

TRIALS AND PILOTS FOR CONNECTED AND AUTOMATED MOBILITY

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INTRODUCTION

Undoubtably, society will benefit from Connected and Automated Mobility (CAM) in various ways. First, safety. Highly automated vehicles exchanging information will realize a collective artificial intelligence that can overcome the capabilities of humans to drastically reduce the number of accidents. Second, traffic efficiency. Exchanging information of maneuver intentions and real-time monitoring of real-traffic conditions for optimal traffic efficiency are just a couple of examples of the potential of CAM to improve the capacity and efficiency of roads. Third, passenger comfort. Vehicles driving in a highly automated manner will transform the concept of passenger, allowing for a more relaxed and fruitful traveling time on-road. Overall, reduction of environmental impact of road traffic is a final goal that can be boosted thanks to CAM.

As it was stated in the Strategic Deployment Agenda released in October 2019 by key stakeholder associations, 5G will be a booster for the realization of CAM and thus, bring all societal benefits to reality.

For this reason, the 5G Public Private Partnership, which aims at ensuring that Europe leads the development and deployment of 5G in Europe, has been continuously funding along the last years several projects which contribute to designing, developing, testing, validating, and promoting the potential of 5G-based vehicular communications (so-called V2X communications) for CAM.

It is worth noting that the term V2X refers to communication between a vehicle and anything else, yielding terms such as V2V (vehicle-to-vehicle), V2N (vehicle-to-network), V2I (network-to-infrastructure), or V2P (vehicle-to-pedestrian).

This brochure aims at providing a schematic and visual summary of the key use cases, key performance indicators, and tests and pilots being conducted in the context of research and innovation projects funded by the 5G-PPP which contribute to enabling efficient and reliable 5G-V2X communications for CAM.

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May 2021 - Automotive Working Group



PUBLIC-PRIVATE PARTNERSHIP

V2X USE CASES



As the number of use cases distributed in the different 5G-MOBIX Test-Sites is very high, they have been classified in some Use Case Categories (UCCs), classification extracted from 3GPP technical specifications.

Advanced driving use case: Advanced driving enables semi-automated or fully-automated driving. Each participant shares its local data and driving intentions on the vehicles case, with cooperating entities in the proximity. This allows the participating vehicles to coordinate trajectories and maneuvers.

Platooning use case: Enables vehicles to form groups dynamically while traveling together. Information is exchanged among members and maneuvers are coordinated by the platoon leader, allowing them to drive as compact groups and the following vehicles to be driven autonomously.

Extended sensors use case: This use case contemplates raw sensors data and live video to be exchanged among participating members. This enables every participant to be aware beyond what can be perceived by its own sensors, enabling a more complete view of the local environment.

Remote driving use case: Remote driving enables a vehicle to be commandeered from a remote location for when the occupants cannot drive themselves or for vehicles on hazardous environments. This use case is also considered for cloud-enabled public transportation.

Vehicle quality of service reporting support use case: This use case enables V2X applications to be informed on the CCAM system status. Notifying participants on current quality of service and expected variations, delivering a smoother experience.

www.5g-mobix.com



Teleoperated driving: 5GMED will demonstrate that a teleoperator can control the L4 autonomous car from a remote location and ensure the Dynamic Driving Task Fallback with full safety, adding a new reliable mode to the dynamic driving task (DDT) fallback procedure specified by SAE J3016.

Road infrastructure digitalization: 5GMED will move forward the road infrastructure closer to Inframix level A. Two different services will be tested: 1) automatic incident detection, with a 5G connected camera processed by an IA in the Edge, and 2) Traffic Flow Regulation in Real time by providing speed recommendations to a selected group of Connected Autonomous vehicles, improving road safety.

Follow Me infotainment: 5GMED will demonstrate service continuity of intense infotainment (Enjoy Media Together and Tour Planning) and media applications in cross-border situation with dynamic service migration from MEC to MEC.

www.5gmed.eu



Tele-operated Driving (ToD): is defined as remote control of an automated vehicle through a mobile radio network. ToD is meant to complement automated driving by bringing the tele-operator, located in the Vehicle Control Centre (VCoC), into the control loop in situations where an automated vehicle cannot handle on its own.

High Definition (HD) maps: being considered one of the corner stones of an autonomous car, the generation and distribution of these maps allow integrating information such as lane markings, barriers and other information which can be used by the automated driving functions. The HD maps can also be used as the base upon which more dynamic information can be stored, e.g., road works and accidents.

Anticipated Cooperative Collision Avoidance (ACCA): this use case relates to the possibility to anticipate certain road hazards to reduce the probability of collisions, particularly in situations when these hazards are out of the field of view of the vehicles' sensors. It allows to build a situational awareness of the road in quasi real-time manner, and to notify nearby vehicles about collision risks.

www.5gcroco.eu



On the definition of the use cases 5G CARMEN followed a selective approach to guarantee the selection of the most demanding use case, needed to measure the relevant 5G KPIs. 5G CARMEN started with a pre-selection of candidate use cases:

Cooperative Maneuvering, Situation Awareness, Green Driving and Video Streaming.

The outcomes of the first field trials led to the understanding that measuring the most demanding 5G related KPIs requires to target SAE Level 4 vehicle automation. Consequently, the first two use cases have been selected for the next phase of on-field pilot activity and have been merged in two new highly demanding use cases, that are going to be tested on field:

Cooperative and automated (CAAM) lane-change maneuvers. In this use case a vehicle needs to change lane from overtaking to first lane or vice-versa. It performs lateral control in Autonomous Driving Level 4 thanks to a very accurate and timely awareness of the surroundings, enabled by 5G. Both centralized and decentralized approaches are considered, leveraging on low-latency V2N2V connectivity integrating V2V communication. In one scenario the lane change is triggered by an Emergency Vehicle (EV) approaching thanks to the Back Situation Awareness capability enabled by 5G connectivity.

Cooperative and automated (CAAM) in-lane maneuvers. In this use case, a vehicle is on the first lane and plans to exit the motorway in moderate-high traffic situation, with vehicles in front obstructing the view. Thanks to Vehicle Sensor and State Sharing capabilities enabled by 5G, the vehicle can sense what the vehicle in front senses and thus decide to keep Level 4 automation, and stay in lane, re-planning the exit without calling back the driver and switch to Level 3 automation. In a second scenario the decision to stay in lane will be triggered by an approaching Emergency Vehicle detected through Back Situation Awareness.

www.5gcarmen.eu



5G BLUEPRINT

Automated driver-in-loop docking functionality: Within this use case, 5G-Blueprint explores a driver assistant system for docking articulated vehicles within warehouses and distribution centers, as well as enabling a mobile harbor crane with teleoperation functionality, so that it can be operated from a remote-control center by a teleoperator. Communicating optimal driving paths to the tractor and maneuvering the crane in safety-critical situations will be highly time-critical.

Cooperative Adaptive Cruise Control based platooning: Platooning of trucks has been a widely discussed topic in logistics for a while now. However, this use case revolves around the fundamental strategy of platooning by relying on 5G, while the driver is removed from the cabin of the truck and placed in a remote location from where they can control the vehicle. The system is aimed at being partly automated wherein the lead vehicle can be driven by a driver in the cabin or a teleoperator and the following vehicle(s) can be automated.

Remote takeover operations: Remote takeover defines the process in which a remote operator takes control of a distant vehicle. To enable remote takeover, it is necessary to monitor and adjust the vehicles to steer and drive remotely from the control center. Remote takeover operations are integration tests verifying the function of all major components (vehicle, remote station, teleoperation center) of the teleoperation solution.

Automated Barge Control: the channel navigation of the barges will be teleoperated along with partial automation. Cross-border passing will be given a priority whereas channel navigation, port entry, and exit efficiency will be enhanced by reducing crew requirements for barge navigation.

www.5gblueprint.eu



Automated Cooperative Driving: MEC-enabled 5G RAN nodes, enhanced with AI, continue to gain more intelligence and capacity to support dynamic vehicles platooning, cooperative lane change and see-through view for safe automated overtake capabilities.

Awareness Driving: enables reliable exchange of road traffic status data to provide V2X real-time traffic info and cooperative intersection collision control and user comfort through traffic jam chauffeur.

Sensing Driving: share observations gained by sensors, and advanced environmental information, to gain enhanced situational awareness for Vulnerable Road User (VRU) collision avoidance and preventive framework through connected maintenance.

Uninterrupted infotainment passenger services on the go: enable multimodal passengers to exploit the high-performance capabilities for 360° immersive multi-user gaming on the go and 3D real-time virtual collaboration on the go.

Multimodal services in uninterrupted and seamless service delivery to goods tracking visibility in multimodal cross border logistics and 5G-based Proactive and Multimodal Management of Passengers and Freight.

www.5g-routes.eu



Automated & Remote Vessel navigation in busy port environment: Demonstration of Port Digital Twin based on 5G connectivity and slicing will be used to control semi-autonomous vessels in the challenging environment of a port area. High-bandwidth (preferably full HD) camera feeds and sensor data are sent in real-time from the vessels to the command centre, and real-time steering commands are sent to the remote vessel. KPIs: Port safety, reduced dwell times, reduced personnel, etc.

Data-enabled assisted navigation in severe weather/water conditions: Demonstration of remote inspection, fraud detection, insurance by implementation of a data-enabled assisted navigation application using IoT sensing system and video cameras installed in port and on a ship and barges (cargos). The UC application that we propose will permit a safer port operation and more security regarding navigation of ships with the help of assisted operation / navigation even in severe weather and water conditions. KPIs: Increased safety, electronic map accuracy, etc.

Smart warehouse / freight logistics: Demonstration of lean warehouse, human-AGV collaboration, remote monitoring & control the feasibility by applying the 5G technology in an overall logistics context, for optimizing warehousing operations through an integrated state-of-the-art operational system based on Automated Guided Vehicles (AGVs). KPIs: Increased operational efficiency, productivity, warehouse capacity, etc.

www.vital5g.eu

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| USE CASE | TELE-OPERATED DRIVING | HD MAPPING | ANTICIPATED COOPERATIVE COLLISION AVOIDANCE | VEHICLE PLATOONING | ADVANCED DRIVING |
|--------------|-----------------------|------------|---|--------------------------|------------------|
| KEY 5G KPI | RELIABILITY | DATA RATE | DELAY, LOCALIZATION ACCURACY | RELIABILITY/ E2E LATENCY | E2E LATENCY |
| 5G-MOBIX | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5GMED | ✓ | | | | |
| 5GCroCo | ✓ | ✓ | ✓ | | |
| 5G CARMEN | | | ✓ | | |
| 5G-Blueprint | ✓ | | | ✓ | ✓ |
| 5G-ROUTES | | | ✓ | ✓ | ✓ |
| VITAL-5G | | ✓ | ✓ | | |

2/3

| USE CASE | EXTENDED SENSORS | CAAM LANE CHANGE | BACK SITUATION AWARENESS | VEHICLE SENSORS AND STATE SHARING | VIDEO STREAMING |
|--------------|------------------|------------------|--------------------------|-----------------------------------|--------------------|
| KEY 5G KPI | E2E LATENCY | LATENCY | COVERAGE, RELIABILITY | LOCALIZATION ACCURACY | LATENCY, DATA RATE |
| 5G-MOBIX | ✓ | | | | |
| 5GMED | ✓ | | ✓ | ✓ | ✓ |
| 5GCroCo | | | | | |
| 5G CARMEN | | ✓ | ✓ | ✓ | |
| 5G-Blueprint | | | | ✓ | |
| 5G-ROUTES | ✓ | ✓ | | ✓ | ✓ |
| VITAL-5G | ✓ | | | ✓ | ✓ |

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| USE CASE | CAAM IN-LANE | ROAD INFRASTRUCTURE DIGITALIZATION | FOLLOW-ME INFOTAINMENT | DISTRIBUTED PERCEPTION | VEHICLE QoS SUPPORT |
|--------------|----------------------|------------------------------------|------------------------|------------------------|------------------------|
| KEY 5G KPI | LATENCY, RELIABILITY | RELIABILITY | DATA RATE, CONTINUITY | DATA RATE, LOW LATENCY | DATA RATE, RELIABILITY |
| 5G-MOBIX | | | | | ✓ |
| 5GMED | | ✓ | ✓ | | |
| 5GCroCo | | | | | |
| 5G CARMEN | ✓ | | | | |
| 5G-Blueprint | | | | ✓ | |
| 5G-ROUTES | ✓ | | | | |
| VITAL-5G | | | | | |

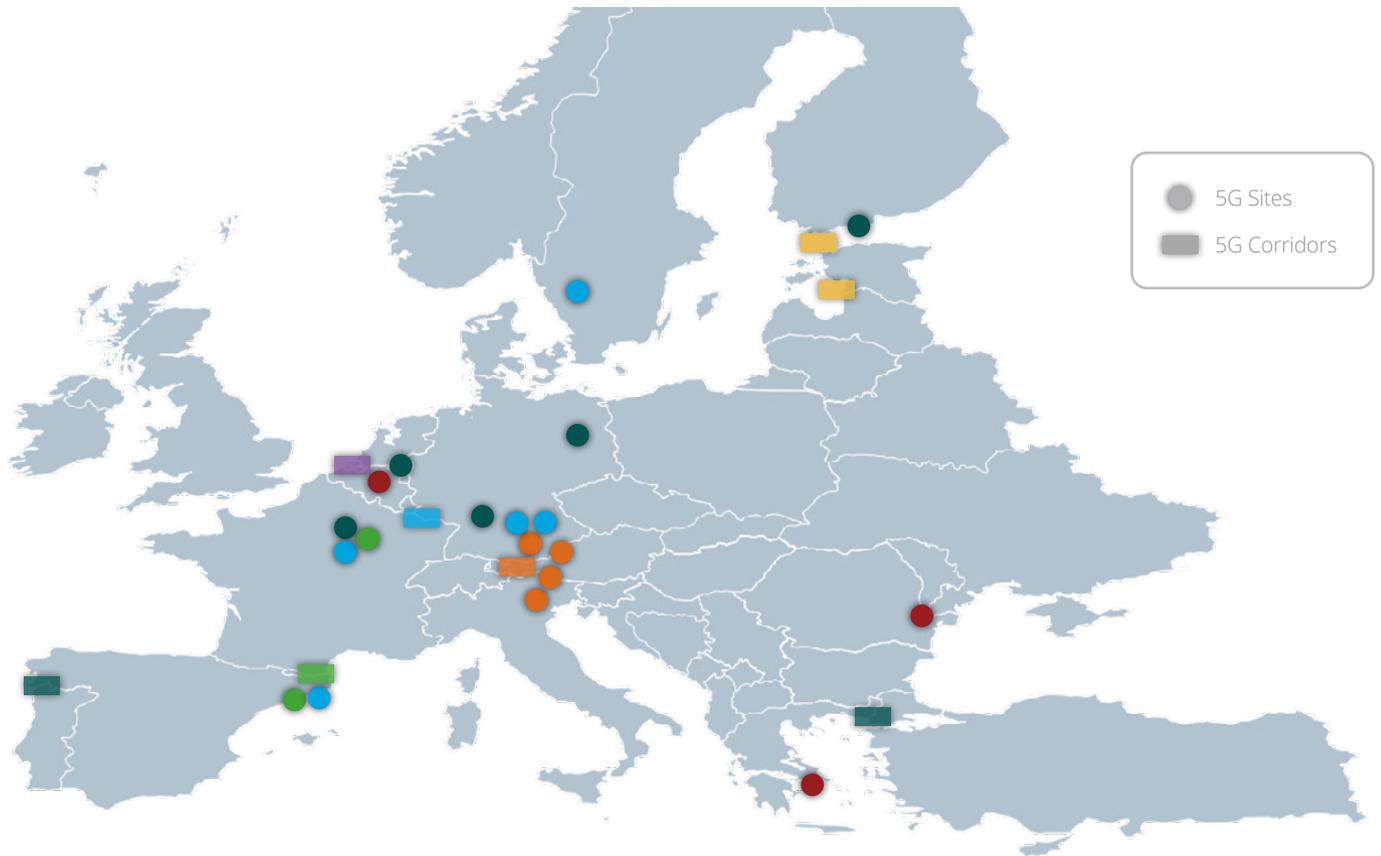
TESTED 5G TECHNOLOGIES

| | RELEASE TESTED | 5G DEPLOYMENT | | TECHNICAL FEATURES | | | | | |
|--------------|----------------|---------------|----|--------------------|-----|--------------|------|----|-----|
| | | NSA | SA | 5G NR | MEC | NET. SLICING | pQoS | AI | PC5 |
| 5G-MOBIX | 15/16 | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| 5GMED | 16 | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5GCroCo | 15 | ✓ | | ✓ | ✓ | | ✓ | | |
| 5G CARMEN | 15 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| 5G-Blueprint | 16/17 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| 5G-ROUTES | 16/17 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| VITAL-5G | 15/16 | | ✓ | ✓ | ✓ | ✓ | | | |

TERMINOLOGY

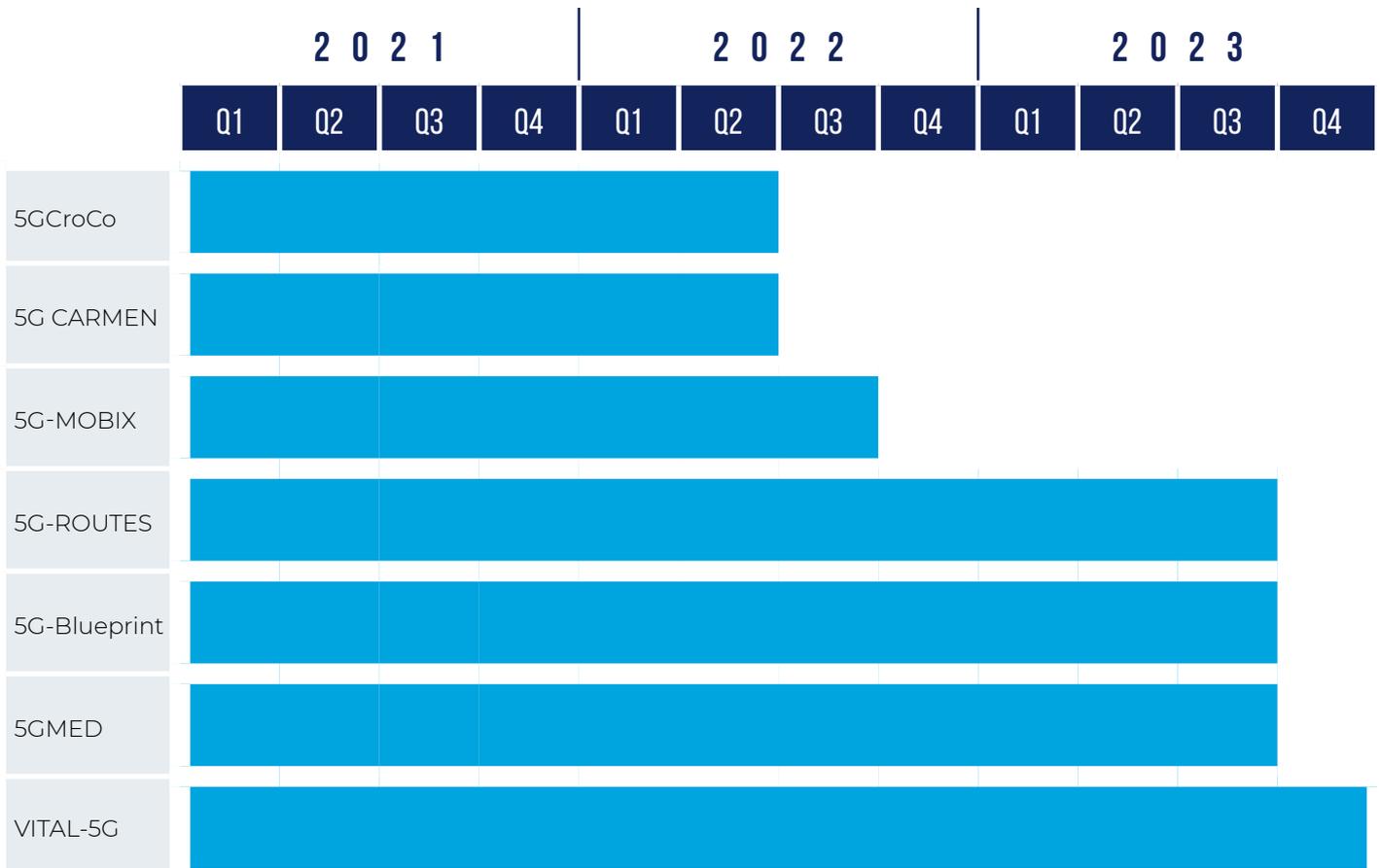
- **NSA:** Non-standalone;
- **SA:** Standalone;
- **5G NR:** 5G New Radio;
- **MEC:** Mobile Edge Computing;
- **Net. Slicing:** Network Slicing;
- **pQoS:** predictive Quality of Service;
- **AI:** Artificial Intelligence;
- **PC5:** interface to allow direction communication between devices in a 5G network.

CARTOGRAPHY



| | | | |
|-------------------------|---|----------------------------|---|
| <p>5G-MOBIX</p> | <ul style="list-style-type: none"> • Vigo - Porto (Spain-Portugal Corridor) • Kipoi - Ipsala (Greece-Turkey Corridor) Hard borders • Berlin and Stuttgart (<i>German</i>) • Espoo (<i>Finland</i>) • Paris (<i>France</i>) • Eindhoven-Helmond (<i>Netherland</i>) • *China Test Site: Jinan • *South Korea Test Site: Yeonggwang | <p>5GCroCo</p> | <ul style="list-style-type: none"> • Corridor France-Germany-Luxembourg • Barcelona (<i>Spain</i>) • Monthléry (<i>France</i>) • Munich (<i>Germany</i>) • A9 5G-ConnectedMobility Testbed (<i>Germany</i>) • AstaZero (<i>Sweden</i>) |
| <p>5GMED</p> | <ul style="list-style-type: none"> • 65 km, with 35 km of shared infrastructure road / train. Corridor E-15 Figueres – Perpignan • Castellolí Track (<i>Spain</i>) • TEQMO Centre, Paris (<i>France</i>) | <p>5G-Blueprint</p> | <ul style="list-style-type: none"> • 5G cross-border in waterways and high-ways between Belgium and The Netherlands |
| <p>5G CARMEN</p> | <ul style="list-style-type: none"> • Corridor Germany-Austria-Italy • Trento (<i>Italy</i>) • Munich (<i>Germany</i>) • Brenner Pass (<i>Italy-Austria</i>) • Kufstein (<i>Austria-Germany</i>) | <p>5G-ROUTES</p> | <ul style="list-style-type: none"> • 5G cross-border Via Baltica-North corridor: • Latvia - Estonia • Estonia - Finland |
| | | <p>VITAL-5G</p> | <ul style="list-style-type: none"> • Port of Galati (<i>Romania</i>) • Port of Antwerp (<i>Belgium</i>) • Port warehouse/logistics hub of Athens (<i>Greece</i>) |

TIMELINE



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