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D7.3. Policies, regulations, and standardization for 5G CAM deployment

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Nature	
PR	Prototype
RE	Report
SP	Specification
TO	Tool
OT	Other

Synopsis	From the technical challenges encountered in 5GMED, a set of recommendations have been prepared to policy makers, regulatory framework and standardization bodies to encourage the deployment of 5G-enhanced mobility services
List of Keywords	5G; CAM; Mobility; cross-border; roaming; recommendations; policy; regulation; standardization

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ACRONYMS AND ABBREVIATIONS

Table 1: Acronyms

Acronym	Full name
3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5GNR	5G New Radio
5G-PPP	5G Infrastructure Public Private Partnership
ACS-GW	ACS-Gateway
AID	Automatic Incident Detection
AMF	Access and Mobility Management Function
C2V	Centre - Vehicle (C2V) cooperation
CACC	Cooperative Adaptive Cruise Control
CAM	Connected, Automated Mobility
CAV	Connected and Automated Vehicle
CEN	European Committee for Standardization
CEF	Connecting Europe Facilities
C-ITS	Cooperative ITS
C-V2X	Cooperative Vehicle-to-Everything communication
DDT	Dynamic Driving Task
DN	Data Network
DVB	Digital Video Broadcasting
ePLMN	Equivalent Public Land Mobile Network
ERA	European Union Agency for Railways
ETSI	European Telecommunications Standards Institute
FRMCS	Future Railway Mobile Communication System
GSMA	Global System for Mobile Communications
GSOA	Global Satellite Operator's Association
HPLMN	Home Public Land Mobile Network
HRR	Home Routed Roaming
HO	Handover
ISAD	Infrastructure Support for Automated Driving
ISG	(ETSI) Industry Specification Groups
ISO	International Organization for Standardization
LBO	Local Breakout
LIDAR	Light Detection and Ranging / Laser Imaging Detection and Ranging
MCM	Maneuver Coordination Messages
MCS	Mission Critical Services
MCS	Modulation and Coding Scheme
MEC	Multi-access Edge Computing

MNO	Mobile Network Operator
NRI	Network Reselection Improvements
NSA	Non-Stand Alone
NTN	Non-terrestrial Network
OS	Open Source
PLMN	Public Land Mobile Network
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
REM	Relay of Emergency Messages
SA	Stand Alone
SAE	Society of Automotive Engineers
SMF	Session Management Function
SNS JU	Smart Networks and Services Joint Undertaking
SSIG	Standardisation Special Interest Group
TFR	Traffic Flow Regulation
TISA	Traveler Information Services Association
TMC	Traffic Management System
TR	Technical Report
TS	Technical Specification
UC	Use Case
UE	User Equipment
UIC	Union Internationale des Chemins de fer
UNIFE	European Rail Industry
UPF	User Plane Function
VNF	Virtual Network Function

1. Introduction

1.1 Project Summary

The objective of 5GMED has been to demonstrate advanced Connected and Automated Mobility (CAM) services for the automotive sector and railway communication services along the Mediterranean cross-border corridor between Figueres, Spain and Perpignan, France. These services were enabled by a multi-stakeholder compute and network infrastructure deployed by MNOs, neutral hosts, and road and rail operators, based on 5G.

Given the proximity of the E15 highway and the high-speed rail track in the considered cross-border section, the 5GMED consortium has demonstrated how a multi-stakeholder 5G infrastructure featuring a variety of technologies, including Rel.16 5GNR at 3.5 GHz, unlicensed mm-wave, network slicing and service orchestration, can be used to jointly deliver Automotive and Railway use cases.

5GMED has implemented four use cases: Remote Driving (UC1), Road infrastructure digitalization (UC2), Enhanced Railway Communication Services (UC3) and Infotainment services (UC4).

The technical activities of 5GMED have been complemented by a carefully designed impact maximization strategy including:

i) demonstrations in key industrial events,
ii) concrete measures to influence standardization and policy makers,
iii) cost-benefit analysis of the 5GMED deployment models, and
iv) joint exploitation and business models.

5GMED ambitions to become one of the reference Innovation projects for Road and Railway automotive mobility deployment in cross-border scenarios, with the aim of being replicated across Europe and trigger further investments through the CEF2 Digital program.

1.2 Deliverable overview

This deliverable describes the key aspects identified during the implementation of the 5GMED use cases and the network deployment, in relation to the policy, regulation and standardization framework of the 5G for CAM ecosystem.

These key aspects are gaps, obstacles, lessons learnt, best practices which have been gathered and integrated in a set of recommendations to be considered as part of the Policy, Regulation and Standardization framework, to promote and facilitate the continuity of this and other related projects', and in general to facilitate the large-scale deployment of 5G-enhanced mobility services.

The document contains an introduction of activities done by other R&D projects (ICT-53) and a description of the 5GMED use cases. The deliverable continues to present the policy, regulation and standardization framework that is relevant for 5GMED. The last chapter focuses on the specific challenges tackled by the project with respect to network implementation and at Use Case level, resulting in recommendations towards policy, regulation and standardization.

1.3 Work by other R&D projects

Three Horizon 2020 projects selected for funding in the 5G-PPP ICT-18-2018 Call, 5G CARMEN [1], 5GCroCo [2] and 5G-Mobix [3], conducted studies related to deploying 5G for Connected and Automated Mobility (CAM) on European road transportation cross-border corridors.

In these deployment studies, it was important to identify the additional connectivity requirements to deliver Connected, Automated Mobility services along five European Cross-Border-Corridors, as well as the delta investment in 5G access infrastructure, with respect to the already existing or planned 5G infrastructure.

The projects tested 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. These projects highlighted the potential for 5G technology to enhance cross-border connectivity and to revolutionize cross-border communication and connectivity and enable advanced, real-time CAM services.

In addition, 5G-MOBIX, 5G-CARMEN and 5GCroCo released a joint whitepaper on "5G technologies for connected automated mobility in cross-border contexts", a joint meta study which examined the determinants of the 5G infrastructure investment delta and related research questions in various European cross-border corridors for Connected and Automated mobility services. Although the individual project studies had analyzed a broad scope of corridors, with different geographical and topologic settings, and applying different methodologies, it was possible to compare project results with regard to the benefits brought by 5G in comparison with 4G when it comes to important features as throughput, delay and round-trip times, and reliability. In addition, some deployment recommendations could be extracted in relation to 5G network spectrum, low-latency and deployment of MEC data centers. Finally, the three projects agreed on the need for overcoming the lack of a clear and harmonized service deployment roadmap for all stakeholders including OEMs and MNOs. This challenge is currently being addressed by the CEF Programme.

Together with 5GMED, the projects selected for funding in the 5G-PPP ICT-53-2020 Call 5GRAIL ("5G for future RAILway mobile communication system") [4], 5G-Blueprint ("Next generation connectivity for enhanced, safe & efficient transport & logistics") [5] and 5G-ROUTES ("5th Generation connected and automated mobility cross-border EU trials") [6] have concluded or are concluding deployment studies for their target 5G-enhanced mobility services and have extended the work achieved in the ICT-18 projects.

The standardization plan of 5GRAIL, described in its deliverable D7.3 "Dissemination, communication and exploitation activity report" focus on FRMCS (which is not under the scope of 5GMED). FRMCS is based on 3GPP, ETSI and UIC Specifications, in this regard the delta between the project and the existing specifications related to FRMCS have been identified and an implementation roadmap in future FRMCS versions have been proposed.

In 5G-Blueprint, a proposal to promote the development of innovative solutions based on the project technologies and architecture is presented in D8.4: Final Dissemination, Standardization, Exploitation and Joint Activities Report. 5G-Blueprint worked on the automated barge control, remote takeover, automated docking, CACC-based platooning and teleoperated crane use cases and this document identified the relevant technologies to be standardized in order to guarantee their adoption in the market. Relevant standard bodies for the project were CEN, ISO, ETSI, 5GAA, 3GPP and TISA.

In 5G-ROUTES, Deliverable D5.9 "Report on standardisation activities and spectrum" presents a standardization plan explaining the important role of standardisation for CAM for 5G, connectivity technical enablers and vertical standardisation (personal communications, emergency, automotive, railways, smart cities, logistics, etc.). The document provides an overview of key standardisation bodies, pre-standardisation organizations and other stakeholders that are initially identified as relevant to the scope of 5G-ROUTES. Focus is established on ITU, ETSI, ISO, CEN, 3GPP, the C-ROADS Platform, and UIC. The project will publish a final deliverable on this topic.

1.4 5GMED Use Cases

This chapter presents the requirements that must be met by the project use cases: remote driving, road infrastructure digitization, enhanced railway communications services, and follow-me infotainment. This information is further detailed in 5GMED deliverable D2.1 "Use case stories definition, requirements and KPIs".

UC1: Remote Driving

In order to offer remote assistance to a Connected and Automated Vehicle (CAV) beyond its operational design parameters, the following requirements had to be met:

- The remote driver shall provide support under adverse weather conditions, accidents, transitioning from highways to urban roads, undefined traffic conditions, etc. until the vehicle can resume operation again.
- In terms of 5G network design, a very high amount of data from video and other sensors must be transmitted to the remote station, and commands must be transmitted to the vehicle actuators. This operation needs extremely low latency and high level of reliability, this means there are high Quality-of-Service (QoS) requirements, which become particularly critical when the CAV crosses international borders.

UC2: Road Infrastructure Digitalization

This use case aimed at establishing an intelligent Traffic Management System (TMC) to ensure the safe and efficient flow of traffic on highways where Connected Vehicles (CVs) share the road with traditional non-connected vehicles.

- This relies on cooperative sensing, and data aggregation from CV sensors and external sources like traffic cameras and roadside sensors.
- A TMC processes this data and generates intelligent traffic management strategies, which are then transmitted to the CVs via the 5G network. There are two primary categories of traffic management strategies under consideration: warning traffic strategies (addressing accidents, stalled vehicles) and global traffic strategies (addressing abnormal behaviors like traffic congestion)
- The TMC sends regulatory commands (e.g., lane changes, speed adjustments) to groups of vehicles traveling in proximity to these areas of concern.

UC3: Railway services

Different requirements had to be met depending on the service type: performance services (or those related to the operations of the train) and passenger services (related to the user experience).

Railway performance services had to meet the following requirements:

- Advanced Sensors Monitoring On-Board, which involves monitoring the status of non-critical train systems through data communication between on-board sensors, ground-based train control information systems, and railway personnel
- Railway Track Safety, which focuses on the detection of hazards on rail tracks using on-board LIDAR sensors and image processing at the MEC.

Railway passenger services require:

- Wi-Fi for Train Passengers, which ensures high-performance and seamless Wi-Fi access throughout the entire cross-border corridor, including tunnels.
- Multi-Tenant Mobile Service, which uses 5G small cells on board to provide high bandwidth and low-latency access to a neutral MNO service.

UC4: Follow-Me Infotainment

This use case was about delivering various forms of high-quality media content (e.g., 360º video live-streaming, virtual reality video) in real-time while maintaining a consistently high level of Quality-of-Experience (QoE) and QoS. This service is intended for passengers traveling at high speeds by either car or train along the cross-border corridor.

The use case primarily focused on demonstrating and evaluating the dynamic relocation of Virtual Network Functions (VNFs) responsible for delivering media services to end-users. These VNFs move across different Edge nodes to remain in close proximity to users as they traverse the corridor. The UC presented challenges related to ensuring uninterrupted service even during VNF migrations, with a strong emphasis on achieving minimal latency and consistently high data rates.

2. Policy

This chapter lists the relevant public policy initiatives that have already been adopted at EU level, with a direct or indirect impact on the development of 5G for CAM services.

Table 2: Overview of European Policy Landscape

Policy	Description
European Green Deal [22]	Roadmap to turn the EU climate neutral by 2050, by boosting the efficient use of resources by moving to a clean, circular economy and by restoring biodiversity and cut pollution including cleaner, cheaper and healthier forms of private and public transport
EU Road Safety Policy Framework 2021-2030 [23]	It provides new intermediate targets and comprehensive measures to halve the number of fatalities and serious injuries on European roads by 2030
Digital Europe Programme (DEP) [24]	Bridge the gap between digital technology research and market deployment. It will benefit Europe's citizens and businesses, especially SMEs
European Mobility Data Space initiative (EMDS)	Encourage a broad European ecosystem of data providers and users, facilitating the adoption of common building blocks, supporting policymaking by enabling data sharing and reuse for efficient multimodal mobility and traffic management, as well as for measuring the progress of sustainable urban mobility across Europe
The European Strategy on C-ITS	It further elaborates on how 5G works together with existing short-range communication technologies
The ITS Directive Revision in 2023 [25]	It aims to take account of technological developments, such as mobility services and accelerate the availability and enhance the interoperability of digital data that feeds services, such as multimodal journey planners and navigation services. The new directive recognizes technological innovation and ultimately, the large-scale deployment of mobility services in a technologically neutral way.
EU toolbox for 5G Security [26]	The toolbox lays out a range of security measures aiming to mitigate risks effectively and ensure secure 5G networks are deployed across Europe.
CEF Digital Programme [27]	Major public financing support action launched by the EC for accelerating private investments in 5G infrastructure, including 5G Corridors, intended to enable Connected and Automated Mobility solutions.

5GMED and similar ongoing projects have a high potential to impact the CEF Digital Programme, which aims to foster investment and support the decision about "when, where and how" to deploy 5G and related services. In particular, the innovation projects address many implementation aspects that can resolve technical uncertainties. In addition, some of the 5GMED partners are also involved in CEF 5G Corridors projects (studies and / or deployment), as Cellnex and Autopistas.

3. Regulation

This chapter offers an overview of the relevant regulatory initiatives, which have already been adopted at EU level, with a direct or indirect impact on the development of 5G for CAM services:

Table 3: Overview of Regulatory Framework in Europe

Regulation	Description
Roaming regulation [28]	The Roaming Regulation 2022 ((EU) 2022/612) bans roaming charges (Eurotariff) within the European Economic Area (EEA), which consists of the member states of the European Union, Iceland, Liechtenstein and Norway. This regulates both the charges mobile network operator can impose on its subscribers for using telephone and data services outside of the network's member state, and the wholesale rates networks can charge each other to allow their subscribers access to each other's networks.
Data Act [29]	Regulation on harmonised rules on fair access to and use of data, which provides the main principles and guidelines for accessing and using data within the European data economy. Manufacturers will have to design their products in a way that allows users - both businesses and consumers - to take full advantage of the data created while using connected devices.
Artificial Intelligence Act [30]	Regulation which aims to ensure that fundamental rights, democracy, the rule of law and environmental sustainability are protected from high-risk AI, while boosting innovation and making Europe a leader in the field.
EU Cybersecurity Act [31]	It strengthens the EU Agency for cybersecurity (ENISA) and establishes a cybersecurity certification framework for ICT products, services and processes, which will need to be certified only once to be recognised across the European Union.
European Chips Act [32]	This regulation establishes a framework for strengthening the semiconductor ecosystem in the EU by bridging the gap between research and innovation and industrial activities and creating a framework to ensure security of supply by attracting investments and enhancing production capacities in semiconductor manufacturing
Gigabit Infrastructure Act [33]	It is an agreed proposal to replace the 2014 broadband cost-reducing directive (BCRD) by the gigabit infrastructure act (GIA) with the aim of accelerating the deployment of gigabit network infrastructure across Europe by lowering the high costs of deployment of communication infrastructure caused by the permit-granting procedures before deploying or upgrading the networks, speed up the deployment of the networks, provide legal certainty and transparency for all economic actors involved, and provide for more efficient planning and deployment

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	processes for operators, an providing minimum harmonisation nature also addresses deployment and access to in-building physical infrastructure. It is expected to facilitate cross-border applications.

4. Standardisation

This section introduces the relevant standardisation bodies and how the 5GMED partners are involved in the related working groups. Finally, it shows the outputs obtained by 5GMED project related to standardization.

4.1 Standardisation bodies and standards

Standardization body	Description
ETSI [7]	The European Telecommunications Standards Institute (ETSI) is an independent, not-for-profit, standardization organization operating in the field of information and communications. ETSI supports the development and testing of global technical standards for ICT-enabled systems, applications and services. In Working Group 1, addressing applications and user requirements, the applications are defined for Cooperative ITS (C-ITS) and the facilities layer for C-ITS is standardized that ensure the interoperability within the ITS stations, thanks to C-ITS services and C-ITS messages definition.
3GPP [8]	The 3rd Generation Partnership Project (3GPP) is a collaboration between seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC). Initially, 3GPP focused on creating standards for 3G mobile systems based on evolved GSM specifications. Over time, its scope expanded to include 4G (LTE) and 5G technologies. 3GPP's work encompasses radio access, core network, interworking with non-3GPP networks and service architecture standards.
SAE [9]	SAE International (formerly the Society of Automotive Engineers) is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive and commercial vehicle industries. The association's core competencies are life-long learning and voluntary consensus standards development.
UIC [10]	UIC (Union Internationale des Chemins de fer) is the worldwide professional association representing the railway sector and promoting rail transport. Regarding the future of railway telecommunication systems, the UIC works on the design of the FRMCS (Future Railway Mobile Communication System) in close cooperation with the different stakeholders of the railway sector. It will be the successor of the GSM-R but also a key enabler for rail transport digitalisation. UIC's working groups are interfaced with UNITEL, ERA, and ETSI TC RT. The missions of these groups also include the build and delivery of the FRMCS specifications which follow the European Process. The FRMCS specifications will be completed

	with ETSI Technical specifications, delivered by the ETSI Railway Telecom technical committee. UIC FRMCS working groups (cf. UIC website : https://uic.org/rail-system/telecoms-signalling/frmcs)
5GAA [11]	The 5G Automotive Association (5GAA) is a global, cross-industry organisation of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services. Created in September 2016, 5GAA has rapidly expanded to include key players with a global footprint in the automotive, technology and telecommunications industries. This includes automotive manufacturers, tier-1 suppliers, chipset/communication system providers, mobile operators and infrastructure vendors.
GSMA [12]	GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. More than 750 mobile operators are full GSMA members and a further 400 companies in the broader mobile ecosystem are associate members. The GSMA leads different working groups, divided into the following streams: • Networks, roaming and interconnect. • eSIM and devices. • Emerging technologies. • Fraud and security. The Networks, roaming and interconnect stream contains, among other Working Groups, the Network Group (NG). The Networks Group (NG) specifies technical, operational, and performance requirements to support international roaming and interworking, taking into account technology evolutions, and it focuses on compatibility and interoperability aspects of the signalling and inter-working of roaming between Public Land Mobile Networks and public switched networks. In addition to that, the group specifies a common infrastructure abstraction and exposure of a set of capabilities, resources, and interfaces offered by an operator's virtualisation/cloud infrastructure. It becomes then obvious, that GSMA Networks Groups should be considered when targeting technologies and regulations impacting CCAM services supported by 5G in cross-border scenarios, as they are considering many of the issues that may arise when different operator networks are connected.
SSIG	The SSIG (Standardisation Special Interest Group) is the group created for the satellite industry interested to promote the satellite into different standardization bodies, mainly the 3GPP. This group help satellite industry coordinate the contributions to 3GPP. The SSIG group is arranged through online meetings (via-teams) where new standardisation proposals are presented, a summary overview of the status of previous proposals is given and future steps to be prepared for the 3GPP plenary and the working groups.

GSOA [13]	GSOA (Global Satellite Operator's Association) is widely recognised as the representative body for satellite operators by international, regional, and national entities, including regulators, policymakers, standards-setting organizations like 3GPP, as well as international organizations such as the International Telecommunications Union (ITU) and the World Economic Forum (WEF). GSOA is the "Market Representation Partner" for the satellite sector in 3GPP where 5G standards are set. 3GPP works on numerous items concerning NTN (non-terrestrial networks). The Standards Working Group coordinates member positions and ensures that GSOA gives political weight to drive forward Study and Work Items in 3GPP that are important for the integration of satellite with terrestrial and the 3GPP 5G ecosystem. The Standards Working Group also works on other satellite standardisation matters and engages with other stakeholders such as NGMN (the Next Generation Mobile Network Operators Alliance), GSMA and GCF to support the evolution of satellite standards and/or NTN matters within 3GPP and other forums.

The main relation between 5GMED and the standardization ecosystem was identified within the following working groups:

- 3GPP: working groups for defining the global specifications for 5G. This includes everything from the air interface to network architecture and protocols.
- ETSI: 5G dedicated working groups.
- SAE: 5G dedicated working groups.
- 5GAA: working groups dedicated to development standards for 5G-enabled mobility services
- SSIG: the working group created for the satellite industry interested to promote the satellite into different standardization bodies, mainly the 3GPP. This group is in charge of coordinating the 3GPP standardisation contributions.
- GSOA: is the global CEO-driven association representing the satellite industry. GSOA provides a platform for collaboration between companies involved in the satellite ecosystem globally and a unified voice for the sector.

Since FRMCS is out of the scope of the 5GMED, creating liaisons with UIC has not been the project's target.

4.2 5GMED partners' involvement in standardisation groups

Different 5GMED partners are involved in the initiatives mentioned above, allowing to discuss the aspects of the project with impact on the relevant standards.

Through its affiliate BULL SAS (FR) that was ETSI participant and is focused offering on private networks for Mission Critical Services (MCS), **ATOS** monitors some ETSI Industry Specification Groups (ISG). Some ISG are related for possible contributions in the form of indirect content such as experience reports or by means of PoC-based by using their specifications. In particular, ETSI MEC (the reference group on Multi Access Edge technologies), ETSI NFV (focused on Network Function Virtualisation orchestration and management) and ETSI ZSM (with the goal of defining an architecture for network service automation). Looking at 5GMED UC4 results, all media application services were designed considering NFV orchestration paradigm and are deployed at Edge.

On the other hand, ATOS is a member of two ETSI open-source groups for several years now, related to network management and orchestration solutions. The first OS group is ETSI OSG OSM that is developing an open-source MANO stack aligned with ETSI NFV information models. ATOS has contributed to it through the work developed in projects like 5GTANGO / 5GENESIS and Affordable5G (from 5G PPP) but not in the 5GMED case since other orchestrator solution was chosen. ATOS was a member of the OSM Technical Steering Committee for some release cycles. The second OS group is the so called ETSI Software Development Group TeraFlowSDN (SDG TFS) that is developing an open-source cloud native SDN controller enabling smart connectivity services for future networks beyond 5G. However, 5GMED did not adopt this SDN controller element neither in the small-scale testbed nor production 5G SA network at cross-border.

Finally, ATOS monitored industrial initiatives such as GSMA Open Gateway that is producing a common network API framework that allows service developers to access certain operator network capabilities exposed by functions. Although this is not an SDO, it has relevant impact in terms of UEs localization that could be used in the geo-localized automatic trigger together Decision Engine (DE) module indicating the Orchestrators to migrate the UC4 edge service.

CTTC, as a research center, plays a significant role in shaping the future of communication technologies through its active participation in several key standardization bodies, such as ETSI. Here, CTTC strategically targets specific Industry Specification Groups (ISGs) that directly address the advancements in 5GMED related areas.

CTTC focuses on two key ISGs: Zero-touch Service Management (ZSM) and Multi-access Edge Computing (MEC). ZSM aims to automate service management processes, streamlining network operations. CTTC proposes applying principles derived from the proposed architecture with Use Case 4 (UC4) of 5GMED. This approach could involve implementing a "close loop automation" system featuring a Decision Engine, enabling intelligent and automated service management. On the other hand, the MEC ISG focuses on providing edge computing capabilities closer to network users. CTTC actively participated in the development of ETSI MEC Release 3 and made valuable contributions by developing a proof-of-concept for a bandwidth management API.

Beyond participation in ISGs, CTTC actively fosters collaboration and innovation by contributing to several open-source projects within ETSI. These projects play a crucial role in driving industry adoption of new technologies. A key example is the open-source MANO (OSM) project, which delivers an NFV (Network Functions Virtualization) orchestrator for service lifecycle management. This aligns directly with CTTC's current activities related to UC4 of 5GMED. Additionally, CTTC leads the ETSI TeraFlowSDN (TFS) project, a cloud-native SDN controller with significant implications for Transport Network Slicing activities. While its current Technology Readiness Level (TRL) is 4, indicating it's still in the validation stage, TFS holds immense potential for future advancements. Notably, 5GMED has already contributed to solidifying transport network slices within the ADRENALINE Testbed, demonstrating the practical application of this technology.

Collaboration extends beyond ETSI. CTTC also actively monitors the development of network slicing data model definitions for transport networks within the Internet Engineering Task Force (IETF).

Specifically, they track the progress of the TEAS (Traffic Engineering Automation System) and CCAMP (Control Plane Common Architecture Multi-layer) initiatives. This data model is partially supported by ETSI TeraFlowSDN, highlighting the importance of collaboration between standardization bodies to ensure interoperability and consistency across different technologies.

Hispasat participates in different groups to promote the NTN (Non-terrestrial networks) topics and ensure that the work items/proposals for the satellite part are aligned with the point of view of the satellite operators. Since the 3GPP is the main organization to standardize cellular technology, Hispasat assist to the plenaries and some working groups following and supporting topics mainly related to 3GPP RAN and SA groups.

On the other hand, as the 5G-NTN was standardized in 3GPP Release 17, there are a lot of modifications and standardizations that must be addressed during the upcoming releases for the satellite part. Because of that, Hispasat also participates in the SSIG (Standardisation Special Interest Group) indicating its preference and feedback on the satellite aspects that should be standardized, what are the existing blocking points for the commercialization of 5G-NTN technology, supporting proposals from different companies or organizations in the satellite sector and promoting/disseminating internal actions for the 5G-NTN development, as promoting 5GMED with the satellite industry. Moreover, Hispasat is part of the GSOA (Global Satellite Operator's Association) members and participates in the standardization working group to ensure that the point of view of all satellite operators is taken into account to be shown in the 3GPP plenaries/working groups as a single voice.

IRT participates in different groups to promote NTN, namely 3GPP and SSIG. One focus is the integration of satellite in terrestrial mobile networks 5G/6G. Latest IRT research projects explored the way to keep the continuity of the 5G-SA slicing over non 3GPP radio links and specifically for 5GMED, satellite links. Other focuses are the orchestration and cybersecurity when satellite is integrated in the cellular networks. This is mainly addressed in 3GPP.

It is relevant to mention that **SNCF** is involved in standardisation regarding the FRMCS, nevertheless FRMCS is out of the scope of the 5GMED project. For example, this was the scope of other projects like 5G RAIL.

VEDECOM has an important role in standardization bodies and associations dealing with vehicular communications.

Three major ones are introduced hereafter where VEDECOM is member:

- **ETSI**, European Telecommunications Standards Institute, which one Technical Group (ITS) is fully devoted to the standardization of Intelligent Transport Systems and particularly in C-ITS communications covering vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to centre (V2C), vehicle to network (V2N), vehicle to pedestrian (V2P), vehicle to railways (V2R), vehicle to grid (V2G), vehicle to home (V2H).
- **3GPP** where some technical specifications (TS) address requirements on cellular communications for vehicular communications, especially within the scope of five areas: advanced driving, platooning, remote driving, extended sensors, vehicle QoS support.

- **5GAA**, 5G Automotive Association, a global cross-industry organisation of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services.

Valeo is an active member of the 5GAA. It is important for Tier1 to understand and to influence the best state of the art technologies to be developed to ensure the best services and solutions for future mobility. There are bridges between 5GAA and 3GPP which enable us to follow and be aware of the 3GPP line. Valeo is part of ETSI too, and especially in the ITS committee. Valeo focuses on the WG1 which is tackling the applicative part (features and messages that are exchanged).

4.3 Existing standards related to 5GMED

In this section the standards that are related to 5GMED activities have been analyzed. Three main topics have been considered: satellite, roaming and C-ITS messages. Later in D7.3 section 5, the related standardization outcomes of 5GMED are presented.

4.3.1 Satellite standards

The satellite use cases are described in the 3GPP Technical Report TR22.822 "Study on using Satellite Access in 5G" [14], which provides the preliminary use cases for the satellite access in 5G, with some kind of similarities with the 5GMED use cases, especially with 5GMED use case 3. It covers two different use cases described in the TR22.822 where the satellite appears as "Satellite transborder service continuity" (section 5.6 of the standard), ensuring that during the trip between two different terrestrial coverage/services areas the satellite ensure the service continuity when the terrestrial coverage becomes unavailable. In this case, the satellite architecture is based on relay node instead of 5G backhaul as 5GMED. The other use case with similar approach is the "5G moving platform backhaul" (section 5.10 of the report), where a train operator aims to provide 5G coverage to its passengers/staff during a trip between two countries. In this case, the train operator aims to provide seamless connectivity along the trip by 5G base station/Small cell on-board the train, similar approach with the 5GMED Use Case 3.

In both use cases described in TR22.822, the key requirement is related to "the 5G system shall support the use of satellite links between the radio access network and core network and within the core network, by enhancing the 3GPP system to handle the latencies introduced by satellite backhaul.", this requirement has been addressed and achieved during 5GMED UC3 test/proof-of-concepts.

In the same way, 3GPPP's Technical Report TS 22.261 for the "Service requirements for the 5G system" [15](section 6.46) includes the necessary requirements to enable the satellite access, that have been a fundamental pillar and have been achieved during the 5GMED project, "A 5G system with satellite access shall support service continuity between 5G terrestrial access network and 5G satellite access networks owned by the same operator or owned by different operators having an agreement."

Another related Technical Report is the 3GPP TR28.808 [16] for the "Study on management and orchestration aspects of integrated satellite components in a 5G network".

On the other hand, 3GPPP's Technical Report TR38.821 for the "Solutions for NR to support non-terrestrial networks (NTN)" [17] includes non-terrestrial network architectures to bring satellite into the 5G ecosystem. Therefore, one of the possible 5GMED enhancements for the satellite part would be to upgrade the protocols used to the 5G NR protocol instead of the DVB protocol (mainly used and optimized for satellite communications), regenerative payloads that it's part of the standardization of 3GPP release 19 on board the satellite to have a set of network functions (e.g. RAN-oriented) on board the satellite in order to reduce latency, improve throughput, etc. Incorporating these enhancements would mean not having the gNodeB/Small Cell on-board the train, but a kind of relay node that would serve as an indirect communication with passenger user equipment.

4.3.2 Roaming

In GSMA, Official Document NG.113 [18], the roaming process between two PLMN is defined, and two types of roaming are proposed: Home Routed Roaming (HRR) and Local Breakout (LBO) roaming. In the first one, the device will be served by its home core network through the visited one, which keeps most of the control over device's traffic with its home MNO but obliges all the data-plane packets to be forwarded to the home UPF by the visited UPF. This will add one more segment to the path of the end-user data, and therefore more latency. In LBO roaming, in contrary, the visited core network will have full control over device's traffic and no home forwarding is needed. However, HRR is the roaming solution adopted by the operators today for voice and data services, whereas LBO roaming is not expected to be used massively in early stages of 5G systems. The detailed process of both types of roaming are explained in 3GPP specification TS 23.501 [19]. Both roaming techniques have been deployed in 5GMED.

In addition, the 5GAA Automotive Association Technical Report Cross-Working Group Work Item Network Reselection Improvements (NRI), several techniques have been defined to reduce the interruption time during the process of roaming. These improvements were described in 5GMED D3.1 and include: UE roaming with new registration, UE roaming with AMF relocation and RAN assistance, and UE roaming with AMF relocation and handover. In 5GMED, these improvements were added to the network by deploying the following:

- N14 interface: This interface is defined between two AMF to exchange the context information about UEs changing AMF. The N14 interface and its procedure is defined in 3GPP specifications TS 23.502 [20] for the process of changing AMF in the same PLMN. In 5GMED, we combined the process defined for N14 with both HRR and LBO roaming to implement the two types of roaming with N14 interface.
- ePLMN: The French and Spanish PLMN are defined as equivalent PLMNs to speed up the process of selecting the PLMN when doing the roaming.
- Inter-PLMN handover: The French and Spanish cells at the border are configured as neighbor cells in order to replace the slow cell reselection process by handover process when doing the handover.

4.3.3 C-ITS messages

The Use Case 2 of 5GMED, Road infrastructure digitalization, has demonstrated how to ensure the safe and efficient flow of traffic on highways where both connected and non-connected vehicles coexist. A Traffic Management Center (TMC) has been designed to generate intelligent traffic management strategies by processing information received from vehicles as well as roadside sensors.

Subsequently, these strategies are communicated to and executed by connected vehicles within the affected area.

In that perspective, communications between the different entities, vehicles, roadside sensors, TMC, are using the messages C-ITS specified at ETSI in ITS Technical Group.

For the purpose of the Project, possible enhancements of such messages, have been identified and implemented as a proprietary version for the testing in Use Case 2.

5. 5GMED challenges and outcomes regarding standardization, policy and regulation

This chapter presents the challenges and lessons learnt of the four 5GMED use cases: remote driving, road infrastructure digitization, future railway mobile communications, and follow-me infotainment.

This information is further detailed in the following documents:

- 5GMED deliverable D2.1 "Use case stories definition, requirements and KPIs".
- *5GMED Paper "*Cross-border 5G Seamless Connectivity for Connected and Automated Mobility: Challenges, Network Implementation, and Lessons Learnt".
- *5GMED Paper "Seamless connectivity for Digital Trains"*

The standardization outcomes related to these challenges are also indicated in this section. In addition, the challenges faced by the project suggest several recommendations for a more appropriate policy and regulatory framework which can encourage the deployment of CAM services based on 5G (cellular communications).

5.1 5GMED Challenges

For all the Use Cases implemented in the 5GMED project, delivering continuous and seamless services in cross-border scenarios has brought significant challenges including those related to cross-border operation and those related to specific use case applications.

5.1.1 Cross-border related challenges

Challenges in cross-border have been generally related to the limited cooperation and information exchange between PLMNs (Public Land Mobile Networks), managed by different Mobile Network Operators (MNOs) and primarily focused on roaming procedures for mobile phone users. Therefore, achieving the objective of providing uninterrupted and seamless CAM services in cross-border scenarios has been a complex endeavor.

In the context of 5GMED, seamless connectivity and service continuity across borders are critical, especially in challenging environments such as the Perpignan-Figueres cross-border corridor. This corridor presents unique environmental conditions, including rural areas and an 8 km tunnel, which necessitate the deployment of specialized network infrastructure. To address these challenges, a combination of 5G and complementary technologies such as 70 GHz IEEE 802.11ad and satellite communications is utilized to ensure continuous coverage. Additionally, high-speed movement across borders introduces the challenge of Inter-RAT handovers and roaming interruptions. While 5G networks mitigate these issues within the home network, cross-border roaming still leads to unacceptable service interruptions. 5GMED has implemented roaming optimization techniques to minimize latency and ensure low-interruption connectivity.

Furthermore, edge computing plays a crucial role in reducing latency by placing compute resources close to users, yet legacy home-routed roaming disrupts this efficiency by rerouting data through the home network. To combat this, 5GMED deploys distributed UPFs within MEC nodes, ensuring low-latency connectivity even in cross-border scenarios. Similarly, Inter-MEC resource handovers are optimized to maintain service continuity when crossing borders, ensuring that edge computing resources are properly transferred between MEC nodes of different MNOs.

Finally, network slicing continuity across borders remains a significant challenge, as each network operator may have different policies and resource configurations. To address this, 5GMED introduces a slice federation concept, allowing network slices to be seamlessly transferred between operators, ensuring uninterrupted service quality for users and applications when crossing international borders.

Inter-RAT (Radio Access Technology) handover under difficult environmental conditions

The Perpignan-Figueres cross-border corridor covers rural areas, and a rail track extends through an 8 km tunnel, with coverage limitations. It is then essential to deploy a specialized network infrastructure that incorporates various radio access technologies to provide services in areas where the 5G network coverage is deficient, including:

- 70 GHz IEEE 802.11ad, and satellite communication for coverage in remote and isolated regions within the railway scenario.

These additional technologies complement the 5G network, ensuring connectivity even in challenging areas and coverage gaps.

Roaming with Low Interruption Time

The movement of User Equipments (UEs) at high speeds leads to connectivity problems that 5G networks typically can resolve when the UE is within the coverage area of its home PLMN (h-PLMN). However, the roaming process typically results in significant interruption times and latency, which are unsuitable for advanced CAM services.

In current roaming techniques the service interruption ranging from several hundred milliseconds up to minutes, which is unacceptable for most advanced CAM services. Within a train environment, where the train is moving at exceptionally high speeds and accommodating numerous connected users, this interruption time can be even longer due to the simultaneous roaming of many users. In 5GMED, various roaming optimization techniques have been put in place.

Roaming with low latency

A critical component in 5G networks to achieve low latency is edge computing, which reduces latency by placing distributed computing resources in close proximity to users. In 5GMED, distributed instances of the User Plane Function (UPF) are deployed within the MEC nodes.

Latency becomes particularly critical in cross-border regions due to the legacy roaming method known as home-routed roaming (HRR). In HRR, all user data is routed back to the UPF in the h-PLMN, even if the UE is currently within a v-PLMN. This HRR approach is not appropriate for the deployment of edge computing. As all user data is directed to the home UPF, the use of MEC servers loses its effectiveness when the UE is not connected to its h-PLMN.

Inter-MEC resources handover

Many services in 5GMED have been based on Multi-access Edge Computing (MEC), which brings processing, storage and networking resources closer to the network edge and facilitates the compliance of high-bandwidth and low-latency requirements. The vehicle may change the MEC node where it is connected to during its journey. In that case, since in 5GMED it is considered that the edge compute resource is collocated with the telecom sites (gNodeBs), there is a 5G handover but also possibly a handover from one compute resource to another. The edge nodes can be both on the same side of the border or cross-border.

At the cross-border, MEC platforms might have different MNOs. Then, if there is no coordination between the two MNOs, the MEC resources assigned to a service is released in the source country without securing the MEC resources in the visited country. This situation leads to a service interruption like in the case of roaming. Therefore, a service orchestrator has been implemented in 5GMED in order to transfer smoothly and without interruption service data from a MEC in one side of border to another MEC in the other side. This service orchestrator takes care of establishing communication between MECs on the two sides of the border and ensures that resources are reserved in the MEC of the visited country before releasing the resources in the MEC of the source country.

Cross-border network slicing continuity

Network slicing represents a distinctive feature within 5G networks, enabling the partitioning of a single physical network infrastructure into multiple isolated and flexible logical networks, referred to as slices. These slices can be customized to accommodate the unique demands of diverse users or applications by assembling a variety of resource components, including core, transport, and radio network elements. Network slicing allows different tenants to have their own isolated slices with specific QoS requirements. Although the standardization of network slicing within 5G networks is well-established, the implementation of network slicing across borders presents a particular challenge. The primary issue arises from the fact that different network operators may have distinct slicing policies, configurations, and resource availability. Thus, transferring a slice from one PLMN to another becomes a complex task. In 5GMED, the slice federation concept is proposed to provide network slicing continuity across different PLMNs, allowing users to seamlessly access services and maintain a consistent network experience when crossing the border.

5.1.2 Use-case related challenges

This section presents an overview of the challenges faced by the project that were specific to the use cases. Additional detail has been provided in those use cases with higher impact in standardization, policy and regulation.

Challenges related to UC1 (Remote Driving)

Table 4 outlines the specific technical challenges associated with three core services in the context of remote driving: Service 1: Minimum Risk Maneuver, Service 2: Request for Remote Assistance, and Service 3: Teleoperation Maneuver. For Seamless services along the corridor, only Service 3: Teleoperation Maneuver requires seamless 5G connectivity through roaming along the corridor, whereas Services 1 and 2 do not. Furthermore, LBO is not necessary for any of the services, and in particular for service 3 where the remote driver system will be hosted in the cloud. As the LBO might inject more interruption time, using Home Routed Roaming (HRR) would be the best option for this use case. In terms of Inter-MEC resource handover and Inter-RAT (Radio Access Technology) handover, none of the three services currently need these capabilities for their functionality. The challenge of implementing 5G cellular SA (Standalone), Release 16 and beyond is highlighted for

Service 2: Request for Remote Assistance and Service 3: Teleoperation Maneuver, both of which require these advanced 5G standards, while Service 1: Minimum Risk Maneuver does not.

Table 4: UC1 (Remote Driving) Technical Challenges

Technical Challenges		Service 1: Minimum Risk Maneuver	Service 2: Request for Remote Assistance	Service 3: Teleoperation Manoeuver
Seamless services along the corridor	Roaming for 5G connectivity	-	-	Yes
	Inter-MEC resource handover	-	-	-
	Inter-RAT handover	-	-	-
Implementation 5G cellular SA, R16 and beyond		-	Yes	Yes

<u>Challenges related to UC2 (Road Infrastructure Digitalization)</u>

Table 5 outlines the technical challenges associated with three critical services: Service 1: Relay of Emergency Messages, Service 2: Automatic Incident Detection, and Service 3: Traffic Flow Regulation. For Seamless services along the corridor, all three services require 5G connectivity with roaming to ensure uninterrupted communication as vehicles move through the corridor. LBO can be advantageous over HRR in this use case, especially if MECs are used in order to reduce the latency. The slight difference in the interruption time will not affect the services as they don't require real time communications. In terms of Inter-MEC resource handover, none of the services currently demand this capability, as indicated by the lack of requirements for this technical aspect. Inter-RAT handover (most importantly with 4G networks) can be useful for all services, especially as vehicles transition between different coverage areas, ensuring that the services remain functional during these handovers. The implementation of 5G cellular SA (Standalone), Release 16 and beyond is crucial for all three services, especially to reduce latency.

Table 5: UC2 (Road Infrastructure Digitalization) Technical Challenges

Technical Challenges		Service 1: Relay of emergency messages	Service 2: Automatic Incident Detection	Service 3: Traffic Flow Regulation
Seamless services along the corridor	Roaming for 5G connectivity	Yes	Yes	Yes
	Inter-MEC resource handover	-	-	-
	Inter-RAT handover	Yes	Yes	Yes

Implementation 5G cellular SA, R16 and beyond	Yes	Yes	Yes

Challenges related to UC3 (Railway) focus on Gigabit Train:

Table 6 outlines the key technical challenges associated with two primary services.

Passengers' services require a significant amount of bandwidth in the track to train connectivity. To solve this issue an architecture including multi-MNOs with different technologies and managed by a Neutral operator is required as the one proposed in 5GMED. Nevertheless, even in this case this type of architecture is not always enough to cover all railway tracks: for instance, many parts of the tracks cannot be covered with 5G because their location is higher than any gNodeB or they go through very rural zones where there are no populated cities/towns. A medium complexity in the orography (as is the case of this portion of the Mediterranean Corridor) introduced several coverage problems, as was learned in the project. 5GMED proposed the use of additional RATs (IEEE 802.11ad) to solve the situation.

The results of the project have demonstrated that Passengers' services need RATs of Gigabit capacity to fit all their requirements (something that is not possible to solve with only a 5G-modem connection inside the train). Gigabit radio solutions are needed to provide this kind of services (as mmWave radios based on 802.11ad 70 GHz or low-orbit satellite connectivity).

This is not exclusive to passengers' services. Railway oriented applications also need a significant amount of bandwidth, as is the case with the LiDAR usage or applications relayed on CCTV cameras per coach.

The Gigabit Train challenge has also relevant requirements for the 5G Network: the regional distribution of traffic is needed to grow up the 5G networks with the appropriate scalability. 5GMED propose LBO roaming as one example of this requirement.

The Gigabit Train imposes a new generation of train networks (based in fiber and 10G Ethernet capabilities) and, in general, scale the ground network until 10G speed interfaces.

Finally, the deployment of this type of Gigabit Networks requires relevant capabilities to provide inter-RAT HO between different technologies at the required Gigabit performance, -something which is not obvious- with the appropriate flexibility to choose the preferred network for each service (according to each service requirement). Then, a simple gateway implementation is not enough to support this scenario, and an implementation as the 5GMED ACS-GW provides is absolutely needed. An ACS-GW functional description is described in deliverable D5.1 "Railways application requirement analysis report".

Table 6: UC3 (Railway services) Technical Challenges

Technical Challenges	**P1 service status of non-critical systems of the train**	**P2 service Detect obstacles**	**B1 service high-performance Wi-Fi access**	**B2 service Multi-tenant Mobile service**

Seam-less services along the corridor	Roaming for 5G connectivity	Yes	Yes	Yes	Yes
	Inter-MEC resource handover	-	Yes	-	-
	Inter-RAT handover	Yes	Yes	Yes	Yes
Implementation 5G cellular SA, R16 and beyond		Yes	Yes	Yes	Yes
Gigabit Train		No	Yes	Yes	Yes

Concluding, for safety services, the most important requirements are latency and reliability, which are provided by 5G networks. MEC will be required and reducing interruption time is crucial in order not lose any information. For Business services, the most crucial requirement is the bandwidth. It can be provided by combining 5G with other technologies such as 802.11ad and satellite. As MEC is needed, LBO should be the best option for this use case.

Challenges related to UC4 (Follow-Me infotainment)

Table 7 outlines the key technical challenges associated with two primary services: Enjoy Media Together Service and Tour Planning Service. For Seamless services along the corridor, both services require roaming for 5G connectivity to ensure continuous access to media and information as users move through different coverage areas along the corridor. Inter-MEC resource handover is necessary for both services, ensuring that the edge computing resources are seamlessly transferred when crossing different mobile network operator (MNO) zones, allowing uninterrupted media and tour planning experiences. As MEC is required, the LBO is the best option for this use case and the slight increase of interruption time can be easily solved using the application buffers. Inter-RAT handover, which involves transitioning between different radio access technologies, is not required for either service. The implementation of 5G cellular SA (Standalone), Release 16 and beyond is essential for both services to deliver the high bandwidth, low latency, and advanced features necessary for infotainment experiences like sharing media and tour planning.

Table 7: UC4 (Follow-Me infotainment) technical challenges

Technical Challenges		Enjoy Media Together Service	Tour Planning Service
Seamless services along the corridor	Roaming for 5G connectivity	Yes	Yes
	Inter-MEC resource handover	Yes	Yes
	Inter-RAT handover	-	-

Implementation 5G cellular SA, R16 and beyond	Yes	Yes

5.2 Recommendations towards policy and regulation

The objective of this chapter is to expose the findings and technical challenges in 5GMED as recommendations for policy makers and regulatory authorities to evolve the current legislation and regulatory framework to incentivize the future development and evolution of the 5G-enhanced mobility services.

5.2.1 Recommendations related to challenges in cross-border

Several challenges have been identified regarding the implementation of 5G and other technologies in cross-border areas. Table 8 highlights the issue of limited coverage within a single radio access technology, especially in rural and border areas. A cooperative approach between mobile network operators (MNOs) and satellite operators could address this challenge, improving coverage through the use of alternative technologies such as satellite and mmWave for rail services.

Table 8: Lack of coverage within a single Radio access technology

Description of Challenge	Lack of coverage within a single Radio access technology
Relevance	Border areas are often sparsely populated, giving MNOs little incentive to provide for increased capacity or coverage in those areas. Areas of low or no coverage appear close to the border, which is threatening the CAM and train applications' continuity. There is a big coverage challenge in rural areas, where 5G coverage is limited and it might be difficult to provide backhaul transport services.
Policy recommendations	In specific situations, CAM services could be served with another radio access technologies besides 5G. For this purpose, the cooperation between MNOs and satellite operators must be encouraged, being satellite a viable connectivity alternative for some areas and specific services. Furthermore, coverage in tracks can be improved using mmW for Rail. As described in section 3.4.3, 5GMED has developed an application capable of witching between these diverse technologies depending on their availability.
Regulatory recommendations	Satellite and other technologies are not always suitable to deliver CAM requirements, therefore before using these alternative solutions, regulation should be in place in order to maximize 5G deployment. Neutral host strategy, where several MNOs are sharing the infrastructure, reducing deployment costs should be regulated in cross-border areas. In addition, the administrative burden to build and set a 5G site operational should be reduced, by unifying needed permits at European or national level instead of the, in many cases, different local permits needed.

In terms of roaming interruptions, Table 9 outlines the lack of international agreements for cross-border handovers, which leads to service interruptions of up to one minute. The recommended regulatory actions include mandating synchronization and bilateral discussions between MNOs to ensure continuity in roaming services.

Table 9: Roaming with low interruption time

Description of Challenge	**Roaming interruptions are a big concern since 5G-based CAM services depend on ensuring continuity of roaming. Currently there are no international agreements for cross-border handovers between MNOs.**
Relevance	This situation entails several consequences: - Loss of connection up to 1 minute - New connection needs to be established and a new data session needs to be set up - Steering the UE to a preferred network might result in request denials - Currently, the regulatory framework about roaming for SA networks is only defined for basic roaming, but not for 5G-based CAM services (service continuity not ensured)
Policy recommendations	In order to minimize interruption time, policy makers need to promote and financially support the development and deployment of different CAM services (including Road and Rail), which in turn will boost the interest of the MNOs to configure Inter-PLMN handover, once they see a monetary return to it (new user/SIMs coming from CAM services)
Regulatory recommendations	Regulatory framework to foster the adoption of seamless Inter-PLMN HO in cross border, in particular having into account that no roaming fees apply any more in EU countries. Operators should be forced to configure inter-PLMN Handover in their Cor e networks and in the radio nodes facing their counterparts in neighbour countries. In addition, to ensure inter-PLMN handover works, it is recommended that all mobile operators agree to synchronise their networks. This means using the same frame structure and the same clock reference. However, selecting a common national solution is nowadays the priority. But this decision should consider what neighbouring countries may have already decided. Mobile operators are expected to discuss cross-border coordination issues on a bilateral, or multilateral basis and additionally in respective industry forums. The involvement of policymakers and/or administrations in these discussions can, if required, be a useful complement.

Table 10 addresses the challenge of high data latency during roaming, which hinders the deployment of critical low-latency services like remote driving. Distributed UPFs (User Plane Functions) and Local Breakout roaming are proposed as solutions to reduce latency.

Table 10: High data latency

Description of Challenge	**Currently, users in roaming experience a high data latency due to the fact that all data traffic is redirected to the home network.**
Relevance	This high latency does not allow for critical low latency applications, such as remote driving.
Policy recommendations	Similar to the previous policy recommendations, CAM (and other low latency services) development and deployment should be supported by public funds. This will push the deployment of a network architecture with low latency in roaming situations as the MNOs will be able to monetize it.
Regulatory recommendations	

	Mobile networks operators should be compelled to deploy Distributed-UPFs in their new 5G SA networks, thus enabling Local Break Out (LBO) roaming, where the data stay in the visited network, thus reducing the e2e latency (as described in section 2.4.1)

Table 11 focuses on ensuring service continuity during Inter-MEC (Multi-access Edge Computing) resource handovers, with policy recommendations aimed at federating Edge/Cloud resources across operators.

Table 11: Inter-MEC resources handover to ensure service continuity

Description of Challenge	**At the cross-border, MEC platforms might belong to different MNOs. Then, if there is no coordination between the two MNOs, the MEC resources assigned to a service will be released in the source country without securing the MEC resources in the visited country. This situation will lead to a service interruption like in the case of roaming.**
Relevance	Networks are designed to facilitate service and network function virtualization. This entails the necessity of having one domain orchestrator for each PLMN to manage and monitor the virtualized/cloud-native elements and their life-cycles. In the context of cross-border scenarios, a UE utilizing a virtualized service may need to switch to a different PLMN when crossing the border. This transition demands the allocation of resources and configuration of the same service within the v-PLMN. Consequently, it becomes imperative to establish a cross-border interface between the two domain orchestrators of the PLMNs in different countries.
Policy recommendations	Encourage federation and possibility to access to the Edge/Cloud capability of an operator, or even other operators that are part of the federation, by just connecting to a single platform. Encourage GSMA Open Gateway adoption to boost Network API and Edge federation
Regulatory recommendations	Regulators should focus firstly on the identified priorities: interoperability, service continuity, precise positioning and cyber security. Moreover, how to handle non-compliance (e.g., lack of service continuity, safe response to cyber-attacks, etc.).

Finally, Table 12 discusses the complexities of cross-border network slicing, recommending a regulatory framework for network slicing federation to ensure service continuity across different PLMNs. This would require operators to coordinate their network slicing configurations to meet the requirements of CAM services.

Table 12: Cross-border network slicing

Description of Challenge	**Although the standardization of network slicing within 5G networks is well-established, the implementation of network slicing across borders presents a particular challenge. The primary issue arises from the fact that different network operators may have distinct slicing policies, configurations, and resource availability. Thus, transferring a slice from one PLMN to another becomes a complex task**
Relevance	Network slicing represents a distinctive feature within 5G networks, enabling the partitioning of a single physical network infrastructure into multiple isolated and flexible logical networks, referred to as slices. These

	slices can be customized to accommodate the unique demands of diverse users or applications by assembling a variety of resource components, including core, transport, and radio network elements. Network slicing allows different tenants to have their own isolated slices with specific QoS requirements.
Policy recommendations	Encourage the coordination of 5G network slicing configuration between cross-border operators as an efficient way to provide the requirements needed by CAM services and applications.
Regulatory recommendations	Create a regulatory framework that establishes the need for a network slicing federation concept in order to provide network slicing continuity across different PLMNs, allowing users to seamlessly access services and maintain a consistent network experience when crossing the border. Push network vendors to follow slicing 3GPP standards, thus facilitating inter-PLMN slicing configuration.

5.2.2 Recommendations related to the implementation of the Use Cases

There are specific recommendations related to the use cases, in particular Use case 1 (Remote Driving) and UC3 (Railway).

Recommendations related to UC1 (Remote driving)

Remote Management has the potential to complement automated driving by performing the monitoring, assistance and operation of a high-level Automated Driving System when needed. A remote intervention shall be necessary when the Automated Vehicle is not able to address a specific traffic situation, in this case a human operator can monitor its actions and surroundings remotely and intervene.

Remote driving is already taking place in some regions, specifically in off-road environments being the driver at a different location (as for example warehouses or ports).

However, on public roads, remote driving faces several safety challenges related to connectivity (a reliable connection between remote driver and vehicle needs to be ensured), human factors (how human drivers can maintain situational awareness and remain alert), and cybersecurity (minimization of risks associated to i.e. unauthorized takeovers)

Currently, there is no policy or regulatory framework addressing the topic, and it is important that projects like 5GMED, in synergies with other CCAM projects, are consulted and support in building a set of guidelines and requirements that consider all the technical complexities (regarding connectivity, human factors, and cybersecurity) to remove any uncertainties and provides a solid framework to make sure that remote management services are deployed safely.

Recommendations related to UC3 (Railway):

The implementation of high-speed rail communications and cost-effective solutions is critical for improving railway services and operational efficiency. Table 13 emphasizes the need for cost-effective Gigabit Train technology, highlighting the importance of providing financial incentives, fostering public-private collaborations, and reusing existing trackside infrastructure. This will enhance passenger experiences, particularly on long-haul journeys.

Table 13: Achieve cost-effective Gigabit Train

Description of Challenge	**Achieve Cost-effective Gigabit Train**
Relevance	Passenger experience drives high quality and seamless connectivity services, especially on medium/long-haul journeys that today are often poorly covered by mobile operators.
Policy Recommendations	- Provide financial incentives for railway operators and track infrastructure managers to integrate Gigabit Train technologies alongside FRMCS (Future Railway Mobile Communication System) investments. This could include subsidies for technology upgrades or grants for research and development in trackside network capabilities. - Encourage collaborations between the public sector and private companies to share the costs and benefits of deploying Gigabit Train technology. This can help address the financial barriers for railway operators and ensure the implementation of high-performance networks. - Harmonize regulations across different jurisdictions to streamline the deployment of Gigabit Train technologies and trackside networks. - Establish frameworks for cost-sharing models and new collaborative models between railway operators, mobile network operators, neutral operators, and railway infrastructure managers to lower the financial burden of deploying high-performance networks. -Offer targeted support or subsidies to expand trackside networks in less profitable or remote areas. This can help ensure that Gigabit Train technology is deployed across all regions, not just to profitable ones. - Reuse existing infrastructure along track (catenary poles, etc…) to minimize the deployment of new infrastructure (as in 5GMED Gigabit train). - Finance the deployment of 5GMED technologies, such as 802.11ad and satellite backhauls, that provide Gigabit connectivity along the railway track to 5G onboard picocells or onboard Wi-Fi access points.
Regulatory Recommendations	- Facilitate the acquisition of licenses and permits for the installation of necessary infrastructure along the railway track, including the use of unlicensed spectrum. - Establish comprehensive technical standards for the deployment of trackside networks and on-train systems, including guidelines for Gigabit architecture, performance, and interoperability. - Establish regulations that encourage the sharing of both passive and active infrastructure between different telecommunications operators and railway infrastructure administrations. - Create public funding programs and grants to support the development and deployment of 5G support technologies, such as 802.11ad and satellite backhauls.

Additionally, Table 14 focuses on reducing the cost of railway communications, suggesting policy measures such as infrastructure sharing and the deployment of 5G support technologies, with regulations facilitating streamlined approval processes.

Table 14: Reduce cost of Railways communications

Description of Challenge	Reduce Cost of railways communications
Relevance	Communications cost reduction is crucial for maintaining affordable and efficient railway operations, ensuring that both passenger services and critical infrastructure are sustainable and competitive.
Policy Recommendations	- Ensure the sharing of passive and active infrastructure for all services, both critical and non-critical, aimed at passengers and trains. - Reuse existing infrastructure and use new lightweight and easy-to-install materials for poles, avoiding the need to turn-off power of rail catenaries. - Finance the development and deployment of 5G support technologies, such as 802.11ad backhauls, to reduce operational costs and improve overall efficiency.
Regulatory Recommendations	- Create regulatory incentives for railway administrators and telecom operators to use more efficient and cost-effective backhaul technologies, while ensuring compliance with quality and safety standards. - Introduce regulations that simplify approval processes for reusing infrastructure and adopting new technologies and materials in the railway environment, ensuring safety and minimizing service disruptions. - Implement regulatory frameworks that prioritize funding and deployment of 5G support technologies, such as 802.11ad backhauls, ensuring effective integration into existing railway infrastructure and compliance with interoperability and safety standards.

To improve self-sustainability, Table 15 calls for the adoption of renewable energy solutions to power railway infrastructure autonomously, reducing both operational costs and environmental impact.

Table 15: Improve self-sustainability

Description of Challenge	Improve self-sustainability
Relevance	Self-sustainability is key to reducing operational costs, minimizing environmental impact, and increasing the resilience of railway infrastructure, particularly in remote areas.
Policy Recommendations	- Eliminate dependence on the electrical grid by implementing self-sustaining power systems, reducing costs and improving deployment speed. - Encourage the adoption of technologies that enable self-sustainability in remote nodes, following the logic of eliminating fiber optic connectivity in these areas. - Promote self-sustainability through new collaborative business models between railway operators and technology companies.
Regulatory Recommendations	- Establish regulations that incentivize the use of renewable energy sources and self-sustaining technologies in railway infrastructure, reducing regulatory burdens and providing tax benefits for sustainable projects. - Create a regulatory framework that facilitates the implementation of self-sustaining solutions along tracks, ensuring the technical and

	economic viability of the projects, as well as access to financing for the research and development of these technologies.

The rapid deployment of communications technologies, as highlighted in Table 16, is essential for enhancing service quality and operational efficiency. Key recommendations include reusing existing infrastructure and adopting innovative materials to speed up deployment, supported by regulations that prioritize fast-tracking infrastructure projects.

Table 16: Rail communications speed of deployment

Description of Challenge	Rail communications speed of deployment
Relevance	Rapid deployment of new technologies is essential for improving service quality, reducing downtime, and meeting increasing demands for connectivity and operational efficiency in the railway sector.
Policy Recommendations	- Use new lightweight and easy-to-install materials for poles, enabling faster deployment without the need to interrupt energy to catenaries. - Incentivize the reuse of existing infrastructure along track to reduce the time required for deploying new connectivity technologies. - Develop new collaborative models that allow neutral operators and railway infrastructure managers to deploy technology more quickly.
Regulatory Recommendations	- Implement regulations that prioritize the rapid approval of railway infrastructure projects that use innovative materials and technologies, ensuring safety standards are met. - Create policies that simplify administrative and regulatory procedures for the reuse of existing railway infrastructure, enabling the quick implementation of technological upgrades and minimizing service interruptions. - Modify regulations to facilitate and accelerate collaboration between the railway sector and telecom operators, reducing regulatory barriers and encouraging innovation in the deployment of new technological infrastructure.

5.2.3 Additional recommendations

The following are additional recommendations for policy making:

- **Guidelines and support to extend investments in 5G SA, encouraging commercial deployment**: 5G NSA can already be found in commercial networks. However, 5G SA commercially availability needs to be further extended. Some needed features to deploy 5G for CAM services are conditioned by the existence of the right standards and the commercial compliant equipment. Set clear guidelines and targets for network coverage, capacity, and quality of services, to use a standardized approach that balances data privacy concerns in the efficient deployment of 5G services, and to implement robust and up-to-date legislation.

- **Alignment of roadmaps and priorities among stakeholders;** this is necessary for the right investment plans and for a coordinated 5G deployment across all EU Member states.
- **Sustainable deployment of networks:** the European corridors will most likely run through large areas in the countryside where power grid may either not be available, or the high supply cost may heavily impact the operations and maintenance of the network infrastructure. Recently, the introduction of new solutions for zero-emission micro-power generation has drawn the attention of MNOs and tower companies (TowerCo) looking to cut OPEX and foster green-power generation. Policy makers should promote investment in self-sustainable sites run by renewable energy, not connected to the power grid and not relying on fiber connectivity.
- **Simplify bureaucratic and administrative processes in order to obtain permits to trial remote driving (and/or other CAM services) on open roads:** 5GMED experienced a long and highly complex process to get the authorization to demonstrate remote driving on the highway in the cross-border. On the Spanish side 3 different governmental bodies were involved:

  Two of them, in order to authorize a physical lane segregation on the highway, due to safety concerns:

  - Spanish Transport Ministry (MITMA): As owner of the AP-7 highway
  - Regional Catalan Road Traffic authority (SCT): As managing entity of AP-7 highway

  And the third one, the General Directorate of Traffic (DGT), to allow a SAE level 4 vehicle to circulate in Spanish roads when was only certified to do so in another country (France).

  On the French side of the border the process was simplified due to the fact that A9 highway is managed and owned by the same private company. The permit to allow an autonomous vehicle to circulate was already granted to VALEO for any highway in France.

  To foster innovation in this area, is fundamental to be able to execute trials in open roads, while ensuring the safety of road users. Therefore, we recommend:

  - To instruct local and regional traffic authorities to prioritize innovation actions and be sensitive to CAM testing and trial needs, facilitating areas to do so. Unfortunately, currently regular operations have a much higher priority than innovation actions, being this the cause for lengthy bureaucratic processes.
  - To promote a single autonomous driving vehicle certification at European Level, directly acknowledged in every state member.
- Other recommendations would be: to promote early deployment in major urban areas and along major transport paths; to unite leading actors in working towards the promotion of global standards; to set clear guidelines and targets, at both national at EU level, for network coverage, capacity, and quality of service; the preparation and execution of spectrum assignments by public authorities as well as 5G public funding for network deployment and R&I; to ensure legacy infrastructure compatibility and data availability; to ensure market strength thanks to i.e. equipment availability.

5.3 Standardisation outcomes

This section explains how the standards mentioned in chapter 2 can be enhanced or updated thanks to 5GMED results, as well as the actions done in the project to achieve this. Also, there is lack of standards regarding the different technologies involved in the project and for those gaps the consortium has analysed if 5GMED has relevant results to move forward to standardisation.

5.3.1 Inter-PLMN HO LBO (roaming)

Roaming refers to the ability to use a User Equipment in a visited network, typically in another country. The mobility from home network to visited network implies Inter-PLMN Handover that refers to the process of transferring the mobile connection from the home Public Land Mobile Network (hPLMN) to the visited PLMN.

The Mobility can be categorized in two types:

- The mobility mechanism in idle mode is called cell reselection. In this scenario, there is no active connection with the home network.
- The mobility procedure in connected mode is called handover (HO). Handover in connected mode is a critical to ensure seamless connectivity, especially in scenarios where a user moves across different network operators' coverage areas. This is particularly relevant in 5G networks, which aim to provide uninterrupted service continuity. In connected mode, the handover process involves several steps to maintain the active session without dropping the connection.

As per 3GPP standards detailed in 4.3, there are two roaming scenarios supported by the 5G Core:

- Home Routed (HR) roaming scenario (Figure 1). The data traffic is redirected to the HPLMN core network via the N9 user plane reference point and SMF-to-SMF communication is done through the N16 control plane reference point.

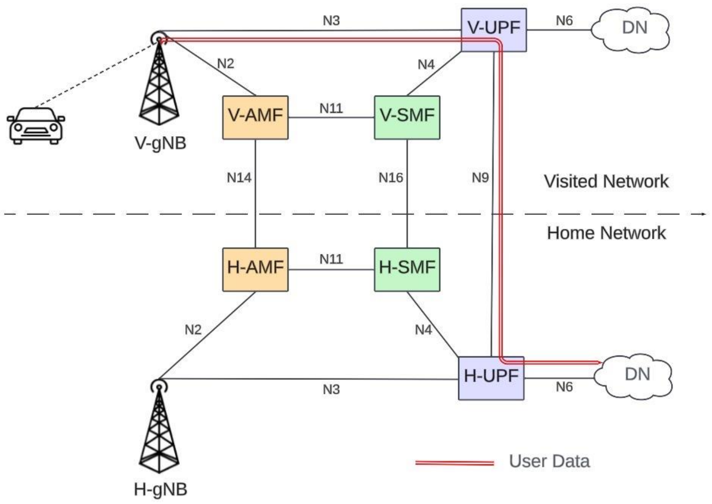


Figure 1: Inter-PLMN Handover in the case of Home Routed roaming scenario

- The Local Break Out (LBO) roaming scenario (Figure 2). The user plane traffic is directly routed from the V-UPF to the Data Network (DN). LBO allows mobile subscribers to sign up to an alternative roaming provider separate from their HPLMN (Home Public Land Mobile Network). It enables inbound roamers to receive data services directly from the visited mobile network instead of tunnelling back to the HPLMN reducing the latency and avoiding transmission bottlenecks.

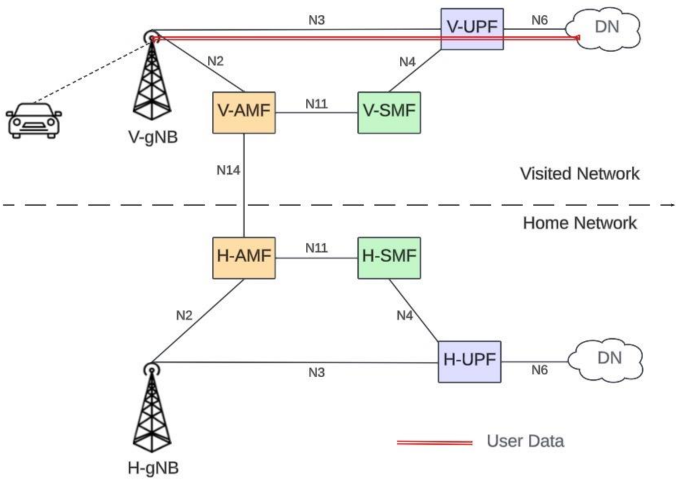


Figure 2: Local Break-Out (LBO) roaming scenario

Home Routed roaming standardization includes idle and connected roaming enabling seamless roaming between two networks by Local Break Out roaming is only standardized in idle mode.

5GMED has successfully implemented LBO roaming in connected mode demonstrating the advantages for use cases where high availability and low latency is required (UC4), it is also relevant to deliver huge amount of traffic to the visited network between countries, for example in UC3-Gigabit train. Further conversations are ongoing with Druid (5G Core provider for 5GMED) in order to promote the standardisation of the proposed solution.

5.3.2 Satellite Slicing

NTN was introduced in 3GPP in March 2017 during Rel. 15. Since then, many work has been carried out by the academics and the industry in order to integrate seamlessly the NTN to terrestrial 5G cellular networks.

IRT Saint Exupery's contribution has been, in particular, and part of it through 5GMED, to develop a way to backhaul the 5G cells of 5G-SA cellular networks over a non 3GPP link (as in 5GMED over a legacy satellite systems) while maintaining the 5G slices, an essential feature of 5G-SA cellular networks.

In the frame of the impact of 5GMED on standardization, and together with the help of Hispasat, IRT tried to push its solution to maintain the 5G slice over a satellite link as described above. Presentations were made to GSOA and to SSIG in this frame. Moreover, IRT supports further initiatives from Hispasat to push it at 3GPP since legacy satellites are still on air and will be for a long while. Another reason for pushing in this direction is, this solution could also be implemented on any non 3GPP link, other than satellite, for example the IEEE802.11ad radio access that was tested in 5GMED.

Satellite slicing and ACS-GW technologies were presented to SSIG and GSOA in order to have their advice for a possible contribution to the 3GPP on this topic. The SSIG feedback is that according to them this is not of an interest in standardisation at this moment.

The question nevertheless may remain to present to 3GPP SA1 since there is certainly an interest for the industry for 5G cell satellite backhauling by MNOs and even more certainly by verticals like aeronautics, automotive or trains.

5.3.3 ACS-Gateway (ACS-GW)

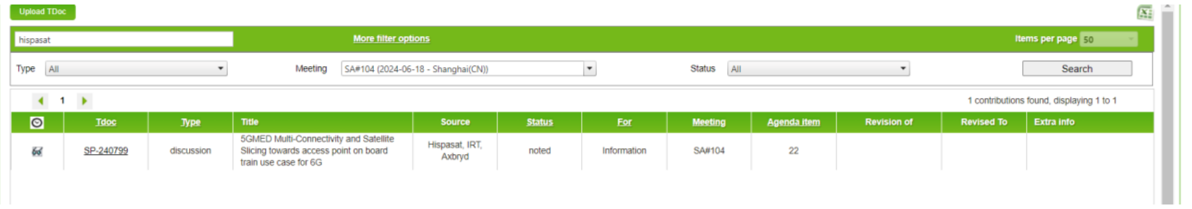
The ACS-GW, tailored for the 5GMED railway scenario, enhances connectivity between train and ground networks using an adaptive packet forwarding strategy that ensures IP mobility and session continuity across various radio access technologies. This system simplifies complex network handovers for train users with an overlay network for each Radio Access Technology (RAT).

The ACS-GW functions as a middleware, connecting the train's central switch to the RATs gateway without being detected by end devices. It classifies data flows on a per-application basis, using configurable rules to identify application IDs. The system tracks application flows, monitors tunnel status, and the train's position, adjusting the RAN association as needed. It also includes a Forwarding Orchestrator, which assigns forwarding policies to applications, determining the appropriate radio technology for packet transmission. For IP mobility, ACS-GW uses IP/UDP encapsulation with tunnels maintained by keep-alive messages that check tunnel status and update NAT bindings.

The ACS-GW has proven to be effective in railway scenarios, but it can also be beneficial in other multi-connectivity scenarios. For example, it can seamlessly manage the transition between satellite and terrestrial networks, ensuring continuous 5G access in mobile environments where multiple RANs must be utilized adaptively. For this reason, the key ACS-GW functions described above were presented at GSOA and 3GPP SSIG meetings to gauge the community's interest in standardizing part of its core components and mechanisms.

Hispasat has presented a TDoc in the plenary session of 3GPP in Shanghai titled "5GMED Multi-Connectivity and Satellite Slicing towards access point on board train use case for 6G". Where it was explained two technologies developed during 5GMED:

- Adaptative Communication System gateway
- Satellite slicing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hispasat | More filter options | Items per page 50
Type All | Meeting SA#104 (2024-06-18 - Shanghai(CN)) | Status All | Search
1 contributions found, displaying 1 to 1

	Tdoc	Type	Title	Source	Status	For	Meeting	Agenda item	Revision of	Revised To	Extra info
	SP-240799	discussion	5GMED Multi-Connectivity and Satellite Slicing towards access point on board train use case for 6G	Hispasat, IRT, Axbryd	noted	Information	SA#104	22			

It has paved the way for proposing the inclusion of these functionalities (satellite slicing and ACS-GW) in the new release (release 20), since they are relevant to industrial cases.

5.3.4 C2V cooperation class prescriptive

Use Case 2 of 5GMED project, Road infrastructure digitalization, aims to demonstrate how to ensure the safe and efficient flow of traffic on highways where both connected and non-connected vehicles coexist. A Traffic Management Center (TMC) is designed to generate intelligent traffic management strategies by processing information received from vehicles as well as roadside sensors. Subsequently, these strategies are communicated to and executed by connected vehicles within the affected area.

Communications between the different entities (vehicles, roadside sensors, TMC) are using the messages C-ITS specified at ETSI in ITS Technical Group, especially CAM, DENM and MCM.

In terms of manoeuver coordination there are two main classes:

- **Agreement-seeking** results in manoeuvre which is achieved by a set of cooperative objects (at least two) in a coordinated manner. By seeking and agreeing to coordinate their actions, at least one of them can reach an identified objective.
- The **prescriptive** concept is an attempt to extend the manoeuvre coordination service to critical situations which cannot be covered by the previously considered concept and so only one entity gives a recommendation of manoeuver to avoid an accident. There is no negotiation.

In relation to maneuver coordination messages (MCM), VEDECOM has proposed to extend the concept Centre - Vehicle (C2V) cooperation, class “prescriptive” with a Traffic Strategy maneuver option that limits the maneuver proposal given to a vehicle to a maneuver type within a set of elementary types that is then elaborated by the automated driving (AD) computer or by the driver, when accepted.

As indicated in document ETSI TR 103 578 [21], providing a complete trajectory with absolute information may be imprecise due to the use of different maps in the transmitting and receiving ITS stations, and also complicated for the transmitting station which does not have all the detailed capabilities of the vehicle for a maneuver, such as braking, direction change, etc. The use of elementary information such as the type of maneuver desired, will avoid having those types of problems, because it will be interpreted by the vehicle AD computer itself or the driver.

On top of that, from a regulatory point of view, accepting that one’s vehicle be remotely controlled with a proposed trajectory, is not something that drivers and in fact car manufacturers will easily adhere to, but a Maneuver type can complement Trajectory in the sense that for connected and non-autonomous (or not fully automated) cars, it will be more appropriate to send the desired maneuver directly so that it is displayed to the driver.

The proposed extension has been tested in 5GMED project, where new fields in ASN.1 (Abstract Syntax Notation One) description of MCM have been introduced to indicate the requested maneuver.

The proposal - Document ITSWG1(23)000144 (MCS Traffic Strategy Proposal) - was uploaded on ETSI website, discussed directly with the rapporteur of the MCS Technical Specification, presented at ETSI MCS meeting on 16th May and agreed to be incorporated in the final draft of MCS specification (ETSI-TS 103 561). Some adjustments in wording have been elaborated by the rapporteur.

The exact proposal has been to incorporate an optional field in the ManoeuvreAdviceContainer as described hereafter:

```
ManoeuvreAdviceContainer ::= SEQUENCE(SIZE(1..16)) OF Manoeuvre
Manoeuvre ::= SEQUENCE {
manoeuvreID INTEGER (0..65535),
executantID StationID,
executantPosition ReferencePosition,
executantHeading Heading,
trajectory Trajectory,
automationAdvice McmAutomationState OPTIONAL
maneuverType       ManeuverType  OPTIONAL
}
ManeuverType ::= ENUMERATED {
undefined (0),
driveStraight (1),
turnLeft (2),
turnRight (3),
uTurn (4),
moveBackward (5),
overtake (6),
accelerate (7),
slowdown (8),
goToLeftLane (9),
goToRightLane (10),
getOnHighway (11),
exitHighway (12),
takeTollingLane (13),
...
}
```

5.3.5 Implementation of 5G SA Network

Nowadays, 5G NSA can already be found in commercial networks. However, as mentioned previously, 5G SA is not yet commercially available and the deployment of an experimental 5G SA network is another technical challenge in 5GMED; in particular, considering the roaming at the border between France and Spain.

In order to achieve the project objectives, the 5GMED consortium has worked on different standardization bodies. In this context, the 5GMED consortium has identified some features which are gaps to actual standards:

- **2-step Random Access Channel (RACH) for NR**: This feature reduces the control plane latency needed to set up or resume a connection. This feature can help reducing roaming interruption times at the border and handover delays in both railway and highway.
- **NR-based Access to Unlicensed Spectrum**: This feature allows 5G devices to use unlicensed band. It can be used in the case of train operator in order to have only one carrier along train trip. However, let's note that radio transmission levels are far less limited than with licensed spectrum leading to reduced covered areas.
- **Satellite access in 5G**: This feature enables 5G devices to use satellite links to connect to gNodeB. As satellite connection is one of the options used to connect devices in delay-tolerant services of the railways use case, this feature may be used.

- **Enhancements to the Network Automation (eNA) architecture**: this feature allows the network to collect and expose a wider range of data. For instance, slice load level information and network performance information could be used in 5GMED to select best RAT.
- **Access Traffic Steering, Switching and Splitting (ATSSS)**: the enhancement in switching techniques allowing a faster moving of traffic data from one RAT to another can be also one of the solutions to reduce delay and service interruption time.
- **Enhanced Network Slicing (eNS)**: The enhancement that is of interest to 5GMED is the new procedure for allocating Access and Mobility Management Function (AMF) and Visited Session Management Function (V-SMF) in connected mode during mobility.

5.4 Standardisation Dissemination

Satellite slicing and ACS-GW technologies were presented to SSIG and GSOA in order to have their advice for a possible contribution to the 3GPP on this topic. The GSOA feedback was quite positive, and Hispasat then prepared a Tdoc for the plenary in Shanghai to present them.

Additionally, VEDECOM presented all topics related to standardization in an event organized by 5GRoutes project for summer school.

6. Conclusions

Policy makers have a key role in the deployment of Connected and Automated Mobility services. They must facilitate the network and service roll-out by encouraging to fulfil the required conditions and support the stakeholders in removing the current obstacles. Policy makers must develop the legal aspects to ensure the deployment of safe services, encourage the investment in the key enabling technologies (including connectivity and 5G), and facilitate the cooperation between parties to ensure the definition of commercially viable business models.

Regulatory entities, both at the national and European level, need to enforce the necessary quality in all the elements that conform the implementation of Connected and Automated Mobility systems, by making audit or certification procedures of those elements such as cellular networks, vehicles and road elements.

Standardisation bodies are in charge of creating common terminology, procedures, metrics, and they make sure that tests, measurements and services are performed and interpreted in the same way across national borders.

The document has described the 5GMED technical challenges and how these can be presented as recommendations for policy makers and regulatory authorities and standardization bodies to evolve the current legislation, regulatory framework and technical guidelines to incentivize the future development and evolution of the 5G-enhanced mobility services.

These recommendations shall be also taken into account in the “5G cross-border corridors” topic of the CEF2 Digital program, where the real deployment of 5G Corridors is happening.

Some of the results and recommendations show consistency with the findings obtained by other projects funded by ICT-18 (like 5GMobix), as well as by ICT-53 (5G-Blueprint).

A joint study among the ICT-53 is recommended in order to be able to further compare the findings and results hence reinforce the message from the projects towards the policy, regulation and standardization bodies.

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