14th ITS European Congress, Toulouse, France, 30 May-1 June 2022

Paper ID 170

# Implementing CAM Services in a Cross-border Environment Using a Dedicated 5G Network

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**Abstract**

Previously, transportation focused to overcome mainly physical barriers, at the present is concentrated in the technological ones. Connected and Automated Mobility (CAM) services appeared to increase safety for all road users. These use notifications, messages, and warnings transferred across dedicated equipment in the road infrastructure, and Autonomous Vehicles (AVs), while Vulnerable Road Users (VRUs) can be reached through mobile devices. As a result, use cases UC2.1, UC3.1 and UC3.3 are integrating CAM services to be tested in a cross-border environment between Latvia and Estonia using a 5G Network. This as a part of the 5G-Routes project to validate the latest 5G features and 3GPP specifications under realistic conditions to accelerate the deployment of 5G End-to-End (E2E) interoperable CAM ecosystems and services.

**Keywords:**

5G-Routes, Connected and Automated Mobility Services, 5G, 5G-V2X Devices

## Introduction

Companies around the world are looking to test functionalities of autonomous vehicles (AVs), busses, and trucks on urban situations. At European level, countries are collaborating to achieve an ambitious Connected and Automated Mobility (CAM), also including circumstances in which road users would need to go across EU countries. The vision of a future with vehicles that can guide by themselves (i.e., without human intervention) and crossing different regions is being built right now.

Mobile telecommunications continue evolving from 3G to 4G, to 5G improving data rate, coverage, and reliability. The telecom industry considers multiple uses of this 5th Generation with the aim to offer novelty services such as the connection of multiple machine type objects (e.g., "smart" devices and sensors, ultra-HD video streaming) as well as ultra-reliable and low latency connectivity towards the full implementation of the AVs; Which also have an impact on the mobility services offered through a single application (MaaS). It should be noted that this is not just the next generation of telecommunications technologies, but the opportunity of developing entirely new applications using industrial technologies. 5G is also a major challenge for MNOs, as changes and improvements in network infrastructure are needed not only by making updates but by creating a new network infrastructure for future connectivity (Figure 1).


**Figure 1. V2X Communication - Use Cases Enabled by 5G (Qualcomm)**

The transport and automotive industry expect to take advantage of those benefits to — connect — vehicles and infrastructure, share the information gathered and produced to — cooperate —, with the ambitious aim to — automate mobility — (CCAM) (*CCAM - European Partnership on Connected, Cooperative and Automated Mobility*, n.d.). In transport, connection and communication in real time are essential aspects, but in a door with multiple locks, 5G is only one of the keys. Going further, interoperability and fusion to combine data from multiple sources such as the installed equipment on intersections and in AVs to make available highly automated mobility services are additional challenges being pursued. In practice, how to plan in advanced maneuvers, routes, trajectories for AVs? Or produce specific VRUs warning messages to warn them from potential risks? Cooperative mobility services that first need to be connected, tested, and confirmed.

Lab test and real-life trials are planned during the 5G-Routes project which aim is to validate the latest 5G features and 3GPP specifications under realistic conditions, so as to accelerate the widespread deployment of 5G E2E interoperable CAM ecosystems and services in digitized motorways, railways and shipways throughout Europe. This European funded project expects to test innovative CAM applications functioning across a designated 5G cross-border corridor (‘Via Baltica-North’) spanning across 3 EU member states borders (Latvia-Estonia-Finland)(*Home - 5g routes project*, n.d.).

**The 5th Generation of Communication**

Progressively the potentialities of 5G continue been tested in diverse scenarios. These going from drones to ships to airplanes to AVs are transforming transport. In real life telecommunication companies continue working to supply commercial 5G networks. In that sense, OOKLA presents the multiple 5G deployments (i.e., blue points) and potential areas with commercial 5G (i.e., red points) in Europe (Figure 2) through an interactive 5G Map (*Ookla 5G Map - Tracking 5G Network Rollouts Around the*

*World*, n.d.).

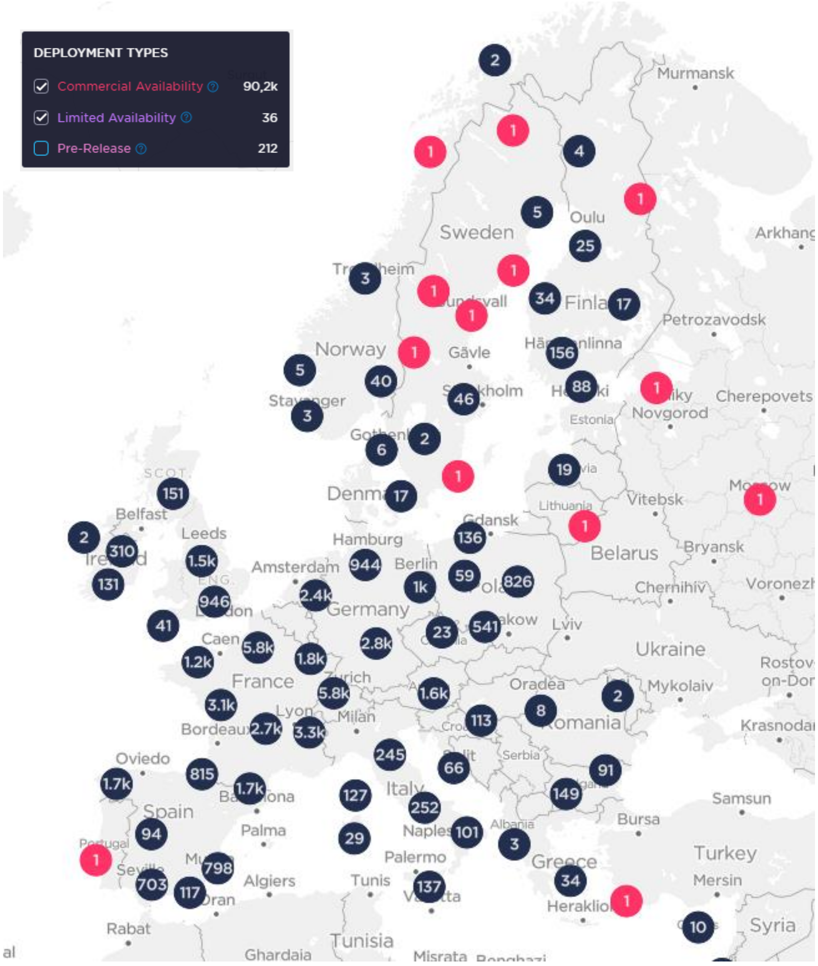


**Figure 2. OOKLA - Availability of 5G Network**

Transport requires an upgrade of the equipment installed on intersections (i.e., RSUs) and vehicles (i.e., OBUs) to support 5G. This to enable the interchange of messages (e.g., CPM, SPATEM, MAPEM) and provide advanced functionalities to enhance safety for all roads users. In those matters, the 5G Automotive Association Working Group 5 presents a technical report with a list of C-V2X Devices available on the market with the potential to operate under 5G (*List of C-V2X Devices 5GAA Automotive Association Technical Report*, n.d.).

With regards to the C-V2X OBUs reported, there are only 5 devices capable to enable 5G functionalities respecting to the ones commercially available for LTE-V2X (Table 1).

**Table 1. 5GAA - C-V2X Devices Available on the Market - OBUs**

| | |
|---|---|
| LTE-V2X direct communications (PC5) | 18 |
| LTE-V2X mobile network communications (Uu) | 12 |
| 5G-V2X mobile network communications (Uu) | 5 |

In terms of the C-V2X RSUs, the majority cover LTE-V2X communication respect to the 5G-V2X (Table 2).

**Table 2. 5GAA - C-V2X Devices Available on the Market - RSUs**

| | |
|---|---|
| LTE-V2X direct communications (PC5) | 20 |
| LTE-V2X mobile network communications (Uu) | 16 |
| 5G-V2X mobile network communications (Uu) | 6 |

Technology companies in the area mobile devices business are looking to attract new customers promoting products and services related to 5G (*Revisiting iPhone 12 5G Performance Across the Globe*, n.d.). In this way, it is notable the impact on the usage of 5G network considering a release of a new smartphone able to use these communication technologies (Figure 3). On the other hand, mobility companies are taking advantage of this advancements to increase safety of connected VRUs with the development and testing of new applications.

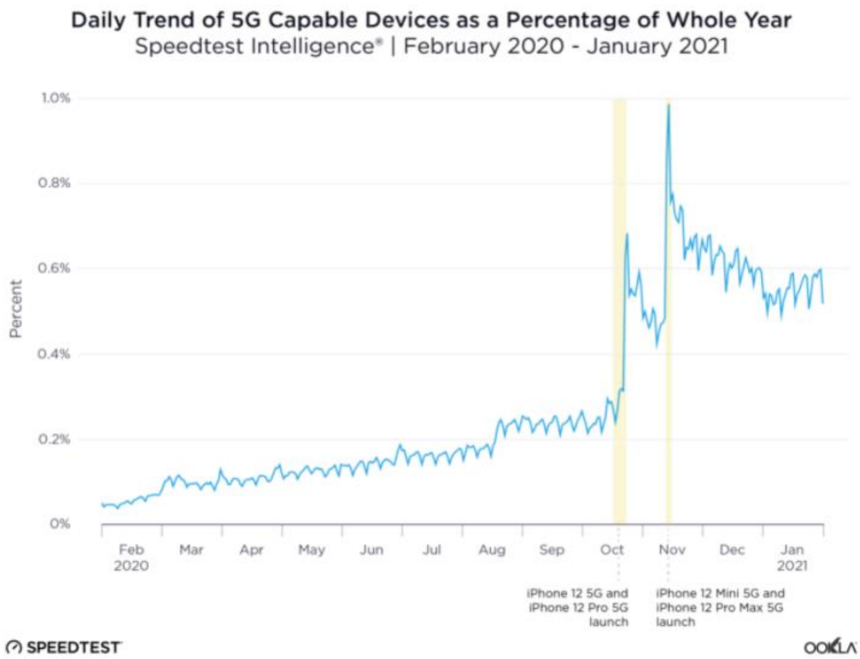


**Figure 3. OOKLA - Speed Test - 5G Capable Devices, February 2020 - January 2021**

**Connected and Automated Mobility in 5G-Routes Project**

With the aim to confirm 5G features and 3GPP specifications in real conditions, 5G-Routes project considers the following automotive use cases:

- Automated Cooperative Driving
- Awareness driving
- Sensing driving
- Uninterrupted infotainment passenger services on the go
- Multimodal services

These consider field trials in a cross-border environment between the countries of Latvia and Estonia (Figure 4) in which the use cases UC2.1, UC3.1 and UC3.3 are expecting an upgrade of the road infrastructure to be tested. Selected intersections in the cities of Valka and Valka are being equipped with the latest traffic equipment and communication systems to transfer the required C-ITS messages using a dedicated 5G network.


**Figure 4. 5G-Routes Project - Location of the Field Trials**

Bikernieki racetrack located in heart of Latvia capital Riga is also included in the project as an opportunity to test these use cases in a closed and safe environment to verify the functionalities and technologies prior to their demonstration in Valka and Valga. Bikernieki may seem like a typical 5G test environment as well as other projects, but this is the first place in Europe where a virtual cross-border provision of two MNO networks is provided, thus enabling cross-border applications to be tested and validated.

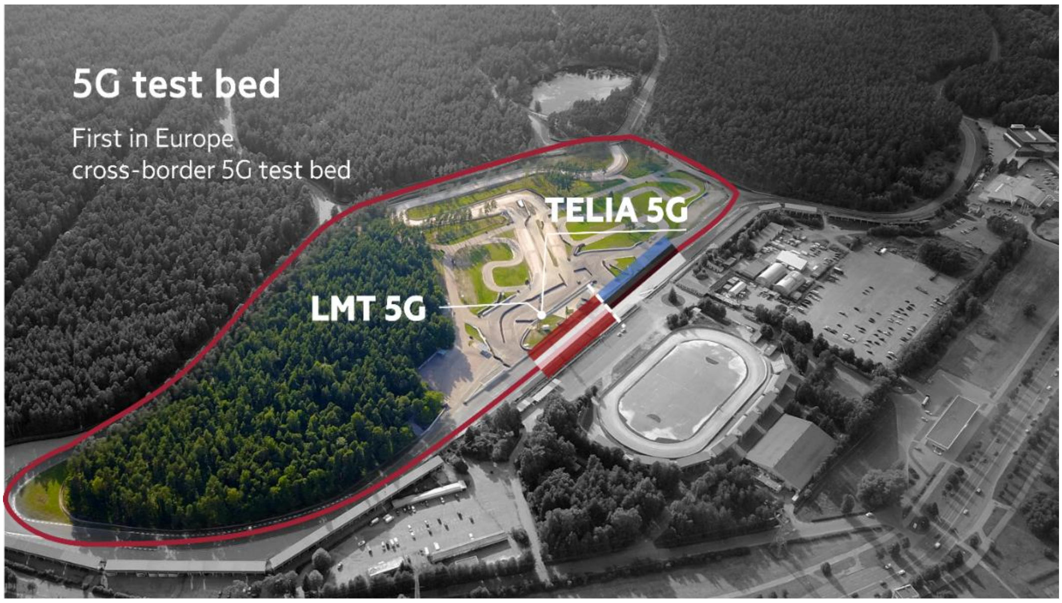


**Figure 5. 5G-Routes - 5G Test bed Bikernieki Racetrack**

The 5G-ROUTES project is unique because it is planned to run trials to validate the capabilities and functionality of three 5G releases:

- Release 15 - Identify the 5G capabilities at this moment.
- Release 16 – Demonstrations in real environment of the latest 5G opportunities and compare improvement of technologies between existing release.
- Release 17 – Provide a vision for future technological improvements and validate them in trial sites.

*Use Case 2.1: Real-time Traffic Info and Cooperative Intersection Collision Control*

SWARCO is applying its expertise in the topic of CAM enabling services for VRUs and AVs through the use case 2.1 Real-time traffic info and cooperative intersection collision control. This awareness driving use case primary goal is to assure and enable a reliable exchange of road traffic status data between VRUs, AVs "drivers" and Traffic Management Centers (TMCs) through enhanced real-traffic video fed and controlled via V2X communication standards considering 5G network. With focus on the continuity of the service, the UC2.1 approach allows first the collection of information of the existing traffic management services to its further analysis. Second, the comparison between the existing TM systems and the improved C-ITS services which integrates the capabilities of the 5G network to collect and interchange data. Finally, the real-time traffic visual monitoring and the control of an intersection traffic enables a safe passing for VRUs in a pedestrian crossing and a collision warning between vehicles.

As consequence, it is expected a boost of the automated driving due to the improvements of the C-ITS services produced by a more coordinated transport networks (e.g., enhancement in terms of vehicle position speed, driving trajectories, collision warnings, user comfort in traffic jams) and simultaneously the integration of novelty services for VRUs, such as safe passing, to make them aware about the potential road hazards.

The company is using advanced traffic monitoring systems and road infrastructure technologies such as smart traffic lights, Safe-Light systems (i.e., Ground projection of light for pedestrian safety), roadside units, cameras with artificial intelligence GDPR compliance, to improve safety for all road users.

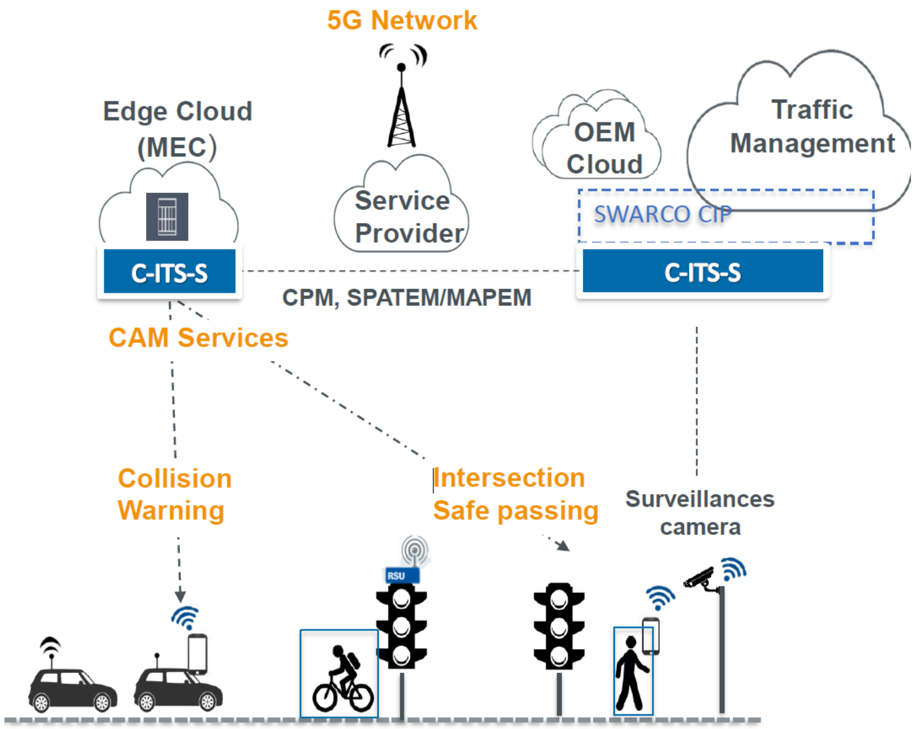


**Figure 6. 5G-Routes Project - UC2.1 Schematic Description**

*Use Case 3.1: Sensor Info Sharing for Cooperative Situation Awareness*

This use case allows connected vehicles to exchange information with other connected road users in the neighborhood and with infrastructure, regarding objects detected by their sensors, so that these can be warned of objects on a potential collision course. This use case will hence guarantee the safety for all involved nearby vehicles. Through the data observed from other vehicles and the infrastructure, the vehicles get a more holistic view of the local traffic situation. Vehicles uses their own sensors (e.g., HD camera, lidar), and sensor information from other vehicles, to form a complete view of the traffic situation. This will allow automated vehicles to safely perform an automated maneuver.

5G brings to the UC3.1 an accurate view of the traffic situation, the latency of the communication between vehicles must be small, so that the location of the object detection, received by the vehicle, does not deviate substantially of the transmitted location. Through the ultra-reliable low latency communications (URLLC) service the latency between the vehicles and the network can hence be decreased. Slicing may assure to assign sufficient resources to the connected vehicles to exchange data reliably. MEC (Multi-Access Edge Computing) allows to place the broker, which routes the message traffic between vehicles, at the edge of the network or near the core, which will shorten the latency from one vehicle to another.

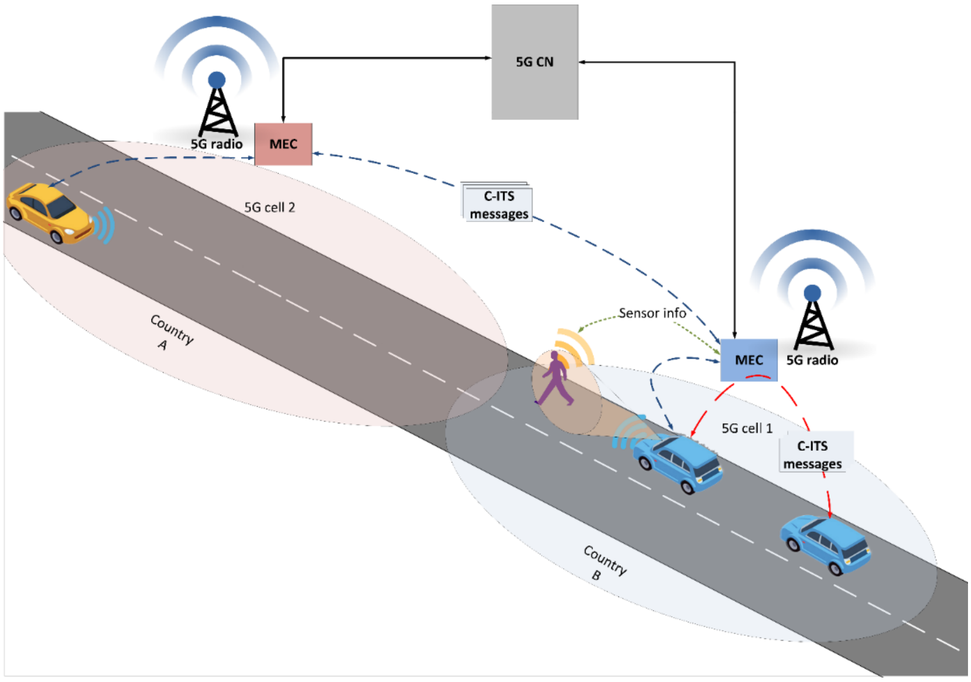


**Figure 7 : 5G-Routes Project – UC3.1 Schematic Description**

*Use Case 3.3: Vulnerable Road User (VRU) Collision Avoidance*

In the VRU collision avoidance use-case, connected VRUs inform about their presence and not connected VRUs can be detected by the infrastructure. Then, information about localization of VRUs and vehicles is exchanged between road users using MEC services, so that, every participant, i.e., a VRU or a vehicle, can be aware of the situation of other participants in its vicinity and can adapt its behavior appropriately to avoid any collision. As illustrated in Figure 8, V2X communication can support such application by enabling:

- Communication between VRUs and vehicles
- Deployment of smart intersection
- Perception sharing between vehicles

As such applications require a continuous update regarding the situation, i.e., location, speed, direction of travel of road users to smoothly anticipate any risk and avoid sudden emergency braking due to late detection, ensuring real time communication and network availability is required in all conditions. By supporting URLLC and exchange of information between multiple sources (here, vehicles), roadside infrastructure and VRUs, 5G technology is expected to supply features to meet these requirements.

For UC3.1, 5G enables the use of MEC which is a key technology to support low latency communication and information sharing between all the participants. Besides, as the number of connected devices might be important, e.g., few thousands in crowded city centers, it should provide the appropriate resources. Improve position accuracy of communicating devices, especially VRU smartphones, is a crucial challenge and 5G could support localization enhancement, for instance, by providing access to RTK corrections or using massive MIMO antennas. The cooperation between MEC from multiple operators is essential as data exchanged for collision avoidance are targeting users in a geographical area, e.g., an intersection, and such users may be paired to different operators.

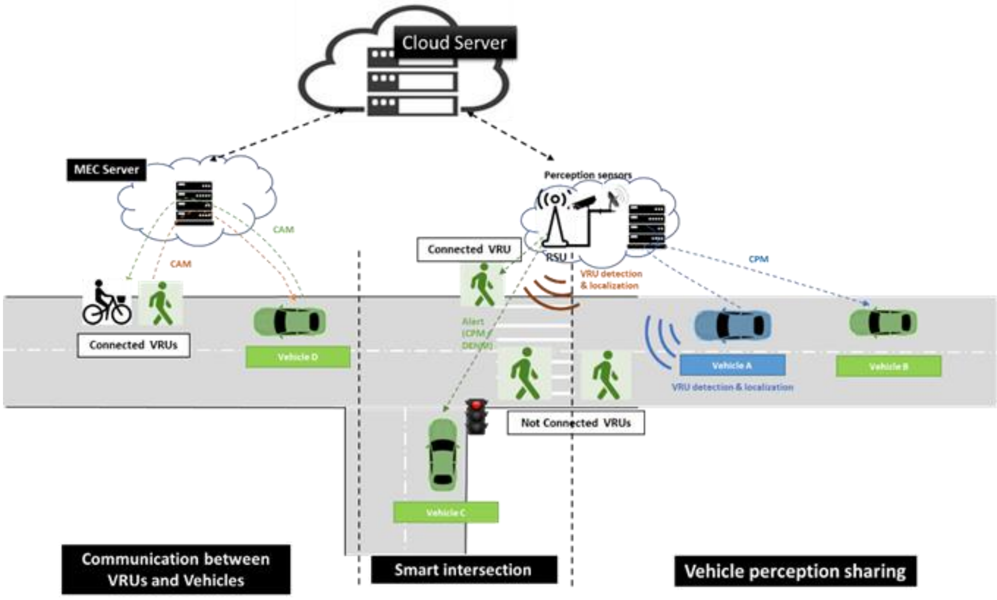


**Figure 8. 5G-Routes Project - UC 3.3 Schematic Description**

The different functionalities expected to be tested during the lab trials and field trials consider an incremental improvement approach. The process consists in the testing of features on laboratory to then continue with the validation in real locations. Table 3 presents the projected timeline for the complete implementation of the use cases.

**Table 3. 5G-Routes Project - Projected Workplan for the Lab and Field Trials (To be confirmed)**

| 2022 | | | | | | | | | | | | 2023 | | | | | | | | | | | | 2024 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
| J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J |
| | **LAB Trials #1** | | **Field Trial #1 - R.15 NSA** | | | | | | | | **LAB Trials #2** | | | **Field Trial #2 - R.16** | | | | | | | | | **LAB Trials #3** | **Extended Trials R.16/17** | | | | | |

Table 4. 5G-Routes Project - Objectives of the UC2.1, UC3.1 and UC3.3 in function of the TrialsTable 4 summarizes the objectives of the trials based on the iterative process that improve the functionalities of the use cases.

**Table 4. 5G-Routes Project - Objectives of the UC2.1, UC3.1 and UC3.3 in function of the Trials**

| **Use Case** | **LAB Trial #1** | **Field Trial #1** |
|---|---|---|
| **UC2.1** | Verification of network and road infrastructure | Basic features testing of the traffic equipment installed (e.g., data acquisition from the video monitoring system) |
| **UC3.1** | Validate sensor info sharing between two vehicles in 5G network | Sensor data sharing between two vehicles, connected to a single network, with V2X broker implemented on a MEC |
| **UC3.3** | Test the application correct connectivity over a real 5G Network | Evaluation of data messages exchange through 5G network, and technical validation of the pilot site. Evaluation of use case considering vehicle and pedestrians in different conditions, especially at cross border situations |
| | **LAB Trial #2** | **Field Trial #2** |
| **UC2.1** | Transmission and receipt of C-ITS messages (e.g., CPM, SPATEM, etc.) | Establish the functional verification of the safety features enabled at intersection level (e.g., Traffic Light Forecast\Traffic Light Assistant**,** Imminent Signal Violation Warning, Multi-modal Monitoring, etc.). |

| | | |
|---|---|---|
| **UC3.1** | Validate sensor info sharing between vehicles connected to different 5G networks | Validate sensor info sharing when crossing border |
| **UC3.3** | Transmission, receipt and processing of C-ITS messages (CAM, CPM, VAM) between vehicle and VRU | Evaluation of use case considering vehicle and pedestrians in different conditions, especially at cross border situations. |
| | **LAB Trial #3** | **Extended Trial** |
| **UC2.1** | Final validation of results considering the data resulted from the C-ITS Services enabled in both intersections (i.e., Valka and Valga). This means the evaluation of the safety features (e.g., Traffic Light Forecast\Traffic Light Assistant, Imminent Signal Violation Warning, Multi-modal Monitoring, etc.). | Final verification and validation of the CAM services (i.e., Imminent Signal Violation Warning, Collision Avoidance Warning) enabled in the intersection of Valka and Valga considering cross-border aspects using the dedicated 5G network. This includes the assessment of the C-ITS services such as Traffic Light Forecast\Traffic Light Assistant, Safe-light system, Multi-modal monitoring. |
| **UC3.1** | Validate sensor information exchange with other partners and fusion | Validation of the following aspects:<br>Use of slicing for sensor info sharing<br>Use of slicing when crossing border<br>Automated maneuver<br>Automated overtaking during border crossing |
| **UC3.3** | Validation of the communication between vehicles and VRUs in different conditions, i.e., using roadside infrastructure and in out of intersection situations | Tests in the cross-border corridor in intersections equipped with VRU detection systems and in road sections not-equipped with such dedicated infrastructure. |

**Conclusions**

- The 5th generation of communication is transforming mobility through CAM services; However, there is a necessity to upgrade the equipment installed on intersections to support 5G-V2X mobile communication to improve the exchange of information between sensors and devices enabling a more efficient process of detection and monitoring which impact directly traffic management. In the case of vehicles (i.e., automated, or not), the use of C-V2X OBUs should be a requirement for automakers to improve the accuracy of positioning, and speed enabling a new generation of CAM services focus on warnings of all road users through C-ITS messages and notifications in mobile devices.
- Reach interoperability between OBUs, RSUs and mobile devices is being perceived as one of the main challenges to be achieved for the UC2.1, UC3.1 and UC3.3 due to the implementation of the CAM services requires the use of C-ITS messages (e.g., CPM, SPATEM, etc.). This is demanding that the companies involved in the use cases compare, analyze and test compilers and systems.
- The testing of 3GPP specifications for 5G under real conditions expects the release 17 which will be available for the end of the Q2/2022.
- The deployment of the 5G network is a bigger challenge for MNOs than before, telco industry is moving to towards the 5G NFV models to virtualize core network functions which will provide unseen opportunities, not just to transportation and mobility in overall. 5G-ROUTES project will provide a comparison of existing network technologies and network capabilities with the latest 5G rereleases. The conclusions from this project will contribute significantly to the development of the 5G network and their scaling to the deployment of autonomous and connected mobility applications.

**Acknowledgements**

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 951867.

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