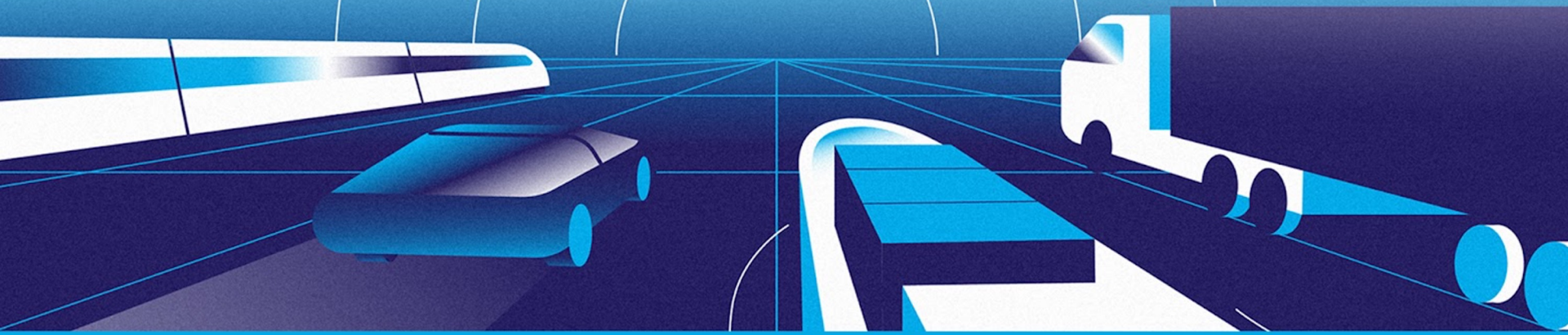
5G FOR CAM IN CROSS-BORDER SCENARIOS: CHALLENGES AND LESSONS LEARNT

SPECIAL SESSION @EUCNC 2023



7 JUNE 2023 | 11:00 AM | ROOM G3

SWEDISH EXHIBITION & CONGRESS CENTRE (GOTHENBURG)

THESE PROJECTS ARE PART OF THE 5G PUBLIC AND PRIVATE PARTNERSHIP
5G PPP WWW.5G-PPP.EU

6G SNS IA

Funded by the EU's Horizon 2020 programme

SESSION CHAIR

Markus Dillinger
Head of 5G R&D for verticals at Huawei | Executive Committee member of 5G Automotive Association (5GAA) and co-initiator | WG CAM vice chairman

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CTTC

Léo Mendiboure
UGE

Andreas Georgakopoulos
WINGS ICT SOLUTIONS

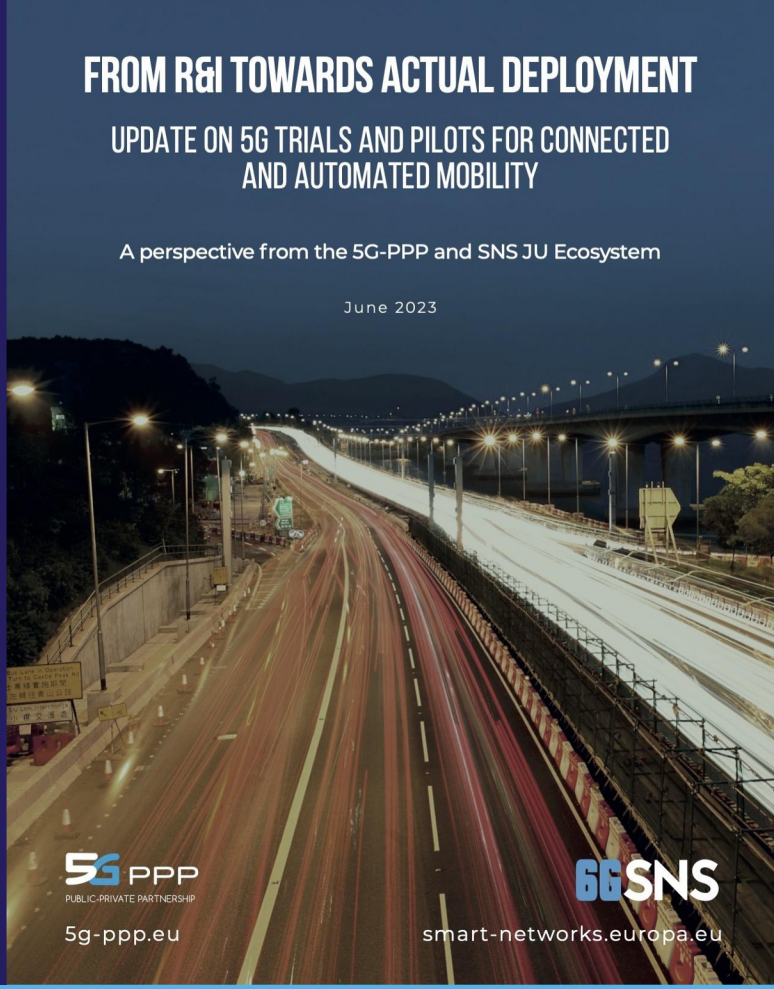
SESSION AGENDA

- *Projects overview*
- *Achievements and lessons learnt*
- *EC's perspective on cross-border challenges*
- *Future R&I challenges for CAM scenarios*
- *Q&A*

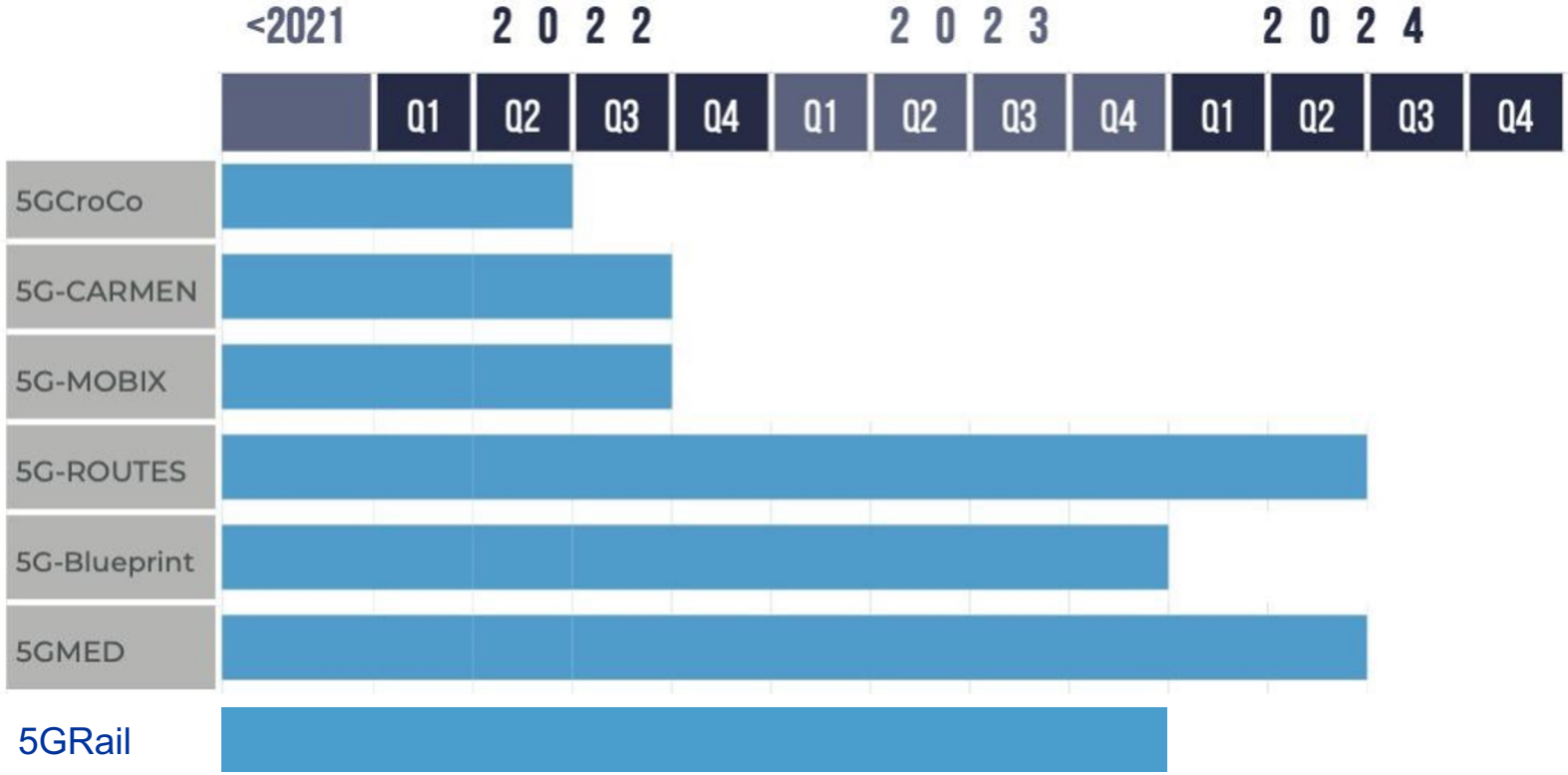
Deployment recommendations

- A joint deployment workshop was held among all ICT-18 projects, 5G-MOBIX, 5G-CARMEN and 5GCroCo, in order to present and discuss the results of each individual project deployment study.
- Sites can be upgraded to include a capacity layer based on the mid-band spectrum such as, e.g., the 3.x GHz band or other legacy bands.
- Extrapolating for areas around the corridors, a significant number of new sites will be required to deploy such a capacity layer – as 5G for CAM and non-related eMBB traffic will grow.
- The most suitable 5G network deployment to provide CAM services along corridors sections would be to start with low-band spectrum (e.g., 700 MHz band) for quickly achieving wide-area coverage, by leveraging primarily existing tower and roof-top sites.

PROJECTS OVERVIEW



TIMELINE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5GCroCo
5G-CARMEN
5G-MOBIX
5G-ROUTES
5G-Blueprint
5GMED
5GRail

LOCATIONS

5G-MOBIX
- **Vigo - Porto (Spain-Portugal Corridor)**
- **Kipoi - Ipsala (Greece-Turkey Corridor) Hard borders**
- Berlin and Stuttgart *(German)*
- Espoo *(Finland)*
- Paris *(France)*
- Eindhoven-Helmond *(Netherland)*
- China Test Site: Jinan
- South Korea Test Site: Yeonggwang

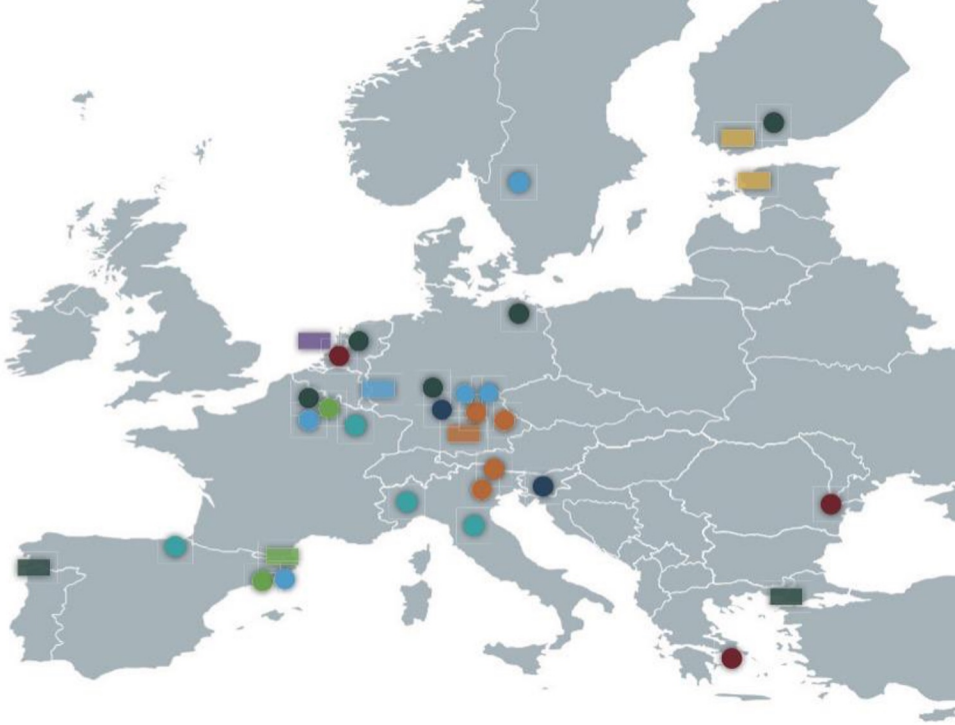
5GMED
- **Corridor E-15 Figueres – Perpignan**
- Castelloli Track *(Spain)*
- TEQMO Centre, Paris *(France)*

5G-CARMEN
- **Corridor Germany-Austria-Italy**
- Trento *(Italy)*
- Munich *(Germany)*
- Brenner Pass *(Italy-Austria)*
- Kufstein *(Austria-Germany)*

5GCroCo
- **Corridor France-Germany-Luxembourg**
- Barcelona *(Spain)*
- Monthléry *(France)*
- Munich *(Germany)*
- A9 5G-ConnectedMobility Testbed *(Germany)*
- AstaZero *(Sweden)*

5G-Blueprint
- **5G cross-border in waterways and high-ways between Belgium and The Netherlands**

5G-ROUTES
- **5G cross-border Via Baltica-North corridor:**
  - Latvia - Estonia - Finland



5GRail prototypes will be tested in simulated and real environments: with pilots in labs and in the field, rolled out in various European sites (France, Hungary and Germany)

TECHNOLOGIES

	RELEASE TESTED	5G DEPLOYMENT		TECHNICAL FEATURES					
		NSA	SA	5G NR	MEC	SERVICE DIFFERENTI-ATION	pQoS	AI	PC5
5GCroCo	15	√		√	√	√	√		
5G-CARMEN	15	√		√	√		√		√
5G-MOBIX	15/16	√	√	√	√	√			√
5G-ROUTES	16/17	√	√	√	√	√			
5G-Blueprint	16/17	√	√	√	√	√		√	√
5GMED	16		√	√	√	√	√	√	√

KPIs

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
5GCroCo	√	√	√		
5G-CARMEN			√		
5G-MOBIX	√	√	√	√	√
5G-ROUTES			√	√	√
5G-Blueprint	√			√	√
5GMED	√		√		

USE CASE	EXTENDED SENSORS	COOP. & AUTOMATED MANOEUVRING	BACK SITUATION AWARENESS	VEHICLE SENSORS AND STATE SHARING	VIDEO STREAMING
KEY 5G KPI	E2E LATENCY	LATENCY	COVERAGE, RELIABILITY	LOCALIZATION ACCURACY	LATENCY, DATA RATE
5GCroCo				√	
5G-CARMEN		√	√	√	√
5G-MOBIX	√				
5G-ROUTES	√	√		√	√
5G-Blueprint				√	
5GMED					

USE CASE	GREEN DRIVING	ROAD INFRASTRUCTURE DIGITALIZATION	FOLLOW-ME INFOTAINMENT	DISTRIBUTED PERCEPTION	VEHICLE QoS SUPPORT	IOT CONNECTIVITY
KEY 5G KPI	SERVICE CONTINUITY	RELIABILITY	DATA RATE, CONTINUITY	DATA RATE, LOW LATENCY	DATA RATE, RELIABILITY	RELIABILITY, LATENCY
5GCroCo						
5G-CARMEN	√					
5G-MOBIX					√	
5G-ROUTES						√
5G-Blueprint				√		
5GMED		√	√			

5GMOBIX

Developing and evaluating **automated vehicle functionalities** using **5G core** technological innovations along **two cross-border corridors and six urban trial sites**

5G-MOBIX Trials

LOCATIONS
- **2** Cross-Border Corridors (CBC)
- **4** complementary European Trial Sites (TS)
- **2** complementary Asian Trial Sites (TS)

NETWORK
- **29** 5G gNBs
- Started with ***NSA*** Architecture, investigated ***SA***

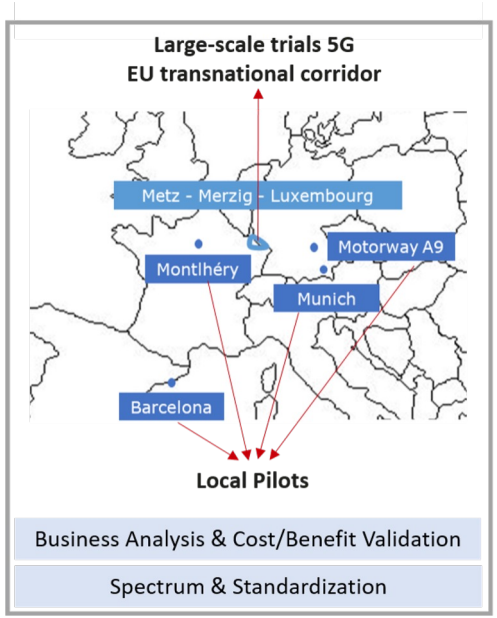
VEHICLES
- ***20*** SAE L4 automated vehicles

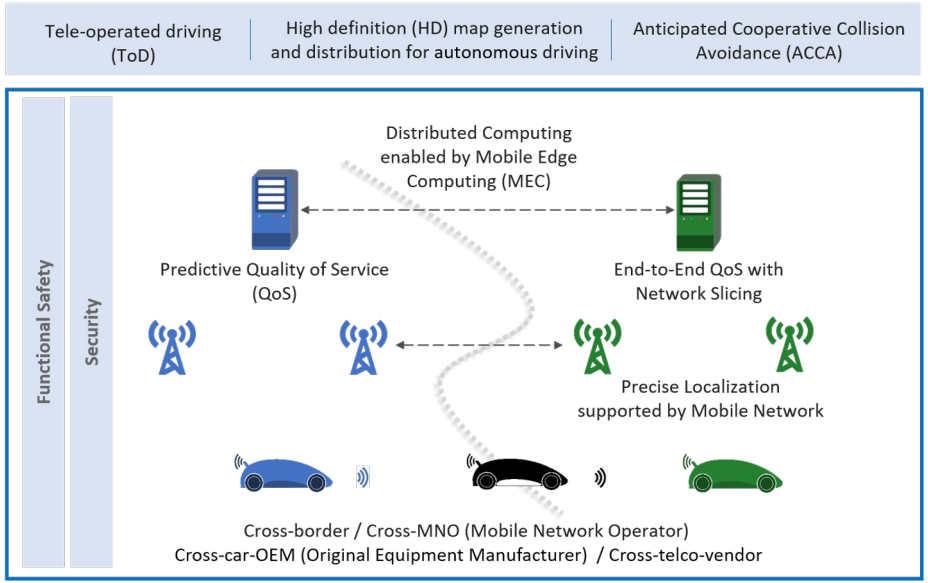
USE CASES
- ***5*** use case categories based on 3GPP TS 22.186, focusing on x-border operation

Advanced Driving | Vehicles Platooning | Extended Sensors | Remote Driving | Vehicle QoS Support

www.5g-mobix.com @_5GMobix @5G-MOBIX

The 5GCroCo project has carried out **large-scale connected car trials** along **the 5G corridor** that crosses the borders between France-Germany and Luxembourg-Germany

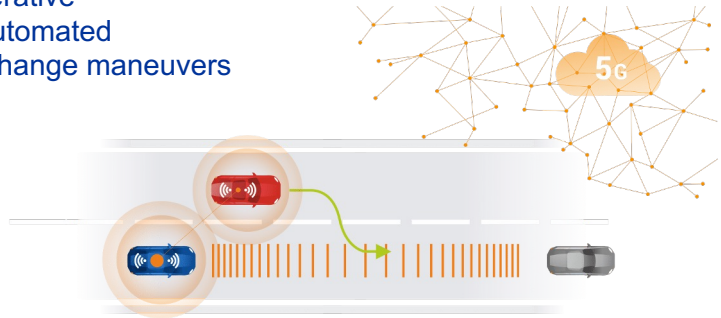




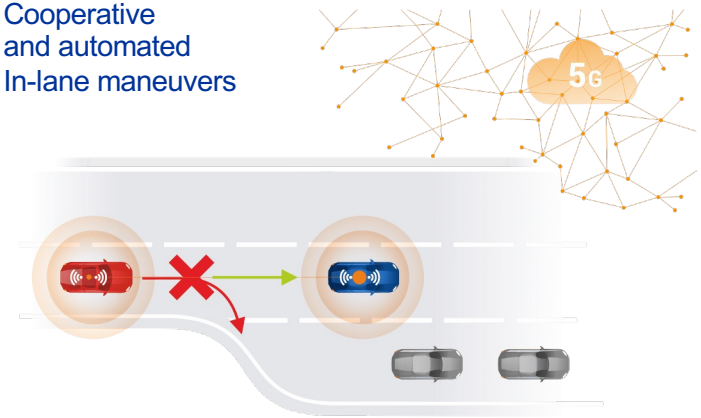
www.5gcroco.eu @5GCroCo @5GCroCo Cross-Border Connected and Automated Mobility

Leveraging on the most recent 5G advancements to provide a **multi-tenant platform** to support **safer, greener and smarter transportation in the self-driving cars industry**

USE CASE 1
Cooperative
and automated
lane-change maneuvers



USE CASE 2
Cooperative
and automated
In-lane maneuvers



AREA:
The project focused on the Bologna-Munich corridor (600km, over 3 countries)

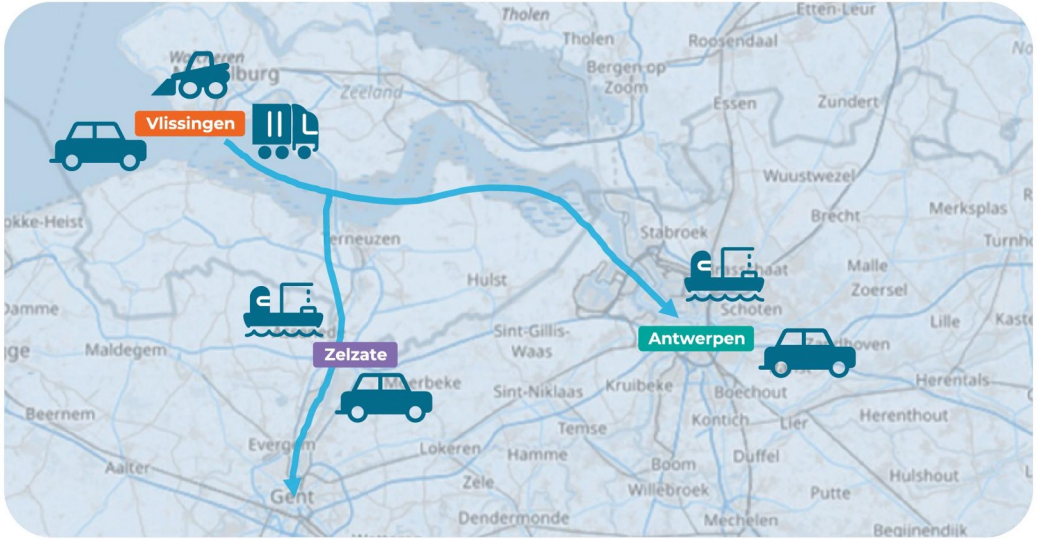
www.5gcarmen.eu @5g_carmen @5G-CARMEN

5G BLUEPRINT

5G-Blueprint designs and validates **technical architecture, business,** and **governance model** for uninterrupted cross-border teleoperated transport based on 5G connectivity

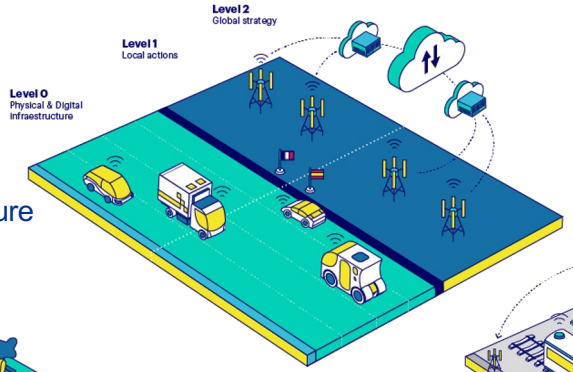
FOCUS AREAS

- **Technology**
- **Business**
- **Governance**



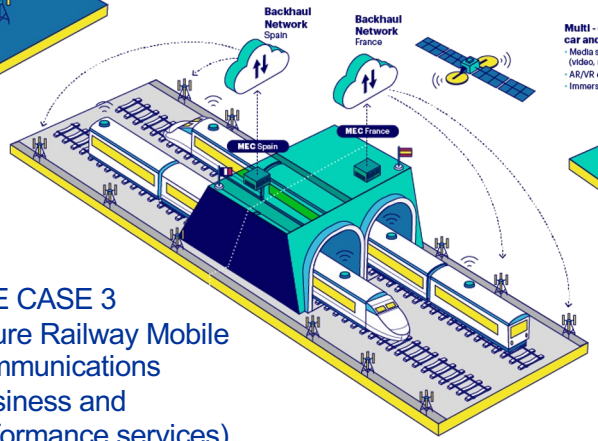
www.5gblueprint.eu @5G_Blueprint @5G-Blueprint Project

5GMED evaluates the capabilities of 5G technologies (3GPP Rel.16) to meet the requirements of advanced CAM and railway use cases along the **Mediterranean Cross-Border Corridor**

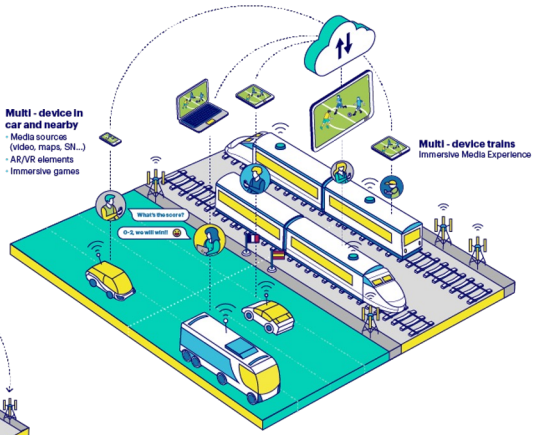


USE CASE 2
Road Infrastructure Digitalisation

USE CASE 1
Remote Driving



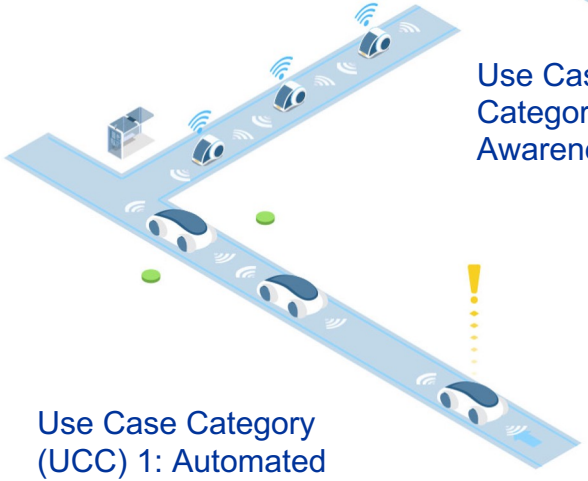
USE CASE 3
Future Railway Mobile Communications (business and performance services)



USE CASE 4
Follow-me Infotainment

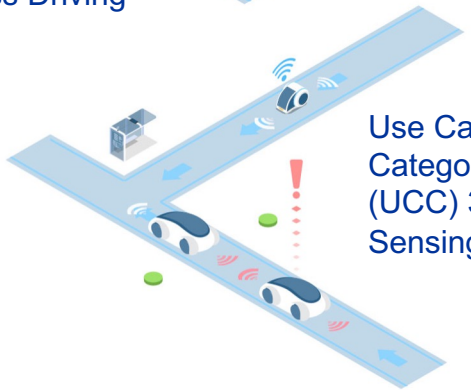
www.5gmed.eu @5GMED_EU @5GMED

5th Generation connected and automated mobility **cross-border EU trials**



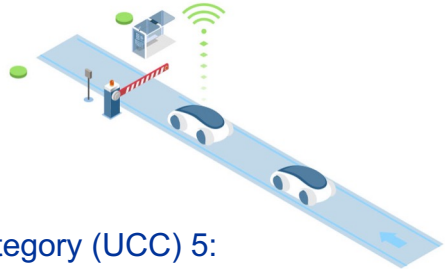
Use Case Category (UCC) 1: Automated Cooperative Driving

Use Case Category (UCC) 2: Awareness Driving



Use Case Category (UCC) 3: Sensing Driving

Use Case Category (UCC) 4: Uninterrupted infotainment passenger services on the go



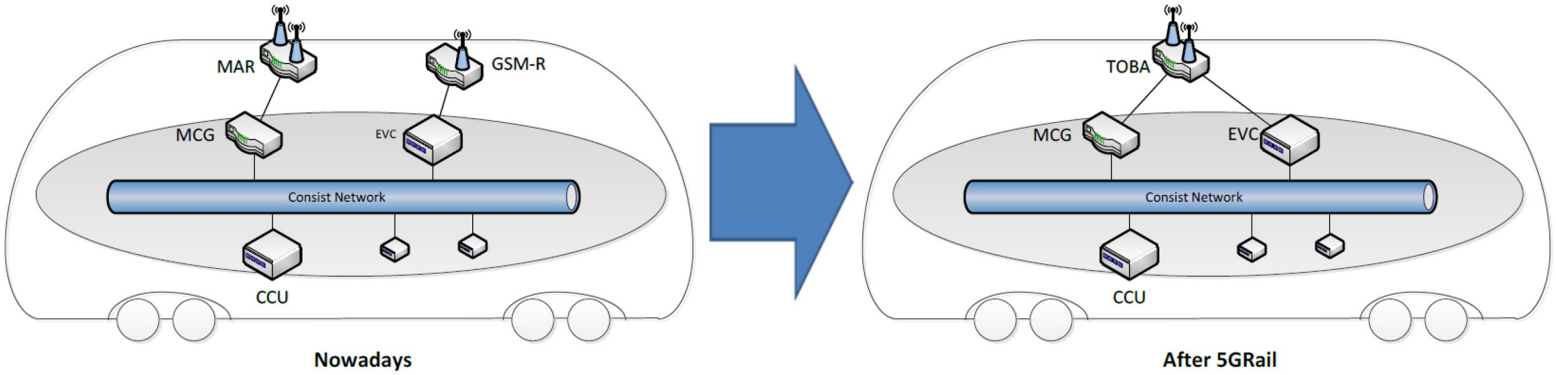
Use Case Category (UCC) 5: Multimodal services

www.5g-routes.eu @5gRoutes @5G-ROUTES Project

5GRAIL paves the way to the **Future Railway Mobile Communication System**

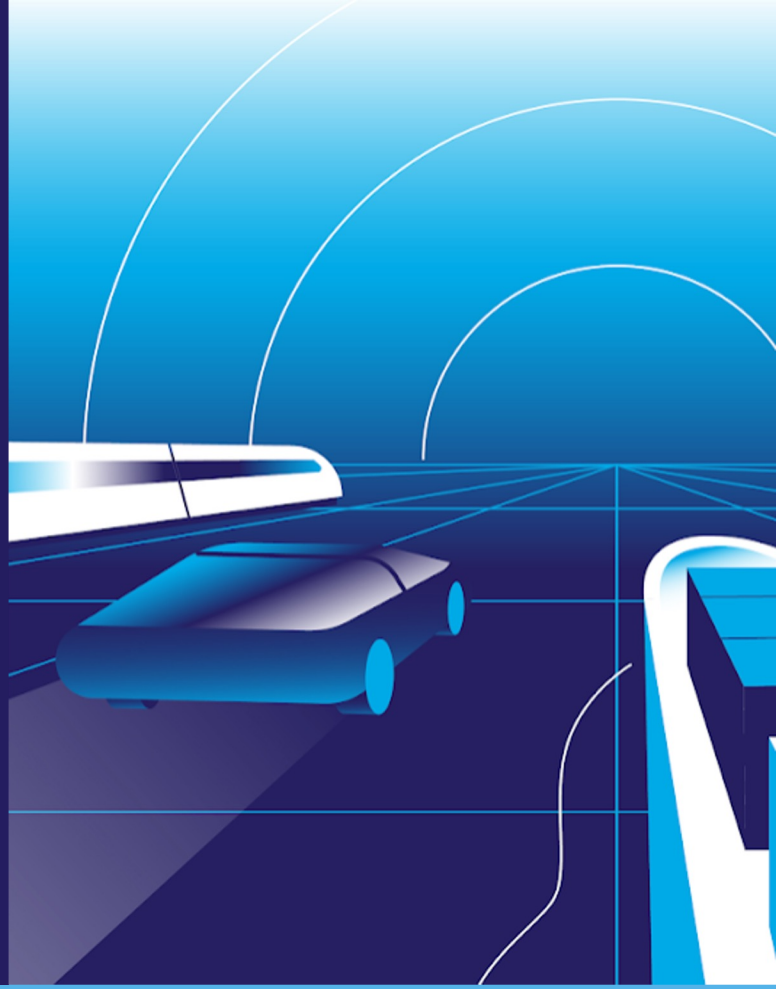
THE 5GRAIL VISION:

Automated trains | New applications related to security (including video capacity) | Remote monitoring and surveillance of vehicle elements (TCMS applications)



www.5grail.eu @5Grail @5GRAIL

ACHIEVEMENTS AND LESSONS LEARNT



5G technologies for connected automated mobility in cross-border contexts

Introduction - key elements in the white paper

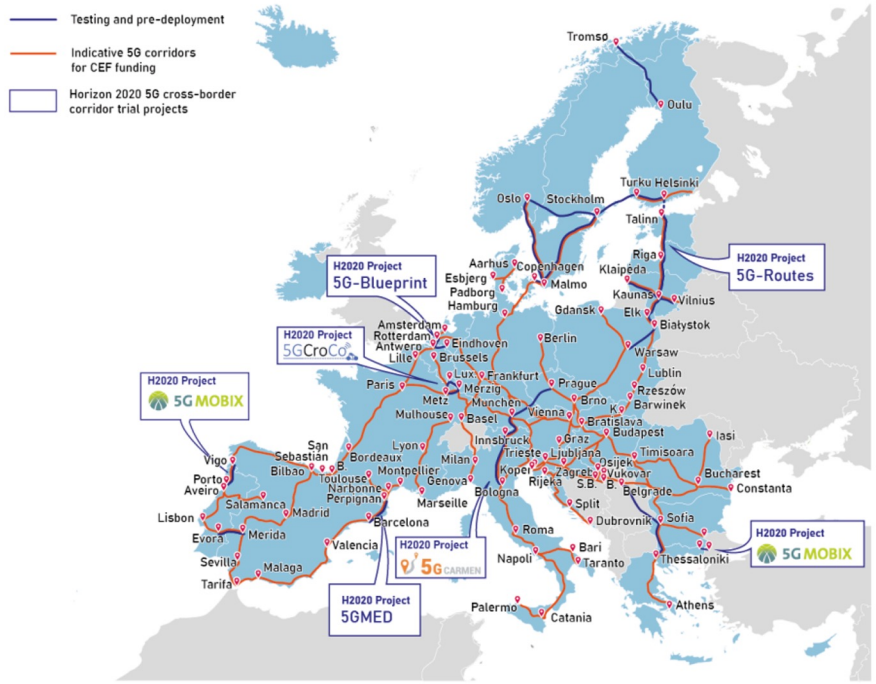
The projects trialled five different solutions which were evaluated to assess the cross-border service continuity.

Further, edge computing capabilities (MEC) and their implications towards service continuity were evaluated.

The research highlights the potential for 5G technology to enhance cross-border connectivity, and the importance of prioritizing inter-PLMN handover in this context.

With further development and implementation, 5G technology has the potential to revolutionize cross-border communication and connectivity and enable advanced, real-time CAM services

Considered corridor areas



Source: https://5g-ppp.eu/wp-content/uploads/2020/10/20201002_5G_SDA_for_CAM_Final.pdf

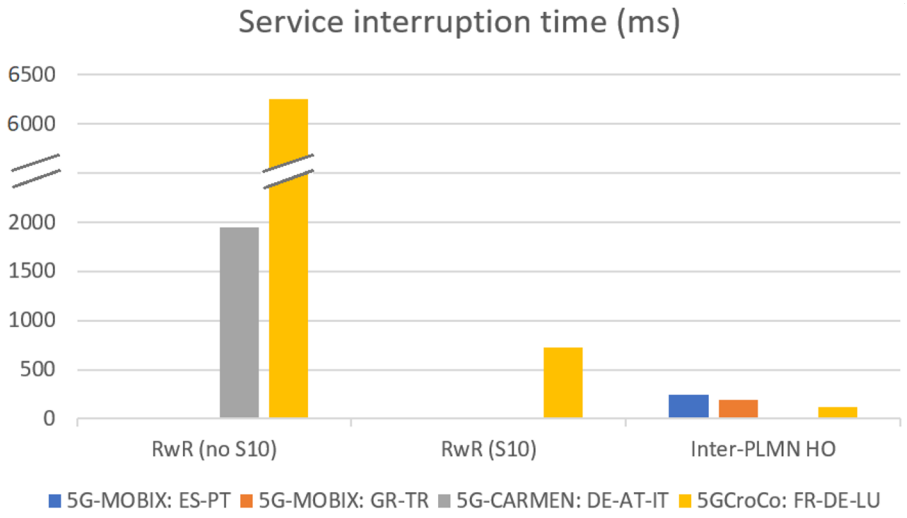
- In these cross-border projects, different approaches to address service continuity were analysed together with an assessment of the performance obtained with 5G (especially compared to 4G).

- 5G-MOBIX: ES-PT (Vigo, Spain – Porto, Portugal)
  - 5G-MOBIX: GR-TR (Thessaloniki, Greece – Turkey)
  - 5G-CARMEN: DE-AT-IT (Munich, Germany – Innsbruck, Austria – Bologna, Italy)
  - 5GCroCo: FR-DE-LU (Metz, France – Merzig, Germany – Luxembourg)

Service continuity

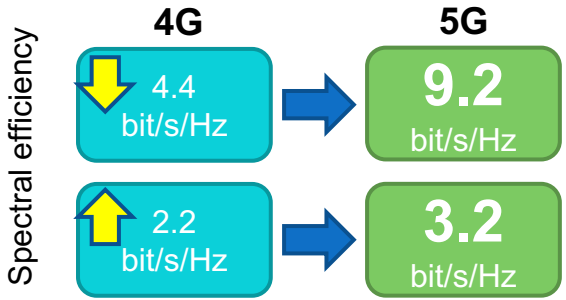
The projects trialed five different options to assess the cross-border service continuity (one baseline, three different network side solutions and one group of end-device based solutions), which can be summarized as:

- 1. Network reselection
- 2. Release-with-redirect (no S10 interface present)
- 3. Release-with-redirect (S10 interface present)
- 4. Inter-PLMN handover
- 5. End-device based solutions



Bar diagram of the service interruption times achieved by the 3 network side solutions trialled in the corridor areas by the three ICT-18 projects (the network reselection baseline is not plotted)

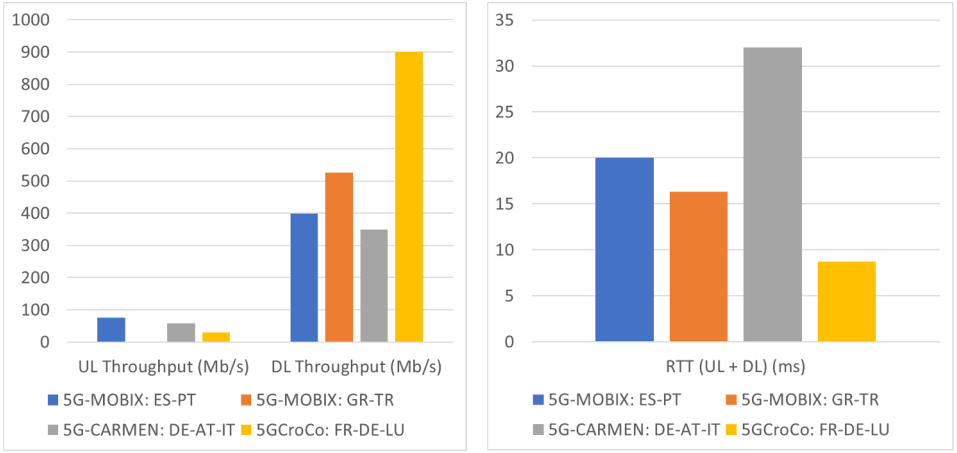
5G performance and improvement compared to 4G



During the trials carried out by the three projects, it was confirmed that 5G will bring a lot of benefits relative to 4G.

In particular, the ICT-18 projects focused their measurements related to the performance of 5G in three main categories:

- 1. Throughput (user experienced data rate) both in the UL and DL
- 2. Delay and round-trip-times
- 3. Reliability

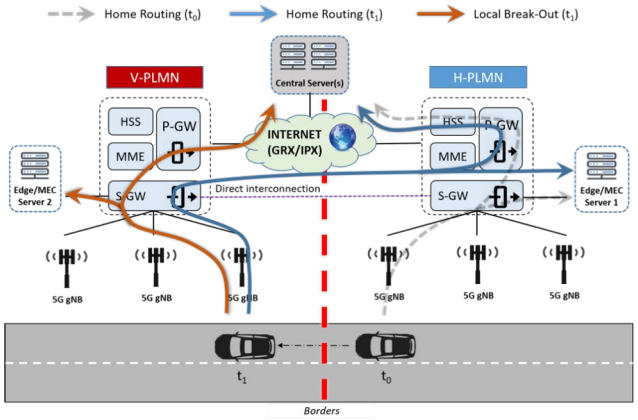


Bar diagram of the performance obtained by the 5G NSA networks deployed in the corridor areas by the three ICT-18 projects (excluding Reliability)

MEC in cross-border

- The term Mobile Edge Computing – MEC describes application server hosting capabilities within the domain controlled by the MNO, e.g., in its data centres or cabinets

- MEC enables controlled end-to-end QoS as the service provider, typically an MNO, has control over the whole data path.



Conclusions and Roadmap Recommendations

- As the most significant outcome from trials in cross-border contexts, the three projects have shown that **seamless service continuity** in cross-border areas is feasible and can be guaranteed provided there is overlapping RAN coverage at both sides.

- **Service interruption times**, decrease from tens of seconds (even up to minutes) that are endured today, down to a few seconds or, even, in the order of a hundred milliseconds.

- 5G was shown to be a capable solution that can significantly **improve performance** compared to previous technologies, mainly 4G, especially in terms of quantitative terms like:
  - reduced latency,
  - higher capacity and
  - spectral efficiency,
  - exposure of APIs like QoS prediction, which are not available in 4G.

- 5G can support, already today, **about 80% of connected/automated driving services** (including all day-1 services) as their requirements are in line with commercially available performance.

Conclusions and Roadmap Recommendations

From the ICT-18 projects experience, the following approach to provide clarity to potential users of the connectivity would be recommended:

- If there is at least a 5G-NSA deployment, deployment projects should implement inter-PLMN handovers. If this is not possible, as a minimum **Release with Redirect using the S10** interface should be implemented. These features are available within 5G-NSA deployments.
- If **coverage** is key for a specific corridor, the focus should be on creating seamless connectivity.
- If **capacity** is key for a specific corridor, the focus should be on QoS mechanisms for service differentiation.

For use-cases where the business case is clear, that require international travel, the deployment will likely need end-device specific implementations

- **Link aggregation and/or multi-sim**/multi-modem solutions provide both the needed use-case specific QoS and seamless cross-border service handover needed earlier than through waiting for full deployment, to expedite service deployment.
  - Trials in 5G-MOBIX demonstrated the clear advantage of **link aggregation** solutions, over link selection ones, in the presence of dual connectivity i.e., dual-modem.
  - On the other hand, **NTN solutions proved unable** to support CAM use case specific QoS in limited trials conducted in 5G-MOBIX.

Conclusions and Roadmap Recommendations

5G-SA

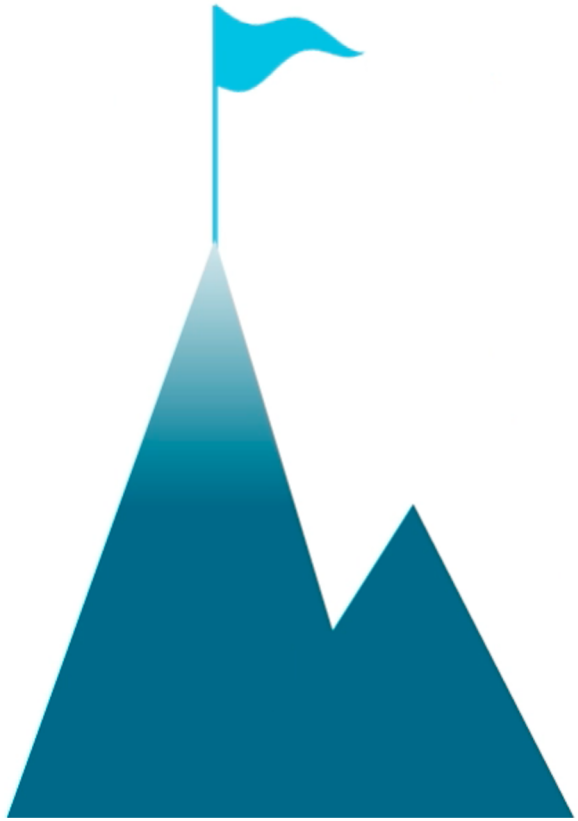
- By using a 5G Core instead of an Evolved Packet Core and discarding the need for control signaling over 4G, 5G SA simplifies network planning (5G New Radio layer, not the 4G one).
- Furthermore, 5G SA supports Session and Service Continuity (SSC) mode 3, which enables seamless Local Breakout Routed Roaming necessary for re-anchoring.
  - This is expected to overcome the limitations of home routing, which increases latency, due to the default traversal of the home network, even in the presence of a local edge server.
- Finally, 5G SA adds Network Slicing as another option to achieve QoS service differentiation.

For demanding use-cases like tele-operation or remote supervision, being able to have a short path between vehicle(s) and Edge/Cloud is critical:

- The ICT-18 projects recommend using 5G SA with SSC mode 3 to prevent very long paths due to home routed roaming.
- This can be either a bespoke specific deployment or within a commercial deployment.

EC'S PERSPECTIVE ON CROSS-BORDER CHALLENGES

FUTURE R&I CHALLENGES FOR CAM SCENARIOS



Q&A

THANK YOU FOR YOUR ATTENTION!

VISIT US AT BOOTHS H03:20 & H05:20!

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5G PPP WWW.5G-PPP.EU

6G SNS IA

Funded by the EU's Horizon 2020 programme