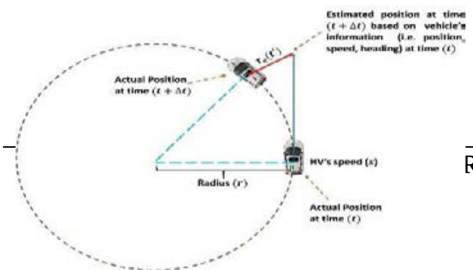


FIG 2 :Emulated RVs 160, CBP 60%



4. CONGESTION CONTROL ALGORITHUM:

Fundamental bound on the relationship betweenthe communication rate and the corresponding range is presented, where as a network becomes dense, nodes need to throttle down the rate and transmission power so as to share the limited channel resources properly. Based on this principle, under an optimal protocol, the vehicles should adapt their rate and transmit power in such a way that minimizes the tracking error for better safety performance.

1. Rate control, which adapts the ITT and decides how frequently the HV should broadcast its own state information in the BSMs.
2. Power control, which adapts the radiated (transmit) power and determine how far the HV's state information should be broadcast, and is mainly based on CBP.

A. Rate Control:

The default mode that determines the ITT is the average number of vehicles Ns(t) within a range of vP ER Range meters from the HV at time t.

Ns(t) = N + (1)Ns(t
vTxRateCntrlIn)

1. Critical event
2. High tracking error

J2945/1 Parameters	Mode/Value
Data Channel Frequency	5855 5865 MHz (ITS channel 172)
Receiver Power Sensitivity	92 dBm
OFDM Data Rate	6 Mbs
vMax IT T	600 ms
vP ERRange	100 m
vT xRateCntrlInt	100 ms
vDensityW eightFactor	0:05
	75
T_{min}	0:2 m
T_{max}	0:5 m
vRP_{min}	10 dBm
vRP_{max}	20 dBm
vMinCBP	50%
vMaxCBP	80%
vSUP RAGain	0:5
B	25

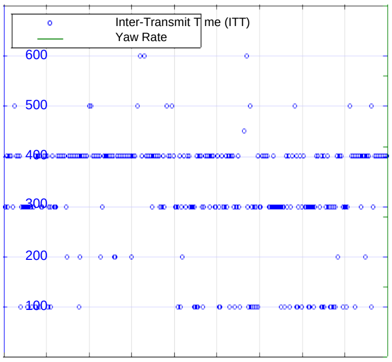
B. Power Control:

When an HV transmits a BSM based on a critical event or due to high tracking error as in the transmit or radiated power (RP)1 is set to the maximum vRP M ax.

Fig. 3: On an ideal circular track, the HV's tracking error is the displacement between the straight (extrapolated) and the actual turned paths

5. SIMULATION RESULT:

1. STATIONARY VEHICLE VALIDATION:



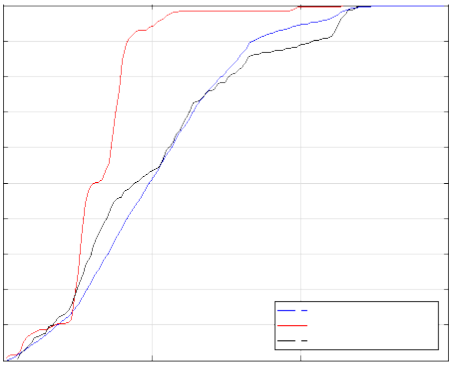
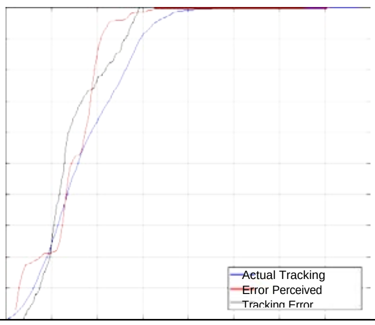


Fig. 4: The ITT drops from 600 ms to lower values in both moving tests, where the HV is either turning (a) or decelerating (b).

2. Moving Vehicle Validation:

In this test, the HV is moving around a circular track of radius r = 100 m at cruise speed of 55 Kph on the skid pad (see Fig. 2(a)). Furthermore, the CGT sets two channel quality levels at 0% PER and 30% PER with 90 seconds for each threshold.



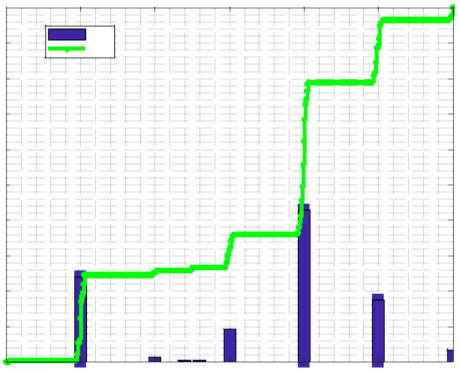
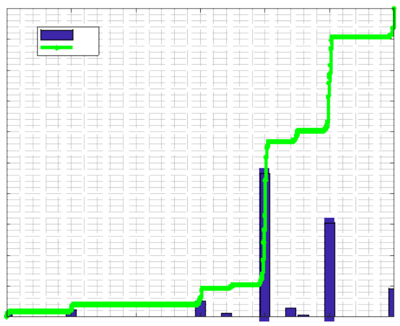


Fig. 5: On a circular track, the ITTs values fall much below 600 ms, where, in contrast to 0% PER in (a), with a lower channel quality (i.e. 30% PER) in (b), many more ITT samples are at 100 ms.

3. Safety Application Aspects: We also plot the CDF of the position error and the (actual) tracking error in Fig. 7 for this test. To reiterate, the former represents the distance between the ground truth and HV unit in terms of ground position when a BSM is transmitted.



(b) PER = 0.3

Fig. 6: Number of RVs = 160, CBP = 60%. The CDFs of position error and tracking error are

well within 1.5 m under the CC algorithm, thus meeting the safety application criterion in congestion environments for two PER thresholds

4. Critical Events Validation:

We next consider the results for a critical event condition such as hard braking. Under the test, the HV drives on a straight path constantly at 90 Kph (or)26 ms1 for a brief interval followed by a sharp deceleration.

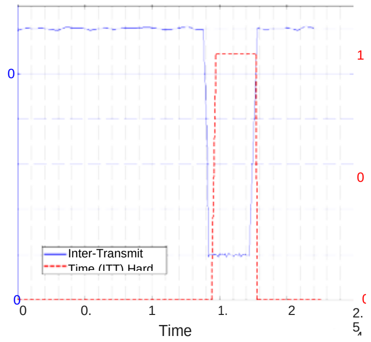


Fig. 7: (a) In a critical event, shown as a binary event (i.e. 0 or 1), the ITT values fall from 600 ms to 100 ms. In (b) the corresponding RP increases to the maximum of 20 dBm.

6.CONCLUSION:

We have presented field test results on DSRC-based V2V system in a congestion environment, which complied with the SAE J2945/1 standard for V2V minimum performance requirements. Our tests

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