5GMED Connected and Automated Mobility and Future Railway Mobile Communication Use Cases in the Mediterranean Cross-Border Corridor

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***Abstract*—The 5GMED project will demonstrate advanced Cooperative, Connected and Automated Mobility (CCAM) and Future Railway Mobile Communications System (FRMCS) use cases along the cross-border corridor between Figueres (Spain) and Perpignan (France), enabled by a multi-stakeholder compute and network infrastructure based on 5G and offering support for AI functions, and deployed by MNOs, neutral hosts, and road and rail operators. Several large-scale trials will be conducted to evaluate the capabilities of 5G to meet the requirements of the use cases in the cross-border mobility scenario. In this paper, we present the 5GMED project, its use cases and the proposed 5G network architecture.**

***Keywords*—5G, use cases, CCAM, FRMCS, cross-border, trials.**

I. Introduction

A number of critical Cooperative, Connected and Automated Mobility (CCAM) use cases imply stringent real-time connectivity requirements, leading to a scenario where best-effort connectivity provisioning does not comply. The majority of current 5G deployments are not designed to meet those requirements, which include the support for ultra-reliable low-latency communication (URLLC)-type services as well as availability in sparsely populated areas for delivering high data-rates. To achieve such objectives, dense cell deployments, including necessary optical fiber roll-out as well as Multi-access Edge Computing (MEC) will be important [1].

In cross-border corridors, Mobile Network Operators (MNO), neutral hosts, and road/rail operators usually own separate network and compute infrastructures, each with their own service orchestration capabilities tailored to the business of each specific stakeholder [2]. As 5G is also expected to be instrumental for railway communications, there is the main objective to adopt novel network architectures that consider all the rail communication services over a single network, instead of the expensive mixture of access networks used today, which leads to the design principles of the Future Railway Mobile Communication System (FRMCS) [3].

Motivated by this context, the 5GMED project aims at the deployment of a multi-stakeholder network and compute infrastructure based on 5G to demonstrate advanced CCAM and FRMCS use cases along the Mediterranian cross-border corridor between Figueres (Spain) and Perpignan (France). In 5GMED, several novel technologies are under investigation to meet the requirements of the use cases. These technologies include enhancements to accelerate 5G roaming procedures across MNOs and neutral hosts, multi-connectivity solutions supporting vehicles and high-speed trains, novel broadband access network architectures for railways, cross-operator service orchestration, and the ability to execute AI-enabled functions at the edge of the network. This paper introduces the 5GMED project, the proposed use cases, and the main features of the network architecture to be deployed along the Mediterranian cross-border corridor.

II. 5GMED Project Overview

The 5GMED project is an innovation action funded by the European Union's Horizon 2020 research and innovation programme under the 5G Public Private Partnership (5G-PPP). 5GMED will deploy a 5G Stand-Alone (SA) network infrastructure along 65 km of the European highway E-15 and the high-speed rail track of the Mediterranean cross-border corridor. It will conduct large-scale trials to evaluate the capabilities of 5G to meet the requirements of CCAM and FRMCS use cases under mobility conditions across the border. Before the execution of the large-scale trials in the corridor, 5GMED will deploy small-scale pilots in three trial sites located in Castellolí (Spain), Montlhéry and Satory (France).

III. 5GMED Use Cases

5GMED defined four use cases to capture the challenges related to both CCAM and FRMCS, namely, 1) remote driving, 2) road infrastructure digitalization, 3) future railways mobile communications, and 4) follow-me infotainment. The validation of these use cases is expected to lead to interesting insights and recommendations that can be valid for future deployment of other use cases. The following subsections describe the main aspects and challenges of the use cases.

A. Use Case 1: Remote Driving

The objective of the remote driving use case is to provide remote assistance to an autonomous vehicle that encounters a complex road traffic situation, e.g., accident, bad weather conditions, etc. When this happens, the vehicle decides to autonomously stop on the emergency lane and to make a request for remote assistance to the teleoperation center. Next, a remote driver tele-operates the vehicle until it reaches a safe position to continue driving. During teleoperation, video images and data from vehicle's sensors (e.g., 360º camera, LIDAR) must be perceived by the remote driver with sufficient quality and short delay, and the actuators of the vehicle must execute commands reliably and with low latency to provide full control to the remote driver.

B. Use Case 2: Road Infrastructure Digitalization

The objective of the road infrastructure digitalization use case is to ensure safe and efficient mobility in highways with mixed traffic where connected vehicles coexist with non-connected vehicles. A Traffic Management Center (TMC) executes intelligent traffic management strategies by processing the information received from vehicles and from roadside sensors. Two types of strategies are considered: (i) warning traffic strategies, and (ii) global traffic strategies. Warning traffic strategies focus on the detection of hazardous events (e.g., stopped vehicle, traffic jam, etc.) and real-time warning notifications from the TMC to vehicles approaching to the risk area. These events can be detected by vehicles' on-board sensors or by cameras on the infrastructure. In global traffic strategies, the TMC analyses the traffic situation to detect abnormal behaviors, devises a traffic strategy, and finally sends regulation commands to groups of vehicles, e.g., change lane or adjust speed.

C. Use Case 3: Future Railways Mobile Communications

The FRMCS use case of 5GMED includes the following performance and business services [3]: (i) massive on-board sensors monitoring, to monitor the status of non-critical systems of the train by transmitting sensors' readings to the train's control center; (ii) railway track safety, to detect hazards on the rail tracks by using LIDAR on-board and AI processing on the MEC; (iii) passenger safety and comfort, to detect dangerous situations on-board (e.g., fire, fights) using cameras on-board and AI processing on the MEC; (iv) high-quality Wi-Fi connectivity for passengers; and (v) Multi-tenant Mobile Service that use 5G small cells on-board the train to provide high-bandwidth & low-latency access to a MNO service.

D. Use Case 4: Follow-me Infotainment

The aim of the follow-me infotainment use case is to distribute several types of high-quality media contents, such as live-streaming of 360º video, video-conferencing, and virtual reality video, synchronously to passengers travelling at high speed by car or train. It consists of moving the virtual functions of the media services across different MEC nodes as the user moves along the cross-border corridor, so that these virtual functions are located close to the user's position at all times, following the user's movements. This ensures very low-latency and high data-rate at all times, yet it poses a challenge in terms of service continuity at the cross-border since media services must be provided without interruptions.

IV. 5GMED Network Architecture

5GMED aims to design a network architecture to meet the strict performance requirements of the use cases in terms of service end-to-end latency, data-rate, reliability, and mobility interruption time. As shown in Figure 1, this architecture is composed of three strata: (i) infrastructure, (ii) functional, and (iii) management and orchestration. The *infrastructure stratum* is designed to provide seamless high-quality connectivity and includes all the interconnection links and equipment. It is divided into four parts: access network, transport network, MEC, and Cloud. The access network is mainly based on two experimental 5G SA networks (one in Spain and one in France), consisting of a 5G NR Radio Access Network (RAN) and a 5G-core network (3GPP Release 16). Both 5G SA networks provide 5G coverage on the E-15 highway and rail track along the cross-border corridor, except for two coverage holes at the south-end of the Spanish side. In order to show how such architecture can be deployed in real-life scenarios including 5G connectivity gaps, the 5GMED infrastructure also integrates other radio access technologies (RAT): C-V2X (PC5 interface) roadside units on the highway, and 70 GHz IEEE 802.11ad access points and satellite connectivity on the rail track. In order to ensure seamless connectivity, the 5GMED consortium is also developing a multi-connectivity unit that facilitates the handover between 5G NR and the other RATs. In addition, the 5G-cores will be configured to minimize service interruption times during cross-border roaming. The transport network consists of fiber optics, microwave, and satellite links. The *functional stratum* includes the core functionalities of the network architecture, and namely the network slicing technology used to provide resources and ensure the QoS to the different use cases. Finally, the *management and orchestration stratum* includes a network management and service orchestration platform, as well as the necessary software tools that collect data from the network and feed it to autonomous AI functions to (re-)optimize the network configuration.

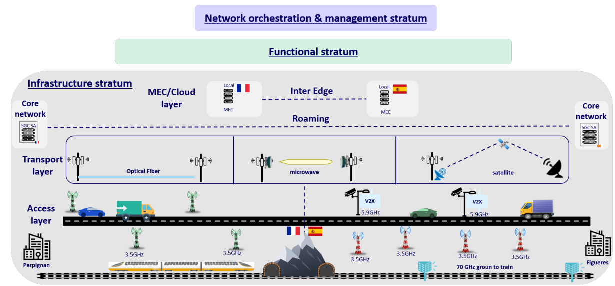

Fig. 1: Overview of the 5GMED network architecture.

V. Conclusions

The 5GMED project aims at building a multi-stakeholder infrastructure based on 5G able to satisfy the requirements dictated by future CCAM and FRMCS use cases. This paper describes the network architecture and presents the four use cases that will be validated using the 5GMED infrastructure that will be deployed along the Mediterranian cross-border corridor. The results will be useful to demonstrate the capabilities of 5G to meet the use cases' requirements.

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