Assessing the impact of CAM messages in vehicular communications in real highway environments

Vincent Charpentier[*‡], Nina Slamnik-Krijestorac[*], Johann Marquez-Barja[*]
University of Antwerp - imec, IDLab research group, Antwerp, Belgium
E-mail: {vincent.charpentier,nina.slamnikkrijestorac,johann.marquez-barja}@uantwerpen.be
[‡]Smart Networks and Services, Fondazione Bruno Kessler, Trento, Italy

***Abstract*—Along with an increased interest for connected vehicles and autonomous driving, the Cooperative Intelligent Transportation Systems (C-ITS) are being investigated and validated through the use of C-ITS messages, such as Cooperative Awareness Messages (CAMs). In this paper we demonstrate a tool to support research on CAMs, since C-ITS deploy the Cooperative Awareness Basic Service to exchange CAMs among road C-ITS entities, e.g., vehicles and roadside units (RSUs). These messages provide awareness of traffic information in the Non-line-of-sight (NLOS) of the vehicle (e.g., speed, location, heading), and are an enabler of improving safety in vehicles. Therefore, it is important that those messages are received at the receiving C-ITS vehicle with low latency. In this demo, we showcase how the size of a particular CAM that carries information about the vehicle and surrounding infrastructure affects the latency. In order to demonstrate this effect, we use two leading technologies that support the first generation V2X communication respectively ITS-G5 (IEEE 802.11p) and LTE-V2X (3GGP). We have tested our proposal in a real life C-ITS testbed, at the Smart Highway located in Antwerp, Belgium.**

***Index Terms*—autonomous driving, C-ITS, CAM, ITS-G5, LTE-V2X, V2X, testbed, vehicular communications.**

I. Introduction

Given the ever increasing number of vehicles on the road, there is an evident increase in the occurrence of road accidents. Thus, it is essential to find effective solutions towards improving safety on the roads. One prominent way to do that are Cooperative Intelligent Transportation Systems (C-ITS) since it supports connectivity between road and user applications, which aims to increase road safety, efficiency and driving comfort.

V2X communication connects vehicles with all other participating C-ITS devices [1]. Vehicular networks rely on Cooperative Awareness Messages (CAMs), specified by the European Telecommunication Standard Instituted (ETSI), and Basic Safety Messages (BSMs) specified by the Society of Automotive Engineers (SAE). A CAM message is constructed out of two mandatory containers, i.e., the basis vehicle and high frequency containers, and two optional containers, i.e., the special and low frequency containers. These two optional containers are mostly used by special vehicles (e.g., emergency vehicles). So, with emergency vehicles it is crucial that those CAM messages are received on time with a low latency.

In order to exchange those messages with its surrounding C-ITS environment, there are currently two leading technologies supporting the first generation V2X communication. The first technology is IEEE 802.11p, which is the basis for ITS-G5 standardized by ETSI and Dedicated Short-Range Communications (DSRC) standards [2,3]. The IEEE 802.11p is extensively tested and analyzed globally considering V2X communications [3]. The second leading technology supporting the first generation V2X is a cellular-based technology that is defined by the Third Generation Partnership Project (3GPP) in Release 14 and 15 named as Long-Term Evolution-V2X (LTE-V2X), the Cellular based technologies can also be referred as Cellular-V2X (C-V2X).

In this paper, we present and demonstrate a portable software tool to investigate how CAM messages affect the latency, in case they carry different amounts of information. In particular, we consider latency as a total time needed for communication (transmission delay over ITS-G5 and LTE-V2X) and computation (constructing CAM message, encoding, decoding). Our demo setup is built on the real-life testbed, Smart Highway (Antwerp, Belgium), and for the performance evaluation it utilizes both ITS-G5 (Cohda MK5) and LTE-V2X (Cohda MK6c) technologies, as well as the On-Board Unit (OBU) in a vehicle, and Roadside Unit (RSU) as a part of the C-ITS infrastructure. We used both for ITS-5G and LTE-V2X 180 channels, with a channel bandwidth of 10MHz, TX power of 23 dBm with a data rate of 6 Mbps.

Fig. 1. Location of the RSUs along the Smart highway testbed implemented on top of the E313 highway in Antwerp, Belgium [4]

II. Technology

1) Smart Highway: The setup we use to demonstrate the experiment is the Smart Highway testbed located in Antwerp, Belgium [5] as shown in Figure 1. It is a 4km highway strip that consists out of seven Roadside Unit (RSU), and one Smart Highway test vehicle, a BMW X5 xDrive25d LO enhanced with an Onboard Unit (OBU) as shown in Figure 4. The Smart Highway also consists of a permanent setup that has one OBU and one RSU as shown in Figure 3, this is the setup we use in this demonstration. CAM messages are sent from the Onboard Unit (OBU) to the Roadside Unit (RSU) over ITS-G5 and LTE-V2X. The OBU from the permanent setup is not mobile, the CAMs are therefore sent every second in time to fulfill the CAM generation standard. So, we mimic if the vehicle is standing completely still.

2) CAMINO: The CAMINO[1] framework is a flexible hybrid V2X connectivity platform for the Cooperative, Connected and Automated Mobility (CCAM) services [4]. It provides integration with existing and future short and long-range V2X technologies such as ITS-G5, C-V2X PC5, and C-V2X Uu (5G/4G). The generated messages can be transmitted in a flexible way by one or multiple V2X technologies, increasing the transmission capacity or enhancing the transmission reliability.

3) DUST: is the The Distributed Uniform STreaming (DUST[2]) framework is a publish/subscribe communication middleware for distributed applications [6]. CAMINO makes use of DUST. All of our developed tools, i.e., the CAM decoder and CAM generator, use DUST as a communication middleware.

4) CAM decoder and generator: We developed a CAM message generator as shown in Figure 2, that takes a timestamp (called timestamp-a) for every CAM that will be created. On the receiving side we developed a CAM decoder as shown in Figure 2, to decode the CAM message and when it is available for the application (fully decoded) we take a timestamp, i.e., timestamp-b. Therefore, latency can be evaluated by measuring the difference between these two timestamps.

III. Demonstration Setup

In the demonstration, we show our system in a realistic vehicular environment, built using the Smart Highway testbed,

[1]CAMINO is developed by the IDLab research group, part of IMEC.
[2]DUST is developed by the IDLab research group, part of IMEC.

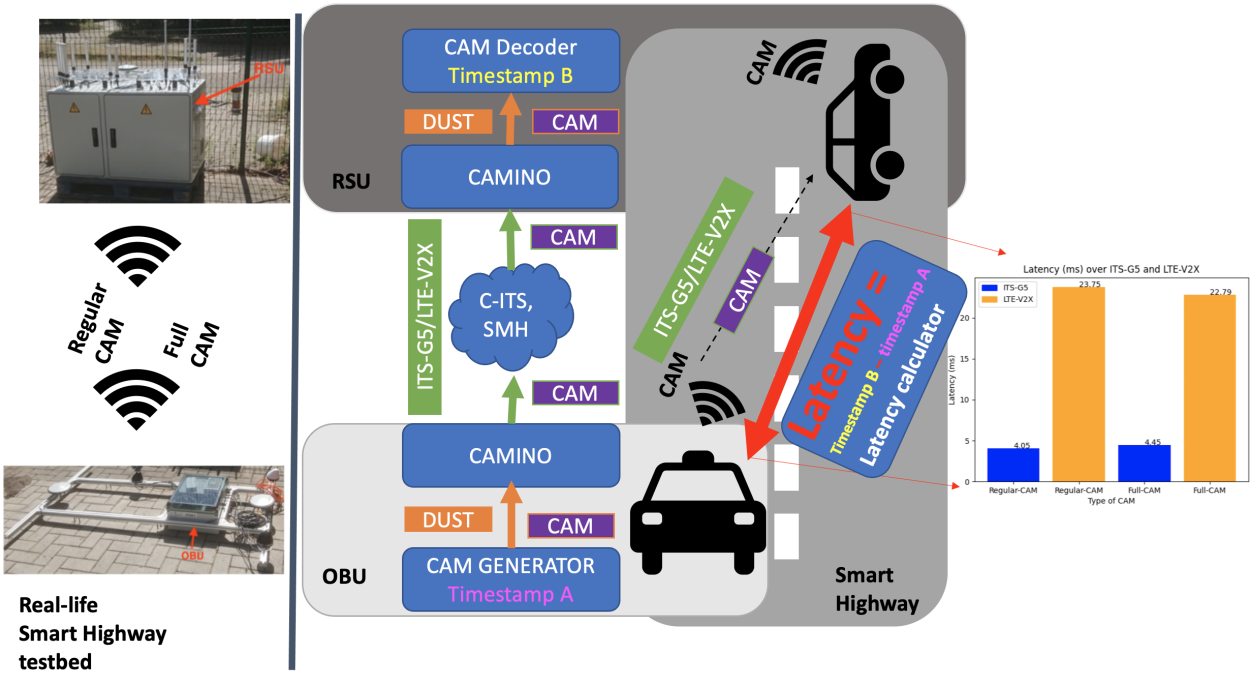

Fig. 2. Visualization of the demonstration environment

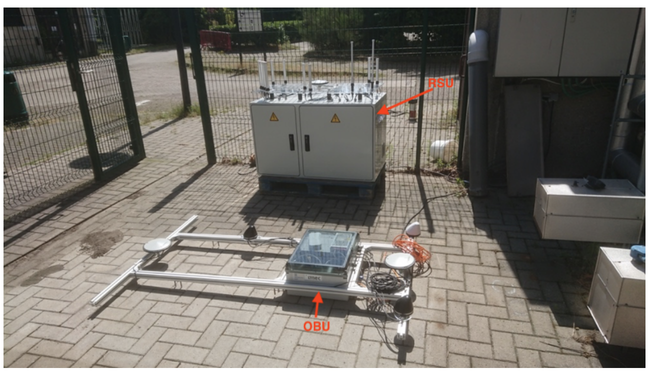

Fig. 3. Secondary test-site of the Smart Highway testbed at Campus Groenenborger of the University of Antwerp

Fig. 4. Smart Highway testbed test vehicle [4]

as shown in Figure 2. The setup consists of three main components: i) the CAM message generator, ii) the CAM message decoder, and iii) the latency calculator. Within the CAM message generator we can specify the type of a CAM message, such as regular CAM message, i.e., a CAM message that consist only of its two mandatory containers. The other option is to send a Full CAM message, i.e., a CAM message that consists of its two mandatory, and two optional containers. This demo also provides insight into the process of selecting the technology type, i.e., ITS-G5 or LTE-V2X, thereby considering the technology compatibility with the size of a CAM message. These insights are provided by our latency calculator, since it calculates the average latency value from the timestamps logged by the CAM generator and the CAM decoder. The results are shown on the bar chart on Figure 2. We will also demonstrate a road with future work we are planning to further research with our system, such as the effect of increasing the distance between the transmitting vehicle vehicle (OBU) and the receiving RSU, on the average latency.

Acknowledgment

This work was carried out with the support of the 5G-Blueprint project, funded by the European Commission through the Horizon 2020 programme under agreement No. 952189. This work has received partial funding from the Fed4FIRE+ project under grant agreement No 732638 from the Horizon 2020 Research and Innovation Programme.

References

[1] S. Chen, J. Hu, Y. Shi, L. Zhao, and W. Li, “A Vision of C-V2X: Technologies, Field Testing, and Challenges With Chinese Development,” *IEEE Internet of Things Journal*, vol. 7, no. 5, pp. 3872–3881, 2020, doi: https://doi.org/10.1109/JIOT.2020.2974823.

[2] R. Molina-Masegosa, J. Gozalvez, and M. Sepulcre, “Comparison of ieee 802.11p and lte-v2x: An evaluation with periodic and aperiodic messages of constant and variable size,” *IEEE Access*, vol. 8, pp. 121 526–121 548, 2020, doi: https://doi.org/10.1109/ACCESS.2020.3007115.

[3] M. N. Tahir and M. Katz, “Performance evaluation of ieee 802.11 p, lte and 5g in connected vehicles for cooperative awareness,” *Engineering Reports*, p. e12467, 2021, [Online] Available: https://onlinelibrary.wiley.com/doi/full/10.1002/eng2.12467, Last accessed on: January, 2022.

[4] D. Naudts, V. Maglogiannis, S. Hadiwardoyo, D. van den Akker, S. Vanneste, S. Mercelis, P. Hellinckx, B. Lannoo, J. Marquez-Barja, and I. Moerman, “Vehicular Communication Management Framework: A Flexible Hybrid Connectivity Platform for CCAM Services,” *Future Internet*, vol. 13, no. 3, p. 81, 2021, doi: https://doi.org/10.3390/fi13030081.

[5] J. Marquez-Barja, B. Lannoo, D. Naudts, B. Braem, V. Maglogiannis, C. Donato, S. Mercelis, R. Berkvens, P. Hellinckx, M. Weyn *et al.*, “Smart Highway: ITS-G5 and C2VX based testbed for vehicular communications in real environments enhanced by edge/cloud technologies,” in *EuCNC2019, the European Conference on Networks and Communications*, June 2019, pp. 1–2, [Online] Available: https://biblio.ugent.be/publication/8642435, Last accessed on: January, 2022.

[6] S. Vanneste, J. de Hoog, T. Huybrechts, S. Bosmans, R. Eyckerman, M. Sharif, S. Mercelis, and P. Hellinckx, “Distributed uniform streaming framework: an elastic fog computing platform for event stream processing and platform transparency,” *Future Internet*, vol. 11, no. 7, p. 158, 2019, doi: https://doi.org/10.3390/fi11070158.