5GMED

Use Cases

This use case catalogue has been prepared in the framework of the 5GMED. 5GMED is a European funded project under the Horizon 2020 programme. For more information about the catalogue contact:

5GMED impact manager: Marjorie Grassler
Email: mgrassler@mobileworldcapital.com

Authors:
5GMED consortium partners

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5GMED

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Summary of the project

5GMED project is an iniciative deployed in the cross-border between France and Spain, focused on designing a joint roads and railways 5G infrastructure architecture in the Mediterranean corridor. It aims to accelerate large-scale 5G deployments along European corridors and demonstrate sustainable business models for future connected and automated mobility. With a total investment of **16 million euros**, 75% of which is funded by the European Commission, the project runs from September 2020 to September 2024.

The 5GMED Project aligns with the European Union's objectives for 5G deployment, particularly the goals set in the **5G Action Plan** and the **Digital Decade Communication**, which aim for full 5G deployment by 2030. The project consortium, coordinated by **Cellnex** Telecom, and with **i2CAT** as technical manager, comprises 21 partners from 7 countries, including prominent entities from the telecom, transport, technology, research, and consulting sectors. The project also receives support from public administrations in both countries, such as the **Occitania Region** and the **Govern de la Generalitat de Catalunya**, who have been driving the **5G corridor** initiative from its inception.

The project tests a wide range of technologies beyond 5G, including onboard sensors to provide advanced connectivity services in a scalable and replicable manner across transport paths.

Partners of the project:


5GMED
Cross-MNO Orchestration
5GMED
• Until April 2024
✓ Complete development of cross-border orchestration between MNOs
✓ Federation of orchestrators based on East/Westbound Interface of GSMA Operator platform
✓ UC4 services orchestrated in MEC servers deployed in the corridor
✓ UC4 services migration through Northbound Interface
• In June 2024
✓ Automated migration of UC4 services triggered by geo-fencing (when UE crosses a specific location)
✓ Using LBO roaming and distributed UPF

5GMED

Introduction

The 5GMED project has been an intense adventure across the Mediterranean corridor between Spain and France. As project coordinator, it's been a journey filled with challenges, from going through cross-border technical and regulatory differences to integrating an ecosystem for the future mobility, with multiple partners with different backgrounds.

What made it all thrilling was pushing 5G's boundaries—integrating satellite, edge computing and 5G technologies, optimizing roaming, and overcoming equipment limitations. The technical difficulties forced us to innovate, but none of this would have been possible without our incredible team. With 21 partners from seven countries, every member played an important role.

Together with support from public administrations like the Occitania Region and Generalitat de Catalunya, we've aligned this project with Europe's 5G goals. As we completed the project, we're proud to be shaping the future of connected, automated mobility in Europe.

José López Luque

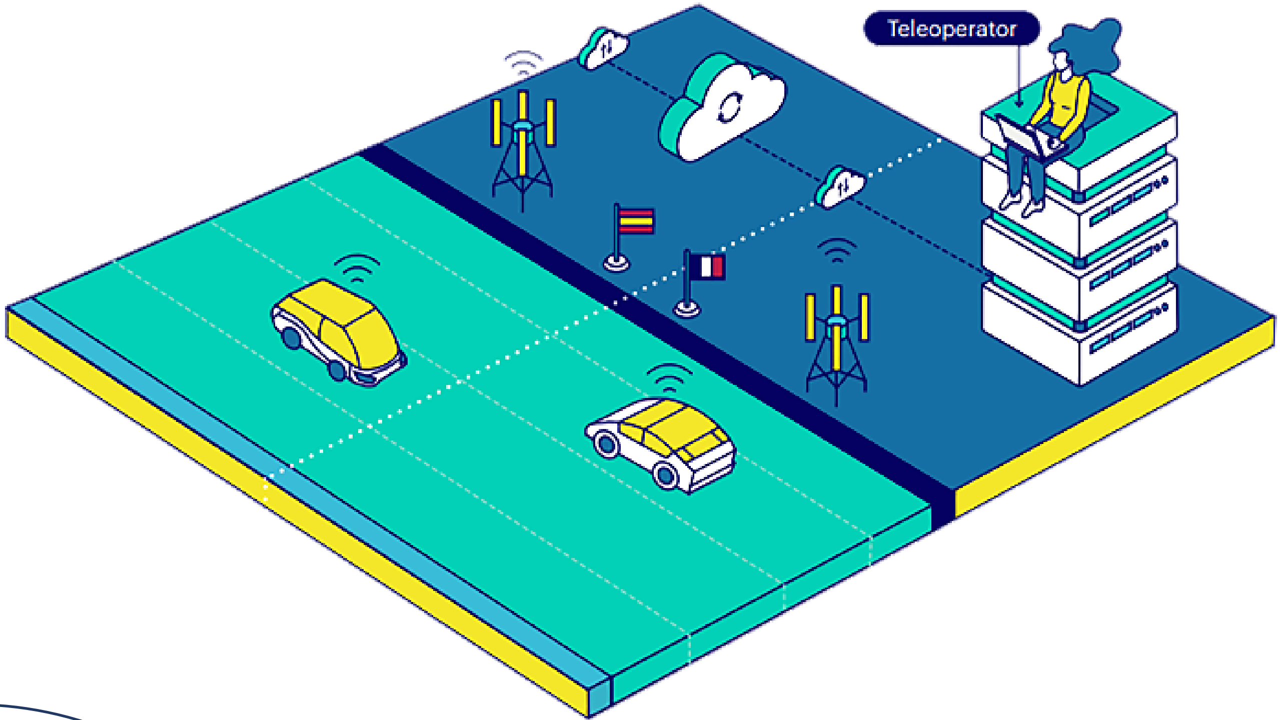
5GMED Coordinator
Innovation Programme Manager
Cellnex Telecom

The 5GMED Use Cases

The 5GMED project has defined a set of use cases to represent the challenges related to both CCAM and the applications of raiways services.

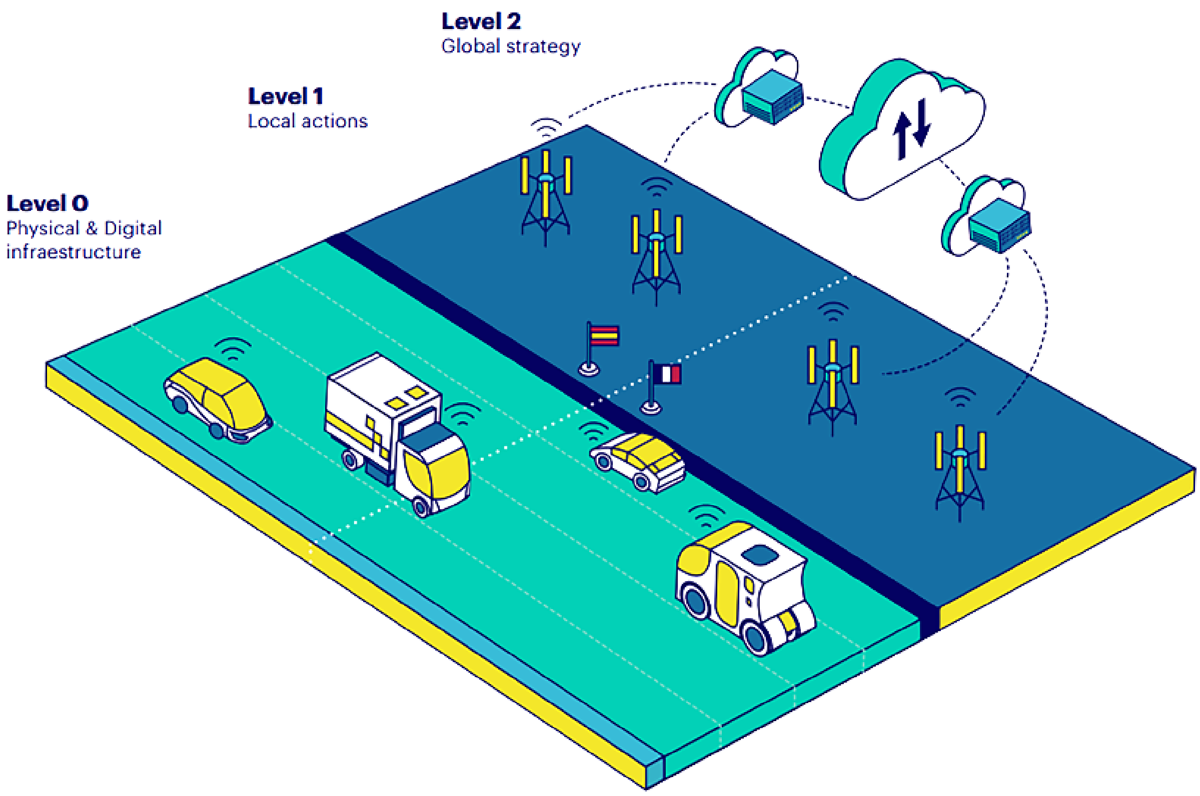
Remote Driving

Focuses on **remote assistance for Connected and Autonomous Vehicles (CAVs)** facing failures or complex traffic situations, allowing remote control via three services: **Minimum Risk Manoeuvre (MRM)**, **Remote Assistance (RRA)**, and **Teleoperation Manoeuvre (TM)**. This use case is deployed in the automotive scenario.



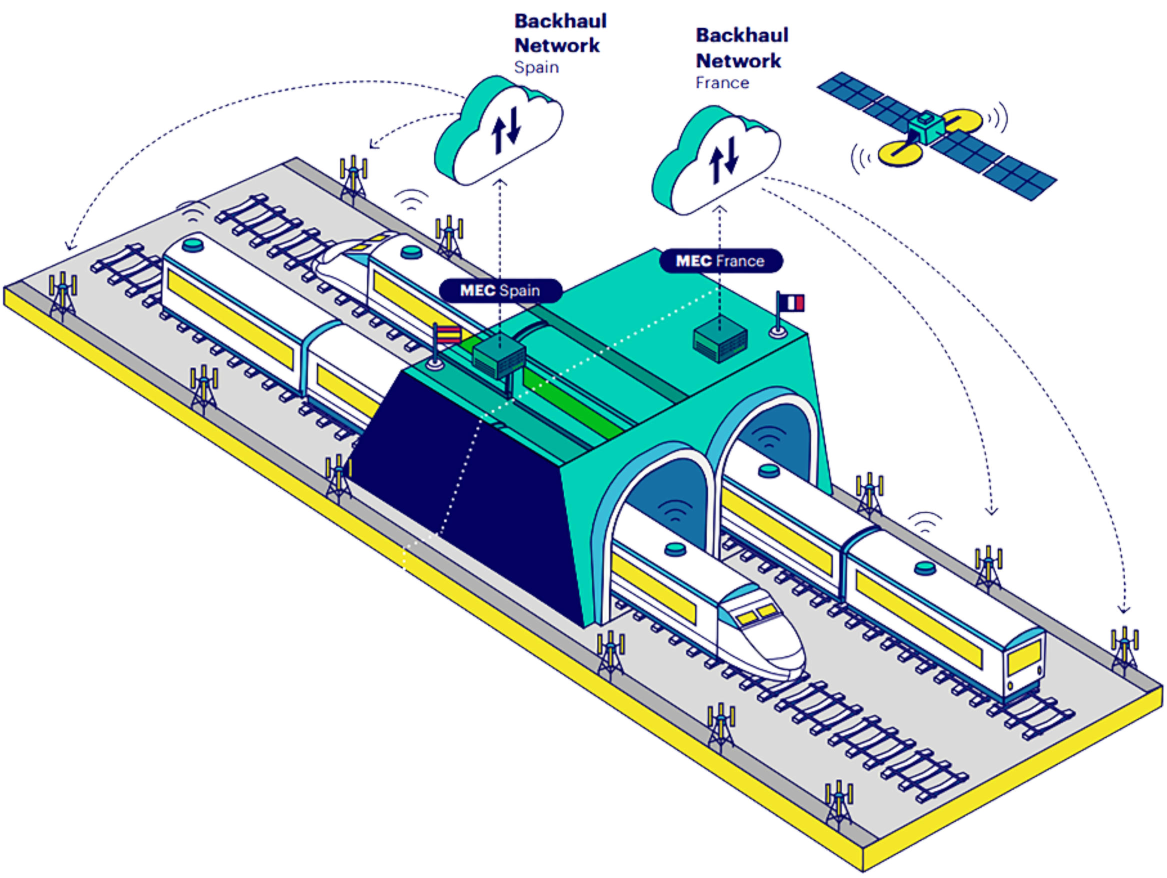
Roads Digitalization

Aims to **ensure safe and efficient mobility on highways** by **integrating data from Connected Vehicles (CVs)** and other sources to create intelligent traffic management strategies. It includes local warning traffic strategies with the **Relay of Emergency Message (REM)** and **Automatic Incident Detection (AID) services**, and global traffic strategies to manage traffic flow. This use case is also deployed in the automotive scenario.



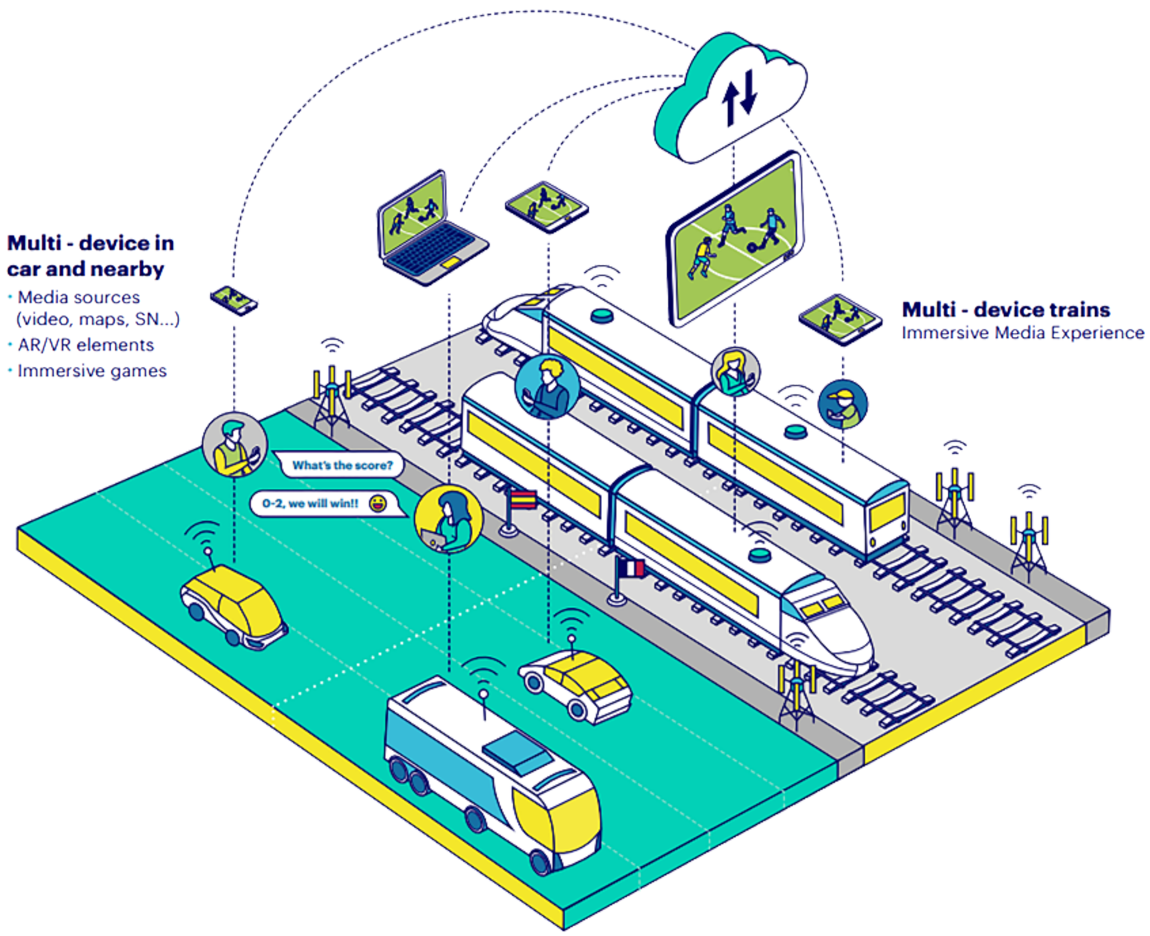
Future Railways

Aims to **ensure safe and efficient mobility on highways** by **integrating data from Connected Vehicles (CVs)** and other sources to create intelligent traffic management strategies. It includes local warning traffic strategies with the **Relay of Emergency Message (REM)** and **Automatic Incident Detection (AID) services**, and global traffic strategies to manage traffic flow. This use case is also deployed in the automotive scenario.



Follow-Me infotainment

Aims to **distribute high-quality media content to passengers in vehicles or trains, ensuring high Quality-of-Experience (QoE)**. It includes the Enjoy Media Together service for synchronized **high-definition movie watching and interaction**, and the **Tour Planning service for VR streaming of Points of Interest (PoIs)**. This use case is deployed in the automotive scenario and partially in the railway scenario, with cloud deployment for testing functionalities in the railway scenario.



Crossborder and Technical Challenges

Delivering continuous and seamless services in cross-border scenarios is challenging due to the transition between different Public Land Mobile Networks (PLMNs) managed by different operators in various countries. Current network deployments show limited cooperation and information exchange between PLMNs, focusing mainly on classical roaming procedures. Achieving uninterrupted services in cross-border regions involves numerous technical challenges, particularly related to mobility.

The technical challenges of 5GMED are divided into the 4 areas detailed on the next page.

01 Challenging Environment and Heterogeneous Radio Access:

The Perpignan-Figueres cross-border corridor features challenging terrain and an 8 km tunnel. Specialized network infrastructure using 70 GHz IEEE 802.11ad, and satellite communication is deployed to address 5G coverage gaps in automotive and railway scenarios, ensuring continuous connectivity in difficult areas.

02 Roaming with Low Interruption Time and Low Latency:

High-speed movement of User Equipment (UE) causes connectivity issues that 5G networks typically resolve within the home PLMN (h-PLMN). However, roaming leads to significant interruptions and latency, unsuitable for high-mobility CAM and railway services. 5GMED addresses this with 5G core and RAN solutions, including edge computing.

03 Cross-border Orchestration:

5G networks utilize service and network virtualization, requiring a domain orchestrator for each PLMN to manage virtualized elements. In cross-border scenarios, UE transitions between PLMNs necessitate resource allocation and service configuration, highlighting the need for a cross-border interface. 5GMED explores the GSMA's common Operator Platform concept for federation and seamless access to Edge/Cloud capabilities across operators.

04 Cross-border Network Slicing Continuity:

Network slicing in 5G enables the partitioning of a single infrastructure into isolated slices tailored to diverse user needs. While standardization is established, implementing slicing across borders faces challenges due to operators' differing policies and configurations, complicating slice transfer between PLMNs.

Overcoming the challenges with a cross-network architecture

5GMED has devised a cross-border network architecture that comprises six distinct layers: network infrastructure, MEC, orchestration, slice management, cloud, and data analytics

01 5G SA Networks:

The internal architecture of two private 5G SA networks deployed in the Mediterranean cross-border corridor between Figueres (Spain) and Perpignan (France) is detailed. Supplied by Druid and hosted in a data center near to Barcelona (Castellolí), these networks include essential functions like AMF, SMF, and UPF. The 5G RAN consists of twelve gNodeBs, with a Distributed Antenna System in an 8-kilometer railway tunnel. Transport network complexity arises from the corridor's orography, employing microwave and fiber optic technologies.

02 Roaming Optimization Techniques:

Inter-PLMN Handover: 5GMED configures inter-PLMN Handover between the networks belonging to two different countries and operators. Thanks to this feature, the applications and services transition between networks is seamless. The interruption time gets reduces from an average on 1 minute to around 100 milliseconds, enabling all kind of CCAM applications.

Ultra Low Latency: 5GMED architecture ensures low latency with two complementary mechanisms. First, deploying different MECs servers so that the user is always as close as possible to the application content. Secondly, these servers can be additionally used to deploy Distributed UPFs, a distributed 5G core architecture that enables Local Break Out (LBO) Roaming, allowing a fast access to this content even in a roaming scenario.

03 Cross-MNO Orchestration:

The NearbyOne orchestrator in 5GMED manages application and cloud-native network function lifecycles across the compute continuum. It integrates with 5GMED services, facilitating proactive migrations in automotive scenarios. Cross-MNO federation, following GSMA's Operator Platform concept, ensures consistent availability of operators' assets across networks and borders via the East-Westbound Interface (EWBI).

04 Slice Management:

The 5GMED slice management layer includes the Network Slice Management Function (NSMF), orchestrating slice instances and subnet requirements. The Network Slice Subnet Management Function (NSSMF) comprises Core, Radio, and Transport components, enabling end-to-end connectivity and efficient resource allocation. A design for network slice federation ensures cross-border slice continuity, utilizing Slice Federation as a Service (SFaaS) triggered by a Slice Federation Manager. Limitations in dynamic slicing implementation lead to static RAN slicing and VLAN-based traffic isolation.

The Mediterranean cross-border corridor

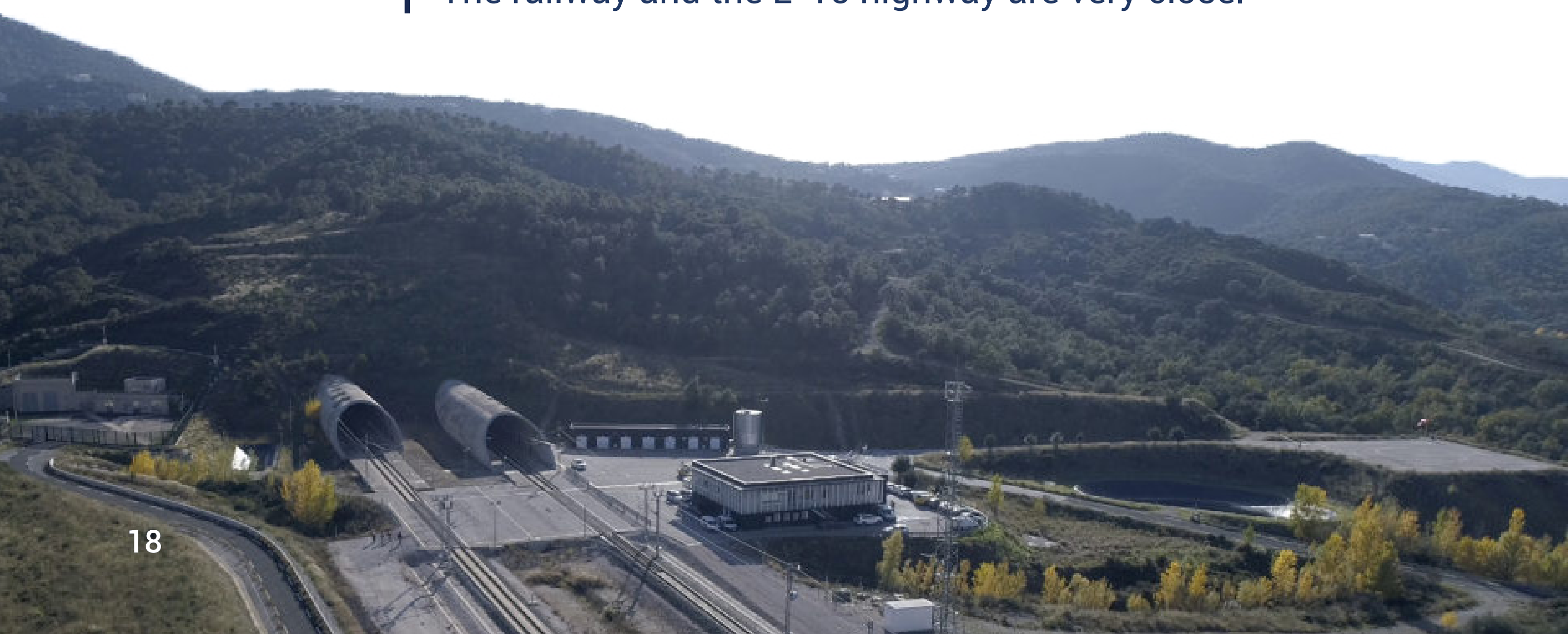
In the segment of the Mediterranean cross-border corridor between Figueras and Perpignan, four different zones can be considered:

Zone 1 | Between Perpignan and Mas Cantarana (11 km approx.). The railways and the E-15 highway are far away from each another.

Zone 2 | Between Mas Cantarana and Le Boulou (12 km approx.). The railway and the E-15 highway are very close.

Zone 3 | Between Le Boulou and La Junquera (14 km approx.). There is an 8.3 km railway tunnel across the border between France and Spain. It is composed of two parallel tubes, one for the trains from France to Spain and the other for the trains running in the opposite direction.

Zone 4 | Between La Junquera and Figueras (25km approx.). The railway and the E-15 highway are very close.



Use Cases' definition

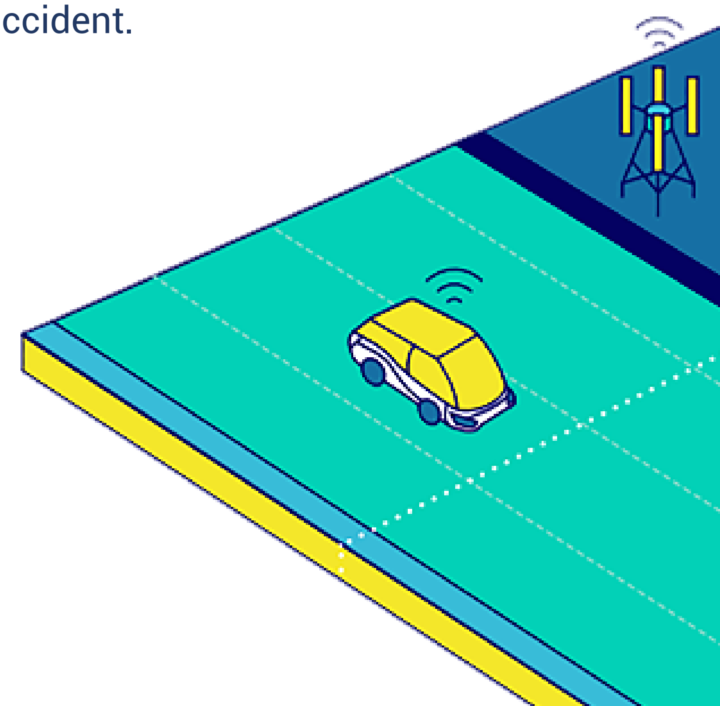
USE CASE

01 Remote Driving

Imagine you are in an autonomous car, known as a Connected and Autonomous Vehicle. These vehicles are designed to handle most driving situations on their own. Achieving truly safe automated driving requires addressing an exhaustive list of conditions an autonomous vehicle might encounter.

Operational Design Domain (ODD)

This list is referred to as Operational Design Domain (ODD) and includes road types, speed ranges, time of day, weather, and many environmental conditions that may affect the operations of the autonomous vehicle. But what happens if they encounter a problem or a tricky traffic situation that's beyond their capabilities? The use case Remote driving approach consist in simulating the exit of the vehicle's ODD by provoking a hardware or software failure (e.g., on cameras or LiDARs) or by encountering unmanageable road conditions, e.g., a hazard like a car accident.



The tested services

1. Minimum Risk Manoeuvre (MRM)

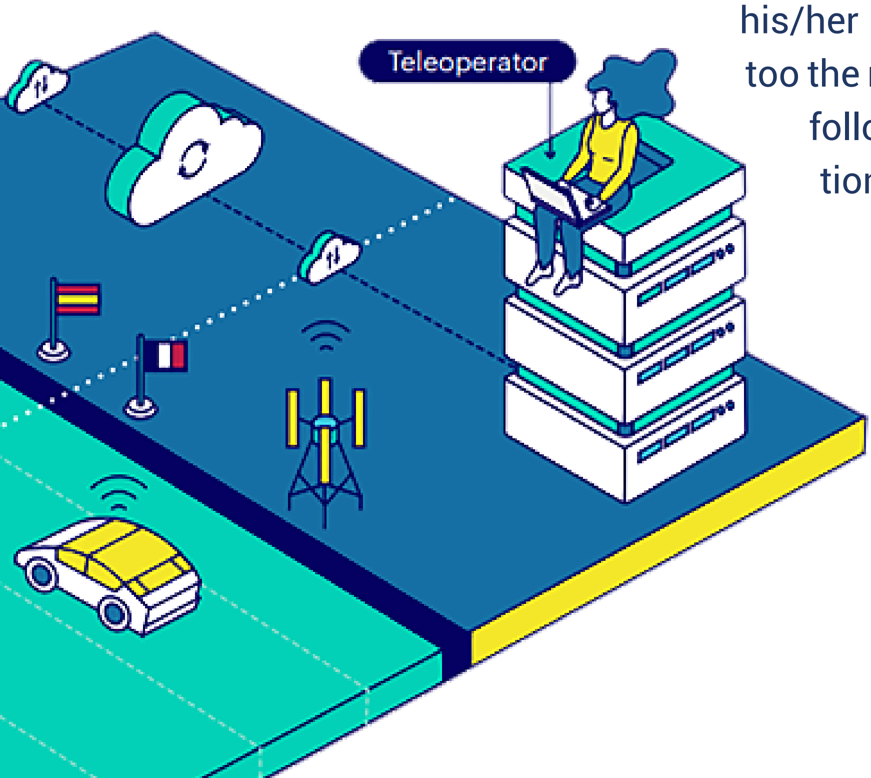
is triggered as soon as the vehicle gets out of its ODD and if no one is present for a DDT Fallback, e.g., a driver who may not react to visual and sound alerts. It is entirely automated in the autonomous vehicle without any assistance from the ground. MRM can result in several outcomes and will eventually end up automatically stopping the vehicle into the safest place according to the onboard computer, e.g., in the emergency lane on a highway.

2. Request for Remote Assistance (RRA)

As soon as the MRM is triggered, and possibly before the vehicle has even come to a full stop on the emergency lane, the vehicle will initiate a request for remote assistance to the Valeo Teleoperation Cloud (VTC). VTC will make a quick assessment of whether remote driving would be manageable in given circumstances and of where to drive the vehicle for safety.

3. Teleoperation Maneuver (TM)

If RRA is conclusive, an assigned remote driving human operator will take control of the vehicle from his/her remote cockpit, and then drive it too the recommended safe location. The following sections describe the actions performed in each service of the remote driving use case



The Vehicle

Valeo's Cruise4U, a prototype of automated driving on highway or motor-way alike road that allows the driver to decide whether to drive manually or prefer to delegate this task.

Results

Using the 5G cellular network, 5GMED demonstrates that a teleoperator can control the car from a remote location and ensure the Dynamic Driving Task Fallback (DDT, specified by SAE J3016) with full safety. This means that 5GMED added a new reliable mode to the DDT fallback procedure.

KPIs

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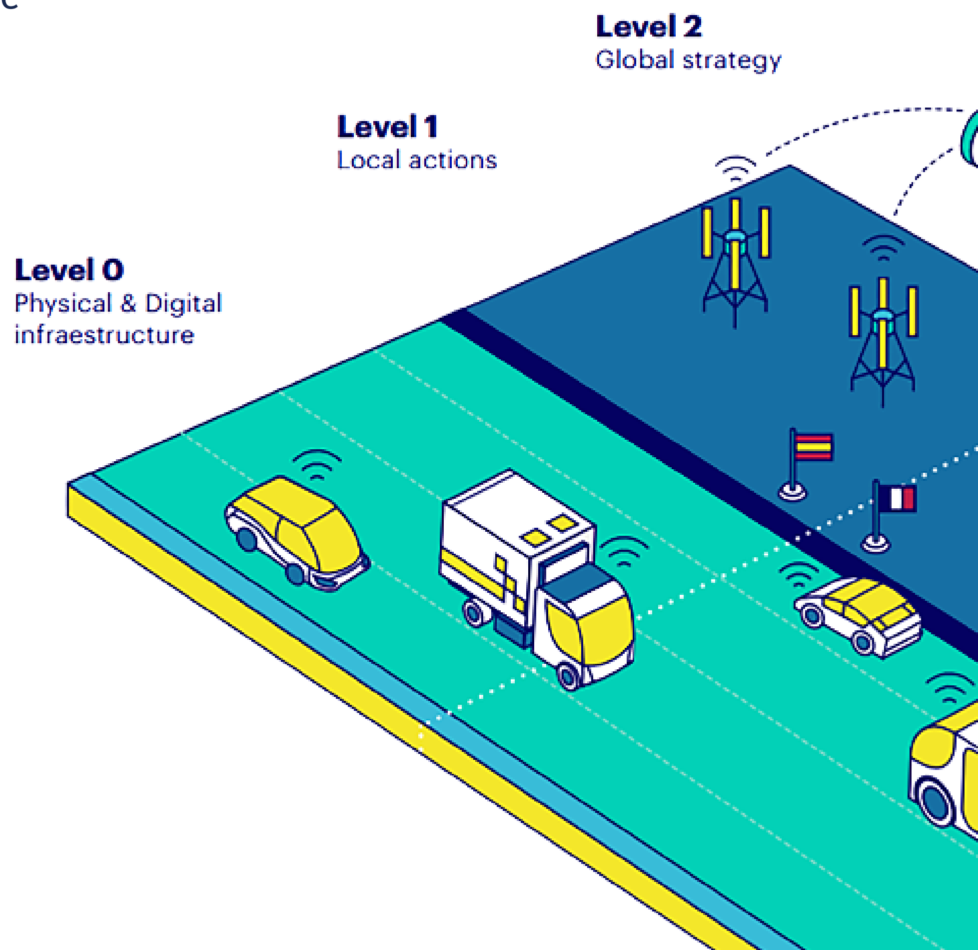
Service KPI Name	1. Minimum Risk Maneuver	2. Request for RemoteAssistance	3. Teleoperation Maneuver
Command End-to-End Latency (DL)			<20 ms, <50 ms
Data End-to-End Latency (UL)		<100 ms	<100 ms
Command message Reliability			99%
Command message Reliability		>95%	>95%
Downlink Service Data-Rate		> 5 Mb/s	> 10 Mb/s
Uplink Service Data-Rate		> 0.5 Mb/s	> 1 Mb/s
Mobility interruption time		< 1 s	< 100 ms

Target values of service KPIs for the remote driving use case

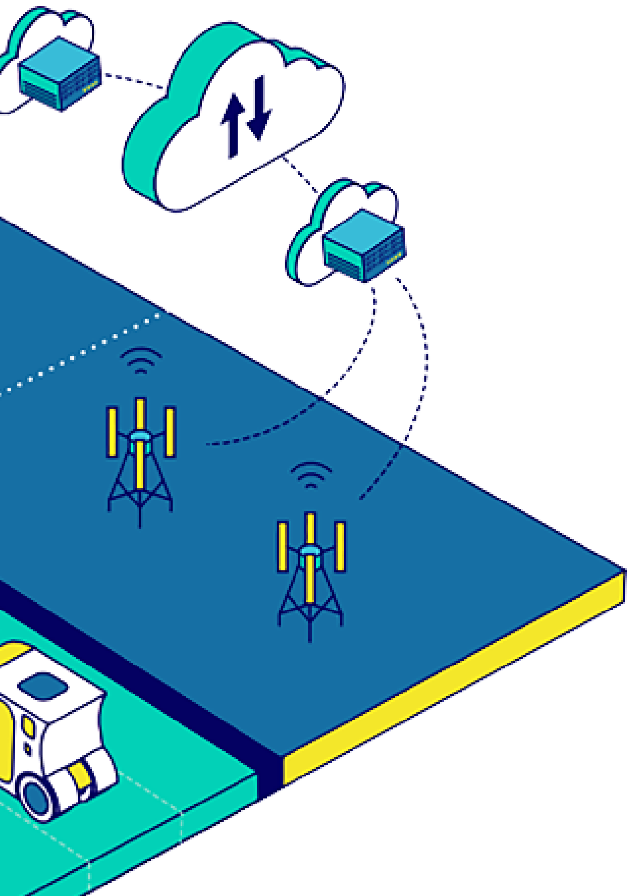
USE CASE 02 Digitalization of the roads

As technology advances, our highways are becoming smarter, thanks to the integration of Connected Vehicles (CVs) and traditional non-connected vehicles. To ensure safe and efficient traffic flow, especially on busy highways, a sophisticated system of data collection and analysis is put into place. Connected Vehicles are equipped with advanced sensors like LiDAR, radar, and GPS. These sensors collect real-time data about the vehicle's surroundings. Additionally, information is gathered from other sources such as traffic cameras and roadside sensors. All this data is sent to a Traffic Management Centre (TMC), where it is processed to create smart traffic management strategies.



The tested services

Warning Traffic Strategies, which is a “real time” service that implies traffic management procedures in a segment of the highway in the cross-border corridor. These warning traffic strategies imply the dissemination in real-time of warning messages and driving actions for automated and connected vehicles close enough in order to anticipate the detection and reaction in hazardous situations. These situations can be an accident, a stopped vehicle, an obstacle on the highway, etc. In this context, real-time means that there is a stringent requirement in terms of latency because the warning message should reach the concerned incoming cars in time to facilitate a safe and efficient reaction to avoid accidents. Simple calculations based on the length of the highway segment under local control, the maximum speed of vehicles, and the braking distances can give an idea on the required latencies. Within the warning traffic strategies service type, two different services are considered:



1. Relay of emergency messages (REM)

In this service, the hazard detection is performed by in-vehicle on-board sensors. The aim of this service is to consolidate the warning emergency messages (also named as hazard notification messages) sent by vehicles to the infrastructure and then send the warning and a traffic strategy from the infrastructure to other vehicles approaching to the hazard.

2. Automatic incident detection (AID)

In this service, the cameras deployed along the infrastructure are responsible for hazard detection. When a hazard is detected, the infrastructure sends emergency warning messages to the vehicles, as well as a traffic strategy.

Global Traffic Strategies imply traffic management procedure on a large portion of the highway or the whole highway. Somewhat like regulating the traffic lights in a city, this will help to regulate the flow of vehicles all along the highway, taking into account all kinds of unexpected events (e.g., prevent or regulate traffic jam, avoid accordion phenomena, suggest offloading actions, etc.). Within this global traffic strategies service type, one service is considered:

3. Traffic Flow Regulation (TFR)

In this service, the cameras deployed along the infrastructure are responsible for hazard detection. When a hazard is detected, the infrastructure sends emergency warning messages to the vehicles, as well as a traffic strategy.

KPIs

	1. Relay of Emergency Messages	2. Automatic Incident Detection	3. Traffic Flow Regulation
Hazard End-to-End Latency	< 200 ms	< 200 ms	
Traffic Regulation End-to-End Latency	< 500 ms	< 500 ms	< 600 ms
Hazard Notification Reliability	99,90%	99,90%	99%
Traffic Regulation Reliability	99,90%	99,90%	99,90%
Uplink Service Data-Rate	10 kb/s	5 Mb/s	5 Mb/s
Downlink Service Data-Rate	7 kb/s	7 kb/s	3 kb/s
Mobility interruption time	< 80 ms	< 100 ms	< 100 ms

Results

01 **Increased Safety:** Immediate hazard detection and communication help prevent accidents.

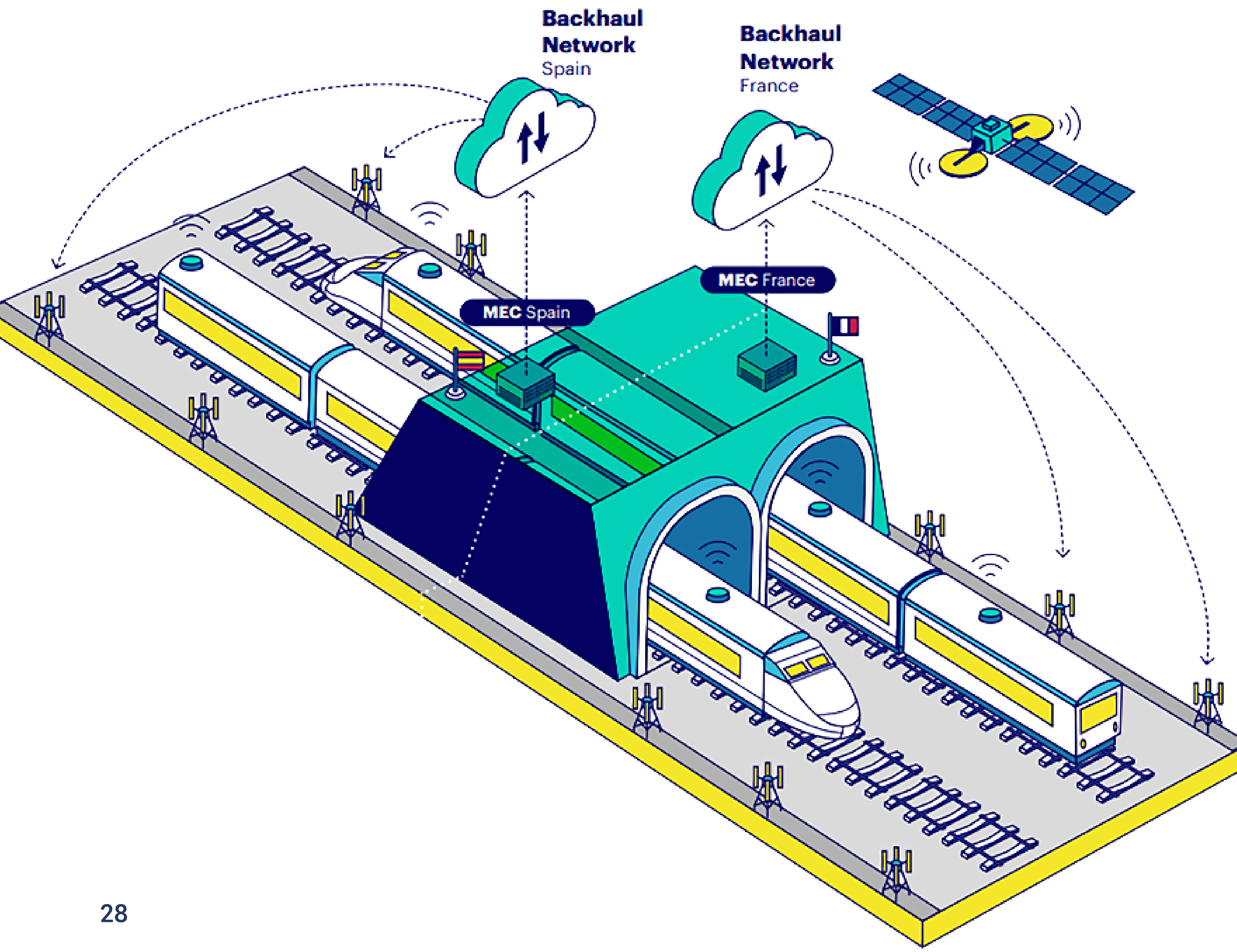
02 **Efficient Travel:** By managing traffic flow intelligently, travel times can be reduced.

03 **Improved Traffic Management:** Real-time data allows for better handling of unexpected situations and overall smoother traffic operations.

USE CASE 03 Future Railways

Enhancing Safety and Comfort with Advanced Communication Systems

The Future Railways Mobile Communication System is set to revolutionize train travel by introducing cutting-edge performance and business services. These enhancements aim to improve both operational efficiency and passenger experience. Let's explore how these new services will work:



Performance Services

1. Advanced Sensor Monitoring On-Board (Service P1)

is triggered as soon as the vehicle gets out of its ODD and if no one is present for a DDT Fallback, e.g., a driver who may not react to visual and sound alerts. It is entirely automated in the autonomous vehicle without any assistance from the ground. MRM can result in several outcomes and will eventually end up automatically stopping the vehicle into the safest place according to the onboard computer, e.g., in the emergency lane on a highway.

2. Railway Track Safety Obstacle Detection (Service P2)

Using a LIDAR sensor on-board and AI-based edge processing, this service will detect any obstacles or hazards on the tracks. This proactive approach enhances safety by preventing accidents before they happen.

Business Services

4. High-Quality Wi-Fi for Passengers (B1)

Video cameras and AI-based edge processing will be used to monitor the train for any dangerous situations, such as fights or other disturbances. This ensures a safer and more comfortable journey for all passengers.

5. Multi-Tenant Mobile Service (B2)

Utilizing a 5G small cell on-board, this service provides high-bandwidth and low-latency mobile access. It supports a neutral Mobile Network Operator (MNO) service, ensuring reliable and fast connectivity for passengers and train operations alike.

KPIs Performance Services

Service KPI Name	FRMCS P1	FRMCS P2	FRMCS P3
Uplink Data Rate	5-6 Mb/s	5-20 Mb/s	32-256 Kb/s (audio) 2-8 Mb/s (video)
Uplink Cloud End-to-End Latency	< 1 s	<100 ms	<100 ms
Command message Reliability			99%
Command message Reliability		>95%	>95%
Downlink Service Data-Rate		> 5 Mb/s	> 10 Mb/s
Uplink Service Data-Rate		> 0.5 Mb/s	> 1 Mb/s
Mobility interruption time		< 1 s	< 100 ms

* **FRMCS** (Future Railways Mobile Communication System)

KPIs Business Services

Service KPI Name	B1	B2
Uplink Data Rate	600 - 750 Mb/s	0.6 - 3.8 Mb/s
Download Data Rate	600 - 750 Mb/s	0.6 - 3 Mb/s
Uplink Edge End-to-End Latency	< 100 ms	
Downlink Edge End-to-End Latency	< 100 ms	>95%
Uplink Reliability	>= 97%	>= 97%
Downlink Reliability	>= 98%	>= 97%
Mobility interruption time	< 10s	< 1s

* **B** (Business Services)

Results

01 **Enhanced Safety:** Advanced monitoring and detection systems help prevent accidents and ensure a safer travel experience.

02 **Improved Efficiency:** Continuous monitoring and real-time data communication streamline train operations.

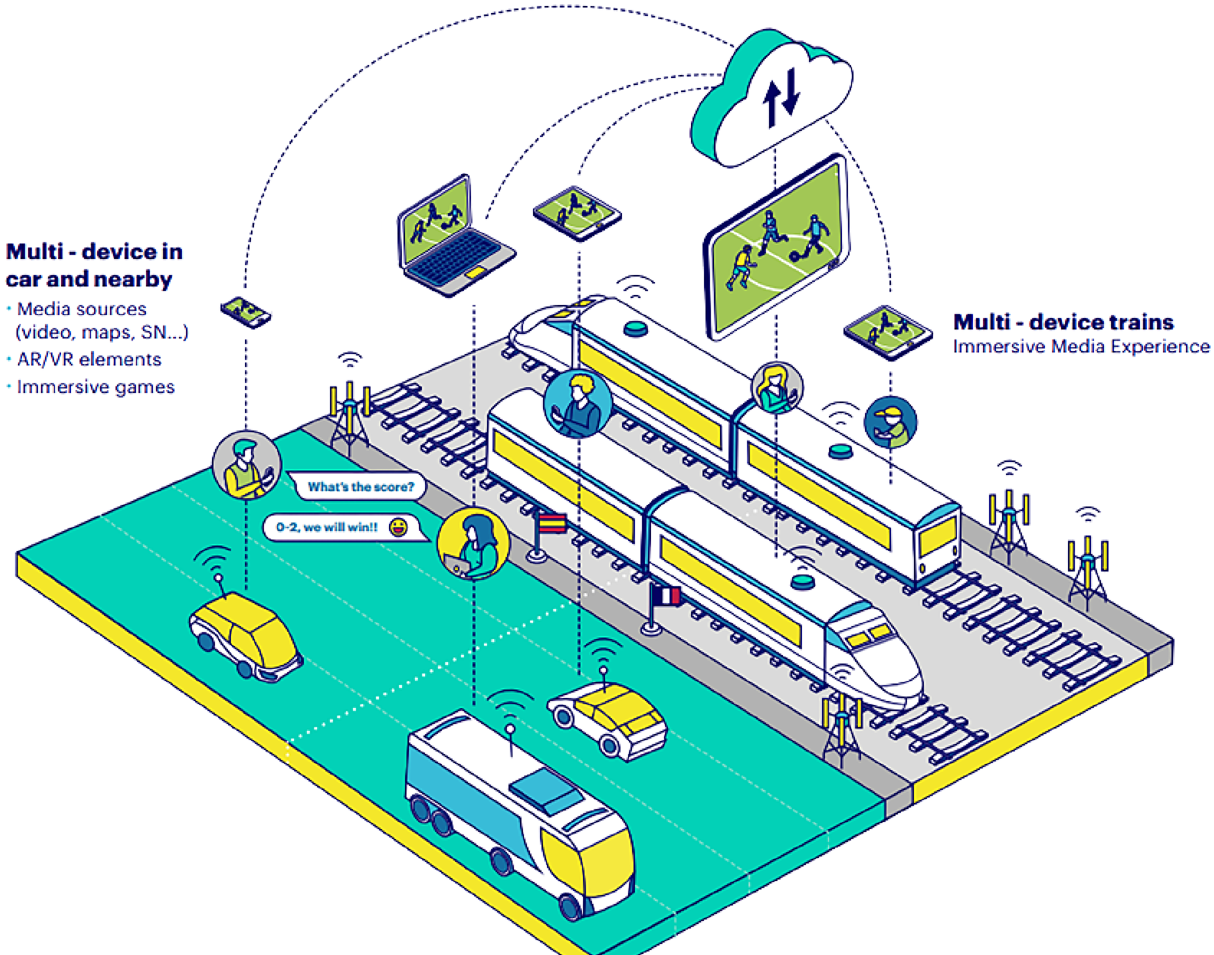
03 **Better Passenger Experience:** High-quality Wi-Fi and reliable mobile service keep passengers connected and satisfied during their journey.

USE CASE 04 Follow-Me Infotainment

Imagine enjoying high-quality media content while traveling at high speeds by car or train, seamlessly and without interruption.

This is the goal of an innovative use case designed to enhance the travel experience using cutting-edge 5G technology. Here's how it works:

The Follow-Me Infotainment use case integrates multimedia streaming and interactive technologies on top of a 5G orchestrated infrastructure. The aim is to create new and enhanced end-user experiences to be consumed while travelling in car or train through the Mediterranean cross-border corridor, being reactive to user requirements as well as environmental and platform-specific aspects.



Seamless Media Experience on the Move

The core idea is to provide passengers with high-quality media content that remains synchronized and maintains a high Quality-of-Experience (QoE) throughout their journey, even across borders. This is achieved using 5G Standalone (5G-SA) technology, which allows the network and applications to follow the user's equipment, ensuring low latency and smooth performance.

Key Services

Enjoy Media Together (EMT): This service allows a user traveling in a vehicle to watch a high-definition movie in perfect sync with another user on the ground. They can interact in real-time, sharing comments and reactions as if they were watching together in the same room. This creates a shared entertainment experience, no matter the distance.

Tour Planning (TP): Utilizing a 5G small cell on-board, this service provides high-bandwidth and low-latency mobile access. It supports a neutral Mobile Network Operator (MNO) service, ensuring reliable and fast connectivity for passengers and train operations alike.

Deployment in Different Scenarios

High-Speed Vehicles: The full capabilities of this use case are implemented for passengers traveling by car. The services are designed to follow the user, providing consistent and high-quality media content throughout the journey.

Railway Scenario: While the full deployment is not yet available for trains, the EMT and TP applications are being tested in the cloud. This testing phase ensures that these services function well with the connectivity provided by the Train Access Network, preparing for a future rollout.

KPIs

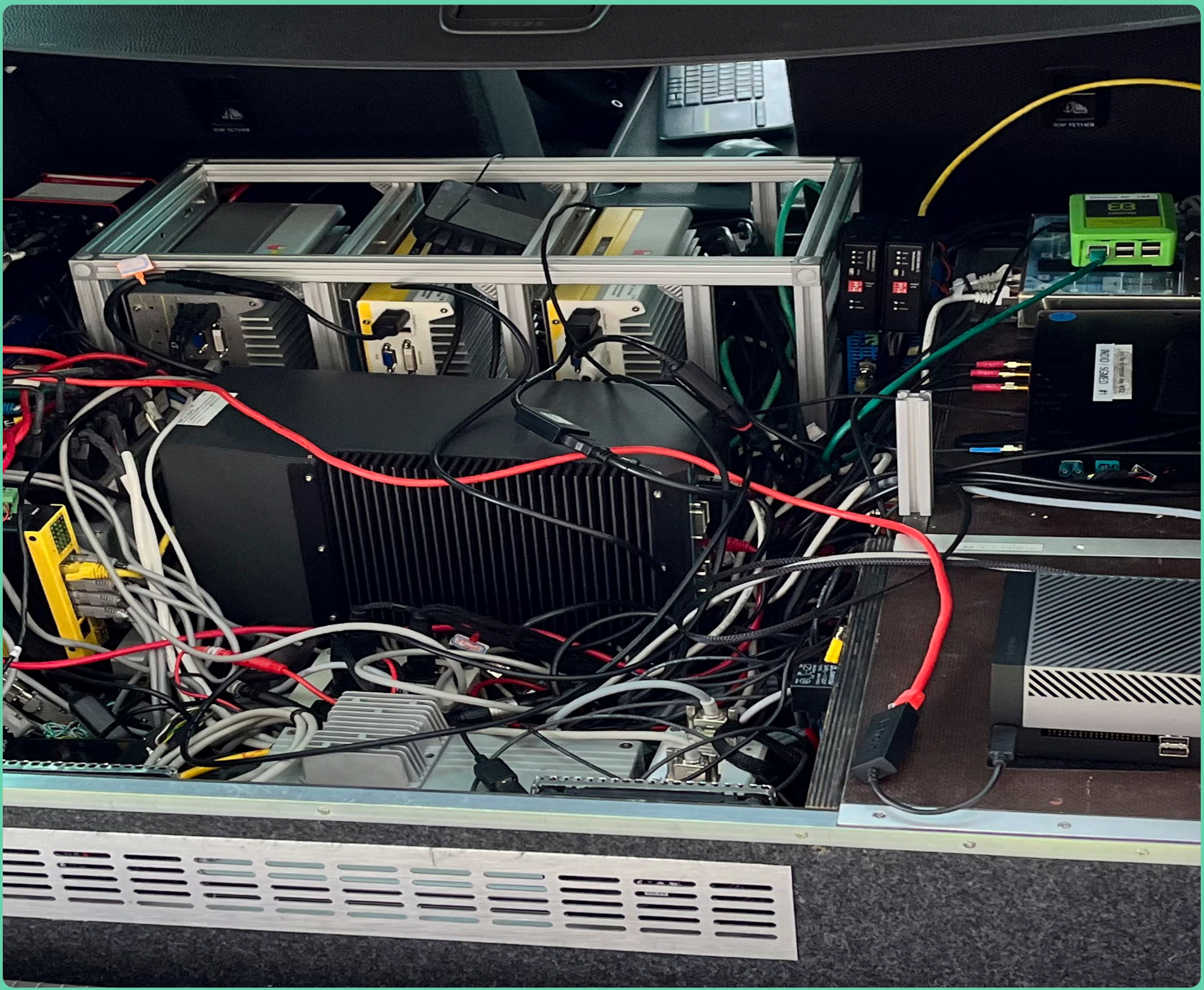
Service KPI Name	Unit	Definition
End-to-end Latency	[ms]	The time it takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source to the moment it is successfully received at the destination
Data-rate	[Mbps]	Amount of application data bits received by a destination application within a certain time window.
Jitter	[ms]	Variation in time delay between when a signal is transmitted and when it's received over the network connection
Framerate	[fps]	Frames per second
Mobility Interruption Time	[ms]	Amount of time with interrupted traffic that the application supports
Reliability	[%]	Ratio between the number of data messages successfully delivered to a destination application divided by the total number of data messages sent
Service Migration Time	[s]	Time elapsed since the migration of a service (which is available at a specific server) is triggered until the service is available at the target server

Benefits for Travelers

01 **Enhanced Entertainment:** Enjoy synchronized, high-definition media content with friends or family, no matter where you are.

02 **Informed Travel Decisions:** Use VR streaming to explore and choose interesting stops along your journey, enhancing your travel experience.

03 **Seamless Connectivity:** 5G technology ensures that media services remain reliable and low-latency, even at high speeds and across borders.



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