Demo: Performance Evaluation of IEEE802.11p Channel Estimation Schemes in Vehicle-to-Vehicle Environments Based on SDR Testbed

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***Abstract*—It is generally difficult to estimate rapid time-frequency variant channels in IEEE802.11p systems due to insufficient number of pilots in a data packet. To resolve such a problem, advanced channel estimation schemes have been developed in literature. However, their performance has mostly been proven through computer simulations, which is insufficient for reflecting the actual road environments. In this paper, we introduce the result of our field trials based on the software defined radio testbed to evaluate the performance of four celebrated channel estimation schemes, namely, LS, STA, CDP, and TRFI in various vehicle-to-vehicle communication environments.**

***Index Terms*—IEEE802.11p, vehicle-to-vehicle, channel estimation, software defined radio, field trial**

I. Introduction

Recently, research on autonomous vehicles and cooperative intelligent transportation system has been actively conducted and vehicle-to-everything (V2X) communication systems are being considered as core technology. To support V2X, the IEEE802.11p standard (hereinafter referred to as 11p) has defined the physical layer specifications with minor variations from IEEE802.11a [1]. In particular, 11p adopted 10MHz bandwidth instead of 20MHz to cope with high mobility of vehicles. By halving the bandwidth, the symbol period and guard interval are doubled, making it more robust to inter-symbol interference, inter-carrier interference and more resistant to multi-path fading. However, a large Doppler frequency shift that shortens the channel coherence-time due to high mobility of vehicles has not been properly addressed in the standard. For this reason, vulnerability to rapid time varying channels still remains an issue.

To resolve such a problem and guarantee high reliability of data even at the fast moving terminals, several advanced channel estimation schemes have been developed in literature. However, their performance has mostly been proven through computer simulations, which is insufficient for reflecting actual road environments. In this paper, we introduce the result of our field trials to evaluate the performance of four celebrated channel estimation schemes, namely, least square (LS) [1], spectral temporal averaging (STA) [2], constructed data pilot (CDP) [3], and time domain reliability test and frequency domain interpolation (TRFI) [4] in various vehicle-to-vehicle (V2V) channel environments.

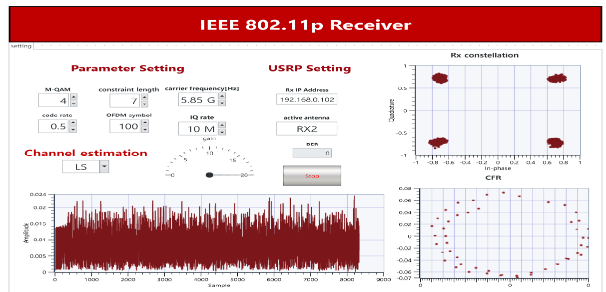

Fig. 1. Console window for IEEE 802.11p Receiver

II. IEEE802.11p Testbed Implementation

For the field trials, we implement a software defined radio (SDR) testbed by utilizing the NI USRP equipments and LabVIEW software. Specifically, we use the USRP-2921 and 2943R equipments for transmitting and receiving ends, respectively, and define the transmit signal waveforms and the channel estimation and signal detection schemes at the receiver using LabVIEW NXG3.0. Fig. 1 shows a console window monitoring the signals being received at the 11p receiver. The receiver can choose the channel estimation method among the aforementioned four schemes. Then, a normal reception and channel estimation can be confirmed through the graphs at the top and bottom right which show the received signal constellations and estimated channel coefficients, respectively.

To meet the 11p standard, we set the center frequency and bandwidth to be 5.85GHz and 10MHz, respectively. For the sake of simplicity, in this paper, the code rate is fixed to 0.5 and the data field has 100 OFDM symbols so that a packet delivers 600 and 1200 data bytes in QPSK and 16-QAM modulation, respectively. The transmit power is set to be 20dBm. In the preamble, the receiver employs the Schmidl & Cox algorithm [5] for time-frequency synchronization and the energy thresholds, e.g., -79dBm for QPSK and -74dBm for 16-QAM to discard packets that are severely damaged by noise.

As shown in Fig.2, we have two cars with similar height of approximately 1.4m to evaluate the V2V performance. For radio transmission and reception, we put the USRP-2921 and 2943R equipments on the transmitting and receiving cars, respectively with laptop computers and isotropic antennas with

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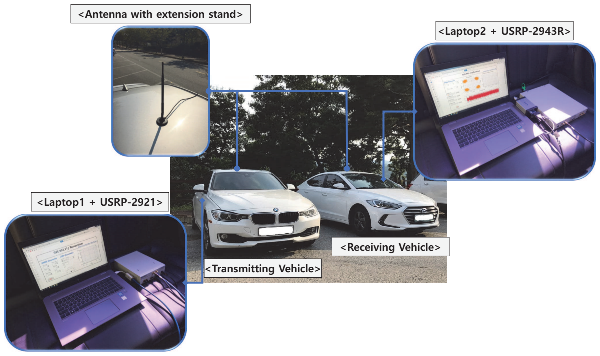

Fig. 2. Photo of equipment setup to perform Field test

gain of 9dBi mounted on top of the vehicles. The extension cable loss is 3dB. We use the gigabit ethernet and PCIe cables for 16-bit quantized IQ data transfer between the laptops and the USRP-2921 and 2943R equipments, respectively.

III. Field Trials and Results

We conduct field tests in four different V2V scenarios: highway, suburban, urban, and approaching. In the highway, suburban, and approaching scenarios, the line-of-sight signals are dominant because low density of vehicles and obstacles. On the contrary, in the urban scenario, none line-of-sight propagation occurs in the shadowed area caused by surrounding vehicles and buildings. We have driven the two cars in the same direction in the highway, suburban and urban scenarios at the speeds of approximately 100km/h, 70km/h and 30km/h, respectively, whereas they moved in the opposite direction at the speed of approximately 110 km/h in the approaching scenario.

In this work, we evaluate the channel estimation performance via packet delivery rate (PDR) that measures the number of correctly received packets at the receiver among the total transmitted packets. Figs.3 and 4 compare the PDR performance of various channel estimation schemes. For all scenarios, we observe that the conventional LS scheme in IEEE802.11p hardly meets the 90% PDR requirement for basic safety messages. In the meantime, it has been recognized in literature [6] that the performance gain of STA is pronounced in the low signal-to-noise ratio (SNR) region attributed to the noise attenuation effect, while CDP and TRFI achieve gain at high SNR. Interestingly, our field trials demonstrate that STA outperforms CDP and TRFI in most cases. This is because the received signals in V2V scenarios are usually measured at low SNR region due to relatively long propagation distance between the vehicles. We expect from the results that STA should be a best choice among the four when we deploy the V2V communication systems. The performance of all schemes, however, rapidly deteriorates as the modulation order and the relative speed (or Doppler frequency shifts) become higher as observed in the approaching V2V scenario with 16-QAM. Therefore, it is still challenging to achieve high data rates in fast moving vehicles and further research needs to be done in the future.

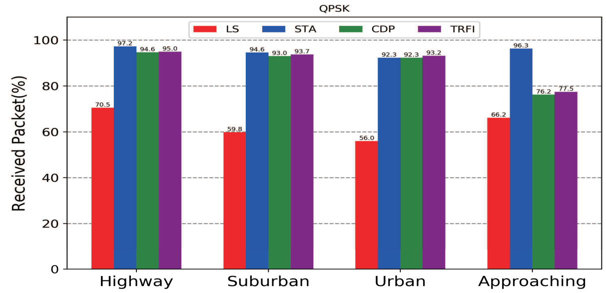

Fig. 3. PDR performance comparison with QPSK

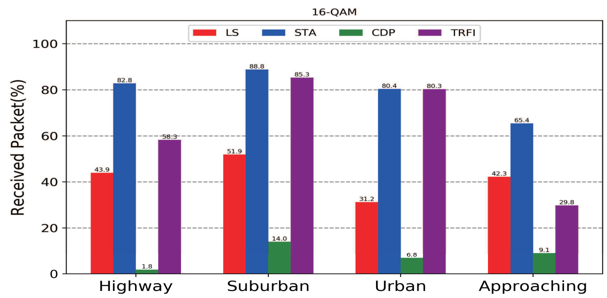

Fig. 4. PDR performance comparison with 16-QAM

IV. Conclusion

In this paper, we investigated the actual V2V performance of four different IEEE802.11p channel estimation schemes. First, we have described the proposed 11p testbed based on the SDR platform. Then, we introduced the result of our field trials in various V2V scenarios. Our experiments demonstrate that STA is generally a better choice than the others in V2V environments attributed to its advantages at low SNR. Further research is still needed to support both higher data rates and faster movement speeds.

V. Acknowledgement

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