5GMOBIX

5G for cooperative & connected automated MOBIlity on X-border corridors

6.3

Plan and Preliminary Report on the Standardisation and Spectrum Allocation Needs

Dissemination level	Public (PU)
Work package	WP6: Deployment enablers
Deliverable number	D6.3
Version	V2.0
First submission date	30/10/2020
Re-submission date	31/05/2021
Last due date	31/05/2021

Editors

Editors in alphabetical order		
Name	**Organisation**	**Email**
Güney, Nazlı	Turkcell	nazli.guney@turkcell.com.tr

Authors

Authors in alphabetical order		
Partner	**Person**	**Contributed to sections**
CATAPULT	Ashweeni Beeharee, Angelos Goulianos	Contributed to section 3.1.1 and 3.2
DALIAN	Yanjun Shi	Contributed to section 4.1
Fraunhofer IIS	Moustafa Roshdi, Elke Roth-Mandutz	Contributed to Annex 2
INTRASOFT	Olga Segou	Contributed to section 2 and 5
KATECH	You Jun Choi	Contributed to section 4.1
KPN	Geerd Kakes	Contributed to section 3.1.2 and 4.1
NOS	Ricardo Jorge Dinis	Contributed to section 4.1
Telefonica	Juan Franciso Esteban Rivas	Contributed to section 4.1
TNO	Pieter Nooren, Ramon Schwartz	Contributed to section 3.1.2 and 4.1
TUB	Xuan-Thuy Dang	Contributed to section 3.1.4
TURKCELL	Nazlı Güney, Hakan Batıkhan	Contributed to section 1, 2, 3, 4, 6 and the Annexes
UL	Ion Turcanu, Latif Ladid	Contributed to section 3.1.1 and 3.2
UPM	Jorge Alfonso Kurano	Contributed to section 4.3
VEDECOM	Oyunchimeg Shagdar, Maissa Boujelben	Contributed to section 3.1.5, 3.2 and 4.1

Control sheet

Version history			
Version	**Date**	**Modified by**	**Summary of changes**
2.0	31/05/2021	N. Güney	Revised according to the feedback received from the internal review process / Submitted to the European Commission

Peer review		
	Reviewer name	**Date**
Reviewer 1	Setaki, Fotini; Nikolitsa, Eutuxia (COSMOTE)	22/10/2020 28/05/2021
Reviewer 2	Shagdar, Oyunchimeg (VEDECOM)	22/10/2020 28/05/2021
Quality Review	Céline Décosse (LIST)	10/2020 19/05/2021

Legal disclaimer

Table of contents

List of figures

List of tables

ABBREVIATIONS

Abbreviation	Definition
3GPP	3rd Generation Partnership Program
5GAA	5G Automotive Association
5G IA	5G Industry Association
ARIB	The Association of Radio Industries and Businesses
ATIS	The Alliance for Telecommunications Industry Solutions
BS	Base Station
BSI	British Standards Institution
CALM	Continuous Access to Land Mobiles
CAV	Connected and Autonomous Vehicle
CBC	Cross Border Corridor
CAM	Connected and Automated Mobility
CEN	European Committee for Standardization
CENELEC	European Committee for Electro-technical Standardization
CEPT	The European Conference of Postal and Telecommunications Administrations
C-V2X	Cellular-Vehicle to Everything
D2D	Device to Device
DoA	Description of Action
EC	European Commission
eMBB	enhanced Mobile BroadBand
ETSI	The European Telecommunications Standards Institute
EU	European Union
FG-VM	Focus Group on Vehicular Multimedia
FG-AI4AD	Focus Group on AI for autonomous and assisted driving
ICEC	In Car Emergency Communication

ICT	Information and Communication Technologies
IMT	International Mobile Telecommunications
ISO	The International Organization for Standardization
ITC	Inland Transport Committee
ITS	Intelligent Transport System
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LBT	Listen Before Talk
MEC	Multi-access Edge Computing
MNO	Mobile Network Operator
mMTC	massive Machine Type Communications
NFAT	National Frequency Allocation Table
NRA	National Regulatory Authority
NSA	Non-StandAlone
RSU	Road Side Unit
SA	StandAlone
SAE	Society of Automotive Engineers
SDO	Standards Developing Organisation
SG	Study Group
SI	Study Item
SIB	System Information Block
SPS	Semi-Persistent Scheduling
TC	Technical Committee
TS	Technical Specification
TSG	Technical Specification Group
TSDI	Telecommunications Standards Development Society

TTA	Telecommunications Technology Association
UN	United Nations
UNECE	The United Nations Economic Commission for Europe
URLLC	Ultra Reliable Low Latency Communications
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
WG	Working Group
WI	Work Item
WP	Work Package
WRC	World Radio Conference
X-border	Cross-border

EXECUTIVE SUMMARY

This document is the 5G-MOBIX deliverable D6.3 "Plan and Preliminary Report on the Standardisation and Spectrum Allocation Needs", which is the first of the two deliverables that will be generated by Task 6.3. The purpose of Task 6.3 is to evaluate the 5G-enabled connected and automated mobility (CAM) use case categories and user stories, which are introduced in the 5G-MOBIX deliverable D2.1 [1], from the point of view of standardisation and spectrum allocation. This is accomplished by identifying the gaps that exist in the standards and analysing the spectrum requirements of the different CAM services in the first phase, which is reported in the current deliverable, and the next step is to offer recommendations to the relevant standardisation and regulatory bodies as a means for effective deployment of these services in the EU.

In previous work, the 5G-MOBIX user stories are already divided into five general use case categories of "Advanced Driving", "Vehicles Platooning", "Extended Sensors", "Remote Driving" and "Vehicle Quality of Service Support" in alignment with the Release 16 3GPP document TR 22.886 "Study on enhancement of 3GPP Support for 5G V2X Services" [2]. For each user story, the 5G-MOBIX deliverable D2.5 "Initial evaluation KPIs and metrics V1.4" defines a certain set of target key performance indicators (KPIs), namely user experienced data rate, end-to-end latency, reliability, position accuracy, mobility interruption time and application level handover success rate, as well as, a specific setting, behaviour and/or functionality to reach those KPIs [3]. The impact of cross-border mobility has also been captured by the project through a number of proposed cross-border issues that are classified into four groups: telecommunications, application, data privacy/security and regulation.

Building on this background, a further analysis is executed within Task 6.3 to identify gaps in standardisation, which can be transformed into technical communications that find their way into study/working items. The main approach of the 5G-MOBIX partners is to monitor and internally report on the activities of the respective groups of the standards developing organisations (SDOs) for the most up-to-date discussions on the identified technical gaps and issues. To the extent possible, the partners seek to utilise the project developments to construct novel methods that go beyond the state-of-the-art, and in the end take the achievements of the project to the SDO meetings as recommendations.

For spectrum allocation, on the other hand, the user story requirements will be translated into "at what frequency range" "how much bandwidth is to be deployed" type of specifications, aiming to highlight the importance of the flexible three-band approach of using low, mid and high-bands in 5G deployments. The principal contribution of 5G-MOBIX will be a 5G spectrum allocation study, tailor-made to the CAM services in the project. Another goal of this task is to investigate the mechanisms needed for interference elimination and seamless mobility at border crossing regions, which directly oblige cooperation among the neighbouring mobile network operators for the relevant configurations on the radio access and core network levels.

In this first deliverable from Task 6.3, the plan and methodology for how the above goals will be achieved during the project are set, also introducing the results of the gap analysis for standardisation of 5G-enabled CAM services. The 5G-MOBIX partners that are active in SDOs are listed, and a preliminary overview of the identified gaps is included in D6.3. The conclusions of 5G-MOBIX on the standardisation and spectrum allocation needs of all user stories, the recommendations developed for the identified technical issues and the views exchanged with SDOs and spectrum management organisations are planned to be reported in the second deliverable at the end of the project.

The rest of the document is organised as follows:

- **"Section 1: Introduction"** gives an overview of the 5G-MOBIX project, and explains the purpose and intended audience of the deliverable.
- **"Section 2: Objectives, Plan and Methodology"** is concerned with the approach taken within the project consortium to come up with the standardisation and spectrum allocation needs of the 5G-MOBIX user stories.
- **"Section 3: Standardisation"** introduces the project work centred around the standardisation activities with a specific focus on the SDOs that aim to deliver 5G for vehicular communications.
- **"Section 4: Spectrum Allocation for 5G-enabled CAM"** mainly discusses the study on spectrum needs of the 5G-MOBIX user stories, along with the current situation for regulations in the 5G-MOBIX countries, where testing and trialling will be performed.
- **"Section 5: Considerations for Large Scale Deployment of 5G-enabled CAM Services"** is related with the issues around numbering resources and cybersecurity.
- **"Section 6: Conclusion"** summarizes the plan and preliminary findings for addressing the standardisation and spectrum allocation needs of the CAM use case categories and user stories covered in the project.

1. INTRODUCTION

1.1. 5G-MOBIX concept and approach

5G-MOBIX aims to showcase the added value of 5G for vehicle-to-everything (V2X) communications by validating the viability of the technology to bring automated driving to the next level of vehicle automation (SAE L4 and above). The potential applicability of various 5G capabilities to advanced connected and automated mobility (CAM) services are being demonstrated by executing trials along cross-border corridors (CBCs) on real European roads and highways using 5G core technological innovations to qualify 5G and evaluate its benefits in the context of the strategic objective of the European Commission for having all European major transport paths covered by 5G connectivity in 2025 [4].

First, critical scenarios in need of advanced connectivity provided by 5G are defined, and then the required 5G features to **design 5G-enabled CAM user stories** are identified **(WP2)**. The matching of these user stories with the relevant use case categories allowed grouping of and close cooperation between the partners, conducting trials on different 5G corridors in several EU countries as well as in Turkey, China and South Korea, towards assessment of the cross-border impact of the 5G-enabled CAM services under consideration. For the trials, 5G-MOBIX **utilizes upgraded existing key assets such as infrastructure and vehicles while new components are developed as required (WP3)**, where the smooth operation and co-existence of 5G within a heterogeneous environment comprised of multiple incumbent technologies such as satellite communications, C-V2X (Rel-14) and possibly ITS-G5 are ensured.

The **trials (WP4)** will allow 5G-MOBIX to perform **technical evaluations, cost/benefit analysis and impact assessments (WP5)**, as a result of which, 5G-MOBIX will **deliver sustainable business models and opportunities for 5G corridors (WP6)**. Derived from a study of the 5G trial sites in the project and the consultations of the public and industry stakeholders outside of 5G-MOBIX, these business models will be the basis for the to-be-proposed deployment options, scenarios and recommendations that will create 5G corridors across the EU for 5G-enabled CAM services.

Two essential and intrinsic factors for deployment of 5G are (1) the availability of standards and spectrum, and (2) an accurate estimation of the related costs to bring these to the market, which will guarantee well-performing CAM services in the 5G corridors targeted by the EU. Through its findings on technical requirements and operational conditions at border crossings, 5G-MOBIX is expected to **actively contribute to standardisation activities (Task 6.3)**, which will help realize cross-border mobility for V2X services. The spectrum allocation discussion, on the other hand, is much more convoluted due to the plethora of options to choose from, and **the pursuit for the optimum assignment of spectrum to CAM services with greatly varying properties and transmission characteristics in the presence of non-CAM traffic from other 5G users as to be covered in 5G-MOBIX (Task 6.3)**.

"5G-MOBIX will be a facilitator and promoter of pan-European 5G-enabled CAM services."

1.2. Purpose of the deliverable

The present document, which is a re-submission, delivers the preliminary results of the work on the standardisation and spectrum management towards 5G for CAM, carried out as a part of Work Package 6 on "Deployment Enablers". The intention in D6.3 is to set the plan and methodology for implementing the standards development and spectrum allocation activities of 5G-MOBIX.

A refined analysis of the standardisation and spectrum allocation aspects of the 5G-enabled CAM use case categories and user stories of 5G-MOBIX depends partially on the output of the trials, and especially those obstacles encountered in the technical domain, where additional standards are deemed necessary, as well as the actual observed metrics for user data rates, latencies and handover success rate that will dictate the amount and choice of spectrum for CAM services. The deliverable D6.7 will encompass the results of this type of an analysis based on the trials.

In addition to D2.1, which specifies the 5G-MOBIX use case categories and user stories, and D2.5 on evaluation KPIs and metrics, D6.3 is related with all other WP6 deliverables. In summary, the related deliverables are listed below:

- **D2.1: "5G-enabled CCAM use cases specifications V2.0".** The main use case categories and user stories of the project, along with the particular cross-border issues that are targeted by each use case category and/or user story, is required in D6.3 for identifying the needs of CAM applications.
- **D2.5: "Initial evaluation KPIs and metrics V1.4".** An evaluation framework is introduced, from which a set of target KPIs for each user story is developed. In D6.3, the KPIs, as upgraded during the trials, will be used as an input to the spectrum allocation study.
- **D6.1: "Plan and preliminary report on the deployment options for 5G technologies for CAM".** The deliverable provides an overview of the CAM requirements for 5G and the evolution of 5G, which are all valuable material for D6.3.
- **D6.2: "Plan and preliminary report on the business models for cross border 5G deployment enabling CAM".** The spectrum allocation strategies and standardisation of 5G as discussed in D6.3 will have a close interaction with the development of business models for 5G-enabled CAM services in D6.2.
- **D6.4: "Plan and preliminary report on EU policies and regulations recommendations".** The regulation of spectrum allocation as covered in D6.3 is a single part of the bigger picture for European regulation and policy making activities as overseen in D6.4.

1.3. Intended audience

The dissemination level of D6.3 is public (PU), and hence will be used publicly to inform all interested parties about the standardisation and spectrum allocation needs of the use case categories and user stories that are addressed in the 5G-MOBIX trials. However, this document is of special interest to the following groups:

a. 5G-MOBIX project consortium members: An internal technical report for all consortium members regarding the relevant standardisation developments as well as the on-going activities for the proper spectrum allocation per trial site.

b. The European Commission (EC): A reporting method towards the EC for monitoring the project progress and for keeping up to date with the latest standards and spectrum regulations. Parts of this document may also be used as a reference for future European policies or calls for research.

c. European telecom operators & vendors: A first insight into the 5G for CAM standards and specifically to the issues of proper spectrum allocation.

d. All CAM/V2X stakeholders: A concise view on the specifications and spectrum allocation aspects of CAM in general, and 5G for CAM with cross-border settings in particular.

1.4. The impact of COVID-19 on Task 6.3

Due to the COVID-19 pandemic, the trialling phase, which is an essential step that might provide Task 6.3 with additional input with respect to standardisation and spectrum management requirements, is expected to start towards the end of Q2 2021, being delayed by over a year with respect to the original plan. Thus, the potential technical contributions from the project partners, which can ideally be captured through field work and testing, have been severely impacted.

2. OBJECTIVES, METHODOLOGY AND TIMELINE

In this section, the aim is to introduce the objectives, methodology and timeline of Task 6.3, with which it will be possible to understand the role and positioning of the task within the 5G-MOBIX project. The type of work and output to be expected from the task will be revealed by exploring the ecosystems for standards development and spectrum management, with an ultimate target of discovering enablers for "5G for CAM".

2.1. Objectives

The objective of Task 6.3 is to identify the gaps that exist in the standards and spectrum regulations that should be addressed for a viable deployment of 5G-enabled CAM services at 5G cross-border corridors, ensuring seamless and reliable mobility across and beyond the EU.

The focus of Task 6.3 is on standardisation and spectrum allocation needs of 5G-enabled CAM services, which are two distinct but somehow interrelated topics that require knowledge and expertise about the activities and working principles of a number of different bodies and organisations to achieve solid contributions in these domains. Within this landscape, the specific objectives of Task 6.3 are the following:

- To provide recommendations and requirements to standardisation work groups and government policymakers in the telecommunications domain for development of standards and spectrum allocation regulations, respectively.
- To perform spectrum management discussions in a "glocal" fashion, where the partners will contact the regulatory entities in their own countries, without losing the overarching goal of connecting the whole European continent.

These objectives are inherently linked with the designed user stories, the internal technical discussions and the observations / conclusions reached during the trials in the project, which are to jointly create valuable insights and know-how about the required evolution in the standards and the way spectrum should be managed by the authorities and the mobile network operators. Thus, this task is heavily dependent on some of the other technical activities in 5G-MOBIX.

2.2. Methodology and Timeline

The staged methodology in Figure 1 illustrates the steps to be taken in Task 6.3, also depicting the required stakeholders. There is an endeavour to develop concrete recommendations, which is closely related with and builds on the results obtained from the 5G-MOBIX technical discussions and the trials, where further below in Figure 2, the timing for the main stages of Task 6.3 are shown to be influenced by the trialling period, which begins at the end of Q2 2021.

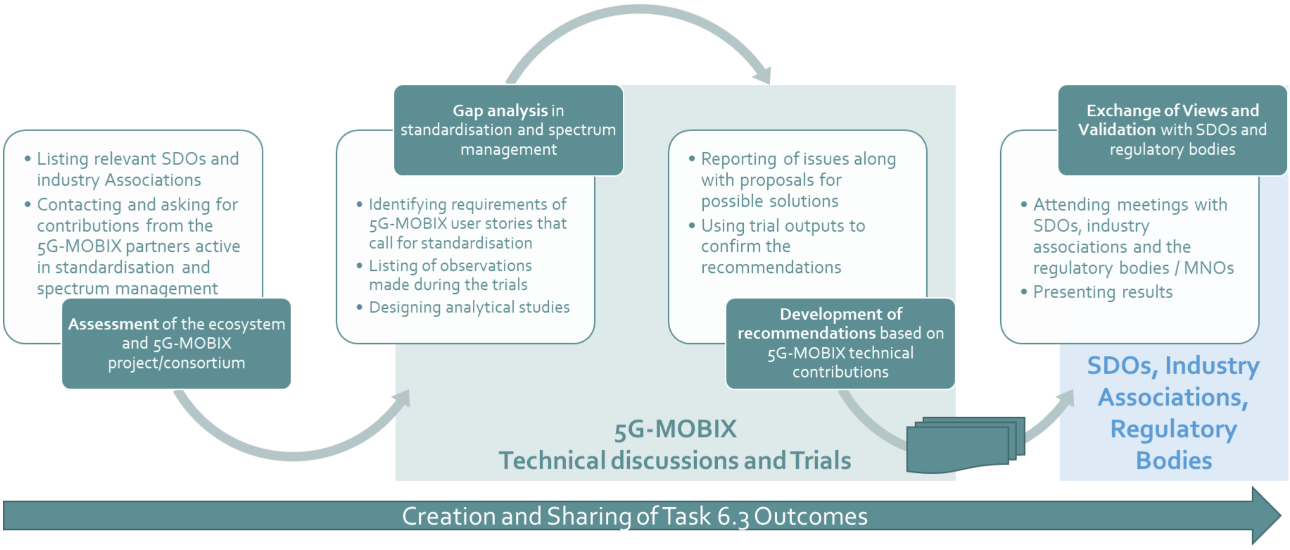


Figure 1 - Task 6.3 methodology

The methodology of Task 6.3 has these five stages:

- **Assessment:** The process begins by assessing how the standards development and spectrum management decisions are made and by which organisations that collectively constitute "the ecosystem". An understanding of the actors and the dynamics of this ecosystem is used to invite the 5G-MOBIX partners with the relevant experience in these domains to contribute to Task 6.3.
- **Gap analysis**: The use case categories and user stories are also to be investigated in terms of the standard functionalities, behaviours and components that are missing as well as their actual spectrum needs as calculated through an analytical study and observed/confirmed during the trials.
- **Development of recommendations:** In the third stage, findings about both standardisation and spectrum management will be developed into recommendations that can be taken/presented to the decision-making organisations of the ecosystem.
- **Exchange of views:** Likely to be an iterative process, in the fourth stage views will be exchanged with the SDOs and the regulatory bodies to have the results of Task 6.3 validated.
- **Share task outcomes:** Until the end of the project, which goes in parallel with all stages, the results will be shared with all interested stakeholders in the form of deliverables (D6.3 and D6.7), reports, published/presented recommendations etc.

At the time of preparation of the resubmission of D6.3, the "assessment" is complete. Next, the assessment stage of the methodology is explained in slightly more detail to demonstrate the actual nature of the responsibilities that has been assigned to the 5G-MOBIX partners, and what kinds of duties are requested from them in this task.

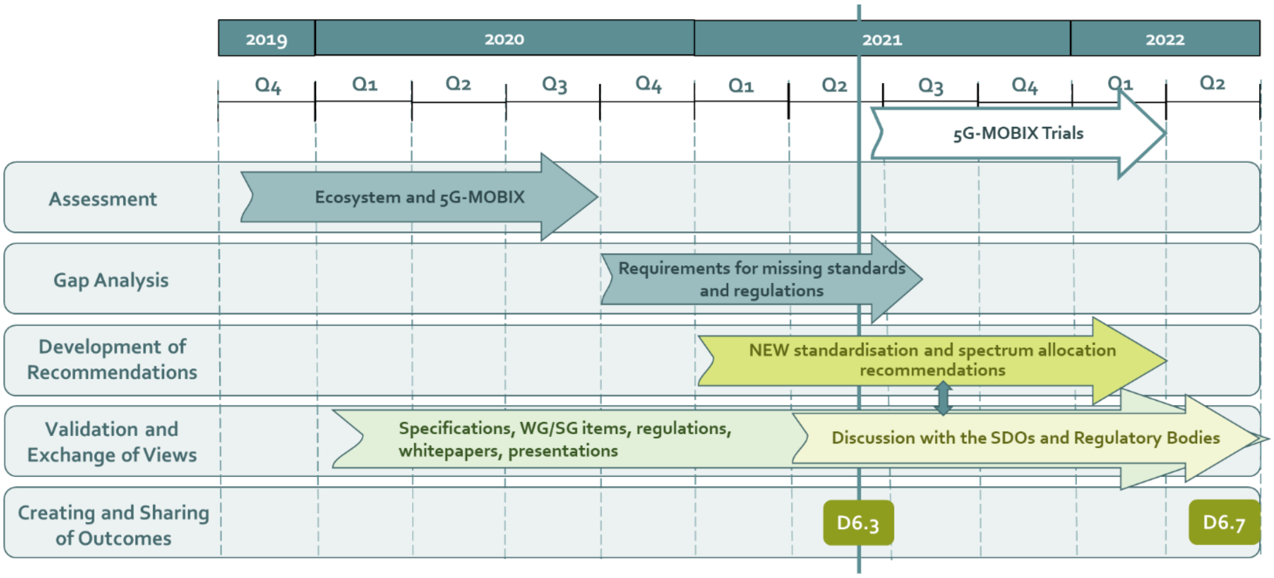


Figure 2 - The timeline for Task 6.3 activities

2.3. Assessment of the Ecosystem

The goal of this stage was to first of all find out the specific external organisations related with this task by separately characterizing the ecosystems around standardisation and spectrum regulations. Using this characterisation as an input, the 5G-MOBIX partners either actively participating in the ongoing work within these organisations or have developed ideas that can be taken to these bodies/institutions are identified and invited to join the task if they have not already done so before.

2.3.1. Standardisation Ecosystem

The standards for connected and autonomous vehicles (CAVs) can cover a broad range of categories such as control systems, communication, data management, security, human factors and artificial intelligence / machine learning (see Annex 1 – BSI Standardisation Study on Connected and Automated Mobility). However, in 5G-MOBIX, the focus will be on the network-based connectivity aspects of CAVs as will be required in 5G-enabled CAM services. Thus, the organisations such as the 3GPP, ETSI and ITU-T, which are developing standards for 5G and vehicular communications as well as associations like 5GAA, GSMA and NGMN that support SDOs with their industry-driven requirements and field work are the most relevant institutions for 5G-MOBIX as illustrated in Figure 3 (with 5G-MOBIX at the centre).

Descriptive general information about these SDOs/associations, their internal organisational structure and an overview of their work towards 5G-enabled CAM are given in

Annex 2 – SDOs and Industry Associations relevant to 5G for CAM. Utilising an updated version of the SDO/industry association list created by the 5G PPP Pre-Standardisation Work Group for 5G PPP Phase 3 standards tracking, feedback was received from 5G-MOBIX partners to form Table 1.

Figure 3 - The most prominent SDOs and industry associations for 5G-enabled CAM

The partners which are not directly involved in standardisation groups, and thus do not appear in the table can also contribute through:

a) Identifying unique results stemming from the project activities. All partners involved in the cross-border corridors and trial sites may offer solutions.

b) Bringing up existing standards and recommendations that may affect 5G-MOBIX development.

c) Participating to workshops, fairs, congresses etc. organised or endorsed by SDOs with 5G-MOBIX related presentations. ETSI Plugtests/Hackfests are especially interesting, as they provide opportunities for hands-on experimentation.

d) Attending workshops, fairs, congresses organised or endorsed by SDOs, and identifying possible impacts to 5G-MOBIX.

Table 1 – 5G-MOBIX partners' participation to standards development

Standards Organisation / Alliance	Group	Involved Partners
3GPP	SA2 - Architecture	FRAUNHOFER
	RAN1 - Radio Layer 1	FRAUNHOFER, TURKCELL
	TSG RAN	TURKCELL

	RAN 2 - Radio Layer 2 & 3	FRAUNHOFER, TURKCELL
	RAN 3 - Iu, Iub, Iur, S1, X2, UTRAN/E-UTRAN	FRAUNHOFER
	3GPP Standardization special interest group (SSIG) on Non-Terrestrial Networks (NTN) -SA2	CATAPULT
ITU-T	Focus Group on AI for autonomous and assisted driving (FG-AI4AD)	TURKCELL
NGMN	Project Portfolio	TURKCELL (Board Member)
5GAA	WG1: Use Cases and Technical Requirements	VALEO
	WG2: System Architecture and Solution Development	FRAUNHOFER, TNO
ETSI	Technical Committee (TC) Intelligent Transport Systems (ITS)	VEDECOM, VTT, Siemens
	Industry Specification Group (ISG) IPv6 Integration (IP6)	University of Luxembourg
	Industry Specification Group on IPv6 Enhanced Innovation (IPE)	University of Luxemburg, TURKCELL
CAR-2-CAR Communication Consortium	WG Deployment	SIEMENS

2.3.2. The Regulatory Ecosystem for Spectrum Management

The strategy to allocate, identify and assign the most suitable bands for 5G communications on a global scale depends on an extensive analysis of the potential frequency bands that are available and the characteristics of the services, which will be offered using these bands, as well as the likelihood of causing interference to existing services because of the allocation decision. In order to be able to offer the three main pillars of 5G communications, namely enhanced mobile broadband (eMBB) with downlink user experienced data rates of 100 Mbps, ultra-reliable low latency communications (URLLC) with minimum user plane latency of 1 ms and massive machine-type communications (mMTC) having 1 million devices per km^2, new bands have to be used in different regions of the radio-frequency spectrum. These new bands considered for 5G New Radio (NR) communications are in Annex 3 – The 5G New Radio (NR) Bands.

The end goal of 5G-MOBIX should ideally be the "identification" of the most appropriate bands for 5G-enabled CAM services. The trials will allow access to the real traffic patterns and resource requirements of the services, which will translate into the coverage and capacity plans of mobile network operators, and eventually the spectrum allocation needs. The 5G technology is different than its predecessors in the sense that there is a large number of bands with unique features, characteristics and bandwidth to choose from, and hence the regulation activities should be coordinated across neighbour countries to ensure service experience continuity.

Despite the huge international spectrum management landscape efforts spent on allocating new bands for 5G NR and publishing the Radio Regulations of the ITU-R, which are partly influenced by the regional bodies such as the CEPT in case of Europe (see Annex 4 – International Spectrum Management Landscape), it is the national governments which decide on the services to be allowed in certain frequency bands, since the Radio Regulations are not legally binding. In the end, it is the National Frequency Allocation Table (NFAT) of the governments that have the final word on the bands, the conditions and the future plans for each service. This is the reason why in 5G-MOBIX, a "glocal approach" will be taken for spectrum allocation discussions of the 5G-enabled CAM services to get the final decision makers on-board first and be ready for the next World Radio Conference (WRC) of the ITU-R.

A recent report by the 5GAA [5] stipulates that the spectrum needs of vehicular network-based communications (V2N), which is also the topic of 5G-MOBIX Task 6.3, is the following:

- *At least 50 MHz of additional service-agnostic low-band (< 1 GHz) spectrum would be required for mobile operators to provide advanced automotive V2N services in rural environments with affordable deployment costs.*
- *At least 500 MHz of additional service-agnostic mid-band (1 to 7 GHz) spectrum would be required for mobile operators to provide high capacity city wide advanced automotive V2N services.*

In the above, the term "additional" means availability of spectrum in addition to the bands that are currently identified for IMT use by mobile communication networks.

3. STANDARDISATION

This section presents the result of the gap analysis that has been performed by the 5G-MOBIX partners to identify a set of topics, which require standardisation contributions in view of current and future cross-border connected and automated mobility enabled through 5G. The initial activities of the partners with respect to standards development for these topics are also listed to further specify the organisations pertinent for each of these areas.

3.1. Input to Standardisation Work

It is essential to look into the standardisation landscape from the point of view of 5G for CAM services at cross-border settings to first of all pinpoint the missing parts in the standards and at the next step explain what needs to be done. In this line of thought, while this section is devoted to the requirements in standardisation analysed internally in terms of topics, the later section is concerned with the solid contributions of the 5G-MOBIX partners to the external parties (i.e., SDOs and industry associations).

Below, the identified gap in standardisation for a particular topic of interest is introduced by referring to the relevant organisations, work groups and the 5G-MOBIX activities, followed with a more in-depth summary and evaluation of the current situation. The main topics included in this part are the following:

- TOPIC-1. Integration of satellite access in 5G
- TOPIC-2. Seamless cross-border roaming in 5G
- TOPIC-3. IPv6-based 5G for Connected & Automated Mobility
- TOPIC-4. Dynamic Service Discovery and Placement in C-V2X Slice for CAM
- TOPIC-5. ETSI ITS Services

3.1.1. Satellite Communications

Table 2 – Overview of standardisation activities on satellite access in 5G

TOPIC-1: Integration of Satellite Access in 5G	
Identified Gap	This topic addresses the case for the lack of terrestrial coverage at the CBC, and/or the situation when the vehicle terrestrial access becomes limited or unavailable. The only way to achieve connectivity continuation when terrestrial networks are unavailable is through the means of satellite access bearers.
Relevant WG/SI/WI	3GPP TSG RAN, WG SA1 Upcoming Meetings: Every month
Reference Documents	3GPP TR.23.737, 3GPP TR 22.822
Related User Stories (if applicable)	Seamless connectivity in the FR-TS
Active Partner(s)	CATAPULT

Cross-border issue	Telecom / Low coverage areas

Coverage and network dimensioning issues in under-served, as well as across cross border corridors, where the terrestrial 5G infrastructure is unable to satisfy the connectivity requirements, impose the utilization of additional communication bearers, associated with satellite communication networks. This is quite critical for CAM messaging, where lack of connectivity could lead to potential serious malfunctioning to the connected/autonomous vehicles involved. It is worth noting that the gaps in terrestrial coverage do not arise from the technical limitations of 5G NR, but from the operational and commercial balance that have correctly guided commercial terrestrial operators in their deployment.

Coverage of sparsely or uninhabited areas will continue to be sporadic, since there is little opportunity to recover large investment costs. Satellite communication systems are probably the only viable solution to address these scenarios, if they are seamlessly integrated into the 5G architecture so that the optimum efficiency can be achieved through technological interactions between 5G mobile and Satcom systems. Recognising this opportunity, industry standard bodies ETSI 3GPP, European Space Agency (ESA), satellite and terrestrial stakeholders have joined forces over the last five years to realise the convergence of satellite and terrestrial communication within 5G.

The standardization effort on the integration of satellite in the 3GPP ecosystem started in March 2017 with an initial 3GPP Release 15 study focusing on deployment scenarios and characterization of propagation channels for non-terrestrial networks (NTN) [6]. A follow-up study on the solutions for adapting 5G NR to support NTN was carried out in 3GPP Release 16. Currently, 3GPP is conducting a work item on 5G NR-based NTN in Release 17 to develop normative specifications. The work is addressing two types of 5G satellite network scenarios. The first type is satellite access in sub-6 GHz for providing outdoor connectivity directly to handhelds and/or IoT devices. The second type is satellite access in higher frequencies for providing connectivity to a local access network via VSAT terminals installed on building roof tops or terminals mounted on moving platforms (vehicle, train, vessel, or airplane).

3GPP is also studying the feasibility of adapting narrowband IoT (NB-IoT) and Long-Term Evolution (LTE) for machine type communication (LTE-M) to support NTN in its Release 17 [7]. This study can form the basis for reducing CBC delays through Low Earth Orbit (LEO) NTN. These delays are experienced when re-establishing the connection in the PLMN of the neighbouring country that is being entered. A possible NTN solution is addressed in [8] clause 4.1.2, where it is proposed that a satellite access network is shared between multiple core networks in a 5G Multi-Operator Core Network (MOCN) sharing architecture. In this case, the shared satellite Radio Access Network (RAN) broadcasts system information for both public land mobile networks (PLMNs) whose core networks are available. These PLMNs may also be with different Mobile Country Codes (MCCs).

The working groups on integrating satellite into cellular systems consider various technical challenges and provide solutions documented into various technical reports (TRs). Example topics being addressed include introduction of new quality of service (QoS) class to support the latency of satellite access and backhaul, definition of new radio access technology types to distinguish satellite access from terrestrial access, extension of network protocol timers to accommodate the latency of satellite networks, adaptation of PLMN selection procedure, and solutions to addressing requirements associated with regulatory services such as lawful intercept, emergency calls, and public warning services. An overview of the satellite related 3GPP activities, as well the scheduled roadmap is illustrated in Figure 4.

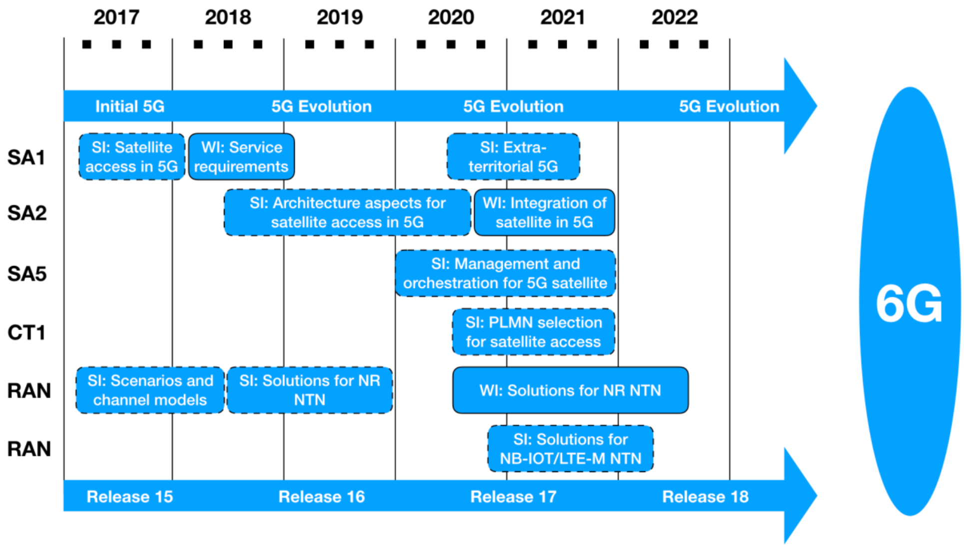


Figure 4 - Satellite related activities in 3GPP roadmap [9]

Hybrid Satellite-Terrestrial Connectivity on FR-TS trials

In 5G-MOBIX, the French trial site resorts to satellite communications. The architectural solutions and use cases for the integration of satellite and terrestrial connectivity are presented in 3GPP TR 22.822 [10] and TR 23.737 [8] referring to hybrid connectivity, satellite backhauling and inter PLMN coverage. Some of these solutions are also demonstrated in [8], however the resolutions to various issues/use cases will be adapted and applied appropriately to the French trial site 5G CAM development. In particular, to maintain reliable and seamless connectivity irrespectively of the vehicle's location and availability of terrestrial 5G network, the On-Board Unit (OBU) in the FR trial site will have access to both terrestrial and non-terrestrial radio bearers through an intelligent routing device. This is indeed aligned to 3GPP Release 16 on Multi-Access PDU through support of Access Traffic Steering, Switching and Splitting (ATSSS) between 3GPP and non-3GPP access network [11].

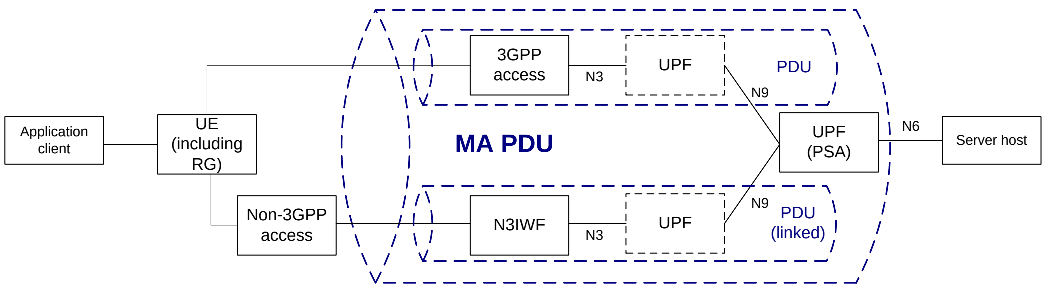


Figure 5 - Multi-Access PDU

Due to the lack of Non-3GPP Inter-Working Function (N3IWF) network function and the lack of support of Multipath TCP (MPTCP) and Quick UDP Internet Connections (QUIC) multibearer protocols on the OBU and the trial 5G Core, an alternative IP-based architecture will be initially developed and deployed in alignment with ATSSS principles. In this approach, a smart routing engine will automatically determine the most appropriate bearer based on signal strength, communications statistics, connectivity predictions and preferred mode of connectivity. For instance, this would mean using the satellite bearer for critical traffic, whenever the terrestrial 5G NR is unable to satisfy the connectivity requirement (e.g. due to unavailability, signal degradation, etc). Such conditions will be covered during the trials as part of WP4. This is associated with ATSSS switching artefact.

Another capability of the intelligent routing device is bonding of 5G and satellite bearers. This fulfils the requirement of seamless connectivity, since maintaining two active communication channels at any time allows for connectivity persistence in the case that one channels drops. This is associated with ATSSS splitting artefact. The architecture to be deployed in the FR-TS is shown in Figure 6. Further features will be added in line with the advancements on the 5G Core network side with respect to the N3IWF functionality and the MPTCP support on the vehicle side.

Engagement with Standards

The Catapult is member of ETSI 3GPP and is an active contributor to discussions around the NTN topic. It has also been a member of the Standards Special Interest Group (SSIG) since 2018 [12]. The work on the CAM use cases within 5G-MOBIX (WP2/WP3) has provided Catapult with information about real challenges and gaps in terrestrial 5G deployments that need to be addressed. In turn, Catapult has provided these inputs into the SSIG that have translated into work items and reports, that have been supported by Catapult through its membership in ETSI 3GPP.

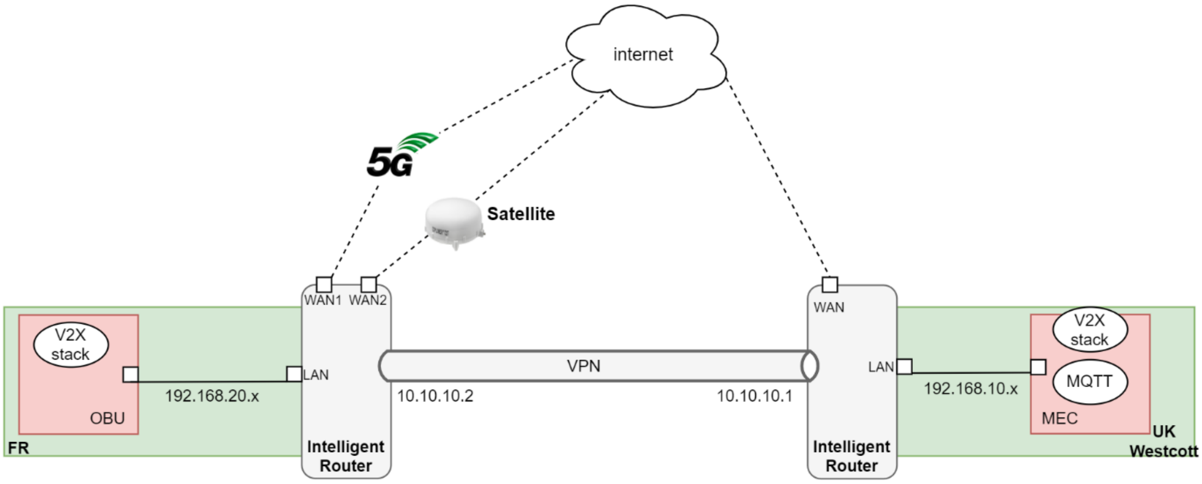


Figure 6 - Hybrid 5G-satellite intelligent routing-based deployment at the French test site

3.1.2. Roaming

Table 3 – Overview of standardisation of seamless cross-border roaming in 5G

TOPIC-2: Seamless cross-border roaming in 5G	
Identified Gap	Automotive use cases drive new requirements for roaming, as many use cases depend on continuity of connectivity that goes beyond what is offered in current mobile network roaming. In order to obtain interruption times of at most a few seconds in cross-border CAM services, several approaches are being investigated: inter-PLMN handover, fast registration and dual SIM (make before break) connectivity. All of these approaches are expected to require development and standardisation of new network and device functions in 3GPP. Furthermore, each method, whether centred around the UE or around the networks, depends on the availability of specific information (e.g., preferred visited networks, neighbouring cells) from other networks to make the correct decisions and provide the steering towards the new next network. This information is currently not exchanged between networks involved in regular roaming. Scalability is a leading requirement: in the European mobile ecosystem, there are thousands of potential combinations of home and visited networks involved in cross-border CAM services. The information exchanges between networks must be able to deal with this.
Relevant WG/SI/WI	• 3GPP TSG RAN, TSG SA (SA1, SA2)
Reference Documents	• GSMA IR.73 'Steering of Roaming Implementation Guidelines', Version 5.0, 04 May 2020 • GSMA NG.113 '5GS Roaming Guidelines', Version 3.0, 17 November 2020
Related User Stories (if applicable)	ALL user stories with inter-PLMN handover and roaming
Active Partner(s)	TNO, KPN
Cross-border Issue	Telecom / NSA-SA roaming interruption Telecom and application / Session and service continuity

Most requirement documents only state the maximum end-to-end latency, implying this should also work when changing networks. This is also the case for the specification listed in 3GPP technical documents [13], [14]. 5G-MOBIX deliverable D2.5 [3] also states the maximum disconnect time, taking in to account that vehicles might at a specific moment lose the connection for brief moment when changing the network. The maximum disconnect time as stated in D2.5 can be very strict for some use cases, being less than 5 ms. This is in sharp contrast with the interruption times typically found in inter-PLMN roaming today, which are at least on the order of tens of seconds, potentially further increasing if steering of roaming techniques are used for selection of a specific visited PLMN. To bring down the interruption time, different measures can be taken by both the mobile network and the UE inside a vehicle.

Measures at the UE focus on optimizing the search and reconnect:

- In fast registration approaches, the goal is to have the UE register in the new network within the allowable interruption time. To speed up the registration, the UE receives a hint on the new network to register on before it is disconnected from the initial network. The hint can be provided by an application running on the device/SIM or, in a later phase, from the network. Furthermore, to benefit from this hint, it will be necessary to prevent the UE from doing a complete scan for candidate networks, as is typical UE behaviour today. With current approaches this can already be achieved by manually controlling the connect behaviour (preventing automated searches). The application will trigger a network search before the connection is lost and steer the UE to a new network. Initial tests at the Dutch-Belgium border show that the reconnect time can become as low as 1 or 2 seconds (depending on the PLMN chosen).

- In dual modem setups, a connection to the new network is set up before the initial connection is lost (e.g., make before break). In current implementations, this would require two SIM cards and two modems to temporarily have parallel connections to the two networks. Also, currently an application is needed, capable of steering each UE and routing the traffic over the correct network.

Measures from the network are focused on the steering of roaming and providing a handover between bordering networks:

- Optimizing steering of roaming aims at selecting the best network for the UE and its services. The HPLMN is responsible to set up the roaming agreements with the VPLMNs and allows the UE to make use of them. The UE should always be steered to the most optimal network, be it to utilize the specific services it requires or to benefit from the best (wholesale) roaming business model and rates. Therefore, current technologies need to evolve from denying services on non-preferred networks to steering the UE toward the preferred network.

- In inter-PLMN handover approaches, the well-known intra-PLMN handover is extended to work across PLMN borders. In 4G, this involves introducing an S10 interface between MMEs of the two bordering network operators. In 5G SA architectures, this translates to an N14 interface between the AMFs (potentially absorbed in the overall N32 interface between the two operators' SBA architectures in the control plane). As pointed out by earlier measurements in trials by Ericsson [15] and as also stated in D3.2 of the 5G-CroCo project [16], there is no noticeable interruption because of the handover and the latency keeps well below 100ms during such inter-PLMN handovers. Currently the N14 interface has not yet been earmarked to be used as a roaming interface. Although the inter-PLMN handover has been described since 2006 in 3GPP release 8, it has as of yet not been adopted by operators. This is probably due to the lack of demand and the complex integration that is required.

In the long term, the SA seamless roaming should have the following key features to best support cross-border CAM use cases:

- The selection of the next network is under the control of the HPLMN;
- When available, the UE's current network provides an inter-PLMN handover to the next network;
- When such a handover is not available, the UE takes measures to minimize the interruption time;
- The selection of the next network is based on the current availability of CAM services and takes into account the UEs subscription profile to differentiate between UE groups in the HPLMN.

These improvements depend on development and standardisation of new UE and network features in 3GPP. In addition, the technical and business interactions between the operators need to be agreed upon in roaming agreements according to GSMA guidelines, and supported by OSS systems. A common requirement to come to scalable solutions for these and other topics is that they involve a minimal level of network integration and specific configurations between operators.

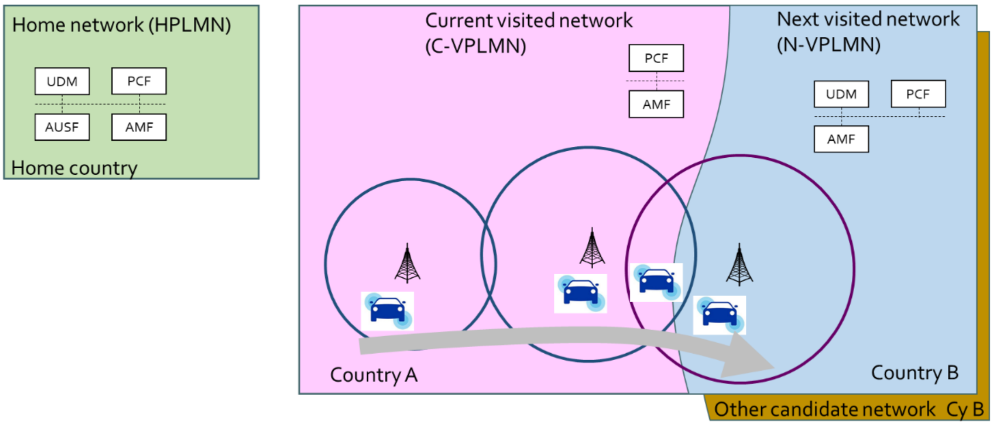


Figure 7 - Three network roles involved in European roaming for CAM use cases

As illustrated in Figure 7, there are three network roles in roaming for automotive use cases. The vehicle has a SIM and subscription from the home network (HPLMN) and is crossing the border between country A and country B. As a result, the UE has to move from one visited network (VPLMN) to another. The technical approaches outlined earlier focus at avoiding or reducing the interruption time when transferring from the current visited network (C-VPLMN) in country A to the next visited network (N-VPLMN) in country B. Each of the approaches, whether centred around the UE or around the networks, depends on the availability of specific information (e.g., preferred N-VPLMNs, neighbouring cells) from other networks to make the correct decisions and provide the steering towards the N-VPLMN. This information is currently not exchanged between networks involved in regular roaming.

When we zoom out, we see that in the European mobile ecosystem, with 3-4 mobile operators per country (not counting MVNOs), there are thousands of potential combinations of HPLMN, C-VPLMN and N-VPLMN. This brings a clear requirement for scalability: the information exchanges between networks must be able to deal with the many operators in the Europe that will be involved in CAM services. The setup of these information exchanges is still in a very early stage. As expected, the types of information to be exchanged depends on the technical approach used to reduce the interruption time.

Below, we list some of the key information required for network and for UE-centred approaches, together with a first view on potential solution directions to provide the information in a scalable way. As can be expected, in the network-centred approaches (Table 4) the C-VPLMN needs information on neighbouring cells and preferred roaming networks.

Table 4 – Key information and potential provisioning solutions in network-centred seamless roaming for CAM

Information required by C-VPLMN	Source	Potential provisioning solution
RAN data of bordering PLMN at gNB level (border cells only) - **Cell ID** - **Frequencies**	N-VPLMN candidates	- Data sharing infrastructure between (European) operators - Extension of Automatic Neighbour Relation (ANR) function for dynamic discovery through UE reports
VPLMNs allowed and preferred by HPLMN	HPLMN	- Extending the policy from the HPLMN to the C-VPLMN
Available services available in the bordering PLMNs	N-VPLMN candidates	- Data sharing infrastructure between (European) operators - Inclusion in HPLMN-VPLMN roaming agreements

The inter-PLMN handover via the N14 interface requires the availability in the C-VPLMN of RAN data of bordering candidate N-VPLMNs to configure the neighbour cell information (frequency, cell ID) in gNBs on the border. As manual configuration is not feasible when scaling up, a separate mechanism is required to exchange this information. Note that this is only needed for the cells in border areas where seamless handovers are required, such as cells that cover highway border crossings. The mechanism could be implemented through a centralised/cloud-based data sharing infrastructure where each mobile operator provides and obtains the required border cell information. An alternative can be an extension of the current Automatic Neighbour Relation (ANR) function. The ANR function uses UE measurements and reports of cell identifiers of neighbouring cell to dynamically build up a Neighbour Relation Table (NRT) for a gNB. The currently defined ANR function is limited to identifying cells in the same PLMN. An inter-PLMN extension would probably require the provision of new information via the gNB to the UE on the set of PLMNs and RATs to scan for neighbour cells. This would be to ensure that the neighbour cells searched for and reported by the UE and used by the gNB are indeed suitable for inter-PLMN handover.

The gNB in the C-VPLMN steers the UE to the N-VLPMN. As in today's roaming practice, the HPLMN typically has a preference for specific networks in the new country B. Therefore, the HPLMN must be able to steer the selection of the N-VPLMN that the gNB in the C-VPLMN hands the UE over to. Thus, the selection of the N-VPLMN does not only depend on the signal strengths measured by the UE and reported to the gNB in the C-VPLMN, but also on VPLMNs allowed and preferred by HPLMN. This information can be exchanged between HPLMN and C-VPLMN via policies applied according to the subscriber profiles. The HPLMN can determine its preferred VPLMNs on the availability of specific standardised CAM services in the candidate N-VPLMNs if this information is also exchanged via such a data sharing infrastructure. Depending on the frequency of the information updates, the selection of the N-VPLMN can be made dependent on the near-real time availability of the CAM services.

In device-centred approaches (Table 5), the device requires information to select the preferred PLMN and set up PDU sessions in the correct slice to the correct data network for its CAM services. This can be achieved through the careful application of UE Route Selection Policies (URSPs) on the UE. The URSPs are provisioned on the UE by the HPLMN and combine several inputs (e.g., location, domain descriptors in the form of standardised FQDNs) to determine the correct routing.

Table 5 – Key information and potential provisioning solutions in device-centred seamless roaming for CAM

Information required by device	Source	Potential solution direction for provisioning
Availability of handover functions at border	HPLMN and C-VPLMN	SIM application provisioned by HPLMN based on roaming agreements or data sharing infrastructure
Preferred VPLMNs in bordering country	HPLMN	SIM application provisioned by HPLMN based on roaming agreements or data sharing infrastructure
CCAM services or entry for service discovery available in bordering networks	N-VPLMN (or C-VPLMN after registration in new network)	- A dynamic name service resolving a static domain name identifying the service at the request of the device - A central application service providing the available services to the device
Data network in which a CAM service is deployed,	N-VPLMN candidates (or C-VPLMN after registration in new network)	- A dynamic name service - A central application service - URSP rules on UE provisioned by HPLMN
Identifier (S-NSSAI) of slice that supports CAM service with Slice Service Type (SST) and Slice Differentiator (SD)	N-VPLMN	- Static V2X value of SST with static and standardised SD values for individual CCAM services, requested by device and provided by N-VPLMN during registration - URSP rules

GSMA is the best entry point to drive the development and standardisation of the information exchanges described above and summarised in Table 4 and Table 5. The functional requirements can be taken on board in GSMA's work on roaming guidelines. From GSMA (or GSMA Europe), requests for development and standardisation of specific features can be liaised to 3GPP.

3.1.3. IPv6

Table 6 - Overview of standardisation activities on IPv6-based 5G for Connected & Automated Mobility

TOPIC-3: IPv6-based 5G for Connected & Automated Mobility	
Identified Gap	This topic addresses the lack of IPv6 integration in vehicular communications (i.e., connected mobility). To tackle this issue, a number of actions have to be

	taken, such as defining best IPv4 to IPv6 transition practices, gather support and create awareness of the impact of IPv6 on vehicular communications. This topic will also address the lack of clearly defined requirements and reference architectures that are needed to enable the deployment of IPv6 for 5G-enabled CAM. This can be addressed by demonstrating real-life use cases of IPv6 deployments and trials in the 5G for CAM context.
Relevant WG/SI/WI	• ETSI Industry Specification Group on IPv6 Integration (ISG IP6) Upcoming Meetings: Completed (December 2020) The activities of this ETSI ISG have been recently concluded, with University of Luxembourg actively participating and contributing to its standardization activities, producing an ETSI Group Report (GR) that summarizes the ongoing worldwide V2X standardisation initiatives that target the introduction of IPv6 for V2X communications and related applications and services. The document also reports best cases on IPv6 transition strategies for vehicular communications, describing a number of concrete use cases where the introduction of IPv6 could bring benefits. • ETSI Industry Specification Group on IPv6 Enhanced Innovation (IPE) Upcoming Meetings: Every month
Reference Documents	ETSI GR IP6 030 V1.1.1 - 2020-10, "IPv6-based Vehicular Networking (V2X)" [17] ETSI GR on "IPv6-based 5G for Connected and Automated Mobility"
Related User Stories (if applicable)	-
Active Partner(s)	University of Luxemburg, TURKCELL
Cross-border Issue	To be determined through the activities at the IPE

One of the key technologies required in 5G deployments supporting CAM is IPv6. In particular, IPv6 facilitates IP-enabled applications to be applied and used in vehicular communications. It provides several advantages covering important needs in CAM, such as (1) the large space of addressing due to the exhaustion of IPv4 address space, which impacts the growing of internet continuity, (2) the improvement of mobility and security services, (3) the addition of node auto-configuration mechanisms to facilitate the configuration of connected equipment, and others. In addition, the emergence of Automotive Ethernet for in-vehicle communications, combined with the possibility of remote access and monitoring of specific in-vehicle sensors and functionalities, naturally brings in the need for IP communications. In case of 5G-enabled CAM, relevant connectivity-based services could be enabled by IPv6, such as remote diagnostics, advanced and remote driving, extended sensors, Cooperative-Advanced Driving Assistance Systems (C-ADAS), cloud-assisted platooning, and others.

The recently established ETSI ISG IPE aims to identify and describe IPv6 based solutions, look into the derived requirements and reference architectures that are needed to enable the deployment of IPv6 across the new and evolving technology domains. In particular, it aims to provide and demonstrate use cases and proofs of concept to support innovation on IPv6 networking topics and validate standards-based approaches. One of the work items within this ISG is "IPv6-based 5G for Connected and Automated Mobility". In this context, 5G-MOBIX can contribute by analysing the requirements of IPv6 for the 5G for CAM use cases. In particular, contributions from the cross-border pilots to define the session continuity between and when crossing different networks will enable essential networking capabilities in the future.

3.1.4. Network Slicing

Table 7 - Overview of standardisation activities on 5G Dynamic Service Discovery and Placement in C-V2X Slice for CAM

TOPIC-4: Dynamic Service Discovery and Placement in C-V2X Slice for CAM	
Identified Gap	An approach for service discovery and placement in C-V2X slice in order to guarantee service continuity and low latency response of CAM services deployed in RSU edge. Specifically, SDN and ICN based communication is proposed to replace DNS based service discovery in the 3GPP C-V2X standard architecture and thus eliminate DNS overhead in high mobility use case. The design is based on the use case requirements at DE TS.
Relevant WG/SI/WI	TBD e.g., TSG RAN, WG SA1 Upcoming Meetings: TBD Every month
Reference Documents	Internet-Draft draft-irtf-icnrg-5gc-icn-04
Related User Stories (if applicable)	C-V2X for platooning and extended sensors in the DE-TS
Active Partner(s)	Technical University of Berlin
Cross-border issue	Telecom and application / Session and service continuity

Background

Addressing the challenges from future vertical applications such as CAM is one of the main design objectives for the 5th generation mobile network (5G). 5G features manifold improved network performance in terms of latency, bandwidth, number of connected devices, mobility, among others. The most important features for CAM support are Cellular Vehicle-to-Everything (C-V2X), new radio, and Network Slicing (NS). C-V2X enables vehicles to communicate with other components of the driving infrastructure. NS enables multi-tenant access to the 5G network infrastructure by configuring and composing virtualized core and access network (CN, AN) functions (VNF), fitting each application service's QoS requirements.

Besides the 5G network, CAM applications also rely on other technologies, such as big data analytics, IoT, and machine learning to process the massive amount of data generated by the roadside infrastructure and create situational perceptions for the AVs. One important but less mentioned feature of 5G is its role as an integration platform for those technologies. A core part to attain this vision is the integration with multi-access edge computing (MEC), bringing compute nodes close to the roadside and AVs, and using it for the deployment of low latency CAM applications, e.g., for object detection, traffic analysis, and 5G VNFs themselves. Given these aspects, 5G allows for novel solution approaches implemented as special NSs to be integrated into and enhance 5G core functionalities, e.g. a NS with network functions for information-centric networking (ICN) communication, which can be combined with and take advantage of the 5G core VNFs.

Identified Gaps

The future CAM scenarios with high mobility and data intensive requirements expose the limitations and inefficiencies of the predominantly host-centric IP-based communication in current mobile vehicular networks, i.e., limited support for one-to-many communications, requiring identities of the communication endpoints to be known in advance [18] or relying on the host resolution service (DNS) with high delays.

As specified by current 3GPP standards, 5G network enables V2X communication through radio interface for vehicles (data plane Uu) with unicast and sidelink interface (PC5) for direct V2V with multicast, broadcast and unicast modes. Certain 5G core functions involve in the provisioning and control of V2X connectivity, e.g., access and mobility function (AMF), policy control function (PCF), Unified data management (UDM), etc. These functions authenticate and manage users' V2X connectivity based on subscription data, e.g., location, frequencies, etc, stored both in core network and user devices. In addition, V2X Application and V2X Application Server (AS) are the respective components of the client-server based V2X applications services. CAM services are deployed as ASs, which provide traffic information for AVs. V2X applications are deployed in AVs, which receive information from the ASs. Endpoints of the ASs are solicited by the 5G core or preconfigured in the AVs. More details of the related 5G V2X architecture are provided in [19], [20].

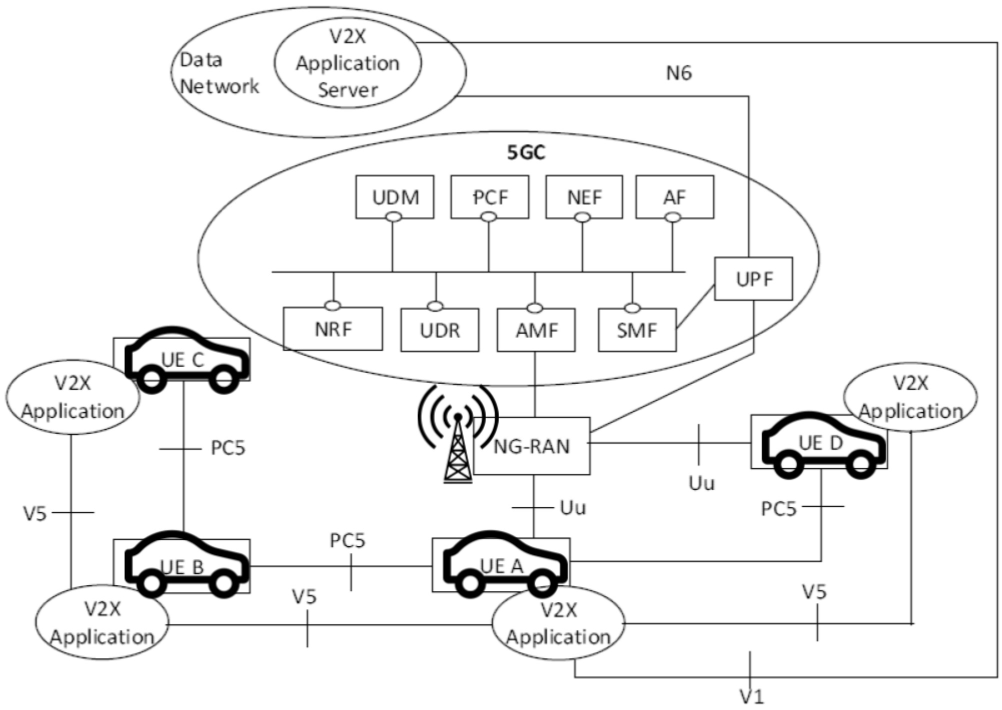


Figure 8 - Non-roaming 5G System architecture for V2X communication over PC5 and Uu reference points (3GPP TS 23.287 version 16.3.0 Release 16)

The standard C-V2X architecture, depicted in Figure 8, assumes

- V2X services are implemented with client-server based architecture and ASs are deployed behind Core network.
- The AS Endpoints are known in advance or resolvable using DNS service, and the Endpoint information is available at the CN or preconfigured at UEs.

These assumptions are not applicable or result in high overhead for C-V2X deployment with the following characteristics:

- V2X services can be deployed anywhere in the distributed MEC, i.e., on vehicles, RSUs, gNodeB.
- The services are context aware, i.e., the service endpoints and information provided to AVs are different depending on their locations, application types, and traffic situations, etc.

Proposed Approach

A typical requirement of the wireless edge networks for CAM is the co-existence of heterogeneous radio technologies and routing protocols required by different applications and devices, which are not integrated and managed by mobile broadband systems (5G). This poses significant challenges for the end-to-end management of application data flows, e.g., sensor data streams and control signals, across the cloud, edge, 5G, and sensor network domain. Needless to say, the IP based connectivity requires protocol translation to be carried out at each network domain border, i.e., from the sensor network to IP broadband, 5G core to data center virtualized network. As the result, the added transmission delays and mobility management complexity make it challenging to provision CAM applications with the required latency and other QoE parameters.

Taking advantage of the ICN paradigm, we propose a S-ICN overlay on top of a C-V2X network slice, which connects and manages the content exchange among the MEC infrastructure, AVs and road sensors. Figure 9 shows a hybrid network architecture to support V2X and D2D communication, which extends the 3GPP's 5G architecture for V2X [19] with a Software Defined ICN (S-ICN) segment. The S-INC V2X is an effective access network (AN) consisting of point of attachments (PoA) with multiple interfaces of different wired and wireless technologies, i.e., the RSUs with Wi-Fi, mmWave, 5G, and BLE to connect with road sensors and vehicles. On each PoA, the interfaces are managed by an S-ICN router, which controls data flows based on the information being transferred, e.g., sensor data, control information, application data, etc. The PoA may also contain a mobile far-edge host providing storage and computing capability for local data processing or local SDN control applications.

This infrastructure allows most generated data to be processed and communicated in the AN resulting in very high throughput, low latency, and reduced load on the cellular network. In order to fully support mobile applications, a mobile PoA (installed on vehicle or user equipment) must be fully integrated with guaranteed QoS requirements for on-board sensors and applications. The resulting challenges for mobility management, session continuity, and end-to-end flow control are addressed within the C-V2X slice.

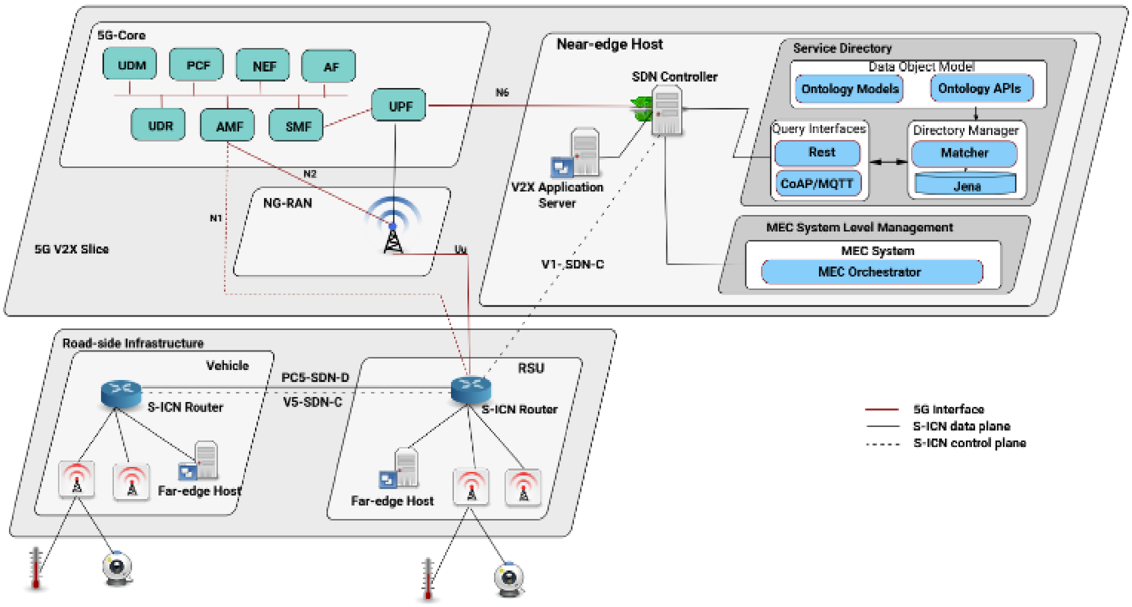


Figure 9 - Architecture of a Software Defined Information Centric Network Slice for C-V2X Application

In the proposed system, the 5G slice in effect provides a reliable and low latency back-haul for the S-ICN control plane. The V2X servers components specified in the 5G V2X architecture are implemented with a global S-ICN controller, an ICN service broker (service directory), and other CAM applications, which are hosted in the near-edge close to the network core or in data centre infrastructure as shown in Figure 9. The S-ICN controller is connected with the S-ICN routers through the 5G core UPF over N6 interface and the NG-

RAN (gNB) over Uu interface. In the NG-RAN, this control plane is extended to the mobile S-ICN routers (on AVs) through the V5 (SDN-C) interfaces. The V2X based control plane can also be used for the exchange of control information among the centralized and mobile SDN controllers.

3.1.5. ITS Services

Table 8 - Overview of standardisation activities on ETSI ITS Services

TOPIC-5: ETSI ITS Services	
Identified Gap	ETSI TC ITS WG1 is currently developing technical specifications (TS) of the Collective Perception Service (CPS) and the Manoeuvre Coordination Service (MCS), which are facilities layer protocols to support applications in the domain of road and traffic safety. 5G-MOBIX has been implementing and testing draft versions of CPS and MCS for its different CAM use-cases. The results and lessons obtained from 5G-MOBIX development and testing activities can provide useful insights to build stable long-standing standards of CPS and MCS.
Relevant WG/SI/WI	ETSI ITS TC ITS WG1 Upcoming Meetings: every month
Reference Documents	• ETSI TR 103 562, ETSI TS 103 324 – CPS • ETSI TS 103 561, ETSI TR 103 578 – MCS
Related User Stories (if applicable)	Advanced Driving, Extended Sensors
Active Partner(s)	VEDECOM
Cross-border issue	Telecom and application: Session and service continuity

- **Collective Perception Service (CPS):** Cooperative Awareness Service (CAS) is specified in 2011 to improve perception of CVs (including CAVs). The benefits of CAS can be obtained only when the penetration of CVs is relatively high. Unfortunately, in the early phase of the C-ITS deployment, the penetration of CVs will be low i.e., most vehicles on the road will be non-connected vehicles and other non-connected road users. The CPS, which is currently being specified by ETSI, is expected to extend vehicles' perception particularly these early phases of C-ITS deployment by providing data about objects (i.e., other road participants, obstacles and alike) detected by sensors mounted in vehicles and roadside infrastructure. The ETSI ITS WG1 has published a technical report ETSI TR 103 562, which presents a draft CPM format and different strategies of message generation rules (message generation frequency and content/container inclusion management). The group is currently working on a technical standard. While the benefit of CPS is obvious, the followings are some open issues requiring careful thoughts, validations, and experimentations in order to develop a solid standard:
    - CPM generation frequency,
    - object inclusion management,

  - the maximum number of objects that can be announced by a single CPM,
  - redundancy control,
  - infrastructure capability of providing CPS w.r.t that of a vehicle, and
  - data processing overhead induced by CPS.

  Because CPS has been integrated and tested in different trials sites of 5G-MOBIX, the project is able to provide valuable contributions for the future standard.

- **Manoeuvre Coordination Service (MCS):** Automated driving is an important future topic for the automotive industry. Current designs of automated driving systems are only reactive to traffic situation. Therefore, automated vehicles are only able to react to manoeuvres of other vehicles which are currently executed and recognized. Alternatively, it is possible to predict future manoeuvres and react to them. Unfortunately, a prediction is based on assumptions which can be wrong and therefore the prediction can also be erroneous. ETSI is currently specifying the Manoeuvre Coordination Service (MCS), which is intended to reduce prediction errors by exchanging detailed information about intended and/or desired manoeuvres between vehicles and infrastructure. Furthermore, the MCS provides possibilities to coordinate a joint manoeuvre if several vehicles intent to use the same space at the same time. Even though the CPS and MCS work items (WI) have started at the same time, the progress of the MCS WI is much slower, the TR is still in early draft version. Indeed, the concept of MCS is trickier since it has a direct impact on vehicle control, and hence functional safety, as well as on intelligence distribution (among vehicles and infrastructure), leading to responsibility issue. 5G-MOBIX is testing both the vehicle-oriented and the infrastructure-oriented manoeuvre coordination service, and hence the results will be helpful for in progressing the MCS WI.

3.2. Activities of 5G-MOBIX Partners within the SDOs and Industry Associations

Table 9 – List of contributions of 5G-MOBIX partners

SDO/ Industry Association	1. Title and Document Number 2. Place / Date	Related topic / issue	Involved Partner(s)
3GPP	TR 22.822, "Technical Specification Group Services and System Aspects; Study on using Satellite Access in 5G;(Release 16)"	Integration of NTN/ Satellite Access in 5G	Catapult
3GPP	TR 38.811, "Technical Specification Group Radio Access Network; Study on New Radio (NR) to support non-terrestrial networks (Release 15)"	Integration of NTN/ Satellite Access in 5G /	SSIG on NTN
3GPP	TR. 38.821, "Technical Specification Group Radio Access Network; Solutions for NR to support non-terrestrial networks (NTN) (Release 16)"	Integration of NTN/ Satellite Access in 5G	SSIG on NTN
3GPP	TR.23.737, "Technical Specification Group Services and System Aspects; Study on	Integration of NTN/ Satellite Access in 5G	Catapult

	architecture aspects for using satellite access in 5G (Release 17)"		
3GPP	TR.28.808, "Study on management and orchestration aspects of integrated satellite components in a 5G network "	Integration of NTN/ Satellite Access in 5G	SSIG on NTN
3GPP	TR.24.821, "Study on PLMN selection for satellite access "	Integration of NTN/ Satellite Access in 5G	SSIG on NTN
3GPP	TR.36.763, "Technical Specification Group Radio Access Network; Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN)"	Integration of NTN/ Satellite Access in 5G	SSIG on NTN
ETSI	ETSI GR IP6 030 V1.1.1 (2020-10), "IPv6-based Vehicular Networking (V2X)"	IPv6-based Vehicular Networking	University of Luxembourg
ETSI TC ITS	1. Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2, ETSI TR 103 562 V2.1.1 2. Sophia Antipolis, France December 2019	CP Message Format and Data Elements, Sensor Information Container, Perceived Object Container	VEDECOM
ETSI TC ITS	Intelligent Transport Systems (ITS); Vehicular Communications; Informative Report for the Manoeuvre Coordination Service, ETSI TR 103 578	General description of the Manoeuvre Coordination Service, Use Cases	VEDECOM

4. SPECTRUM ALLOCATION FOR 5G-ENABLED CAM

The ecosystem for spectrum management is presented in Section 2.3.2 and Annex 4 – International Spectrum Management Landscape. The 5G NR bands under consideration by the regulatory bodies responsible from spectrum management are an indicator for the limits of the performance that can be achieved with 5G-enabled CAM services, and an essential input for any study that aims to assess whether the spectrum needs of these services can be commercially met in the near future. In Section 4, first of all the current frequency bands assigned to 5G in the 5G-MOBIX countries are presented. Next, a specific spectrum issue encountered at cross-border corridors is discussed. Finally, the spectrum needs study to be carried out for the 5G-MOBIX user stories is introduced.

4.1. The Current Situation in 5G-MOBIX Trialling and Testing Countries

In this section, an overview for the status of spectrum regulations in the countries, where 5G-MOBIX trials will be carried out is given. Even though not established within the project as a CBC trial site, all trial sites can be linked with a future 5G cross-border corridor of the EU, which will need to offer seamless services to vehicles. For instance, Germany has borders with the Netherlands and France, which is a neighbour of Spain. Therefore, the spectrum regulation discussions in all 5G-MOBIX countries are valid when establishing cross-border corridors for CAM. Please visit [21] by "European 5G Observatory" for most up-to-date information about the national plans in Europe.

Table 10 – The situation of 5G regulations in 5G-MOBIX countries [21]

COUNTRY	Main Points
SPAIN	The 3.6-3.8 GHz auction ended in July 2018 and will be used by 5G networks: • Vodafone has eighteen 5 MHz blocks (198.1 million EUR) • Orange has twelve 5 MHz blocks (132.1 million EUR) • Telefonica has ten 5 MHz blocks (107.4 million EUR) The 700 MHz auction initially scheduled for March and then for May 2020 postponed due to COVID-19 likely to the first quarter of 2021.
PORTUGAL	NO COMMERCIAL 5G YET • Multi-band auction (700/900/1800/2100/2600/3600 MHz) postponed in March 2020 due again to COVID-19 and rescheduled for October 2020, and further rescheduled to early 2021. • 26 GHz auction expected in 2023.
GREECE	Auction of 2x30 MHz in the 700 MHz band, 2x15 MHz in the 2100 MHz band (plus 2x45 MHz in the same band which is already allocated but licences expire in 2021),

	280 MHz at 6 GHz, and up to 2,500 MHz in the 24 GHz – 28 GHz range completed on December 17, 2020.
TURKEY	NO COMMERCIAL 5G YET – NO PLANS
FINLAND	• The 700 MHz band frequencies were assigned in November 2016. • In May 2018, the government launched a consultation to free spectrum in the 3.6 GHz band. • The 3.6 GHz band spectrum auctions took place in September 2018. • Elisa, first 5G network in Europe launched in June 2018. All players launched 5G since then. • Early award of trial licences to a large number of companies (October 2015-October 2017). • Auction for the 26 GHz (25.1- 27.5 GHz) spectrum ended on June 8, 2020. The incumbent MNOs each got a 5G licence at 7 MEUR giving them the right to use 800 MHz of spectrum.
FRANCE	• 5G launch by SFR in November 2020, by Bouygues Telecom and Orange France in December 2020 • 700 MHz frequencies assigned in December • Consultation on 5G, • Trial licences and trial cities, 2017-2020 • 5G pilot window, Jan. • Provision of mid-band spectrum for trials in selected • 5G roadmap, July • 5 GHz auction completed on October 1st, 2020. Results of the positioning auction published on October 20th, 2020.
GERMANY	• The 700 MHz frequencies assigned in June 2015. • "5G for Germany", autumn 2016. • 5G spectrum roadmap, 2018. • Final conditions for 5G Auction, November 2018. • 4-3.7 GHz (300 MHz) and 2 GHz (2x60 MHz) 5G auction ended in June 2019 raising 6.55 billion EUR (of which 4.18 billion EUR for 36 GHz spectrum). Licences include coverage obligations. • 100 MHz reserved for local and regional purposes in 3.7-3.8 GHz spectrum. Applications opened on November 21st, 2019. • 26 GHz spectrum expected to be potentially awarded upon application. • Vodafone and Deutsche Telekom launched 5G in July 2019, Telefonica in October 2020. The new player 1&1 Drillisch has not launched 5G yet.

THE NETHERLANDS	• Connectivity Action Plan, July 2018. • In December 2018, the Netherlands Authority for Consumers and Markets (ACM) published a 5G paper "5G and the Netherlands Authority for Consumers and Markets". • Multi-band 700/1500/2100MHz completed in July 2020 and 1.23 billion EUR was raised • 3400-3450 and 3750-3800 MHz intended for local use scheduled respectively for 2022 and 2026 • 5G launch by VodafoneZiggo in April 2020, by T-Mobile and KPN in July 2020
SOUTH KOREA	The results of the auctions that took place in 2018 are as in the following: • 3.42 - 3.5 GHz LG Uplus • 3.5 - 3.6 GHz KT • 3.6 - 3.7 GHz SKT • 26.5 - 27.3 GHz KT • 27.3 - 28.1 GHz LG Uplus • 28.1 - 28.9 GHz SKT
CHINA	• China Telecom got 5G test spectrum resources with a total bandwidth of 100MHz from 3400MHz to 3500MHz frequency bands. • China Mobile obtained a total bandwidth of 260MHz including 2515MHz-2675 MHz frequency bands, 4800MHz-4900MHz frequency bands, among which 2515-2575 MHz, 2635-2675 MHz and 4800-4900 MHz are newly added bands, and 2575-2635 MHz band is mainly used to redevelop China Mobile's existing TD-LTE(4G) band. • China Unicom got 5G test frequency resources with a total bandwidth of 100MHz from 3500MHz to 3600MHz frequency bands. • China Broadcast Network got 700MHz, and may get 4.9GHz.

4.2. Spectrum Issues Encountered at Cross-Border Scenarios

The initial 5G network tests performed at the Greece-Turkey (GR-TR) cross-border corridor have given valuable insights to the field experts regarding some additional concerns about the configurations that should be jointly made by the mobile network operators (MNOs) on both sides of the corridor because of the change in the flexible spectrum usage policies with 5G NR systems (see [22]). In particular, the 5G NR specification proposes Time Division Duplexing (TDD) unlike previous mobile network generations, which resorts to Frequency Division Duplexing (FDD). Currently the majority of 5G commercial networks are deployed at the 3.5 GHz frequency band (3.300-4.200MHz) as a cost-effective balance between coverage, capacity and network investments [23], and thus the combination of the 3.5 GHz range and 5G NR is becoming the first major rollout of TDD cellular networks in many countries [24]. The 5G-MOBIX project is in a position to pioneer identification of potential performance problems with such networks at cross-border regions, which can be alleviated through a collaboration of the neighbouring MNOs. The need to agree on a common TDD frame structure to eliminate the excessive interference especially on the uplink (UL) channels is one of the main observations of the GR-TR corridor.

TDD, which is expected to be widely employed in mobile networks with the advent of 5G, is considered the prevailing technique to optimize spectrum usage and allow for flexibility in bandwidth allocation between the UL and downlink (DL). In FDD, already utilized in large-scale LTE mobile networks, different frequency channels are used for the UL and DL, separated by a guard band to avoid interference between the two. The channel size is the same for both, and in order to support the significantly higher download demands, advanced features such as 256QAM modulation and 4x4 MIMO are employed on the DL. In TDD systems instead, transmission and reception occur in the same frequency channel, with different time slots assigned to the user equipment on the UL and DL, respectively. By changing the duration of these, and selecting the appropriate transmission pattern, network performance can be tuned to balance the UL and DL capacities as necessary. However, to avoid interference and subsequent deterioration of performance, any adjacent TDD networks –either 5G or LTE– need to be synchronized, neighbouring base stations must transmit at the same fixed time periods and all devices should only transmit in dedicated time periods [25].

Different frame structures correspond to different trade-offs in terms of performance. For example, the more frequent the DL/UL and UL/DL switching, the lower is the RTT (Round Trip Time). A short latency improves the channel estimation quality (CQI) using TDD channel reciprocity properties and enables fast HARQ retransmissions. More frequent switching therefore has a positive impact on spectrum efficiency in high mobility conditions. The frame structure also affects coverage performance. The guard period (GP) between DL and UL must be large enough to compensate the propagation delay for large cells (and for coexistence with other cells in line of sight).

MNOs need to carefully assess the proper frame structure to optimize their service offerings according to market demands, while at the same time achieve the necessary synchronization with neighbours so that avoid interference. The use of TDD frames that inherently mandate time and phase alignment between radio base stations (BSs) add complexity in the process of preventing interferences and related loss of traffic, demanding a particular level of synchronization with neighbouring networks. At a national level, alignment between operators can be facilitated through legislation and national regulation that administer the spectrum allocation and can publish guidelines to facilitate the necessary synchronization. However, in cross-border network deployments, achieving network synchronization is a difficult task, since a common framework may not be possible.

GSMA and ECC/CEPT have investigated the importance of TDD synchronization in the 3.5 GHz range in [24], with the aim to inform policymakers and mobile operators on relevant aspects, as summarized in the following paragraphs.

GSMA for 3.5GHz TDD Synchronisation

GSMA has provided a set of recommendations, including proposals on the preferred frame structure, for initial 5G launches in 3.5 GHz. As directly relevant to this work, the following recommendations can be highlighted:

- **Recommendation 3 [Synchronization at National Level]:** All networks should use the same frame structure at a national level, with the following recommendations:
  - Where incumbent systems such as LTE exist in the 3.5 GHz range, the LTE and NR systems need to use compatible frame structures. As the best compromise, LTE networks are required to use the frame structure DSUDDDSUDD, while 5G NR networks are required to use either DDDDDDDSUU (with a 3ms shift) or DDDSUUDDDD.
  - Where no incumbent systems are present, the preferred frame structure is DDDSU, with 30 kHz SCS. The Special slot "S" format should be configured with a ratio of 10 Downlinks, a 2 Symbol Guard Period and 2 Uplinks (10:2:2)

- **Recommendation 4 [Synchronization at International Level]:** Networks should be synchronized at an international level; nevertheless, priority is given to achieve synchronization at the national level. International alignment is difficult, due to the number of countries involved, the different migration and implementation timescales and the difficulty of negotiating per operator and neighbouring country. It is anticipated that the preferred frame structures are:
  - DDDSU with 30 kHz SCS;
  - DDDDDDDSUU (with a 3ms shift) or DDDSUUDDDD, only if LTE is present at the band.

- **Recommendation 5 [Cross-border Coordination]:** To manage cross-border coordination, even though the use of a common frame structure is favoured, it is considered unlikely due to the domino effect that shall involve a large number of countries. Localized alternatives are proposed:
  - In the border areas where neighbouring countries have selected the same frame structure, all the synchronized base stations can be used on either side of the border with limited coordination efforts.
  - In the border areas where neighbouring countries have not selected the same frame structure operators will need to engage in additional coordination efforts. Discussions and agreements of operators on bilateral or multilateral and in respective industry forums are necessary and the involvement of policymakers and/or administrations can be a useful complement.

- **Recommendation 6 [Co-existence of non-synchronized networks]:** Where no agreements on the frame structure can be reached, the following practical solutions to coexistence of networks are proposed:
  - Localized frame structure (i.e. indoor usage);
  - Network optimization (such as base station location, antenna, direction, and power limits);

- Downlink blanking where operators, on both sides of the border, agree to stop the use of some of their downlink slots when the other operators are using an uplink slot - although, this will impact performance and may not be supported;
- A step-by-step migration based on the regional timings of 5G deployments and 4G migrations; 4G networks to be migrated to a different band or to 5G technology;
- Commercial agreement between 5G operators and incumbent 4G operators (including acquisitions, re-farming, and reprogramming);
- Reduce capacity near the borders, i.e. by only using a part of allocated spectrum;
- Use alternative bands within the cross-border area;
- Avoid co-channel use and aim to use adjacent channels – temporary band plan at the border;
- Use club licenses, spectrum and infrastructure sharing.

ECC on National and Cross Border Synchronization

According to ECC report 296 [26], about the coexistence of MFCNs (mobile/fixed communications networks) in n78 band, synchronized operation avoids any BS-to-BS and Mobile Station (MS)-to-MS interference, therefore allowing coexistence between adjacent networks without the need for guard bands or additional filters. However, the deployment of synchronized networks means that all MFCNs in the same band should use a common phase clock reference and a compatible frame structure to avoid simultaneous UL/DL transmission. The report also underlines that the separation distance between two unsynchronized macro base stations/networks is up to 60km for a co-channel configuration and up to 14km for adjacent channel operation. Moreover, the ECC Rec 15(01) [27] on cross-border coordination for MFCN in (3400-3800) MHz, explicitly denotes that among the frame structures defined for NR by 3GPP, NR frame DDDSUUDDDD and DDDDDDDSUU are compatible with the LTE frame structure configuration. This is clearly reflected in GSMA Recommendations #3, #4.

To ensure nationwide outdoor deployment for NR mid band, technology experts advocate that the best coexistence method is to synchronize all networks in the same band independently of used TDD technology (ex. 5G, LTE, WiMAX). Synchronized operations mode maximizes spectral efficiency, minimizes implementation cost and is feasible/implementable from a technology (i.e. Active Antenna Systems - AAS) perspective. Advanced radio functionality such as LTE-NR aggregation, AAS beamforming and scheduling enhancements can further improve both user plane and control plane connectivity characteristics and the performance of the radio link, and shall be greatly beneficial for the V2X services. Future coming technologies, such as cross-link interference cancellation, will certainly improve the flexibility of operating different NR TDD frames in a local fashion or in a more wide-area network deployment.

In the context of the 5G-MOBIX project, the NR TDD DDDSUUDDDD (4+2+4) SFS 3:8:3 that is used widely in 5G commercial network deployments, is proven suitable for V2X applications, ensuring wide-area coverage for mobility as well as, very good performance in terms of UL and DL throughput. This frame structure is in alignment with GSMA Recommendations #3, #4 on synchronizing networks. At the same time, NR TDD DDDSUDDSUU (4+1+3+2) SFS 10:2:2, also in alignment with GSMA recommendations #3, #4 is offering better UL performance, an important advantage for the 5G-enabled CAM use cases.

4.3. Spectrum Allocation Needs of 5G-MOBIX User Stories

This section introduces the basic ideas of a study to be undertaken in 5G-MOBIX Task T6.3 on the spectrum needs in relation to selected use cases of the project as implemented by the corresponding technologies. The study aims to estimate the amount of bandwidth required for the introduction of use cases for direct communications and network-based communications, as applicable. For specific cellular technologies, this would mean LTE-V2X and NR-V2X (C-V2X), and the consideration of PC5 and Uu interfaces.

The study will involve several stages, somewhat mirroring a similar effort undertaken by the 5GAA in the "Study for spectrum needs for safety related intelligent transportation systems – Day 1 and advanced use cases" June 2020 report.

- The starting point of the study is the 5G-MOBIX User Stories under the 5 Use Case categories.
- Subsequent analysis will be made on these to extract higher-level functional and operation specifications –are direct communications involved or network communications? And these are further detailed with additional questions. How many actors involved? Basic identified communication requirements? What is the nature of the messages exchanged?
- Finally looking at the specific operation scenarios (road geometries, geographic density and speed of the road users, detailed message exchange specifications, spectral efficiency assessment of radio technologies considered…) estimations for spectrum needs for communications for the User Story will be carried out.
- A number of conclusions will then be drawn cross-checking and consolidating the results of this estimations with the actual results and measurements collected at the 5G-MOBIX Test Sites.

This study is expected to be carried out for the duration of Task T6.3 and this report intends to include just some parts of it.

4.3.1. 5G-MOBIX Use Cases & User Stories

5G-MOBIX defines a set of 5G-enabled use cases pivoting around some autonomous driving manoeuvres, which have been classified in the following 5 areas: advanced driving, platooning, extended sensors, remote driving and vehicle QoS support. These 5G-MOBIX use case categories are based on a 3GPP Technical specification, in which descriptions are broad enough to accommodate different implementations for each use case category.

The message types considered will be either periodic / synchronous or event-triggered. Periodic messages define a relatively constant baseline for the spectrum needs. This is because road users transmit such messages regularly and at all times when active. The contribution of event triggered messages to the overall spectrum need is, on the other hand, more stochastic, in the sense that use cases which employ such messages may or may not occur at the same time at any given location, and this can result in a highly variable demand for spectrum.

- Messages
    - Periodic [Broadcast]
    - Event triggered [Broadcast, groupcast, unicast]
        - Repetitive
        - Non-repetitive
            - Time sensitive
            - Non-time sensitive

In this section, a first assessment of the requirements of the Use Cases / User Stories is carried out in the aspects of messaging (size, frequency, latencies) and bandwidth, taking into account a preliminary view on the operational descriptions of the UCs, and estimating the combination of simpler 3GPP 5G Rel. 16 based Use Cases that could serve as basis for the composition of the 5G-MOBIX UC.

As a general comment on how this preliminary composition was made to extract final requirements, message sizes were roughly added, usually the stricter latency was chosen, the higher frequency of messaging was chosen, and bandwidth data rates were added, as well.

4.3.1.1. UC Category 1: Advanced Driving

4.3.1.1.1. User Story #1: Complex manoeuvres in cross-border settings

- Scenarios: Lane merge for automated vehicles, automated overtaking, HD maps

For these scenarios, of a relatively smaller complexity than the combined actions for the other UC categories and USs, the 5GAA report already presents a briefing on their major requirements:

Table 11 – Requirements and Description for Lane Merge and HD maps

Story	5GAA equivalent	Requirements & Description
Lane merge for automated vehicles	Cooperative lane merging	V2V 20 ms e2e latency, 300 byte messages Broadcast, groupcast, unicast
HD maps	High-definition map collection and sharing	V2N Data rate of 4 Mbps UL, 16 Mbps DL Broadcast / Continuous + Event-triggered

In the specific case of overtaking, since this is the focus of US #2 and US #3, requirements will be considered to be similar, being considered to be a combination of Collective perception of environment, Multi-PLNM environment, Information sharing for high/full automated driving, Cooperative collision avoidance, and certain aspects of Cooperative lane changing and Emergency trajectory alignment, as specified in 3GPP TR22.886 V16.2.0.

This translates into the following preliminary requirements, considering a Release 16 based implementation:

Table 12 – Messaging and Bandwidth Requirements for Lane Merge and HD Maps

Requirement	Type	Description
Messaging	V2V Broadcast	Considering the freeway speeds and trajectory intersection nature of this case, strict specifications are chose for this UC. - 10 Hz, 10 ms e2e latency, 3600 byte messages [12KB for L5] Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms

4.3.1.1.2. User Story #2: Infrastructure assisted advanced driving

This User Story can be considered to combine the functionalities of Collective perception of environment, Multi-PLNM environment, Information sharing for high/full automated driving, Cooperative collision avoidance and certain aspects of Cooperative lane changing and Emergency trajectory alignment, as specified in 3GPP TR22.886 V16.2.0.

Table 13 – Messaging and Bandwidth Requirements for Infrastructure assisted advanced driving

Requirement	Type	Description
Messaging	V2V Broadcast	Considering the freeway speeds and trajectory intersection nature of this case, strict specifications are chose for this UC. - 10 Hz, 10 ms e2e latency, 3600 byte messages [12KB for L5] Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms

4.3.1.1.3. User Story #3: Cooperative Collision Avoidance

This User Story can be considered to be the only one that seems to have a 3GPP equivalent, namely the 'Cooperative Collision avoidance of connected automated vehicles'. Since this case is defined in 3GPP already considering trajectory information exchanges and coordinated driving manoeuvre support, it will be considered that it covers the requirements for 5G-MOBIX.

Table 14 – Messaging and Bandwidth Requirements for Cooperative Collision Avoidance

Requirement	Type	Description
Messaging	V2V Broadcast	- 10 ms e2e latency, 2 Kbyte messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 10 Mbps for Cooperative collision avoidance - E2e latencies < 10 ms

4.3.1.1.4. User Story #4: Cloud-assisted advanced driving

This User Story is focusing on assisting overtaking manoeuvres and as such, requirements should be similar to those of the User Story #1, combining the functionalities of Collective perception of environment, Multi-PLNM environment, Information sharing for high/full automated driving, Cooperative collision avoidance and certain aspects of Cooperative lane changing and Emergency trajectory alignment, as specified in 3GPP TR22.886 V16.2.0.

Table 15 – Messaging and Bandwidth Requirements for cloud-assisted advanced driving

Requirement	Type	Description
Messaging	V2V Broadcast	Considering the freeway speeds and trajectory intersection nature of this case, strict specifications are chose for this UC. - 10 Hz, 10 ms e2e latency, 3600 byte messages [12KB for L5] Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms
QoS	V2V, V2N	- Adjustment of Gaps depending of e2e latency measurements - 10 Hz

4.3.1.2. UC Category 2: Vehicles Platooning

4.3.1.2.1. User Story #1: Platooning with 'see what I see' functionality in CB settings

This User Story can be considered to combine the functionalities of eV2X support for vehicle platooning, Information Sharing for high/full automated platooning, Video data sharing for assisted and improved automated driving and Information sharing for high/full automated driving, as specified in 3GPP TR22.886 V16.2.0.

Table 16 – Messaging and Bandwidth Requirements for Platooning with "see-what-I-see" functionality

Requirement	Type	Description
Messaging	V2V	Set 1 : normal density > 2 m

	Broadcast	- 40 Hz, 25 ms e2e latency, 300-400 bytes messages Set 2: high density = 1 m - 100 Hz, 10 ms e2e latency, 50-1200 bytes messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception (V2V) - Data rate of 15 Mbps for cooperative manoeuvre (V2V) - Data rate of 50 Mbps for exchanges with RSU (V2I) - E2e latencies < 20 ms for cooperative perception, cooperative manoeuvre and RSU exchanges. - Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing

4.3.1.2.2. User Story #2: eRSU-assisted platooning

This User Story can be considered to combine the functionalities of eV2X support for vehicle platooning, Information Sharing for high/full automated platooning and Information sharing for high/full automated driving, as specified in 3GPP TR22.886 V16.2.0.

Table 17 – Messaging and Bandwidth Requirements for eRSU-assisted platooning

Requirement	Type	Description
Messaging	V2V Broadcast	Set 1 : normal density > 2 m - 40 Hz, 25 ms e2e latency, 300-400 bytes messages Set 2: high density = 1 m - 100 Hz, 10 ms e2e latency, 50-1200 bytes messages Periodic and Event-triggered
Bandwidth	V2V, V2N	- Data rate of 50 Mbps for cooperative perception (V2V) - Data rate of 15 Mbps for cooperative manoeuvre (V2V) - Data rate of 50 Mbps for exchanges with RSU (V2I) - E2e latencies < 20 ms for cooperative perception, cooperative manoeuvre and RSU exchanges.

4.3.1.2.3. User Story #3: Cloud-assisted platooning

This User Story can be considered to combine the functionalities of eV2X support for vehicle platooning, Information Sharing for high/full automated platooning and Information sharing for high/full automated driving, as specified in 3GPP TR22.886 V16.2.0. Even though similar in approach to the eRSU-assisted platooning, the introduction of the Cloud server to assist in platooning operations has implications in terms of latencies essentially, and additional requirements in terms of QoS monitoring and control.

Table 18 – Messaging and Bandwidth Requirements for cloud-assisted platooning

Requirement	Type	Description
Messaging	V2V Broadcast	Set 1 : normal density > 2 m - 40 Hz, 25 ms e2e latency, 300-400 bytes messages Set 2: high density = 1 m - 100 Hz, 10 ms e2e latency, 50-1200 bytes messages Periodic and Event-triggered
Bandwidth	V2V, V2N	- Data rate of 50 Mbps for cooperative perception (V2V) - Data rate of 15 Mbps for cooperative manoeuvre (V2V) - Data rate of 50 Mbps for exchanges with RSU (V2I) - E2e latencies < 20 ms for cooperative perception, cooperative manoeuvre and RSU exchanges.
QoS	V2V, V2N	- Adjustment of Gaps depending of e2e latency measurements - 10 Hz

4.3.1.3. UC Category 3: Extended sensors

4.3.1.3.1. User Story #1: Extended sensors for assisted border-crossing

This User Story can be considered to combine the functionalities of Collective perception of environment and Multi-PLNM environment, while the remote inspection and exchange functionality requirements could be in principle considered to be similar to those of a Video data sharing functionality, as specified in 3GPP TR22.886 V16.2.0.

Table 19 – Messaging and Bandwidth Requirements for Assisted Border-Crossing

Requirement	Type	Description
Messaging	V2V Broadcast	- 10 Hz, 10 ms e2e latency (avg. for ~400m range), 1600 byte messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms - Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing

4.3.1.3.2. User Story #2: EDM-enabled extended sensors with surround view generation

This user story adds to the cooperative perception the requirements for collision avoidance and overtaking, so can be considered the combination of the functionalities of Collective perception of environment, Multi-

PLNM environment, Information sharing for high/full automated driving, Cooperative collision avoidance, Video data sharing and certain aspects of Cooperative lane changing and Emergency trajectory alignment, as specified in 3GPP TR22.886 V16.2.0.

Table 20 – Messaging and Bandwidth Requirements for EDM-enabled extended sensors with surround view generation

Requirement	Type	Description
Messaging	V2V Broadcast	Considering the freeway speeds and trajectory intersection nature of this case, strict specifications are chose for this UC. - 10 Hz, 10 ms e2e latency, 3600 byte messages [12KB for L5] Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms - Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing

4.3.1.3.3. User Story #3: Extended sensors with redundant Edge processing

This user story focuses on the cross-border hand-over issues of Edge processing-based Cooperative awareness / extended sensors, so it seems reasonable to think that in terms of communications, the requirements will be similar to those of the User Story #1, as it does not involve in principle support to complex manoeuvres. This User Story can be considered to combine the functionalities of Collective perception of environment and Multi-PLNM environment, as specified in 3GPP TR22.886 V16.2.0.

Table 21 – Messaging and Bandwidth Requirements for extended sensors with redundant edge processing

Requirement	Type	Description
Messaging	V2V Broadcast	- 10 Hz, 10 ms e2e latency (avg. for ~400m range), 1600 byte messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms

4.3.1.3.4. User Story #4: Extended sensors with CPM messages

As other UCs, this US requires capabilities for complex manoeuvres with both connected and legacy vehicles. This is one of the most complex environments so far, and could be considered the combination of the functionalities of Collective perception of environment, Multi-PLNM environment, Information sharing for high/full automated driving, Cooperative collision avoidance and certain aspects of Cooperative lane changing and Emergency trajectory alignment, together with QoS aspects for assisting automated driving and extended sensors, as specified in 3GPP TR22.886 V16.2.0.

Table 22 – Messaging and Bandwidth Requirements for extended sensors with CPM messages

Requirement	Type	Description
Messaging	V2V Broadcast	Considering the freeway speeds and trajectory intersection nature of this case, strict specifications are chose for this UC. - 10 Hz, 10 ms e2e latency, 3600 byte messages [12KB for L5] Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - E2e latencies < 10 ms

4.3.1.4. UC Category 4: Remote driving

4.3.1.4.1. User Story #1: Automated shuttle remote driving across borders

This is a complex US, in which different driving modes are combined, driving environments are varied as well (urban + interurban), and actions are required from the vehicle, in both autonomous and remote modes. The functionalities that can compose this US could be eV2X support for remote driving, Collective perception of the environment, Multi-PLMN environment, Information sharing for high/full automated driving, Changing driving-mode, as defined in 3GPP TR22.886 V16.2.0. Other specific functionalities assessed by 5GPP that could support this US are the Infrastructure based tele-operated driving (autonomous vehicle disengagement + Tele-operated driving). Remote/tele-operation of vehicle relies on Video streaming, and this probably will be the limiting factor in the requirements.

Table 23 – Messaging and Bandwidth Requirements for automated shuttle remote driving across borders

Requirement	Type	Description
Messaging	V2V Unicast	- 10 Hz, 10 ms e2e latency, 3600 byte messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - Data rate of 50 Mbps for exchanges with RSU (as infrastructure based scenario) - E2e latencies < 10 ms

		- Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing

4.3.1.4.2. User Story #2: Remote driving in a redundant network environment

This is a more focused remote-driving US, which focuses on cross-border hand-over functionality of different PLMN and different vehicles. Similar to the previous one in its video-based remote-driving requirements, but with stricter hand-over and QoS requirements. The functionalities that can compose this US could be eV2X support for remote driving, Collective perception of the environment, Multi-PLMN environment, Information sharing for high/full automated driving, Video data sharing and QoS aspects for remote driving, as defined in 3GPP TR22.886 V16.2.0.

Table 24 – Messaging and Bandwidth Requirements for remote driving in a redundant network environment

Requirement	Type	Description
Messaging	V2V Unicast	- 10 Hz, 10 ms e2e latency, 3600 byte messages Periodic
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 50 Mbps for exchanges with RSU (as infrastructure based scenario) - E2e latencies < 10 ms - Data rate of 100-700 Mbps (6 cameras, 720p 30fps video), e2e latencies < 10 ms for Video Data Sharing, 99,99% reliability.

4.3.1.4.3. User Story #3: Remote driving using 5G positioning

This US is similar to the previous case, but it can be argued that the video-based requirements could be not as strict, as the purpose of the remote driving assistance is to support getting the vehicle to a preset location to address the issue. The additional feature to be taken into account is probably the disengagement of the autonomous driving functions. As such, this US can be considered to be the combination of the functionalities of eV2X support for remote driving, Collective perception of the environment, Multi-PLMN environment, Information sharing for high/full automated driving, Video data sharing and QoS aspects for remote driving, as defined in 3GPP TR22.886 V16.2.0.

Table 25 – Messaging and Bandwidth Requirements for remote driving using 5G positioning

Requirement	Type	Description
Messaging	V2V Unicast	- 10 Hz, 10 ms e2e latency, 3600 byte messages Periodic
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 50 Mbps for exchanges with RSU (as infrastructure based scenario)

		- E2e latencies < 10 ms - Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing.

4.3.1.4.4. User Story #4: Remote driving with data ownership focus

This is again a complex environment which requires hand-over of functionalities, involves different entities and assist to manoeuvres. The requirements seem to be similar to those of US# 1. The functionalities that can compose this US could be eV2X support for remote driving, Collective perception of the environment, Multi-PLMN environment, Information sharing for high/full automated driving, Changing driving-mode, as defined in 3GPP TR22.886 V16.2.0. Other specific functionalities assessed by 5GPP that could support this US are the Infrastructure based tele-operated driving (autonomous vehicle disengagement + Tele-operated driving). Remote/tele-operation of vehicle relies on Video streaming, and this probably will be the limiting factor in the requirements.

Table 26 – Messaging and Bandwidth Requirements for remote driving with data ownership focus

Requirement	Type	Description
Messaging	V2V Unicast	- 10 Hz, 10 ms e2e latency, 3600 byte messages Periodic and Event-triggered
Bandwidth	V2V, V2I	- Data rate of 50 Mbps for cooperative perception - Data rate of 10 Mbps for Cooperative collision avoidance - Data rate of 3 Mbps for Cooperative manoeuvre - Data rate of 50 Mbps for exchanges with RSU (as infrastructure based scenario) - E2e latencies < 10 ms - Data rate of 10 Mbps (720p 30fps video), e2e latencies < 50 ms for Video Data Sharing

4.3.1.4.5. User Story #5: Remote driving using mmWave communication

This is the only US that addresses a specific mmWave technology in the V2I link. Since the focus of the US seems to be the evaluation of the usage of this radio access technology, in principle this US will not be considered for the present study.

4.3.1.5. UC Category 5: Vehicle Quality of Service support

In general QoS aspects imply functionalities of monitoring performance parameters of the applications, to determine whether operation conforms with the desired targets, and trigger corrective actions if that is not the case. Requirements thus take form of applications / system being able to request information on connectivity characteristics, performance characteristics, or developing prediction components on performance evolution. In the case of the UC 5 User Stories, parts of the data streams themselves, or specific data streams could be used as a reference for these QoS checking components. In the case of the US #1 the video stream itself and an analysis component at receivers UE could be the way to go. In the others, probably dedicated network performance probe components would be necessary.

However, in terms of spectrum usage, it could be argued that the additional overhead implied by the addition of these QoS monitoring and control components would not impact the requirements of the application itself. A different issue could be whether additional communication and control channels are used for these QoS control, and therefore considerations for additional bands could be the issue.

4.3.2. Spectrum needs evaluation methodology

The basis of the spectrum needs is the differentiation of requirements for the various types of communications and messaging that have been identified in the Use Cases / Use Stories of 5G-MOBIX in the previous section. It has already been mentioned how main differences are due to the following factors:

- Communications mode/type: direct, V2N, V2I (Cloud).
- Messaging modes: periodic and event-triggered.
- Application data exchange modes: messages, streaming.

The methodology to be applied takes into account the required communication data rates, the number of transmitting road users within the effective communication range, and the effective spectral efficiency of the radio access technology considered.

For each of these occurrences, a simulation scenario will be described, as well as the assumptions considered for the estimation of spectrum use. If the scenario and estimation are time-dependant, a story and timeline will be described as well to account for the information flow and exchanges if necessary.

- Assumed topology of a freeway scenario will be a stretch with a total of 4 lanes, 2 in each direction. An estimation of number of vehicles/OBUs will be calculated, under the assumption also that there can be a variety of vehicle speeds in the freeway.

- Assumed number of RSUs is going to be one RSU every 5 Km of freeway.

The assessment of the spectrum needs is in principle going to be approach in an analytical manner, although some assumptions are expected for simplification of the estimation. For example, it will not be considered that a full PHY layer model will be used, so the effect of channel propagation and other physical aspects will not be included. Messages are also not considered with the full 3GPP defined overhead and potential security and redundancy protection frame structures, so related issues will also not be included in the estimation.

However, and for validation purposes, the study will conclude with a consolidation of the results in a comparison with the measurements at the different test sites of the implemented and deployed Use Cases, and if considered necessary, following the same example of the 5GAA report, a comparison with a Monte-Carlo type of simulation can also be considered.

5. CONSIDERATIONS FOR LARGE-SCALE DEPLOYMENT OF 5G-ENABLED CAM SERVICES

5.1. Risk of Exhaustion of Numbering Resources

BEREC recently released a study titled "BEREC guidelines on common criteria for the assessment of the ability to manage numbering resources by undertakings other than providers of electronic communications networks or services and of the risk of exhaustion of numbering resources if numbers are assigned to such undertakings". The study focuses on the issue of a possible exhaustion of numbering resources and the criteria that might allow numbering resources to be assigned to undertakings other than telecommunication providers (denoted as Electronic Communication Network/Electronic Communication Service (ECN/ECS) providers). It includes a survey performed among European NRAs and takes into account M2M/IoT services as a separate category. Based on the results of the survey, it looks like any geographic, mobile or M2M numbers are only assigned to ECN/ECS providers. The type of numbering resources (i.e. E.164, E212, E118, Signalling Point Codes and Operator Identifiers, seen in Table 27) depends heavily on the M2M/IoT use case.

Table 27 - Overview of related ITU international standards

Name	Description
E.164	Titled *The international public telecommunication numbering plan*, E.164 defines a numbering plan for the worldwide public switched telephone network (PSTN) and some other data networks.
E.212	The international mobile subscriber identity (IMSI) is a number that uniquely identifies every user of a cellular network. It also defines mobile country codes (MCC) as well as mobile network codes (MNC).
E.118	E.118 is an international standard that defines the international telecommunication charge card, for use in payphones. It also defines the Integrated Circuit Card Identifier (ICCID), which is used in SIM cards, including eSIM cards.
Signalling Point Codes	It is a unique address for a node (Signaling Point, or SP), used in MTP layer 3 to identify the destination of a message signal unit (MSU).
Operator Identifier	The proper use of ITU-T Recommendation M.1400 – 'Designations for interconnections among network operators' requires the identification of the operators sharing the interconnection, by a standardized and unique code.

The "BEREC Report on Enabling the Internet of Things, BoR (16) 39 (IoT-Report)" provided some conclusions with regard to the use of numbering resources for IoT. It provides a few conclusions on the use of numbering resources. According to this report, scarcity of E.164 numbering resources does not appear to be a barrier, but NRAs should analyse this and solve any occurring problems on national level, e.g. by introducing a new numbering range or increasing the mobile number resources. In the case of E.212 MNC resources, the current national regulation in many member states (MS) does not allow IoT users to be assignees of E.212 although this could be a step to ease change of connectivity providers, thus reducing the risk of competition problems. CEPT suggests[1] the relaxation of E.212 assignment criteria, although this might lead to a scarcity of resources as only a limited number of MNCs are available in many countries. It may also need to administrative burdens for NRAs. Over-the-air provisioning of SIM (e.g. eSIM) is an alternative approach; in this case security, privacy and transparency are necessary. Consequently, this issue should be analysed by the NRAs.

The report also states that permissibility of extra-territorial use of E.212 and E.164 is considered as a key solution to improve economic viability of M2M/IoT use cases. However, it must be ensured that public interests like security, national sovereignty etc. are respected. The use of extra-territorial numbers is covered by the European Electronic Communications Code, article 93(4), which states that in the case of non-interpersonal communications, each MS is responsible to ensure that NRAs/ CAs make available a range of non-geographic numbering resources for use outside the territory of the assigning MS (but within the EU). Non-geographic numbers are numbers not linked to a specific geographic area, (e.g. an area code). Undertakings benefitting from such rights of extraterritorial use of numbers still need to comply with the relevant consumer protection rules and other number-related rules applicable in any Member State where those numbers are used (Article 94.6). The NRA/CA assigning the numbers is responsible to ensure such compliance, impose conditions attached to rights of use, and shall act on the request of the NRA/CA of the country where the number is actually used. At the same time, this is without prejudice to the enforcement powers of the NRA/CA of the country of use. The proposed right of extraterritorial use will benefit M2M communications services in particular. In order to ensure an effective coordination at EU level, BEREC will establish a central registry of numbers with rights of extraterritorial use. Information exchange between NRAs is also enhanced.

The current version of E.118 allows the assignment of SIM numbering resources only to the ECN/ECS providers, more precisely to Operating Agencies[2] (OAs). Since the definition of embedded SIM (eSIM) by GSMA, E.118 has been opened by SG2 (as of July 2018) for review, mainly to take into account the assignment of these numbering resources to eSIM manufacturers (EUM) for generating the EID. Additional considerations around the advantages and disadvantages in the scenarios where the numbering resources are assigned to ECN/ECS providers or to non-ECN/ECS entities are contained in Section 5 of CEPT/ECC Report 274 "Regulatory Analysis of Over-The-Air Provisioning of SIM profiles including its impact on Number Portability[3] in case of the use of Over-The-Air, i.e. in case of use of eSIM. At the moment, the EU

[1] CEPT/ ECC Report 212 and CEPT/ECC Recommendation (17)02.

[2] Operating Agencies (OAs) is defined by ITU in the constitution of the International Telecommunication Union as "Any individual, company, corporation or governmental agency which operates a telecommunication installation intended for an international telecommunication service or capable of causing harmful interference with such a service" https://www.itu.int/council/pd/constitution.html (accessed Sept 2020)

[3] https://www.ecodocdb.dk/document/8209

has legislated that assignment of numbering resources to non-ECN/ECS entities is permitted under the European Electronic Communications Code, although non-ECN/ECS entities need to satisfy certain preconditions. Member States, however, retain the right to permit or allow this on a national level.

5.2. Strengthening the Role of National Regulators in Cybersecurity

According to the EU 5G Cybersecurity Toolbox, the role of National Regulators should be increased in order to ensure that some safeguards with respect to cybersecurity are in place. However, implementation of the 5G Cybersecurity Toolbox is moving at a different pace among the Member States. Specifically, the NIS Cooperation Group has worked on a 5G Cybersecurity toolbox containing a common set of measures to mitigate cybersecurity risks and achieve a level of resilience. The toolbox proposes a set of Strategic and Technical Measures to ensure the deployment of secure 5G networks.

Key measures include:

- Strengthening security requirements for Mobile Network Operators (MNOs) at Member State level.
- Assessing the risk profile of suppliers, and applying restrictions in terms of key assets such as exclusion of a high-risk supplier.
- Ensuring that MNOs adopt a multi-vendor strategy and avoiding dependency on a single supplier.
- Maintaining a diverse and sustainable 5G supply chain.
- Using relevant EU programs and funding.
- Facilitating standardization and certification.
- Making use of other existing frameworks, e.g. relating to the screening of Foreign Direct Investment (FDI) etc.

On July 2020 ENISA issued a report on "Member States' Progress in Implementing the EU Toolbox on 5G Cybersecurity". The report concludes that most Member States (MS) have been taking important steps to implement the Toolbox. Work is still on-going but most MS have been focusing on political decisions to increase the authority of National Regulators and illustrate the need for cooperation in standardisation:

- Most MS are in the process of allowing regulatory authorities powers to regulate procurement of equipment, based on security-related grounds.
- The creation of cybersecurity audits is also a potential new role for national regulators. However, there is still a need to address how cybersecurity audits will be conducted.

- A number of MS have not yet adopted measures to limit the ability of MNOs to outsource particular functions and activities.
- Many MS are facing challenges in defining the process to impose multi-vendor strategies for individual MNOs or at national level.
- Although the process of reviewing and reinforcing network security requirements for operators is well-advanced, progress is slower in when defining security requirements and technical measures since the development of many technologies is still on-going. The role of standardisation is instrumental in this respect and European participation in relevant SDOs is a necessity
- It is crucial that MS exchange information and best practices regarding 5G cybersecurity, and ensure the cooperation of the Commission and ENISA towards the monitoring of the implementation of the Toolbox as well as the implementation of EU-wide actions.

6. CONCLUSION

This document introduces the plan and preliminary report for the standardisation and spectrum allocation needs of the 5G-enabled CAM services of 5G-MOBIX that will be realized at the two cross-border corridors of Spain-Portugal and Greece-Turkey, benefiting from the activities that will be carried out at the other trial sites in France, Germany, Finland, the Netherlands, South Korea and China. The trials are expected to begin in mid-2021 and end in 2022, lasting for about a year, during which the test results will be evaluated in WP5 and the deployment enablers will be studied in WP6. As a part of WP6, Task 6.3 is to be an enabler for deploying CAM technology at cross-border regions by identifying the gaps in the standards and the spectrum regulations as well as taking the necessary actions so that the needs are met, which will support the timing of the European 5G Action Plan for having all major transport paths covered with 5G technology until 2025.

In D6.3, the methodology for Task 6.3 is introduced, which consists of the following five-stages:

1. Assessment of the ecosystem and 5G-MOBIX project/consortium
2. Gap analysis in standardisation and spectrum management
3. Development of recommendations based on 5G-MOBIX technical contributions
4. Exchange of Views and Validation with SDOs and regulatory bodies
5. Creation and sharing of Task 6.3 outcomes

Having completed the first stage, which targets assessment of the ecosystem, the standard developing organisations and industry associations relevant for connected and automated mobility are elaborated on, along with some of their distinct contributions to the ecosystem. Based on the results of the second stage, the focus of the 5G-MOBIX partners will shift towards those organisations, where tangible contributions for standardisation can be done. For Task 6.3, the second stage is recognised to be the most crucial aspect of the overall strategy: without the correct assessment and identification of the 5G-MOBIX partner capabilities and the needs of the user stories, solid recommendations cannot be made. The topics that are explored further in this task from the point of view of standardisation are satellite communications, roaming, IPv6, network slicing, ITS services and MEC.

On the spectrum management domain, the ITU-R is the international organisation leading the spectrum harmonisation of bands, but it is actually the national regulatory bodies that make the final decisions so as to which bands will be used in their territories. This underlies the "glocal" discussions of spectrum allocation for 5G-enabled CAM services, which requires starting this part of the Task 6.3 activities by reaching out to local authorities first, which will help homogenize the identification and assignment of sufficient spectrum for these services across the EU. However, before getting into contact with the authorities, the spectrum needs study for the 5G-MOBIX user stories as introduced in this deliverable should be completed to explain them how much bandwidth will be required at which of the 5G NR frequencies.

References

[1] 5G-MOBIX, "Deliverable 2.1: 5G-enabled CCAM Use Cases Specifications V2.0," 2019. [Online]. Available: https://www.5g-mobix.com/assets/files/5G-MOBIX-D2.1-5G-enabled-CCAM-use-cases-specifications-V2.0.pdf. [Accessed 2020].

[2] 3GPP TR 22.886, "Study on enhancement of 3GPP Support for 5G V2X Services," Release 16.

[3] 5G-MOBIX, "Deliverable 2.5: Initial evaluation KPIs and metrics V1.4," 2019. [Online]. Available: https://www.5g-mobix.com/assets/files/5G-MOBIX-D2.5-Initial-evaluation-KPIs-and-metrics-V1.4.pdf. [Accessed 2020].

[4] Communication of the Commission, *"A 5G Action plan for Europe"*, COM(2016) 588.

[5] 5. T. S-200127, "Working Group Standards and Spectrum, Study of spectrum needs for safety related intelligent transportation systems - day 1 and advanced use cases," 2020.

[6] 3GPPP TR 38.811, "Study on New Radio (NR) to support non-terrestrial networks (Release 15)".

[7] 3GPP TR 36.763, "Technical Specification Group Radio Access Network; Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN) (Release 17)".

[8] 3GPP TR 23.737, "Technical Specification Group Services and System Aspects; Study on architecture aspects for using satellite access in 5G (Release 17)".

[9] X. L. e. al, "On the Path to 6G: Low Orbit is the New High," [Online]. Available: https://arxiv.org/ftp/arxiv/papers/2104/2104.10533.pdf.

[10] 3GPP TR 22.822, "Technical Specification Group Services and System Aspects, Study on using Satellite Access in 5G, Stage 1 (Release 16).".

[11] 3GPP TR 23.793, "Technical Specification Group Services and System Aspects; Study on access traffic steering, switch and splitting support in the 5G system architecture, Release 16".

[12] "SSIG on Satellite integration in 5G," [Online]. Available: https://artes.esa.int/news/integration-non-terrestrial-solutions-5g-standardisation-roadmap. [Accessed October 2020].

[13] 3GPP TS 22.186, "Enhancement of 3GPP support for V2X scenarios (Release 16)".

[14] 3GPP TS 22.185, "Service requirements for V2X services (Release 16)".

[15] Blog Ericsson, "Keeping vehicles connected when they cross borders," May 2019. [Online]. Available: Blog Ericsson, 'Keeping vehicles connected when thttps://www.ericsson.com/en/blog/2019/5/connected-vehicle-cross-border-service-coverage. [Accessed May 2021].

[16] 5G-CroCo, "Deliverable 3.2: Intermediate E2E, MEC & Positioning Architecture," January 2021. [Online]. Available: https://5gcroco.eu/images/templates/rsvario/images/5GCroCo_D3_2.pdf. [Accessed 2021].

[17] ETSI GR IP6 030, "IPv6-based Vehicular Networking (V2X)," [Online]. Available: https://www.etsi.org/deliver/etsi_gr/IP6/001_099/030/01.01.01_60/gr_IP6030v010101p.pdf. [Accessed May 2021].

[18] M. Amadeo, C. Campolo, A. Molinaro, J. Harri and C. E. R. a. A. Vinel, "Enhancing the 3GPP V2X architecture with information-centric networking," *Future Internet*, vol. 11, no. 9, pp. 1-19, 2019.

[19] 3GPP TS 23.287, "Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services (Release 16)".

[20] 3GPP TS 23.501, "System architecture for the 5G System (5GS) (Release 15)".

[21] European 5G Observatory, "NATIONAL 5G PLANS AND STRATEGIES," [Online]. Available: https://5gobservatory.eu/public-initiatives/national-5g-plans-and-strategies/#1533566064328-14011b01-f20a. [Accessed May 2021].

[22] S. Col, N. Kostopoulos, F. Setaki, E. Nikolitsa, A. Berişa and K. Trichias, "TDD Synchronization Testing Over Neighbouring 5G Networks in a Cross-Border Corridor," in *IEEE 5G for CAM Summit, May 11-12*, (Virtual Online), 2021.

[23] GSMA, "Global 5G Landscape, Q4 2020," [Online]. Available: https://data.gsmaintelligence.com/research/research/research-2021/global-5g-landscape-q4-2020 .

[24] GSMA, "TDD Synchronization at the 3.5GHz range – a key step for 5G success," [Online]. Available: https://www.gsma.com/spectrum/resources/3-5-ghz-5g-tdd-synchronisation/.

[25] Ericsson Technology Review, "5G Synchronization Requirements and Solutions," [Online]. Available: https://www.ericsson.com/48e592/assets/local/reports-papers/ericsson-technology-review/docs/2021/5g-synchronization-requirements-and-solutions.pdf .

[26] ECC Rep 296, "National synchronisation regulatory framework options in 3400-3800 MHz," [Online]. Available: https://docdb.cept.org/download/19d5a467-c234/ECC%20Report%20296.docx.

[27] ECC Recommendation (15)01, "Cross-border coordination for mobile / fixed communications networks (MFCN) in the frequency bands: 694-790 MHz, 1452-1492 MHz, 3400-3600 MHz and 3600-3800 MHz," [Online]. Available: http://spectrum.welter.fr/international/cept/ecc-recommendations/ecc-recommendation-(15)01-700-MHz-1500-MHz-3400-MHz.pdf .

[28] SAE International standard J3016, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*, Revised 2018-06-15.

[29] BSI and the Transport Systems Catapult, "Connected and autonomous vehicles. A UK standards strategy. Summary report.," March 2017.

[30] Car 2 Car Communication Consortium, "C-ITS: Cooperative Intelligent Transport Systems and Services," [Online]. Available: https://www.car-2-car.org/about-c-its/.

[31] "ACEA - AUTOMATED DRIVING: Roadmap for the deployment of automated driving in the European Union," [Online]. Available: https://www.acea.be/uploads/publications/ACEA_Automated_Driving_Roadmap.pdf. [Accessed October 2020].

[32] "Connected and automated vehicles by BSI," [Online]. Available: https://www.bsigroup.com/en-GB/cav/. [Accessed October 2020].

[33] "Focus Group on AI for Autonomous and Assisted Driving (FG-AI4AD)," [Online]. Available: https://www.itu.int/en/ITU-T/focusgroups/ai4ad/Pages/default.aspx. [Accessed October 2020].

[34] "UNECE World Forum for Harmonization of Vehicle Regulations (WP.29)," [Online]. Available: https://www.unece.org/trans/main/wp29/meeting_docs_wp29.html. [Accessed October 2020].

[35] NGMN, "V2X White Paper V1.0," 2018.

[36] "The International Telecommunication Union," [Online]. Available: https://www.itu.int/en/about/Pages/default.aspx. [Accessed October 2020].

[37] "Introducing Spectrum Management: Spectrum Primer Series," GSMA , 2017.

[38] "Ministry Economics and climate (July 2020) Results multiband auction," [Online]. Available: https://www.rijksoverheid.nl/documenten/kamerstukken/2020/07/21/kamerbrief-uitkomsten-multibandveiling. [Accessed October 2020].

[39] "Gezondheidsraad (September, 2020) Advies 5G en gezondheid," [Online]. Available: https://www.gezondheidsraad.nl/binaries/gezondheidsraad/documenten/adviezen/2020/09/02/5g-en-gezondheid/Advies-5G-en-gezondheid.pdf. [Accessed October 2020].

[40] "Agendschap Telco (March, 2020) Toezichtarrangement Mobiele Communicatie," [Online]. Available: https://www.agentschaptelecom.nl/binaries/agentschap-telecom/documenten/publicaties/2020/3/06/toezichtarrangement-en-meetprotocollen-mobiele-communicatie/Toezichtarrangement+Mobiele+Communicatie+2019+final.pdf. [Accessed October 2020].

[41] "TRAFICOM published the 700 MHz auction," [Online]. Available: https://legacy.viestintavirasto.fi/viestintavirasto/ajankohtaista/2016/700megahertsintaajuuksienhuutokauppakaynnistyi.html . [Accessed October 2020].

[42] "TRAFICOM published the 3.5 GHz auction," [Online]. Available: https://legacy.viestintavirasto.fi/en/ficora/news/2018/finland8217spathtobecomingaleading5gcountryauctionofthe3.5ghzfrequencyrangeopens.html .

[43] "TRAFICOM published the 26 GHz auction," [Online]. Available: https://www.traficom.fi/en/communications/communications-networks/spectrum-auction-26-ghz-frequency-band.

[44] "Harmonisation of the 5.9 GHz spectrum band for real-time information exchange will improve road and urban rail transport safety," [Online]. Available: https://ec.europa.eu/digital-single-market/en/news/harmonisation-59-ghz-spectrum-band-real-time-information-exchange-will-improve-road-and-urban. [Accessed October 2020].

[45] ETSI GR IP6 030 V1.1.1 , "IPv6-based Vehicular Networking (V2X)," [Online]. Available: https://www.etsi.org/deliver/etsi_gr/IP6/001_099/030/01.01.01_60/gr_IP6030v010101p.pdf. [Accessed October 2020].

[46] "Overview of 3GPP Release 17," [Online]. Available: https://www.3gpp.org/images/articleimages/Releases/rel_17_overviewonly.jpg. [Accessed October 2020].

[47] ETSI White Paper No. 28, "MEC in 5G networks: First Edition - June 2018," [Online]. Available: https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp28_mec_in_5G_FINAL.pdf. [Accessed October 2020].

ANNEXES

Annex 1 – BSI Standardisation Study on Connected and Automated Mobility

The 5G-enabled CAM services comprise both connectivity and automation aspects, since cooperating connected vehicles at a certain automation level as defined in the SAE Standard J3016 [28] will be the main users of these applications and services in the near future. Therefore, when looking into the standardisation needs of these services, the dimensions for connectivity and automation are of equal importance, and ideally both should be taken into consideration.

A 2017-study performed by the British Standards Institution (BSI), together with the Transport Systems Catapult of UK, is a good reference in this respect, since it makes a very comprehensive analysis to pinpoint parts of the international landscape for standardisation that are most relevant to the field of connected and autonomous vehicles (CAVs). The research conducted by the BSI in [29] divides the functionality to be exhibited by automated vehicles into three segments of "localisation", "path planning" and "path following". It is stated that these main functions as well as the properties such as quality, safety and security could be the items that can be standardised for automated vehicles.

The finding of the institution is that *there are few published standards at the time of the research for autonomous vehicles*, but there appears to be a number of new initiatives and technical committees in this area, with a CEN/ISO committee working on standards for road adaptation for Advanced Driver Assistance Systems (ADAS) and autonomous vehicles being one such example.

Most of the published standards as of the year 2017 (for the actual numbers, please refer to the study) appear to fall under one of these categories according to [29]:

- Connectivity/connected vehicles – technology
- Awareness
- Connectivity/connected vehicles – applications
- Localisation

The connectivity-related standardisation is further broken down into the main SDOs in this domain and their activities in Table 28. The concept of Cooperative Intelligent Transport Systems (C-ITS), which appears in the table, refers to transport systems, where the cooperation between two or more ITS sub-systems (personal, vehicle, roadside and central) enables and provides an ITS service that offers better quality and an enhanced service level, compared to the same ITS service provided by only one of the ITS sub-systems [30].

Table 28 – Main SDOs active in CAV communications standardisation [29]

Standards Developing Organisation	Primary CAV communications standards activities
ISO-International Organisation for Standardisation	
• **Technical Committee 204 (TC/204) – Intelligent Transport Systems**	• Developer of the "CALM" (Continuous Access to Land Mobiles) suite of standards, including the jointly adopted C-ITS communications architecture • Extensive work on Co-operative ITS (V2X), higher-level applications and facilities in the C-ITS model (led by Working Group 16) • Working Group 14 has generated many vehicle/roadway warning and control system standards
• **Technical Committee 22 (TC/22) – Automotive Vehicles**	• Recently organized; promotion of the "extended vehicle" concept
CEN – European Committee for Normalization	
• **Technical Committee 278 – Intelligent Transport Systems**	• Sister TC to ISO/TC204 • Considerable collaborative work, particularly through with Working Group 16 (working jointly with Working Group 18)
• **Technical Committee 301 – Automotive Vehicles**	• Sister TC to ISO/TC204
ETSI – European Telecommunications Standards Institute	
• **Technical Committee ITS**	• Jointly adopted to C-ITS communications architecture • Developer of many of the V2X standards, particularly for the road safety applications using the 5.9 GHz spectrum dedicated to ITS
ITU – International Telecommunications Union	
• Task Force established in 2013, investigating standardization tasks force-connected vehicles	
SAE – Society of Automotive Engineers	
• Developer of many message set/data set standards for V2X communications (e.g. J2735, J2945)	
IEEE – Institute of Electrical and Electronics Engineers	
• Development of communications protocols • 802.11p • IEEE P1609	

The general acceptance is that automated vehicles require a degree of connectivity, which brings additional sensorial capabilities, and is an important enabler for many automated driving functionalities [31], but still there may be some cases with highly automated vehicles not relying on connectivity at all. A note in the report about the scope of work is in line with this argument, which states that connected vehicles and autonomous vehicles are distinct but overlapping topics. In fact, the complete scope of standardisation should cover the areas in the "Latest Standards Watch" infogram by BSI displayed on [32].

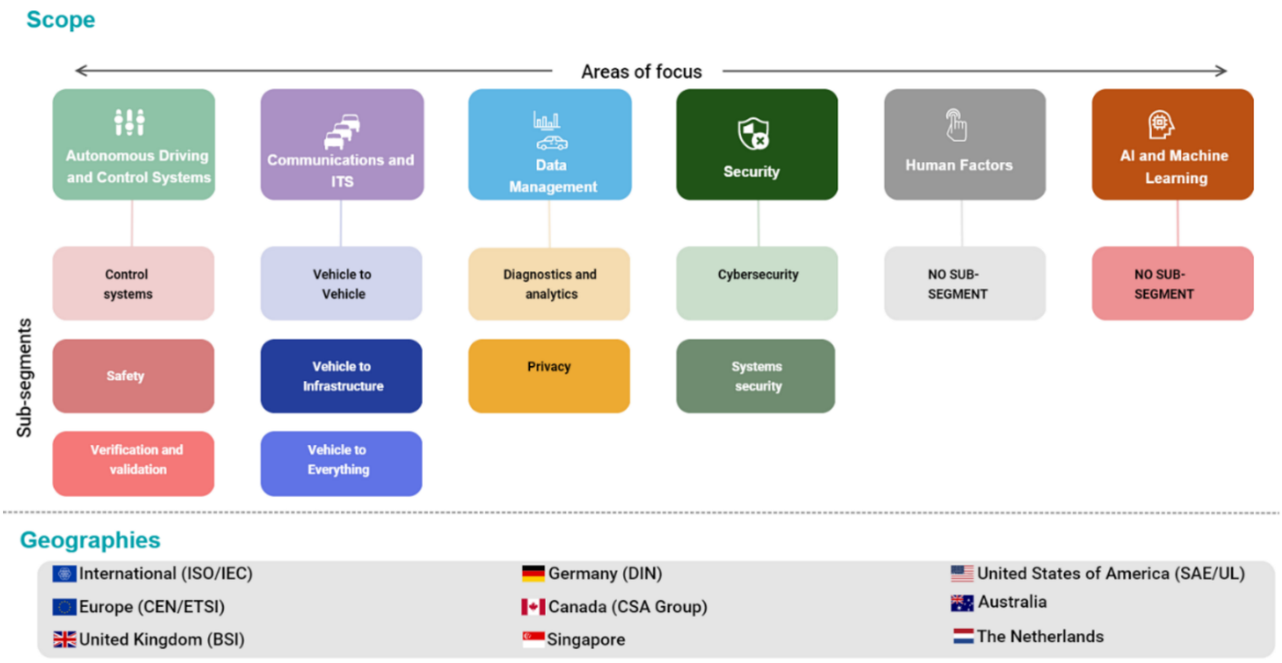


Figure 10 - The scope of standardisation relevant for CAVs by BSI [32]

Annex 2 – SDOs and Industry Associations relevant to 5G for CAM

The European Telecommunications Standards Institute (ETSI) is an independent, not-for-profit, ICT standardization organization in targeting the European and global market needs. ETSI was set up in 1988 by the European Conference of Postal and Telecommunications Administrations (CEPT) in response to proposals from the European Commission. It is the regional body officially responsible for the standardization of Information and Communication Technologies (ICT). It is based in Sophia-Antipolis, France and supports the development and testing of globally applicable technical standards for ICT-enabled systems, applications and services, including many key technologies utilised in 5G deployments (such as Network Function Virtualisation, Management and Orchestration, Slicing etc.).

3rd Generation Partnership Project (3GPP) is a worldwide collaboration of standardisation associations for mobile communication, e.g. GSM, UMTS, LTE and 5G. It was initially founded in 1998 uniting telecommunications standards developing organizations to provide their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. 3GPP currently consists of seven major organisational partners from Asia, Europe and North America to determine the policy and strategy of 3GPP, which are:

- The Association of Radio Industries and Businesses, Japan (ARIB)
- The Alliance for Telecommunications Industry Solutions, USA (ATIS)
- China Communications Standards Association (CCSA)
- The European Telecommunications Standards Institute (ETSI)
- Telecommunications Standards Development Society, India (TSDI)
- Telecommunications Technology Association, Korea (TTA)
- Telecommunication Technology Committee, Japan (TTC)

The 3GPP Organizational Partners may invite a Market Representation Partner to take part in 3GPP to offer market advice and to bring into 3GPP a consensus view of market requirements, e.g. 5G Automotive Association (5GAA), 5G Industry Association (5G-IA), etc. Current major players that drive the standardisation process include:

- Mobile manufacturers of network elements, devices, and chipsets which act as technology drivers, e.g. Huawei, Ericsson, Nokia, ZTE, Samsung, Qualcomm, Intel, Docomo, Xiaomi, etc.
- All major Mobile Network Operators (China Mobile, Vodafone, DT, AT&T…).
- Research Companies (e.g. Fraunhofer, ETRI, ITRI)
- Vertical-domain players in the automotive, public safety, healthcare, automation industries…

3GPP specifications and studies as carried out in Working Groups (WGs) that are formed within the relevant Technical Specification Groups (TSGs) are contribution-driven and led by member companies. Currently, there are three TSGs in 3GPP with each overlooking a specific network element or system aspect as shown in Figure 11.

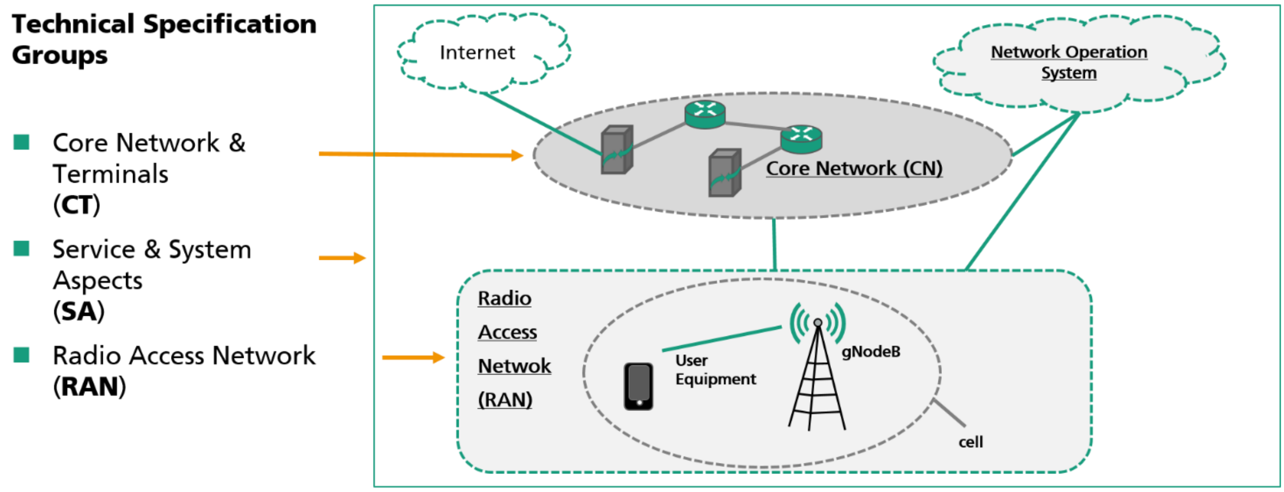


Figure 11 - The Technical Specification Groups (TSGs) within the 3GPP

Each one of the TSGs is divided into WGs which meet regularly and come together for their quarterly TSG Plenary meeting, where their work is presented for information, discussion and approval. Table 29 shows the WGs within each of the specified TSGs.

Table 29 - The list of WGs within the 3GPP

Project Co-ordination Group		
TSG RAN **Radio Access Network**	**TSG SA** **Service & System Aspects**	**TSG CT** **Core Network & Terminals**
RAN WG1 Radio Layer 1 specifications	**SA WG1** Services	**CT WG1** MM/CC/SM (lu)
RAN WG2 Radio Layer 2 & 3 specifications	**SA WG2** Architecture	**CT WG3** Interworking with external networks
RAN WG3 Interface specifications	**SA WG3** Security	**CT WG4** MAP/GTP/BCH/SS
RAN WG4 Radio Performance & Protocol aspects	**SA WG4** Codec	**CT WG6** Smart Card Application Aspects
RAN WG5 Mobile Terminal Conformance Testing	**SA WG5** Telecom Management	
RAN WG6 Legacy RAN radio and protocol	**SA WG6** Mission-critical applications	

The working method for 3GPP releases can be summarized as shown in Figure 12. *Technical documents (TDocs)* are first submitted based on demands and/or required applications. *Study items (SIs)* are then created based on the proposals, and next the results of study items are presented in what is called a *Technical Report (TR)*. Based on the results generated in the TRs, new *work items (WIs)* are proposed and discussed.

After a new work item is agreed upon with a clear description and objectives, work on the final product represented by the *Technical Specifications (TSs)* starts. The study items, the work items, the TR and the TS documents collectively make up a 3GPP release.

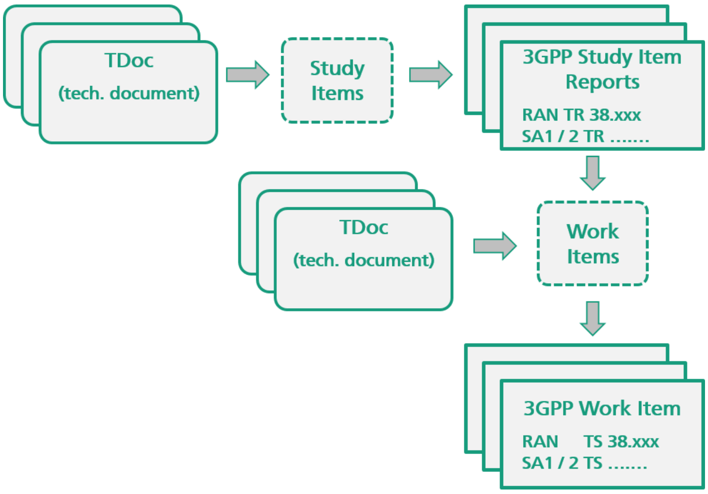


Figure 12 - The working methodology of 3GPP for generating releases

The following figure shows an overview of the timeline of the 5G standardisation process for 3GPP:

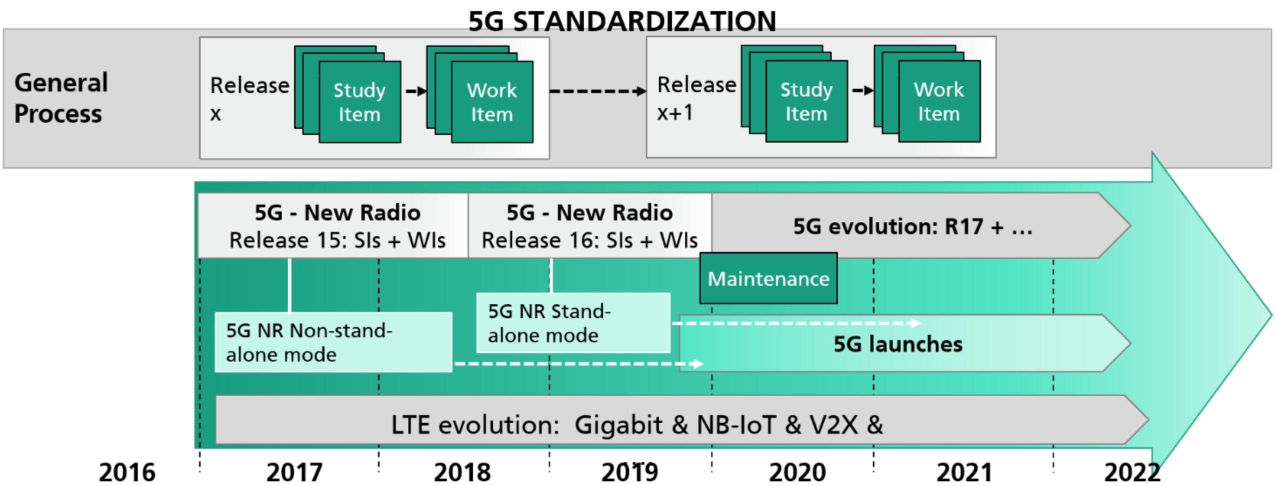


Figure 13 - Standardisation of 5G within the 3GPP

The planned timeline of 3GPP for C-V2X is shown in Figure 14. This figure uses C-V2X to refer to the sidelink communications aspect of vehicular connectivity over the PC5 interface, where there is a direct link between two vehicles or a vehicle and a RSU/pedestrian. On the other hand, 3GPP also defines using the Uu interface as in V2N communications to be C-V2X. Therefore, with the standardisation of the 5G NR-based Uu interface in 3GPP Release 15, using 5G in CCAM applications is possible.

For the scenarios based on the PC5 interface (direct communications), 3GPP Releases 14/15 were mainly developed with the intention of supporting safety critical use cases with focus on reliability and latency requirements. In further Releases 16/17, 3GPP evolves the existing standard towards the support of enhanced use cases such as advanced driving, platooning, etc. as well as passenger infotainment and vehicle traffic optimization.

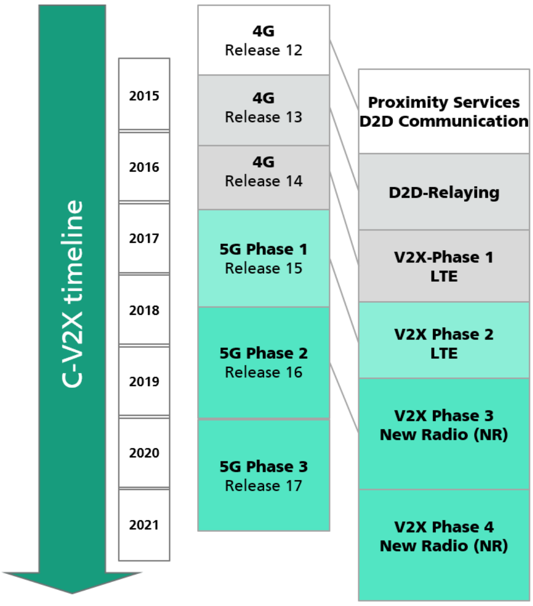


Figure 14 - The timeline for C-V2X communications in 3GPP releases

The International Telecommunication Union is the UN specialist agency responsible from information and communication technologies, where its sector on standardisation (i.e., ITU-T) develops international standards known as *ITU-T Recommendations* which act as defining elements for the ICT industry. ITU-T is directly involved in standardisation of 5G through its specifications on IMT-2020, but it also has several study groups and focus groups that capture the interest of the automotive industry, as well:

- Study Group 17: ITS and automotive cybersecurity (remote SW update)
- Study Group 12: Quality of Service of speech and audio in vehicles
- Study Group 2: Numbering for In Car Emergency Communication (ICEC)
- Study Group 20: ITS and Internet of Things and Smart Cities
- Study Group 16 : Vehicle gateway and in car multimedia platforms
- Focus Group on AI for autonomous and assisted driving (FG-AI4AD) [33]
- Focus Group on Vehicular Multimedia (FG-VM)

The United Nations Economic Commission for Europe (UNECE) was set up in 1947. UNECE's major aim is to promote pan-European economic integration. UNECE includes 56 member States in Europe, North America and Asia. However, all interested United Nations member

States may participate in the work of UNECE. Over 70 international professional organizations and other non-governmental organizations take part in UNECE activities.

In existence for more than 50 years, and with participants coming from all over the world, especially the main motor vehicle producing countries, the World Forum for Harmonization of Vehicle Regulations (WP 29) offers a unique framework for globally harmonized regulations on vehicles [34]. The benefits of such harmonized regulations are tangible in road safety, environmental protection and trade. WP.29 is a permanent working party in the institutional framework of the United Nations with a specific mandate and rules of procedure. At its February 2018 session, the Inland Transport Committee (ITC) acknowledged the importance of WP.29 activities related to automated, autonomous and connected vehicles and requested WP.29 to consider establishing a dedicated subsidiary Working Party (Groupe de Rapporteurs - GR). Following this request, WP.29, at its June 2018 session, decided to convert the Working Party on Brakes and Running Gear (GRRF) into a new Working Party on Automated/Autonomous and Connected Vehicles (GRVA). GRVA's priorities include:

- Safety and security of vehicle automation and connectivity:
  - Functional requirements ("FRAV")
  - Validation Method for Automated Driving ("VMAD")
  - Cyber security (and software updates)
  - EDR / Data Storage System for Automated Driving
- ADAS (Advanced driver-assistance systems):
  - Remote control manoeuvring
  - Automatically commanded steering systems
- Dynamics (Steering, Braking etc.):
  - Advance Emergency Braking Systems
  - Anti-lock Braking System for motorcycles
  - Electronic Stability Control

The International Organization for Standardization (ISO) is an international standard-setting body composed of representatives from various national standards organizations. There are more than 250 technical committees (TCs) within the ISO, which develop the ISO standards. *The ISO / TC-204 on intelligent transport systems is the most relevant technical committee of ISO for the activities in 5G-MOBIX.* Its focus is standardisation of information, communication and control systems in the field of urban and rural surface transportation, including intermodal and multimodal aspects thereof, traveller information, traffic management, public transport, commercial transport, emergency services and commercial services in the intelligent transport systems (ITS) field. ISO / TC 204 is responsible for the overall system aspects and infrastructure aspects of intelligent transport systems (ITS), as well as the coordination of the overall ISO work programme in this field including the schedule for standards development, taking into account the work of existing international standardization bodies.

The relevant Working Group in terms of CCAM is the WG18 on Cooperative ITS, working mainly on the definition of the components for Cooperative ITS, following the ISO 21217 ITS Station architecture. Specifying a basic collection of elements for exchanges of information and data flows between entities in the road environment, in recent times it has been focusing on aspects such as security and authentication between trusted devices –which would be critical for time-critical safety applications, automated driving and remote management of RSUs cooperative components, etc. Other ongoing working items include management of transport data management, which could be of relevance in that it involves application access to the sensor and control network of the vehicles and remote vehicle data access, amongst other use cases. Another interesting working item is the development of the PVT (Position, Velocity and Time) functionality/service in the C-ITS entity.

As can be seen, the ISO/TC204 WG18 addresses higher-level application issues, but these, together with the ETSI work on Cooperative-ITS applications and basic services, should serve as a reference point to which cellular-based services should be compared to, in terms of time-sensitive performance indicators.

European Committee for Standardization (CEN) supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defence and security, energy, the environment, food and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging. *In ITS-related technologies, CEN has coordinated development of standards with ISO to achieve harmonization of standards beyond European states*. CEN/ISO has adopted 71 standards designed to facilitate day-1 operability across Europe.

The relevant Technical Committee within CEN in terms of CCAM developments is the TC278 on Intelligent Transport Systems, and inside this TC, the WG16 on Cooperative ITS. As a consequence of the Vienna Agreement in 1991, strengthening the interactions between the ISO and CEN SDOs, and mainly with the objective of facilitating information exchanges between the organisations and avoiding duplicating of work, some WGs were in fact 'synchronised' and work mirroring each other. The ISO/TC204 WG18 – CEN/TC278 WG16 is one such case, and therefore, the work items above apply for the CEN WG as well.

European Committee for Electro-technical Standardization (CENELEC), on the other hand, is responsible for standardization in the electro-technical engineering field. CENELEC prepares voluntary standards, which help facilitate trade between countries, create new markets, cut compliance costs, and support the development of a single European market. CENELEC adopts international standards wherever possible, most notably through collaboration with the International Electro-technical Commission (IEC) under the Dresden Agreement.

Industry Associations: 5GAA creates specifications in the area of 5G-enabled CAM with a high impact whereas NGMN is an operator-led association that has a task force for C-V2X. GSMA, on the other hand, works towards broader challenges for MNOs. These associations do not have the functionality for developing standards, but their inputs in the form of specifications, views, analyses, field test results and trialling are taken into account by the SDOs.

The 5G Automotive Association (5GAA) is a global, cross-industry organisation of companies from the automotive, technology, and telecommunications industries. The 5GAA was created in September 2016 by few key players representing car makers, producers of telecommunications equipment and firmware manufacturer. Since then, the number of members has rapidly expanded to more than 130 in February 2020 including automotive manufacturers, tier-1 suppliers, chipset/communication system providers, mobile operators, infrastructure vendors and research institutes.

5GAA bridges the automotive and telecommunication industries to address connected mobility and road safety need with applications such as automated driving, ubiquitous access to services, integration into intelligent transportation and traffic management. Members are committed to helping define and develop the next generation of connected mobility and automated vehicle solutions. Its goal is to define and develop end-to-end solutions for future mobility and transportation services, so that incompatibility problems can be avoided.

5GAA is organized in working groups which are:

1. WG1: Use Cases and Technical Requirements
2. WG2: System Architecture and Solution Development
3. WG3: Evaluation, Testbeds and Pilots
4. WG4: Standards and Spectrum
5. WG5: Business Models and Go-To-Market Strategies
6. WG6: Regulatory and Public Affairs
7. WG7: Security and Privacy

The 5GAA Cross-WG Work Item "Network Re-selection Improvement" is related to the x-border topic. The major impact on C-V2X application while crossing the border is the high latency experienced to re-establish the connection in the new PLMN of the neighbouring country. Further detailed discussions are currently ongoing. First publication by the 5GAA regarding the Cross-WG Work Item "Network Re-selection Improvement" is to be made in 2020.

Another relevant 5GAA Cross-WG Work Item is "MEC4AUTO". This work item addresses topics related to edge computing in automotive use cases. Relevant topics to 5G-MOBIX use cases are: single and multi-MNO handover of edge services' data, service continuity, and challenges in cross-border scenarios. This includes optimizing selection of MEC server during mobility while meeting low-latency requirements of different use cases. Technical aspects in both network (core network) and application layers are taken into account in proposed solutions. This work item also plans to publish a white paper with description of the main activities carried out in this Cross-WG by the end of 2020.

The Next Generation Mobile Networks (NGMN) Alliance is an industry organization of leading world-wide Telecom Operators, Vendors and Research Institutes and was founded by international network operators in 2006. Its objective is to ensure that the functionality and performance of next generation mobile network infrastructure, service platforms and devices will meet the requirements of operators and, ultimately, will satisfy end user demand and expectations. The NGMN Alliance will drive and guide the development of all future mobile broadband technology enhancements with a focus on 5G. The targets of these activities are supported by the strong and well-established partnership of worldwide leading operators, vendors, universities, and successful co-operations with other industry organisations.

In February 2015 the NGMN Alliance published its 5G White Paper providing consolidated 5G operator requirements. In June 2016, NGMN created a V2X task force to study and evaluate V2X technologies and requirements and harmonise Mobile Network Operators (MNOs) views on LTE-based V2X and DSRC/IEEE-802.11p. The task force objectives were to reduce time to market of C-V2X technology, and trigger cooperation with the automotive industry. The results of the work were published in a White Paper in June 2018 [35], which presents a summary of the findings of the NGMN V2X task force.

The GSM Association (GSMA) is an industry association that represents the interests of mobile operators worldwide, uniting more than 750 operators with almost 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors.

It has these work groups, where the Networks Group has a special focus on supporting dependable performance of networks for interconnection and roaming that will be the most relevant for cross-border mobility of 5G-enabled CAM:

- Fraud and Security Group
- Interoperability Data Specifications and Settlement Group
- Internet Group
- Networks Group
- SIM Working Group
- Terminal Steering Group
- Wholesale Agreements and Solutions Group

Annex 3 – The 5G New Radio (NR) Bands

International Mobile Telecommunications (IMT) systems, which are investigated within the *ITU-R Study Group 5–Terrestrial Services*, are defined in *Recommendation ITU-R M.1224* to be the following:

> *International Mobile Telecommunications (IMT) systems are mobile systems that provide access to a wide range of telecommunication services including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet-based.*
>
> *IMT systems support low to high mobility applications and a wide range of data rates in accordance with user and service demands in multiple user environments. IMT also has capabilities for high quality multimedia applications within a wide range of services and platforms, providing a significant improvement in performance and quality of service.*

The term IMT has been used initially with 3G, where it was IMT-2000 and the first global IMT frequencies were identified at WRC-92. In the 2000s, WRC-2000 and WRC-07 identified additional frequency bands for IMT in the Radio Regulations. Coming to 2010s, WRC-15 harmonized and identified several additional frequency bands for IMT on the Radio Regulations. The total amount of spectrum identified for IMT transmissions until WRC-19 is depicted in Figure 15.

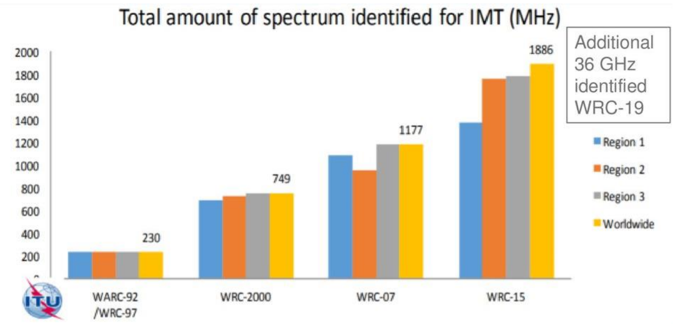


Figure 15 - The total amount of spectrum identified for IMT until WRC-19

At the end of the WRC-19, additional spectrum needed for a broad range of new ultra-high-speed and ultra-low latency consumer, business and government services were identified as shown in Figure 16.

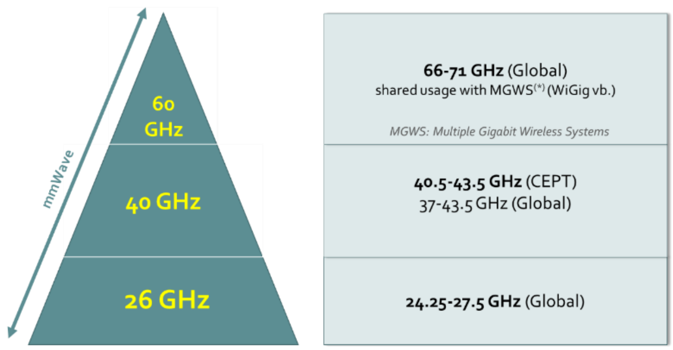


Figure 16 -The global bands identified for IMT during WRC-19

The bands that might be identified during the WRC-23 is included in Table 30.

Table 30 – The WRC-23 bands under consideration

Bands	Region 1	Region 2	Region 3
470-960 MHz	✓		
3300-3400 MHz	✓	✓	
3600-3800 MHz	✓	✓	
4800-4990 MHz	✓	✓	✓
6425-7025 MHz	✓		
7025-7125 MHz	✓	✓	✓
10.0-10.5 GHz		✓	

Analysis of IMT-2020 bands: The current situation with respect to the bands identified for IMT is that there are low, mid and high-bands that can be used for different purposes as depicted in Figure 17. The cross-border areas to be used during 5G-MOBIX for trialling of 5G-enabled CAM services fall under the category of rural and remote areas in general, requiring the deployment of "low band" spectrum. However, the services demand such high data rates that can be supplied by the "high bands", which have recently been identified in WRC-19, while the actual trials will be carried out using the "mid band" for most of the trial sites, the main reason being the availability of equipment from vendors and the permissions granted by the regulatory bodies. Thus, one of the major contributions of the ICT-18-2018 projects will be to provide feedback about the choice of the most appropriate bands and the spectrum needed for the 5G CAM applications to the deployed at the cross-border regions.

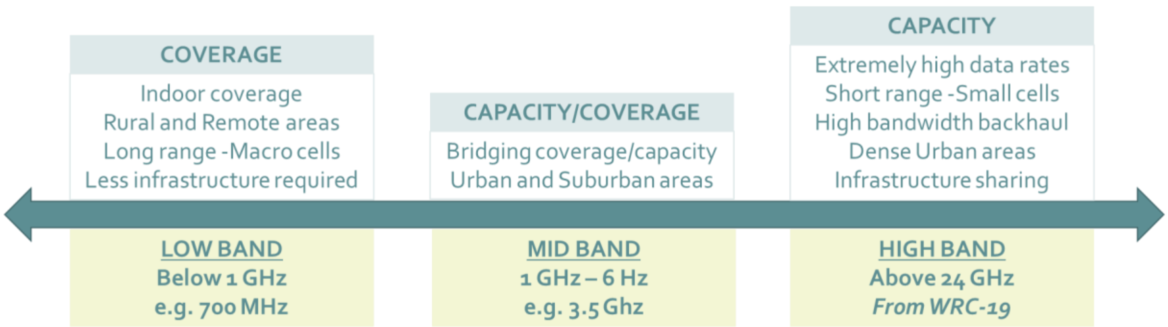


Figure 17 - The spectrum bands for IMT-2020

Annex 4 – International Spectrum Management Landscape

Radio spectrum is a scarce national resource, which carries information for a large number of essential services of the modern era ranging from radio and TV broadcasting, cellular and mobile communications, WiFi, GPS and radar to remote controls. Since the data rate of an application directly affects the spectrum requirements, with higher data rates becoming more demanding in terms of spectrum, a careful analysis of all these services is necessary before any spectrum allocation decision can be made. Another dimension of the spectrum management challenge is that, it is of an international nature because radio waves possibly travel across borders to cause interference with the services in another country.

The solution for effective management of spectrum resources is "harmonisation", which is based on the idea that by using identical and/or compatible frequency bands for the same services across different countries, it will be possible to (1) reduce international interference, (2) decrease mobile equipment costs through better economies of scale and (3) allow roaming of users. The single organisation leading the global spectrum harmonisation efforts and the management of the international spectrum and orbital resources happens to be the radiocommunications sector of the International Telecommunication Union (ITU), a specialized agency of United Nations (UN) responsible from information and communication technologies.

Founded in 1865 to facilitate international connectivity in communication networks, today ITU has three main areas of activity organized in sectors: One sector which allocates global radio spectrum and satellite orbits (Radiocommunications, ITU-R), another which develops the technical standards that ensure networks and technologies seamlessly interconnect (Standardisation, ITU-T), and a third sector that strives to improve access to ICTs to underserved communities worldwide (Development, ITU-D) [36]. In fact, the overall role of ITU is so pivotal for 5G that in 2012 it established a programme on International Mobile Telecommunications (IMT) for 2020 and beyond, which is known as IMT-2020 or 5G following the naming conventions for IMT-2000 (3G) and IMT-Advanced (4G). For IMT-2020, ITU-R coordinates the international standardisation and identification of spectrum for 5G mobile development while ITU-T plays a similar convening role for the technologies and architectures of non-radio elements of 5G systems. Most of the work within ITU is carried out in the technical Study Groups (SGs) and focus groups, which develop *Recommendations* (standards or guidelines), as well as through conferences and meetings that have participation from a large number of stakeholders, including non-members.

With respect to spectrum management, the framework to deliver international *Radio Regulations* as built on the organisational structure of ITU is shown in Figure 18 below. Every three-to-four years, telecom regulators across the globe come together at the World Radio Conference (WRC) to discuss and agree on changes to the Radio Regulations that detail which services are allocated to each band. The highest governance forum of the ITU, which is the Plenipotentiary Conference, is the medium to choose the ITU Officials and the members of the ITU Council, along with the Radio Regulations Board members, who are influential in setting the rules of procedure for performing resolutions during the WRC. The study groups, on the other hand, both develop ITU-R recommendations and provide input to the WRC agenda. The output of the WRC is the set of Radio Regulations as resolved until the next conference.

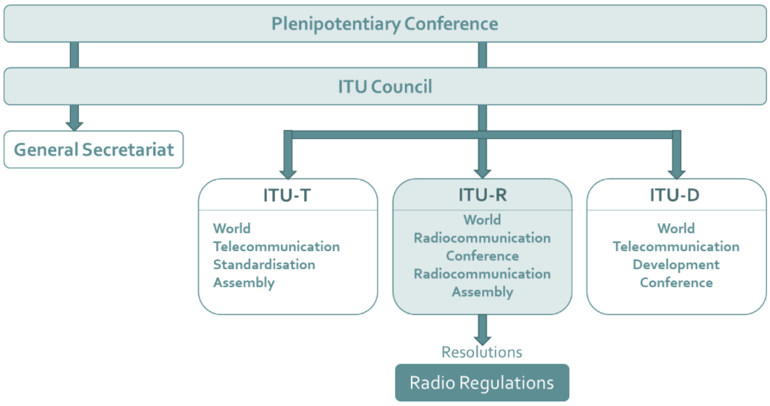


Figure 18 - The framework within the ITU for spectrum management

The world is divided into three regions by the ITU to make it more convenient when performing frequency allocations as part of the "Radio Regulations":

- **Region 1:** Europe, the Middle East, Africa, Russia and Mongolia
- **Region 2:** The Americas including Greenland and some of the Eastern Pacific Islands
- **Region 3:** Asia-Pacific including most of Oceania

Figure 19 - The three regions of ITU-R [37]

In addition to the ITU-R, there are a number of regional groups that serve to bring together national regulators and help them coordinate their activities, which will lead to the required changes taking place at the next WRC. These are shown in Figure 20 below.

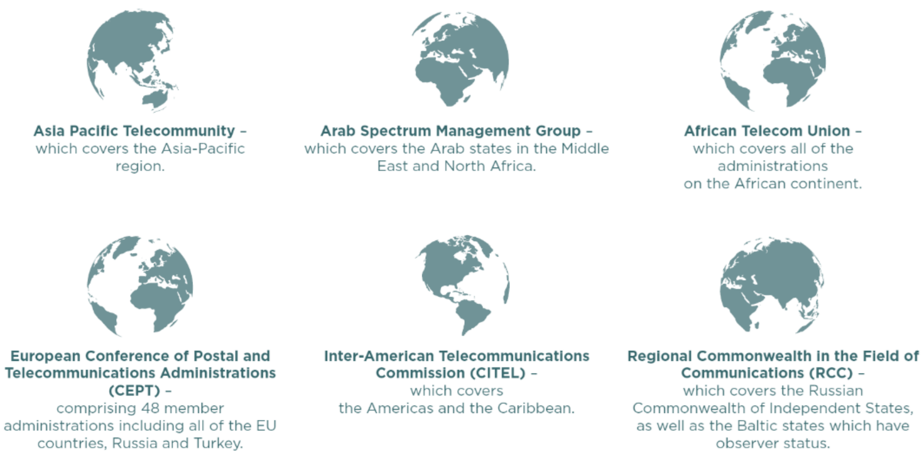
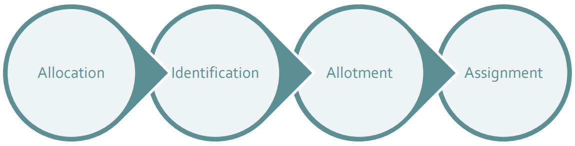


Figure 20 - The regional groups working on spectrum management issues from [37]

A dictionary for spectrum management is needed to differentiate between the cases, where a frequency band is available for a type of service, a limited range of technologies or a specific company as described in the GSMA report [37]:



Allocation: A band is allocated for potential use by a certain type of service (e.g. mobile, satellite or broadcasting) by a national regulator, which is contained in the National Frequency Allocation Table (NFAT), or on an international level through the ITU, as detailed in the 'Radio Regulations'.

Identification: A band may then also be 'identified' for a limited range of technologies (e.g. a band that is 'allocated' to the mobile service will often be 'identified' for International Mobile Telecommunications (IMT) which means it can be used by a specific set of compatible mobile technologies, including all 3G and 4G systems).

Allotment: A less-used term which refers to a decision made at a regional or national level to designate a frequency channel for use by a certain type of service in one or more countries under certain conditions.

Assignment: A specific frequency channel is then 'assigned' to a specific user by a national government or regulator (e.g. a band may be 'allocated' to the mobile service, 'identified' for IMT and then split into several sections which are each 'assigned' to different mobile operators).

Figure 21 - The dictionary for spectrum availability [37]