Smart Highway: ITS-G5 and C-V2X based testbed for vehicular communications in real environments enhanced by edge/cloud technologies

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***Abstract*—Imec is building its Smart Highway testbed for vehicle-to-everything (V2X) communication, located in Antwerp, Belgium. The Smart Highway test site is being built on the E313/E34 highway and shall be extended to the (urban) road network ensuring a connection to the Antwerp / imec Smart Cities initiative providing a mixed environment for testing various V2X communication protocols and autonomous car functionalities. The testbed can be considered as a platform for (1) V2X connectivity, (2) Edge computing, and (3) precise positioning.**

***Index Terms*—vehicular communications infrastructure, testbeds, V2X, connected cars, edge/cloud technologies**

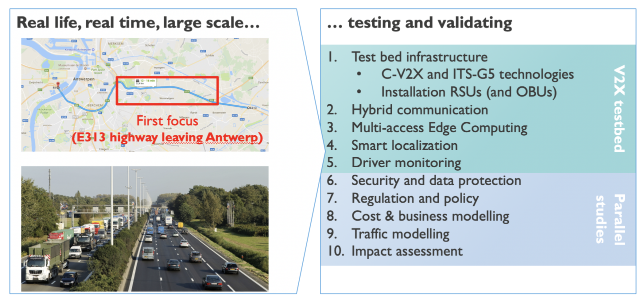

Fig. 1. Smart Highway approach

I. Introduction

The Smart Highway testbed will be one of the most advanced large-scale deployments in Europe focused on the 5G V2X use cases [1], including an optical fiber ring along the highway. This advanced deployment works as an enabler for testing new 5G features such as centralization and virtualization of the network, as well as new edge computing concepts enabling future AI-driven use cases. The initial trials [2], done on April 2019, have publicly demonstrated the feasibility of such ambitious infrastructure deployment.

V2X connectivity: For reasons of flexibility (switching between technologies), future proofness (supporting new upcoming standards) and technology availability (being ahead of the commercial chipsets), our testbed is being equipped with Software Defined Radio (SDR) modules, which heavily increase the technical capabilities of the Smart Highway test bed and enable its evolution towards 5G. By implementing V2X communication technologies in our SDR platform, we aim for having a flexible V2X testbed open to the whole V2X community (open source based). Both the 3.5 and 5.9 GHz bands will be supported, allowing an evaluation of C-V2X in both bands, investigating the coexistence with current technologies such as ITS-G5 (IEEE 802.11p) and optimizing the spectrum usage.

Edge computing: The Smart Highway platform will propagate data from Road Side Units (RSUs) to the backend, where it will be stored and offered for secure retrieval by services (e.g. dashboards, distributed intelligence, machine learning) and / or other backend traffic management platforms. The platform will also allow for configurable data propagation from the backend towards selected (in a geo-aware manner) roadside-infrastructure (e.g. in the case of an accident, the RSU informed of the accident populates this data to the backend, which in turn propagates this data to roadside-units near the accident for swift notification of cars in the vicinity). In addition to the backend, the RSUs are equipped with server-class computing units in order to extend the capabilities to right at the edge. Services will make use of fully hierarchical cloud deployment, providing in this way the maximum flexibility in terms of latency.

Precise positioning: The Smart Highway platform is equipped with GNSS receivers, allowing for GPS, Galileo, or GLONASS positioning. Furthermore, the positioning can be enhanced with RTK correction factors from the FLEPOSS system or from RTK correction signals calculated at the RSUs.

The Smart Highway testbed is located in the area of Antwerp in Belgium. Imec-IDlab is building its Smart Highway testbed for vehicle-to-everything (V2X) communication that will be operational by mid-2019, with already initial trials done in Q1-2019. The Smart Highway testbed is being built over the E313 highway and shall be extended to the (urban) road network ensuring interconnection to Citylab testbed [3] providing a mixed environment for testing various V2X communication protocols and autonomous functionalities. A test site of around 30 km is aimed for, as shown in 1. Along the road, Road Side Units (RSUs) are being installed to support short-range V2X communication (5.9 GHz) based on ITS-G5 and C-V2X (PC5 interface) between the vehicles and the roadside infrastructure. Also long-range V2N communication (3.5 GHz) is aimed for by offering small cell capabilities (Uu interface) in the RSUs and making a connection to the LTE macro eNBs. The long-range communication is based on 4G and will be upgraded towards 5G-New Radio (5G-NR) when available. This testbed addresses the current and future industry and research demand for testing real vehicular communications. Moreover, with this testbed, and through different European and Belgian/Flemish Regional projects we will be able to focus on: a) vehicular communications, b) hybrid communications, c) multi-access edge computing, d) localization, e) driver monitoring, f) security and data protection, g) regulation and policy, h) cost and business modelling, i) traffic modeling, and j) impact assessment.

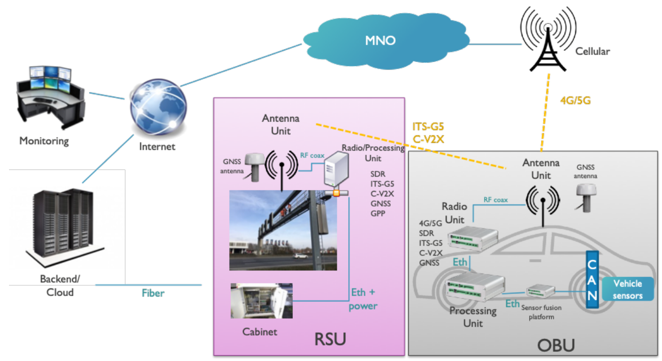

Fig. 2. Smart Highway Architecture

II. Smart Highway Testbed Architecture

The Smart Highway platform consists of the following main features (please, refer to Figure 2):

- **Cloud-based backend** (storing data, offering historical data, allowing data to be queried and interfacing with other traffic data backends to exchange information). Traffic controllers can configure this backend with regards to data propagation rules.
- **Road Side Units (RSUs)**, collecting and sending data from / to vehicles and roadside-infrastructure on the one hand and the backend on the other. A test site of initially 10 km, consisting of ca. 15 RSUs, is aimed for. Along the highway, RSUs are being installed to support direct V2X communication (5.9 GHz) based on ITS-G5 and C-V2X (PC5 interface) between the vehicles and the roadside infrastructure (Vehicle-to-Infrastructure, or V2I). Since the RSUs are equipped with the last generation of SDR boards, we also offer Vehicle-to-Network (V2N) communication (3.5 GHz) based on the Uu interface. The V2N communication is initially based on LTE-A and will be upgraded towards 5G-NR when available. Both commercial and SDR communication modules are integrated in the RSUs. In addition to the communication modules, we have included a server-class general purpose processor (GPP) onboard for enabling edge computing and advanced, future AI-driven use cases. Furthermore, some RSUs have a module for GNSS RTK correction signals and time synchronization (5 ns).
- **Vehicles, with on-board units (OBUs)**, and roadside-infrastructure (dynamic signage, traffic lights, etc.). To setup experiments with real vehicles driving on the Smart Highway testbed site, 2 mobile OBUs are available (one of which permanently mounted on the imec test vehicle) and 1 to 3 additional OBUs will be built, enabling V2I, V2N and V2V (Vehicle-to-Vehicle) communication via the network technologies mentioned above. Also traditional long-range cellular communication using 4G (5G in future) connectivity from a mobile network operator (MNO) is supported. Interfacing towards an onboard processing unit is included, as well as edge computing capabilities employing a desktop-class GPP. Furthermore, the OBUs are equipped with a module for GNSS localization (1 cm) and time synchronization (5 ns).
- **Testbed designed for experimentation and evaluation in real-life scenarios**. On top of the next generation of communications modules, we want to provide the maximum flexibility for experimentation. Following other imec's experimental testbeds federated approach such as Citylab, w.ilab.t, virtualwall[1], the Smart Highway testbed is powered by the jFed[2] experimentation toolkit that allows experimenters to push their code to the nodes, also it offers to experimenters, the possibility of experiment scheduling and a graphical user interface (GUI) with real-time information of the experiment execution. jFed platform is supported by Linux Containers (LXC) to submit the code.

III. Conclusions

In this paper, we have briefly presented the Smart Highway testbed, where several vehicular communications use cases and technologies can be explored. This testbed is open and remotely available to the research community.

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