5GMOBIX

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

6.3

Plan and Preliminary Report on the Standardisation and Spectrum Allocation Needs

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Editors

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

Authors

Authors in alphabetical order		
Name	**Organisation**	**Email**
Batıkhan, Hakan	Turkcell	hakan.batikhan@turkcell.com.tr
Beeharee, Ashweeni	CATAPULT	Ashweeni.Beeharee@sa.catapult.org.uk
Boujelben, Maissa	VEDECOM	maissa.boujelben@vedecom.fr
Choi, You Jun	KATECH	ychoi@katech.re.kr
Dinis, Ricardo Jorge	NOS	ricardo.dinis@nos.pt
Esteban Rivas, Juan Franciso	Telefonica	juanfrancisco.estebanrivas@telefonica.com
Goulianos, Angelos	CATAPULT	Angelos.Goulianos@sa.catapult.org.uk
Güney, Nazlı	Turkcell	nazli.guney@turkcell.com.tr
Kakes, Geerd	KPN	GEERD.KAKES1@KPN.COM
Kurano, Jorge Alfonso	UPM	jak@gatv.ssr.upm.es
Mutafungwa, Edward	AALTO	edward.mutafungwa@aalto.fi
Pastor Figueroa, Giancarlo	AALTO	giancarlo.pastor@aalto.fi
Roshdi, Moustafa	Fraunhofer IIS	moustafa.roshdi@iis.fraunhofer.de
Roth-Mandutz, Elke	Fraunhofer IIS	elke.roth-mandutz@iis.fraunhofer.de
Schwartz, Ramon	TNO	ramon.desouzaschwartz@tno.nl
Segou, Olga	INTRASOFT	Olga.SEGOU@intrasoft-intl.com
Shi, Yanjun	DALIAN	syj@ieee.org
Trichias, Kostas	WINGS	ktrichias@wings-ict-solutions.eu
Turcanu, Ion	UL	ion.turcanu@uni.lu

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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
CCAM	Cooperative, Connected and Automated Mobility
CCSA	China Communications Standards Association
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
ICTA	The Information and Communication Technologies Authority (Turkish NRA)
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 produced by Task 6.3. The purpose of Task 6.3 is to evaluate the 5G-enabled cooperative, connected and automated mobility (CCAM) use case categories and user stories, which are introduced in the 5G-MOBIX deliverable D2.1 "5G-enabled CCAM use cases specifications V2.0" [1], from the point of view of standardisation and spectrum allocation requirements, in order to identify the gaps that exist in the standards and the spectrum allocation regulations, and to offer mechanisms to effectively deploy these CCAM services.

The 5G-MOBIX user stories are divided into five general use case categories of "Advanced Driving", "Vehicles Platooning", "Extended Sensors", "Remote Driving" and "Vehicle Quality of Service Support" that appear in the Release 16 version of the 3GPP document TR 22.886 "Study on enhancement of 3GPP Support for 5G V2X Services" [2]. Each user story demands a certain set of target key performance indicators (KPIs) in the form of user experienced data rate, end-to-end latency, reliability, position accuracy, mobility interruption time and application level handover success rate that are defined in the "Technical Evaluation Related KPIs" section of D2.5 "Initial evaluation KPIs and metrics V1.4" [3] as well as a specific setting, behaviour and/or functionality to reach those KPIs.

The impact of cross-border mobility on the user stories have already been captured by a number of cross-border issues that are classified into four groups: telecommunications, application, data privacy/security and regulation (see D2.1). Building on these initial set of issues, a further analysis of the user stories is to be executed within Task 6.3 by the experts who are knowledgeable in standards, with the intention to identify/formulate technical issues that find their way into study/working items. The main approach of the 5G-MOBIX partners in the standardisation domain is to monitor the activities of the respective groups of the standards developing organisations (SDOs) for the most up-to-date proposals on the identified technical issues,-if possible- offer novel methods to go beyond the state-of-the-art and finally 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 to formulate a 5G spectrum allocation method, tailor-made to the CCAM services discussed in the project.

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 assessment of the ecosystem relevant to the standardisation and spectrum allocation discussion of 5G-enabled CCAM services. The 5G-MOBIX partners that are active in SDOs are listed, and a preliminary overview of the user stories that are most likely to be affected by the upcoming standardisation work is included in D6.3. A more in depth self-assessment of 5G-

MOBIX focusing 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 the subsequent set of Task 6.3 results that will be reported in the second deliverable.

The rest of the document is organized 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 contributions.
- **"Section 3: Standards for CCAM"** introduces the existing scope of the standardisation activities with a specific focus on the SDOs that aim to deliver 5G for V2X communications.
- **"Section 4: Spectrum Allocation for 5G"** discusses the spectrum bands that are or will be made available for 5G NR-based communications, along with the current situation for regulations in the 5G-MOBIX countries, where testing and trialling will be performed.
- **"Section 5: 5G-MOBIX Use Case Categories"** performs a preliminary analysis of the user stories with respect to the standards and spectrum to be utilized in the trials.
- **"Section 6: Conclusion"** summarizes the plan and preliminary findings for addressing the standardisation and spectrum allocation needs of the CCAM 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 cooperative, connected and automated mobility (CCAM) services will be demonstrated by executing trials along cross-border (x-border) corridors 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 CCAM 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 CCAM services under consideration. For the trials, 5G-MOBIX **utilizes and upgrades existing key assets such as infrastructure and vehicles while developing new components as required (WP3)**, and ensures 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.

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 CCAM 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 CCAM 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 CCAM services with greatly varying properties and transmission characteristics in the presence of non-CCAM 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 CCAM services."

1.2. Purpose of the deliverable

The present document delivers the preliminary results of the work on the standardisation and spectrum allocation of 5G, 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 before the actual trials begin.

A refined analysis of standardisation and spectrum allocation aspects for the 5G-enabled CCAM use case categories and user stories of 5G-MOBIX depends 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 CCAM services. The final deliverable of Task 6.3 will encompass this type of analysis.

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 of the other deliverables in WP6:

- **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 CCAM 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 CCAM".** The deliverable provides an overview of the CCAM 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 CCAM".** 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 CCAM 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.

2. OBJECTIVES, PLAN AND METHODOLOGY

The overarching objective of this task is to use the outputs of the project to help set or improve the standards and spectrum regulations for an effective deployment of 5G-enabled CCAM services at 5G 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 CCAM 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 allocation discussions in a "glocal" fashion, where each partner will contact the regulatory entities in their own countries, without losing the larger focus that will connect the European continent completely.

The mechanisms to establish these objectives are inherently linked with the outputs of the project, which are expected to give rise to valuable insights and know-how about the best way to operate the 5G-enabled CCAM services under consideration in order to reach the target KPIs. Thus, this task is heavily dependent on some of the other tasks in 5G-MOBIX.

To comply with the staged methodology anticipated from the tasks of WP6, the work plan to be pursued for Task 6.3 relies on the five stages depicted in Figure 1, which is slightly different than the approach taken in the other tasks due to the fact that there is an endeavour to provide concrete input to external stakeholders, which is closely related with and builds on the results obtained from the field, rather than getting feedback and views from the outside to initiate and/or perform the work.

Figure 1. Task 6.3 methodology

The process in Figure 1 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 in the second stage of self-

assessment to invite the 5G-MOBIX partners with the relevant experience in these domains to contribute to Task 6.3. The use case categories and user stories are also to be self-assessed in terms of the standard functionalities, behaviours and components that are missing as well as their actual spectrum needs as observed during the trials. In the third stage, findings about both standardisation and spectrum management will be developed into recommendations that can be taken to the decision maker organisations of the ecosystem. Likely to be an iterative process, views will be exchanged with the SDOs and the regulatory bodies to have the results of Task 6.3 validated in the fourth stage. Until the end of the project and as a part of the fifth stage, which goes in parallel with stages 2-4, the results will be shared with all interested stakeholders in the form of deliverables (D6.3 and D6.7), reports, recommendations etc.

Next, each stage of the methodology is explained in more detail to demonstrate the actual nature of the responsibilities that will be or has been assigned to the 5G-MOBIX partners, and what type of roles will be requested from them to make this task a success.

2.1. Assessment of the Ecosystem

Before proceeding to the self-assessment stage, it must be clear what type and level of knowledge, technical expertise and/or interaction and involvement with external organisations is going to be required from the 5G-MOBIX partners by characterizing the ecosystems around standardisation and spectrum regulations, which are handled in two separate sub-sections below.

2.1.1. Standardisation Ecosystem

METHOD: The 5G-enabled CCAM services comprise both connectivity and automation aspects, since cooperating connected vehicles at a certain automation level as defined in the SAE Standard J3016 [5] 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 should both 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 [6] 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 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 [6]:

- 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 1.

Table 1. Main SDOs active in CAV communications standardisation [6].

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 [7], 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 [8].

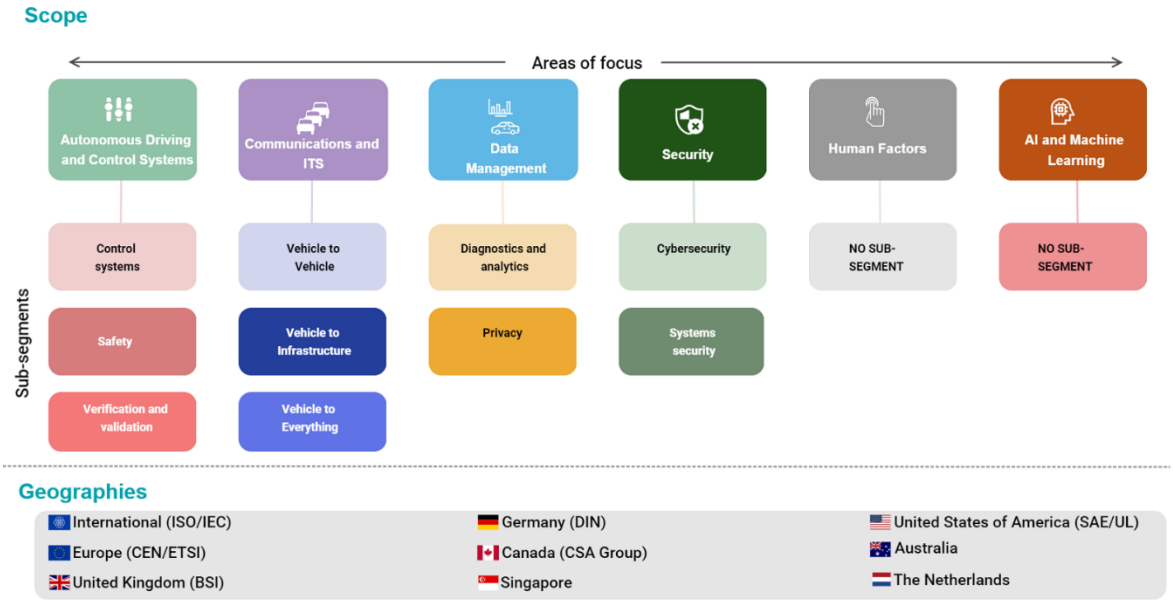


Figure 2. The scope of standardisation relevant for CAVs by BSI [8].

STATUS: The standards for CAVs can cover a broad range of categories such as control systems, communication, data management, security, human factors and artificial intelligence / machine learning as depicted in Figure 2. However, in 5G-MOBIX, the focus will be on the network-based connectivity aspects of CAVs as will be required in 5G-enabled CCAM services. Thus, Section 3 is devoted to a closer look at the relevant organisations such as the 3GPP and ETSI, which are developing standards for vehicular communications as well as associations like 5GAA and NGMN that support SDOs with their industry-driven requirements and field work.

2.1.2. The Regulatory Ecosystem for Spectrum Management

METHOD: Radio spectrum is deemed 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 due to the possible travelling of radio waves 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)** [9]. 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 3 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.

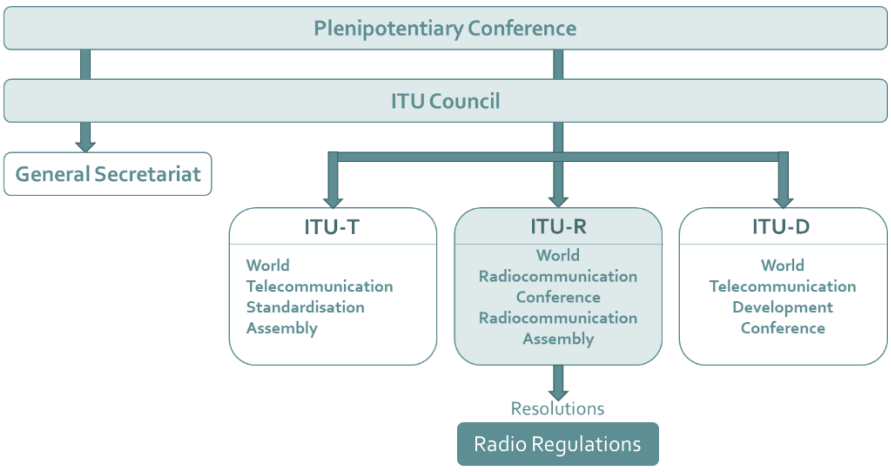


Figure 3. The framework within the ITU for spectrum management

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 4. The three regions of ITU-R [10]

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 5 below.

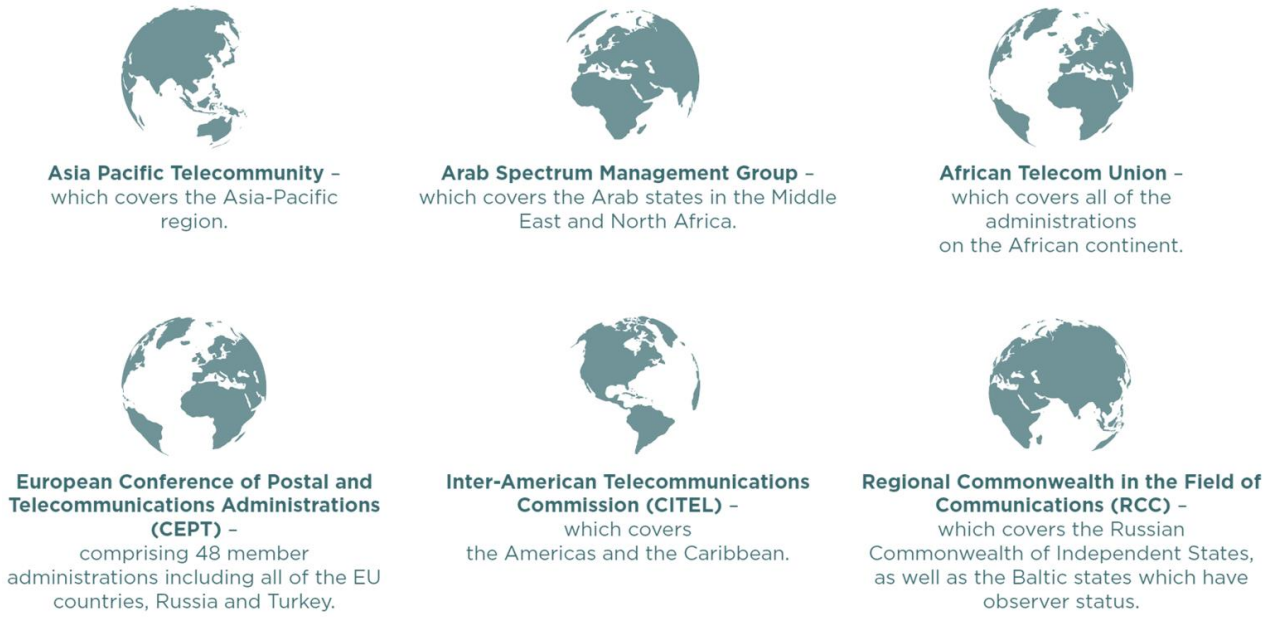
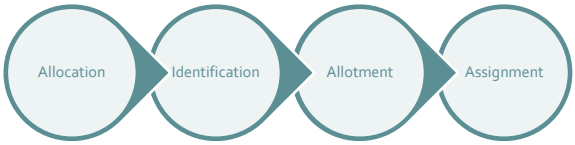


Figure 5. The regional groups working on spectrum management issues from [10].

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 [10]:



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'.

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.

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).

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 6. The dictionary for spectrum availability [10]

Despite the efforts of the huge international landscape that works on spectrum management to create the Radio Regulations of the ITU-R that are also partly influenced by the regional bodies such as the CEPT in case of Europe, 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 CCAM services to get the final decision makers on-board first and be ready for the next WRC of the ITU-R. With respect to Figure 6, the end goal of 5G-MOBIX will be the "identification" of the most appropriate bands for 5G-enabled CCAM services.

STATUS: In order to assess the current situation for 5G spectrum regulations, we take a closer look at the 5G New Radio bands, what is expected from the next WRC and what the current spectrum regulations in the 5G-MOBIX trial locations are in Section 4.

2.2. Self-assessment of 5G-MOBIX Partners, Trials and User Stories

METHOD: In the second phase of Task 6.3, the existing level of interaction between the 5G-MOBIX partners and the relevant organisations will be assessed. Especially, with regards to standards development, a sustained attendance to meetings and getting the support of the other members of a working group for approval of the recommendations is a well-known fact. Likewise, extensive information sharing and lobbying will be required for the spectrum regulation discussions to achieve coherent results in the EU. Thus, the partners that have the organisational structure, resources, expertise, capabilities and relationships to effectively carry out these duties should be identified.

A parallel activity along the lines of the standardisation potential and spectrum needs of the 5G-MOBIX trials and user stories will also be part of the second phase. The user stories as categorized and grouped using the 3GPP document TR 22.886 [2] will be analysed to determine the optimum allocation of spectrum and frequency resources as well as the initial set of those technical issues for cross-border 5G-CCAM services, for which possible proposed solutions will address some of the gaps in standardisation. The implementation details of the trials and the cooperation opportunities between the cross-border corridor sites and the other trial locations will serve to substantiate the analysis on the user stories, which will be a starting point for the third phase.

STATUS: The current level of progress in this stage is that an Excel sheet was shared with the 5G-MOBIX partners to collect preliminary information about their involvement within standardisation activities. At the next step, the individual user story owners was approached to better understand the potential contribution of their user stories to the standardisation and spectrum regulation landscape of the 5G-enabled CCAM services. The initial set of responses to these requests are included in Section 5.

2.3. Development of Recommendations Based on 5G-MOBIX Outcomes

METHOD: It is anticipated that some of the technical issues will be foreseen before the actual development, integration and trialling activities actually begin, since the design and implementation phase of the infrastructure and applications will have to take these problems into consideration. However, the real issues coming from the field during the trials are to make the biggest impact in the standardisation domain due to the uniqueness of the chosen scenarios and tests performed.

On the spectrum regulations side, the trials will allow access to the real traffic patterns and resource requirements of the CCAM 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 chosen from, and hence the regulation activities should be coordinated across neighbour countries to ensure service experience continuity.

STATUS: This work has not started yet.

2.4. Exchange of Views and Validation with SDOs and Regulatory Bodies

METHOD: Depending on the outcome of the analysis in stage 2 for self-assessment of 5G-MOBIX partners, trials and user stories and stage 3, which develops recommendations in line with the project outcomes, the SDOs to which the recommendations should be taken will be determined. The work/study items that are most relevant to the topic will be determined, and the discussions will begin at the working group meetings, particularly targeting the 5G communication related SDOs such as the 3GPP and ETSI.

The spectrum regulations in their own countries will be monitored by the individual 5G-MOBIX partners, but a consensus will be formed between the individual countries to obtain a coherent pan-European spectrum regulation with respect to CCAM services.

STATUS: This work has not started yet.

2.5. Creation and Sharing of Task 6.3 Outcomes

METHOD: Apart from D6.3, which is an intermediate report, Task 6.3 will have one final deliverable to encompass all achieved outcomes within the scope of the work on standardisation and spectrum allocation. The set of outcomes is not limited to specifications and regulation discussions, where the whitepapers/reports published and the presentations made to the public and/or the other stakeholders to share information about the gaps that have been identified will be important achievements of the project.

STATUS: This work has not started yet.

2.6. Timeline

Below in Figure 7, the timeline for the main stages of Task 6.3 are demonstrated. At the time of preparation of D6.3, the second stage of self-assessment is active, where the user stories are being analysed. The third stage is planned to be in line with the trials, as input from the field is considered to be an essential component of preparing recommendations. Last part will be devoted to tangible outcomes.

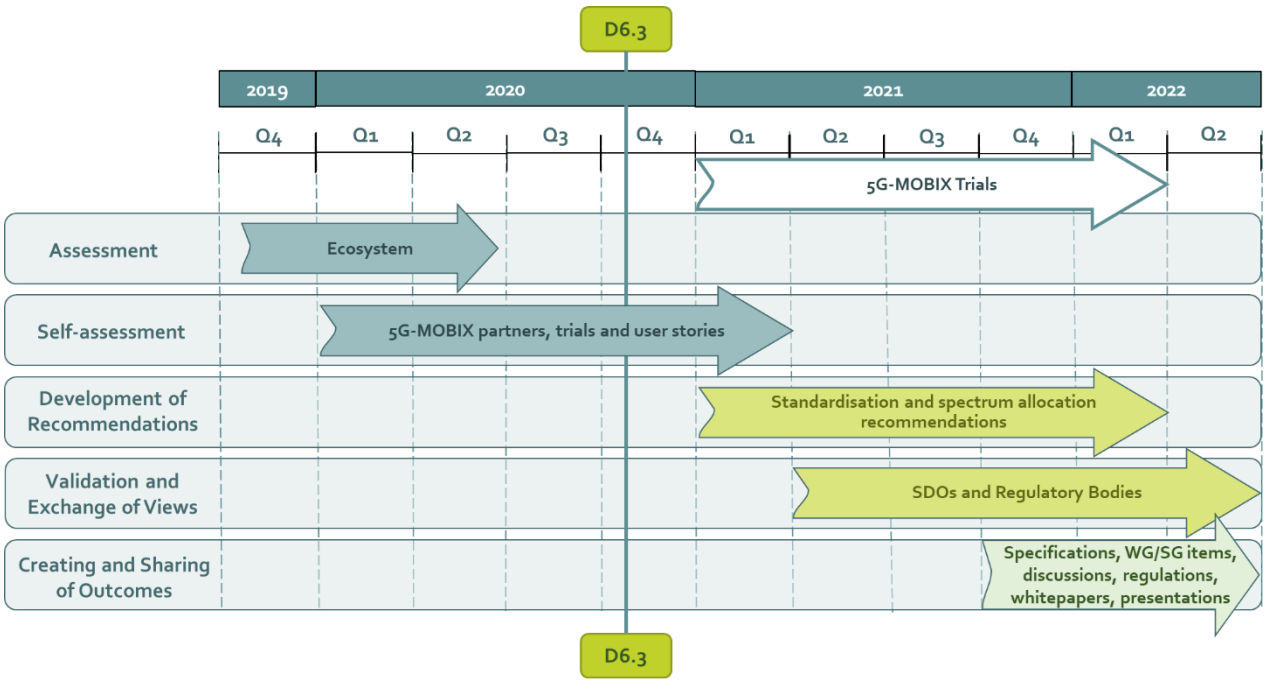


Figure 7. The timeline for Task 6.3 activities

3. RELEVANT SDOS AND INDUSTRY ASSOCIATIONS

This section makes an introduction to the standards developing organisations (SDOs) and the industry associations that can be associated with 5G-enabled CCAM. While the list includes organisations such as 3GPP and ETSI, which are known to have a high impact in the telecommunications domain and participation from the 5G-MOBIX partners (see Section 5), other important SDOs and organisations are also included for the sake of completeness of the discussion and to promote these among the partners for possible contributions in the future.

3.1. Standards Developing Organisations (SDOs)

5G-MOBIX aims to contribute to the standardisation of the communications aspect of 5G-enabled CCAM by analysing the standards that are required in the user stories as well as the results of the trials and the cross-border deployments. A closer look is devoted to 3GPP in the next subsection, since it is the standardisation body that develops 5G and is referred to in the call text for ICT-18-2018.

3.1.1. 3GPP

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 8.

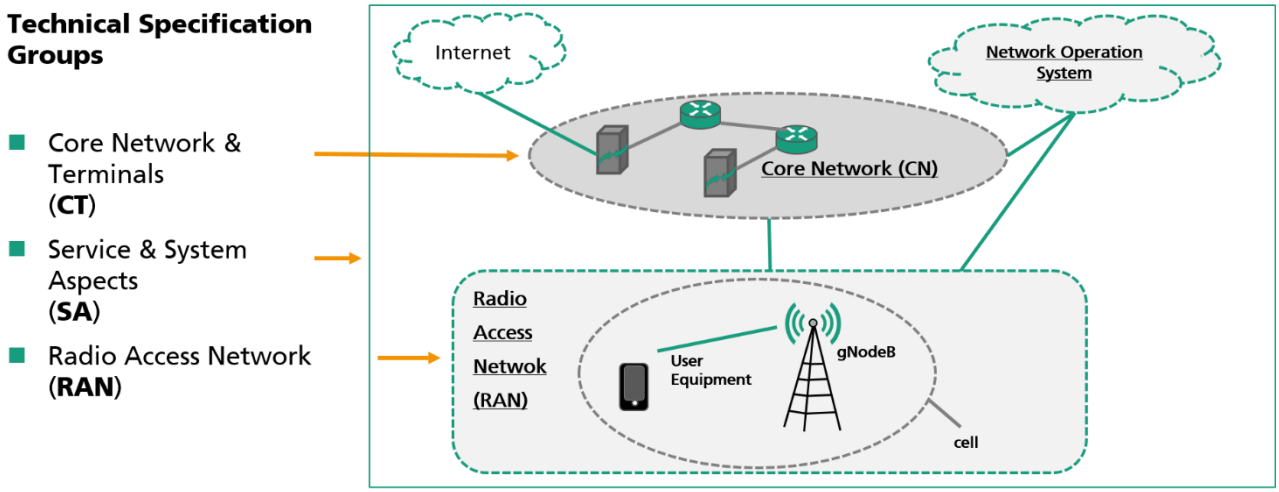


Figure 8. The Technical Specification Groups (TSGs) within the 3GPP

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 2 shows the WGs within each of the specified TSGs.

Table 2. 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 (Iu)
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 9. *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.

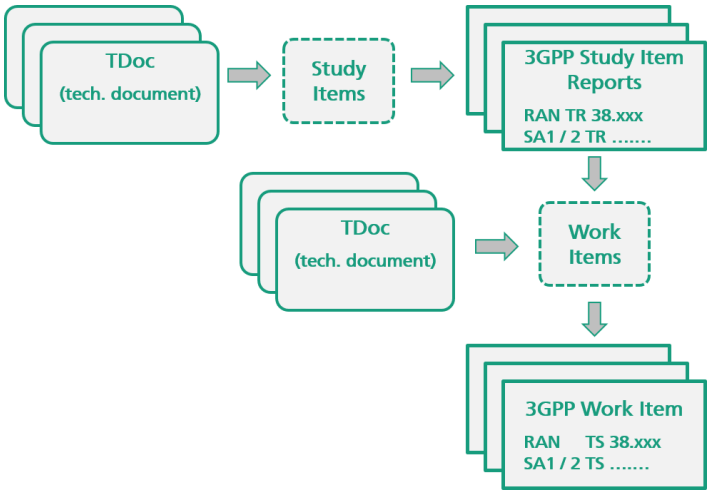


Figure 9. The working methodology of 3GPP for generating releases

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

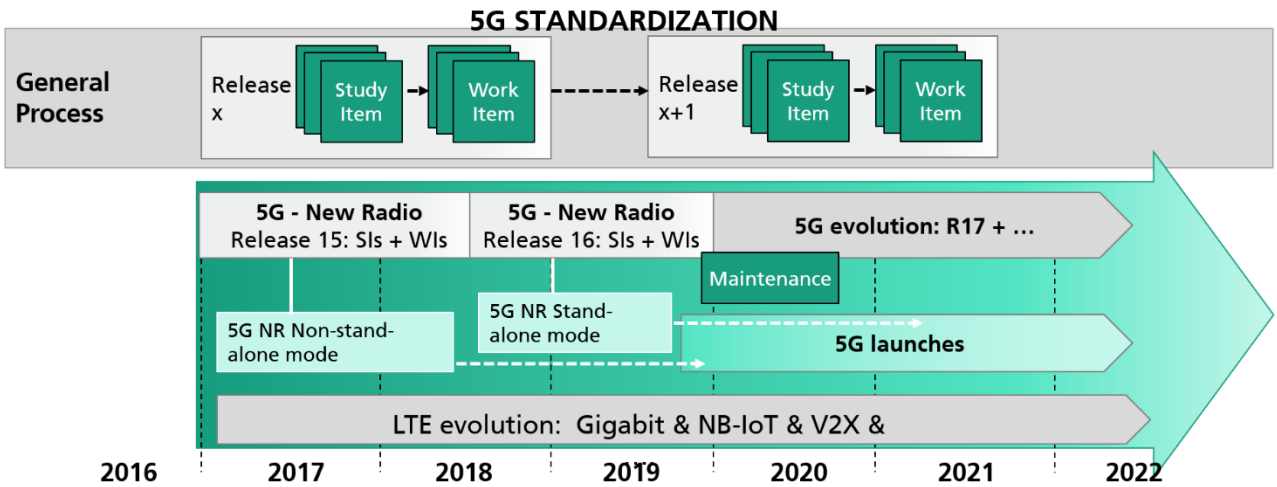


Figure 10. Standardisation of 5G within the 3GPP

C-V2X within the 3GPP

The proposed cellular vehicular communication standard in 3GPP supports four main types of vehicular applications as shown in Figure 11:

- Vehicle-to-Vehicle (V2V): Communication occurs between one vehicle and another vehicle.
- Vehicle-to-Infrastructure (V2I): Communication happens between a vehicle and network infrastructure, e.g., a Road Side Unit (RSU).
- Vehicle-to-Pedestrian (V2P): Communication is between a vehicle and a pedestrian or a cyclist on the street.
- Vehicle-to-Network (V2N): Data transmission is between a vehicle and a Base Station (BS) or V2X application server.

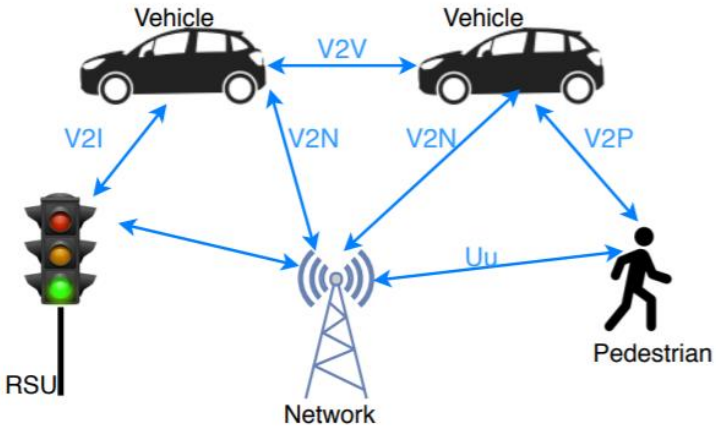


Figure 11. The types of applications for C-V2X communications

The part of C-V2X technology, which embraces the concept of establishing a direct link between two entities through the PC5 interface, is based on an extension of the pre-existing sidelink channel that was developed to enable Device-to-Device (D2D) Communications in 3GPP Release 12 and made use of the uplink frequency channels for transmission. To that end, two new modes (3 and 4) of operations in LTE-based PC5 interface taking place completely over unlicensed frequency bands (i.e., 5.9 GHz in this case) is introduced as in the following:

- In mode 4, vehicles autonomously select their radio resources for transmission without the direct involvement of the BS in the scheduling procedure, irrespective of whether they are under cell coverage or not. Selecting the resources follows a Listen-Before-Talk (LBT) algorithm called Sensing-based Semi-Persistent Scheduling (SPS). If the vehicles are in coverage under a serving cellular cell, they receive their resource pool configuration, transmission and sensing parameters from the serving cell either by:
    - Establishing an RRC configuration and receiving dedicated parameters and configurations from the BS, which allows the BS some control over grouping UEs to share certain

resource pools. However, the resource selection for each transmission by the vehicles remains totally autonomous in these dedicated pools.

- Remaining in an idle state and not establish the RRC connection and use the common configuration provided by the System Information Block (SIB) broadcasted by the serving BS that could be read by all UEs under cellular coverage. Similar to the dedicated configuration the resource selection for each transmission by the vehicles remains totally autonomous.
- If the vehicles are not under cellular coverage, vehicles will make use of parameters that are pre-configured by their vendors.

The following figure shows how mode 4 applications are expected to work under different coverage scenarios.

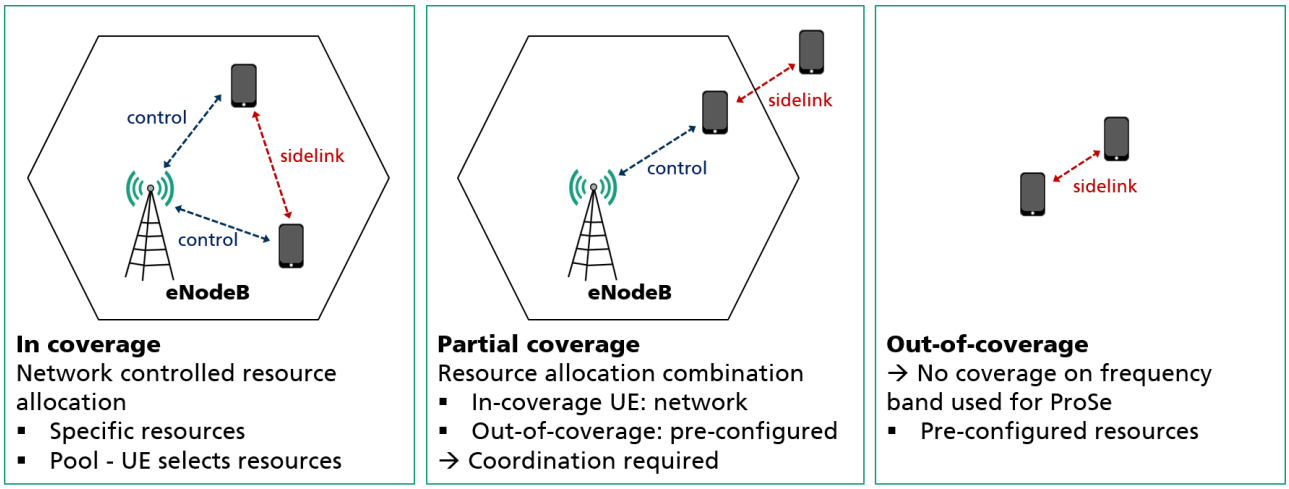


Figure 12. The mode 4 operation of vehicles in V2V communications of 3GPP

- In mode 3, vehicle communication still occurs over sidelink channels, however resource selection and allocation is solely managed by the BS. Thus, mode 3 is only available when vehicles are under cellular coverage and have to establish an RRC connection with the serving cell BS. It depends on each operator to implement its own resource management algorithm that can be classified into two classes namely dynamic scheduling and Semi-Persistent Scheduling (SPS):
  - In SPS, the BS will reserve a specific resource assignment for one vehicle for a fixed amount of transmissions. The vehicle then uses these allocated resources for the specified amount of transmission before sending another scheduling request to the serving BS. This was developed specifically for the case of periodic traffic that is generated with a certain periodicity, thus effectively taking advantage of this expected periodic behaviour to reduce the overhead of sending and receiving scheduling requests.

- In dynamic scheduling, the vehicles will request resource allocation from BS for every transmission, which increases the transmission overhead and causes delay in the packet transmission waiting for the resource scheduling by the BS.

The planned timeline of 3GPP for C-V2X is shown in Figure 13. 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.

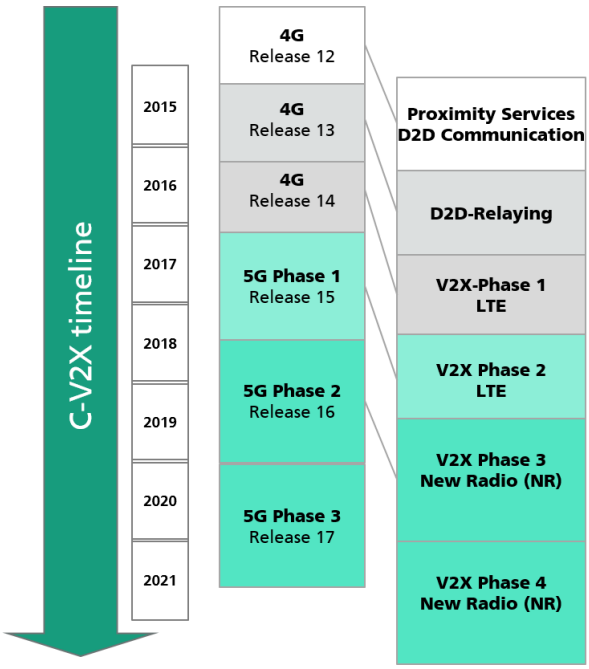


Figure 13. The timeline for C-V2X communications in 3GPP releases

3.1.2. ETSI

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.)

3.1.3. ITU-T

The ITU 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) [11]
- Focus Group on Vehicular Multimedia (FG-VM)

3.1.4. UNECE

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 [12]. 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

3.1.5. ISO

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.

3.1.6. CEN/CENELEC

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.

3.2. Industry Associations

5GAA creates specifications in the area of 5G-enabled CCAM with a high impact whereas NGMN is an operator-led association that has a task force for C-V2X. They do not have the functionality for developing standards, but the inputs received from industry associations in the form of specifications, views, analyses, field test results and trialling are taken into account by the SDOs.

3.2.1. 5GAA

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.

3.2.2. NGMN

The 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 [13], which presents a summary of the findings of the NGMN V2X task force.

3.3. Impact of Standardisation on 5G-MOBIX

The 5G-enabled CCAM use cases and user stories covered in 5G-MOBIX are categorized using the 3GPP TR 22.886 document appearing in 3GPP Release 16 [2], but unlike the 3GPP standardisation activities towards C-V2X communications, which involve both direct/sidelink and network-based communications, the aim of the 5G-MOBIX user stories is to realize and showcase these scenarios using the 5G NR Uu interface that demands the presence of a mobile network operator, which ensures high capacity and high quality links between the communicating parties, where for instance a V2V application in the "Advanced Driving" use case category turns into two V2N links (i.e., V2N2V) over the 5G network.

Contributions to 5G standardisation by addressing the possible problems caused by the cross-border nature of the project are plausible. Some of the telecommunication issues are already discussed in the 5G-MOBIX deliverable D2.1 [1], where an issue for roaming is given below as an example.

Problem:

The major impact on C-V2X applications while crossing the border is the high latency experienced to re-establish the connection in the PLMN of the neighbouring country that is being entered. In commercial networks, the connectivity with the operator in the country that is left behind is completely lost and the user terminal performs a search for existing operators.

Possible solution:

To overcome this problem, inter-PLMN handover could be used. Viewpoint of 3GPP: Technically the procedures are defined.

- The LTE standard covers procedures for voice and data handover between PLMN. These procedures are covered by the current standards.
- For NR it should be a minor issue to allow inter-PLMN HO, e.g. a minor enhancement on the core network side seems to be required, which is called the 5G EPC in case of the 5G non-standalone (NSA) architecture case.

The major impact and effort to implement inter-PLMN handover seems to be more related to the regulations and the contractual agreements between the network operators in different countries rather than the existence or implementation of standards.

4. SPECTRUM ALLOCATION FOR 5G

The strategy to allocate, identify and assign the most suitable bands for 5G communications 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.

4.1. 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 14.

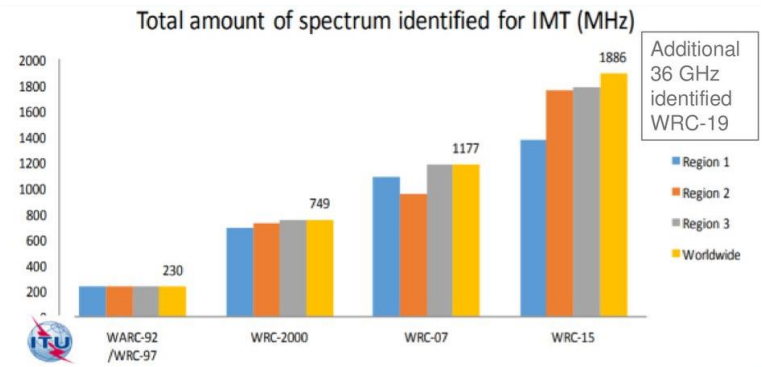


Figure 14. The total amount of spectrum identified for IMT until WRC-19.

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 20.

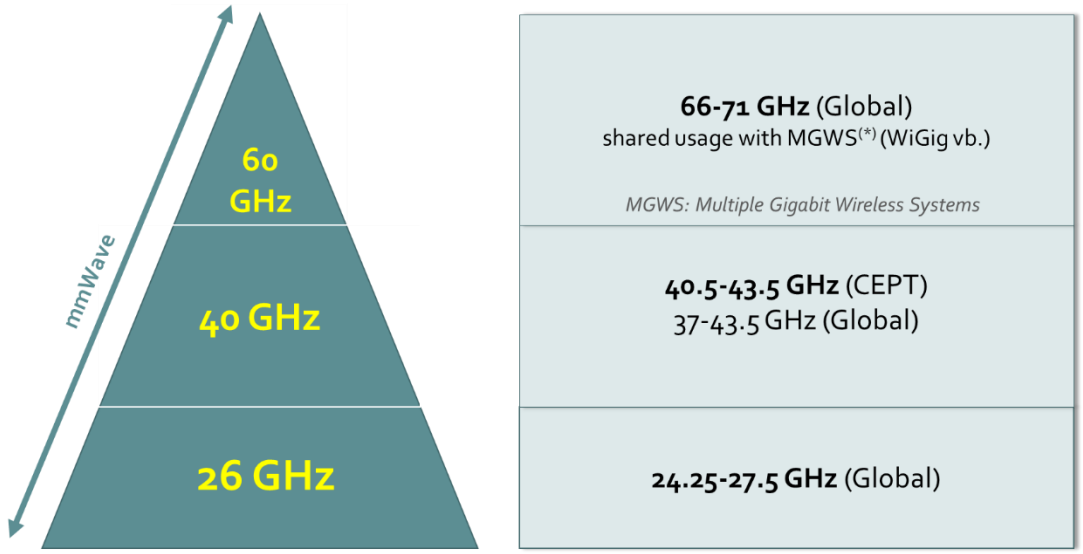


Figure 15. The global bands identified for IMT during WRC-19

The bands that might be identified during the WRC-23 as in Table 3. The WRC-23 bands under considerationa minor analysis is included here.

Table 3. 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 16. The cross-border areas to be used during 5G-MOBIX for trialing of 5G-enabled CCAM 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 CCAM applications to the deployed at the cross-border regions.

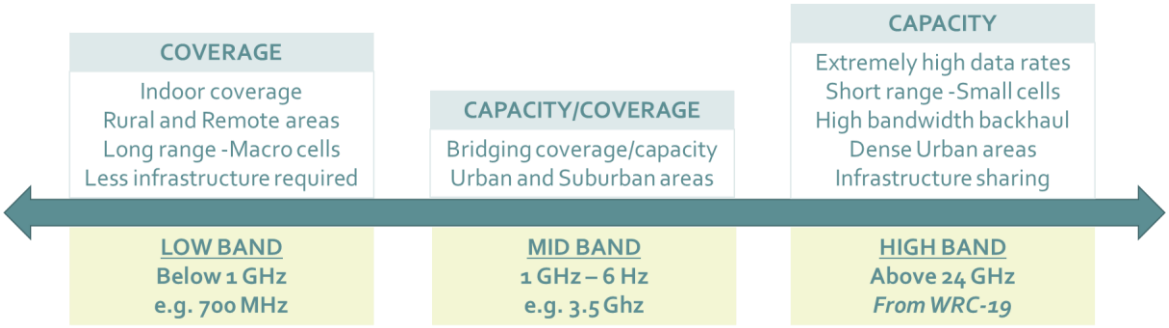


Figure 16. The spectrum bands for IMT-2020

A recent report by the 5GAA [14] stipulates that the spectrum needs of C-V2X 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.

A similar comprehensive analysis will be performed for the 5G-MOBIX use case categories and user stories in the second phase of Task 6.3.

4.2. The Spectrum Regulations for V2X Communications

The discussions for C-V2X communication spectrum mostly focus on the 5.9 GHz unlicensed band that is also used by DSRC / IEEE 802.11p systems, and hence the direct communication aspects of vehicular connectivity. The most recent announcement from the European Commission in this regard is the following [15]:

"The Commission has adopted the Implementing Decision to improve safety of road and urban rail transport. The Decision harmonises across Member States the use of the 5.9 GHz band for real-time information exchange on safety conditions in connected transport.

NEXT STEPS
Member States should assign the 5.9 GHz band for intelligent for intelligent transport systems by 30 June 2021 and they should report to the Commission on the implementation of the Decision by 30 September 2022. The Implementing Decision will be reviewed when market developments call for an update or at the latest by 30 September 2023."

The document for "Commission Implementing Decision" states that *ETSI is currently working on two technical reports dealing with the definition and evaluation of co-channel and adjacent-channel co-existence methods between ITS G5 and LTE-V2X. Relevant standards may be available at the earliest by mid-2021 and could take until mid-2022.* However, as mentioned above, the decision is on V2V and not the network-based communications.

4.3. The European 5G Action Plan

The European Commission's 5G Action Plan [4] aims to launch 5G services in all member states by the end of 2020 as well as ensure uninterrupted 5G coverage in urban areas and along main transport paths by 2025. The ICT-18-2018 projects serve to bring 5G-enabled CCAM services to the cross-border areas in support of the 5G Action Plan. Moreover, the current situation in the 5G-MOBIX trial sites that are among the member states should be assessed to see how well the plan is being followed.

Task 6.4 on "EU policies and regulation – type approval – certification" elaborate more on the implications of the European 5G Action Plan for the services considered within 5G-MOBIX.

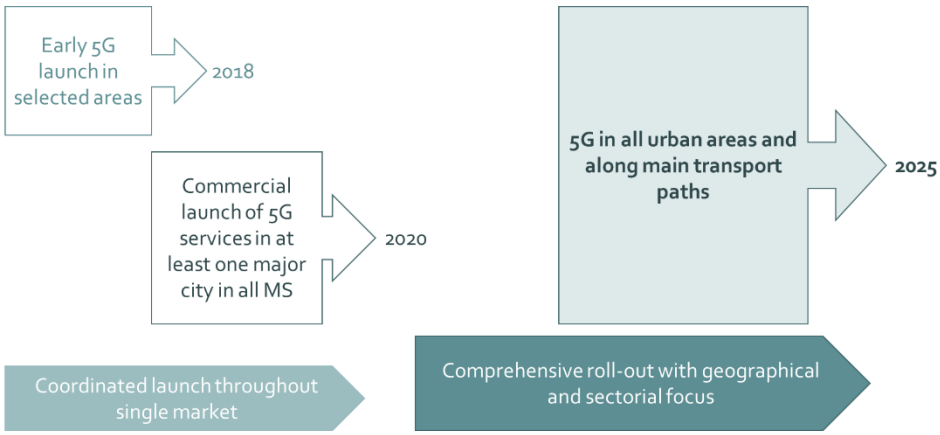


Figure 17. The 5G Action Plan

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

In this section, the status of spectrum regulations in the countries, where 5G-MOBIX trials will be carried out are described, starting with the cross-border corridors (CBCs). Even though not established within the project as a CBC trial site, Germany has borders with the Netherlands and France, which is a neighbour of Spain. Therefore, the spectrum regulation discussions in these countries are essential for a number of other 5G corridors, as well.

4.4.1. Spain

Responding to the different Decisions and Communications of the European Commission from 2012, setting different guidelines and priorities in relation to the deployment of 5G, including spectrum

allocation aspects, the Ministry of Economic Affairs in Spain has been working on a general framework and specific actions to address and follow the different indications of the Commission.

In 2017, the (then) Ministry of Energy, Tourism and Digital Agenda published in December the 5G National Plan1. One of the key aspects of the plan, in relation to the management and planning of spectrum allocation, is the allocation and opening of frequency bands for the provision of 5G wireless broadband services. The bands of 3.4-3.8 GHz, 700 MHz and 26 GHz are specifically mentioned as being of interest for the launching of 5G services across the Union.

The Orden ETU/416/2018, entering into force in April 27th, 2018, takes up on the priorities set up by the Plan and identifies the frequency bands that will be used for wireless broadband, and their current uses – thus hinting at later necessary work for the administrative re-allocation of services provided in them. The frequency bands identified are:

- 1500 MHz: Designed to be used not-exclusively for wireless broadband. Several sub-bands are allocated to State Defence services.
- 26 GHz: Mainly experimental at the moment, with several sub-bands dedicated to space research.
- 42 GHz: Mainly experimental at the moment, with several sub-bands dedicated to space research and services.
- 3400-3800 MHz: Designed to be used for wireless broadband. However, several sub-bands are allocated to State Defence services, and about half of the available channels are already locked in by specific providers. This band is actually the main focus of the Orden.
- 66-71 GHz: Mainly experimental at the moment.

In relation to the 700 MHz band, entering into force in June 26th 2019, the Real Decreto 391/2019 of the Ministry of Economic Affairs and Business of Spain regulates certain aspects in relation to the re-allocation of the 700 MHz band to support 5G services.

This decree is a response to the Decision (EU) 2017/899 of the European Parliament on the use of the 470-790 MHz frequency band in the Union. The 694-790 MHz ('700 MHz') band is particularly addressed in the 2015 'A Digital Single Market Strategy for Europe' Communication of the Commission. In the Communication, the importance of the 700 MHz band is highlighted for the provision of broadband services in rural areas in order to ensure access and connectivity, and stressed the need for a coordinated release of that frequency band. This 700 MHz spectrum band is currently used, as it is the case across the Union for digital terrestrial television but was specified by the UIT in 2015 to be available for mobile services on a primary basis. The rapidly growing wireless broadband traffic and the importance of the digital economy have pushed the move to dedicate the band entirely for wireless broadband.

The Decision initially established June 30th, 2020, as the deadline for making available the use of the frequency band for wireless broadband, but has been finally extended to October 31st, 2020. This presents the interesting opportunity to follow this process in its last weeks before completion, and assess any issues

that might arise from this allocation in the short term. In fact, the decree focuses on how to re-allocate existing broadcasting uses of the 700 MHz channels in the lower sub-bands, for example.

With relation to the 2.3-2.4 GHz band, in Spain this band is being used for telemetry and television mobile radio links services; thus in the short term it could only be used through Licensed Shared Access (LSA). An analysis in using this band for 5G under this conditions is proposed in the 5G National Plan.

In the Spanish part of the cross-border corridor, Telefonica is using 40MHz baseband bandwidth in the band of 1800 MHz which is used for the LTE anchoring of 5G NSA radio. This band is currently covering the Spanish corridor with 4G coverage. The spectrum status of this band in Spain is depicted in Table 4.

Table 4. The 1800 MHz band allocation in Spain

	Bandwidth (MHz)	Frequency (MHz)	Valid until
Telefonica	20 + 20	1710,1 – 1730,1 / 1805,1 – 1825,1	31/12/2030
Vodafone	20 + 20	1730,1 – 1750,1 / 1825,1 – 1845,1	31/12/2030
Yoigo	14,8 + 14,8	1750,1 – 1764,9 / 1845,1 – 1859,9	31/12/2030
Orange	20 +20	1764,9 – 1784,9 / 1859,9 – 1879,9	31/12/2030

The 5G frequency that is going to be used in 5G-MOBIX is the n78 5G NR band (3400 – 3800MHz). This band was auctioned in two different phases making non-continuous spectrum allocations for the majority of the operators. Negotiations between the Spanish regulator "Ministerio de economía y empresa" (Ministry of Economy and Business) and operators are currently pending, with the intent to relocate this band to ensure larger continuous spectrum blocks, which would help to implement high throughput services. The current status of this band is showed in Table 5 below.

Table 5. The status of the n78 band

	Bandwidth (MHz)	Frequency (MHz)	Valid until
Telefonica	20 + 20 + 50	3440 – 3460	18/04/2030
		3540 – 3560	18/04/2030
		3750 – 3800	06/12/2038
Vodafone	90	3660 – 3750	06/12/2038
MasMovil	40 + 40	3400 – 3440	18/04/2030
		3500 – 3540	18/04/2030
Orange	20 +20 +60	3460 – 3480	31/12/2030
		3560 – 3580	31/12/2030
		3600 – 3660	06/12/2038

The initial plan for Telefonica in 5G-MOBIX is to use the upper part of the band (3750-3800 MHz) which provides 50 MHz of continuous bandwidth until the relocation is done. It was expected to be ready before 2021, but it could be postponed after the 700MHz auction in Spain. The 700MHz band auction was

expected to be done in June of 2020 but it was postponed to the first quarter of 2021. Once the relocation takes place, Telefonica theoretically could have up to 90 MHz continuous bandwidth to provide 5G services within this n78 band.

4.4.2. Portugal

The Autoridade Nacional de Comunicações (ANACOM) is the national regulatory authority (NRA) in Portugal for communications, for the purposes of the law of the European Union (EU) and national legislation. It also inherits the assignments, powers and responsibilities of the Comissão de Planeamento de Emergência das Comunicações (Emergency Communications Planning Committee).

The 5G spectrum is not yet allocated, but the auction will take place in 2020. ANACOM has already approved the regulation of the auction for allocation of frequency user rights in the 700 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz and 3.6 GHz bands, presented in Table 6 below.

Table 6. The bands approved for auctioning in Portugal

Bands	Frequencies	Number of lots
700 MHz	703-733 MHz/ 758-788 MHz	6 lots of 2 x 5 MHz
900 MHz	880-885 MHz/ 925-930 MHz	1 lot of 2 x 5 MHz
900 MHz	895,1-898,1 MHz/ 940,1-943,1 MHz 914-915 MHz/ 959-960 MHz	4 lots of 2 x 1 MHz
1800 MHz	1770-1785 MHz/ 1865-1880 MHz	3 lots of 2 x 5 MHz
2.1 GHz	1954,9-1959,9 MHz/ 2144,9-2149,9 MHz	1 lot of 2 x 5 MHz
2.6 GHz	2500-2510 MHz/ 2620-2630 MHz	2 lots of 2 x 5 MHz
2.6 GHz	2595-2620 MHz	1 lot of 25 MHz
3.6 GHz	3400-3460 MHz (with restrictions up to 2025)	6 lots of 10 MHz
3.6 GHz	3460-3500 MHz (with restrictions up to 2025)	4 lots of 10 MHz
3.6 GHz	3500-3800 MHz	30 lots of 10 MHz

Given the project timeline and terminals availability, the initial deployment of cross border 5G network will be done in Non-Standalone option 3x (EN-DC NSA3x) with an LTE anchor layer on band n3 (FDD 1800 MHz) and 5G NR on band n78 (TDD 3700 MHz). The Standalone SA Option 2 will come in a later stage, when 5GCN becomes available for deployment.

Until the 5G spectrum allocation process is completed by Portuguese regulator ANACOM the 5G-MOBIX project will be installed on a test network that will be completely segregated from the commercial network. In the first phase of the project, the 5G radio access network is going to be deployed at 3700 MHz, with an LTE anchor layer at 1800 MHz, which will be granted temporarily for carrying out the

technical trial. In a second phase, it will be possible to migrate the network to 5G commercial spectrum that will be held by NOS.

4.4.3. Greece

The Hellenic Telecommunication and Post Commission (EETT) is an Independent Administrative Authority. It acts as the National Regulator that monitors, regulates and supervises: (a) the electronic communications market, within which fixed and mobile telephony, wireless communications and Internet access providers operate and (b) the postal services market, within which postal and courier service providers operate. EETT is entrusted with the competences to act as the Competition Authority in the said markets.

Particular to the telecommunications market, EETT undertakes many important duties, including (but not limited to) the regulation of issues related to the definition of the relevant markets/products/services, the definition of obligations of operators as well as their supervision and monitoring, management of the National Numbering Plan as well as various related registries, the regulation issues of consumer protection both in the electronic communications and the postal services sector, the management of the commercial radio frequencies, (with the exception off broadcast radio stations and TV spectrum).

EETT is the competent authority for issues regarding the provision and use of telecommunications terminal equipment and radio equipment. The main points of the Greek 5G strategy at this time include the development of a 5G cross-border corridor (Bulgaria, Greece, Serbia) and the awarding of spectrum by the end of Q4 2020. More specifically, the already awarded spectrum at this time is shown in Table 7.

Table 7. Already awarded spectrum in Greece (as of October 2020).

Frequency	Availability	COSMOTE/ OTE	VODAFONE	WIND	Valid until
800Mhz	2x30	2x10	2x10	2x10	Feb 2023
900MHz	2x35	2x10	2x15	2x10	Sep 2027
1800MHz	2x75	2x35	2x25	2x15	40MHz Nov 2029, 110MHz Dec 2035
2.1 GHz FDD	2x60	2x15	2x20	2x10	Aug2021
2.1 GHz TDD	15	5	5	5	Aug 2021
2.6 GHz FDD	2x70	2x30	2x20	2x20	Feb 2030
2.6 GHz TDD	40	20	20		Feb 2030
3.6 GHz FDD	400	60 (OTE) + 60 (Rural Networks)			OTE: Apr 2029, Rural: April 2037

In terms of trial licenses, all interested parties could apply for a trial license at 3.5 GHz band since December 2018[1] while the first 5G trials using trial licenses have been finished by Q4/2019. On February

[1] https://www.eett.gr/opencms/opencms/admin_EN/News/news_0503.html

2020, EETT launched the public consultation on the "granting of rights of use for radio frequencies in the 700 GHz, 2 GHz, 3400 - 3800 MHz and 26 GHz frequency bands"[2] the results of which were announced on June[3]. In July 2020, EETT launched a **Public Consultation on the Tender Document** for the Granting of Spectrum Usage Rights in the 700 MHz, 2 GHz, 3400-3800 MHz and 26 GHz frequency bands and announced the results in September[4]. At the end of September 2020, EETT published the **Tender Document** for the Granting of Spectrum Usage Rights in the 700 MHz, 2 GHz, 3400-3800 MHz and 26 GHz frequency bands[5]. According to EETT, the tender involves the following spectrum, which is also summarized in Table 8 below:

a) 700 MHz: 60 MHz paired spectrum (2x30 MHz) in the frequency bands 703-733 MHz/758-788 MHz,
b) 2 GHz: A total of 120 MHz paired spectrum (2X60MHz) is included in the tender, of which 30 MHz is readily available (1965-1980 MHz and 2155-2170 MHz), and 90 MHz (1920-1965 MHz and 2110-2155 MHz) are allocated to mobile networks operators as follows: VODAFONE (2x20 MHz), WIND (2x10 MHz) and COSMOTE (2x15 MHz).These spectrum rights expire on August 2021 and therefore are included in the tender.
c) 3400-3800 MHz: 280 MHz readily available spectrum exist. Additionally, there are 2x30MHz granted since 2014 to OTE (3440-3470 & 3540-3570) as well as another 2x30MHz (3670-3700 MHz & 3770-3800 MHz), bound by the Greek State exclusively for the provision of electronic communications services to rural areas. OTE's spectrum rights, expiring in 2029, are included in the forthcoming tender for the period after 2029 and until the expiration date of the new spectrum rights in the band and at the same time to make possible the reallocation of them within the same band to enhance effective planning and optimize spectrum use.
d) 24.25 –27.5 GHz: There are 2350 MHz readily available spectrum. In case of existing spectrum rights rearrangement, the available spectrum will increase to 3250 MHz.

The submission of applications to the tender is extended to the end of October. The aim is that the auction will take place by mid of **December 2020**. According to EETT, the proposed process involves a multi-round clock auction with gradually increasing bid, as "the most effective process in ensuring transparency and objectivity to award licenses for spectrum use". This is a competition-oriented practice, where the price of each spectrum segment is to be determined by the market participants.

Table 8. GR Spectrum Availability in the 700MHz, 2GHz, 3400-3800MHz & 26 GHz

[2] Text of the public consultation on granting of rights of use for radio frequencies in the 700 GHz, 2 GHz, 3400 - 3800 MHz and 26 GHz frequency bands : https://www.eett.gr/opencms/export/sites/default/admin/downloads/Consultations/RadioCommunications/PC_5G/PublicConsultation5GBriefENGfinal.pdf
[3] Results of public consultation on granting of rights of use froro radio frequencies in the 700 GHz, 2 GHz, 3400 - 3800 MHz and 26 GHz frequency bands : https://www.eett.gr/opencms/opencms/admin_EN/News/news_0536.html
[4] Public consultation on the Tender Document: https://www.eett.gr/opencms/opencms/admin_EN/News/news_0546.html
[5] Tender document: https://www.eett.gr/opencms/opencms/admin_EN/News/news_0547.html

Frequency	Availability	COSMOTE/ OTE	VODAFONE	WIND	Rural Networks	Total
700Mhz	2x30 MHz	-	-	-		60MHz
2GHz	2x15 MHz	2x15 MHz (expiring Aug 2021)	2x20 MHz (expiring Aug 2021)	2x10 MHz (expiring Aug 2021)		120MHz
3.4-3.8 GHz	280 MHz	60MHz			60MHz (Central Greece)	400MHz
26GHz	2350 MHz	2x112 MHz FDD (Fixed Wireless only)	2x56MHz FDD (Fixed Wireless only)	2x56 MHz FDD (Fixed Wireless only)		2350MHz & 2x224 MHz

4.4.4. Turkey

The Information and Communication Technologies Authority (ICTA) is a national telecommunications regulatory and inspection authority of Turkey. The ICTA works under the Ministry of Transportation, Maritime Affairs and Communications. It has a wide range of duties including spectrum management, authorization, licensing for the installation and use of radio equipment and systems, monitoring and supervision of spectrum, tariffs, creation and maintaining the competition in the sector, setting, auditing and/or having audited QoS standards of all types of services including universal service and determination of principles and procedures regarding setting and auditing of quality of services standards of services.

The ICTA is the main authority in auctions, allocations, monitoring, and supervision of spectrum. For 5G spectrum allocations, ICTA has yet to publish its roadmap but it is expected that the auctions/allocations will be held in 2022-2023 time frame. Although Turkey has historically been a market that is a late adopter in transitioning to a new cellular technology, it has also reaped some benefits of this strategy such as enjoying technology & market maturity, relatively lower investment cost of infrastructure, and cheaper end-user devices, which have paved the way for faster network rollouts and higher customer adoption.

Considering the main 5G spectrum in low, mid and high bands, the current availability and status of these bands can be summarized as follows: 700 MHz band is fully available for allocations to IMT, having already been vacated by terrestrial broadcast services. For the mid-band spectrum, 3400-3800 MHz is not fully available currently as some parts of the band are still being used by civilian and public security services. It has also some assignments for fixed satellite services on paper but there are not any Earth stations using this frequency range. Therefore, ICTA can repurpose this band partially or completely for IMT services provided that the incumbent services are moved to another band, thereby clearing it for IMT usage. For the high band, 26 GHz is mostly used by fixed services (i.e. wireless backhaul) by operators and only the upper portion, which is currently unused, can be easily allocated for IMT. So this makes about 1.3 GHz

available for IMT currently; however, for a full allocation to IMT, all existing services need to be relocated to another band such as 32 GHz, which can be considered as a long term goal since it involves replacement of equipment and associated costs.

In summary, the 5G spectrum auction/allocation process is still work in progress in Turkey, and the operators expect to get more updates from the Regulator regarding the 5G spectrum roadmap within the next year.

4.4.5. Germany

The Federal Network Agency (German: Bundesnetzagentur or BNetzA) is the German regulatory office for electricity, gas, telecommunications, post and railway markets. It is a federal government agency of the German Federal Ministry of Economics and Technology and headquartered in Bonn, Germany. In December 2016 the Bundesnetzagentur launched a public consultation on its document "Points of Orientation for the provision of spectrum for the rollout of digital infrastructures". The aim of the consultation was to identify and provide suitable spectrum in particular for the introduction of "5G", the next generation of mobile technologies, at an early stage.

Interested parties were then invited to submit their views by 1 March 2017. In light of the responses received, the Bundesnetzagentur assumed that all the frequencies in the 2 GHz band (originally called the UMTS band), which was previously assigned until the end of 2020, and the end of 2025 will be used for the rollout of digital infrastructures. In addition, the consultation responses had shown demand for spectrum in the 3.6 GHz band for both nationwide and regional use. Frequencies in this band would have become widely available again as from 2022. The band has already been identified internationally for the introduction of 5G. Thus spectrum here, as well, was decided to be provided for 5G at the earliest possible opportunity. Frequencies in the 3700 – 3800 MHz band were decided to be assigned for particular areas in line with demand. The Bundesnetzagentur decided to provide these frequencies in a further step; that is to say, in an application procedure for area-related regional/local assignments. Finally, spectrum above 24 GHz – in particular the band at 26 GHz – is also to be provided for 5G at the earliest possible opportunity, in line with demand and in consideration of existing uses.

Accordingly, in the period from March to June 2019, the Bundesnetzagentur held the latest spectrum auction in Mainz which contained 41 frequency blocks from the 2 GHz and 3.6 GHz bands. Four companies participated in the auction: Drillisch Netz AG, Telefónica Germany GmbH & Co. OHG, Telekom Deutschland GmbH and Vodafone GmbH. All participants successfully bid on spectrum. The frequency blocks were mostly auctioned in an abstract manner with regard to their location in the spectrum. Only the top and bottom blocks in the 3.6 GHz band were auctioned off specifically, since the 3,700-3,800MHz range has been set aside for local use. The auction ended after 497 bidding rounds with total proceeds of €6,549,651,000.

Following the conclusion of the auction and the presentation of the award notices, the abstract blocks acquired have now been allotted specifically in accordance with the procedure detailed in the President's Chamber decision of 26 November 2018 (BK1-17/001, subsection IV.4.2). The results per company as follows:

	Drillisch Netz AG	Telefónica Germany GmbH & Co. OHG	Telekom Deutschland GmbH	Vodafone GmbH
2 GHz	2 x 10 MHz	2 x 10 MHz	2 x 20 MHz	2 x 20 MHz
3.6 GHz	50 MHz	70 MHz	90 MHz	90 MHz
TOTAL	70 MHz	90 MHz	130 MHz	130 MHz

Figure 18 as illustrated by the Bundesnetzagenture shows the timeline for frequency award proceedings and the coverage obligations imposed by the federal government in Germany. The next spectrum award (planned to take place in 2022/2023) will present an opportunity to establish more far-reaching coverage obligations and thus 5G-specific requirements to be met by the network quality over larger areas.

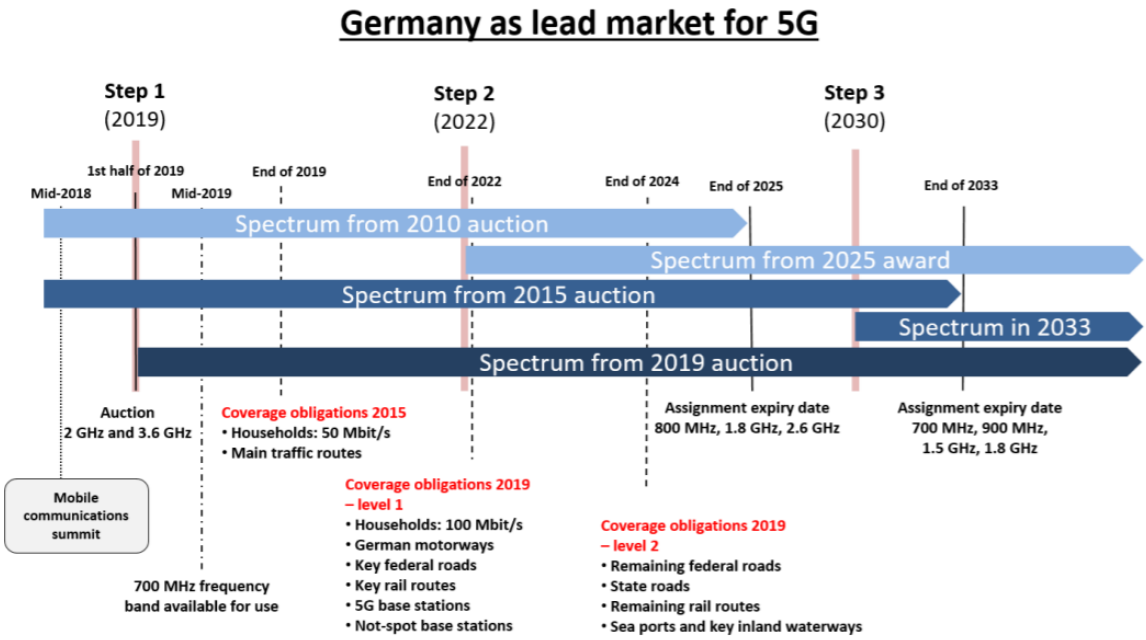


Figure 18. Timing of award proceedings (source: Bundesnetzagentur)

The second step will be taken in the light of the development of 5G deployment as well as 5G applications that has taken place by then. The rollout commitments to be established then will be an important building block for implementing comprehensive 5G infrastructure in Germany and achieving further densification in rural areas too. Ahead of this, consideration is to be given as to whether, and if so how, the rules governing spectrum award can be adapted in such a way that mobile communications coverage in rural areas is the crucial benchmark in the award and the latter is not based primarily on highest financial

bids. This will also include the options of extending spectrum use rights from the 700, 800 and 900 MHz ranges, which will expire in 2025 or 2033. It should also be borne in mind that in the years ahead, a discussion will start on how permanent use can be made of other frequencies below 1 GHz. The Federal Government will request the Federal Network Agency at short notice to thoroughly examine the potential implications of a frequency extension for mobile communications coverage and to present the outcome of this examination by the end of 2020.

4.4.6. France

The National Frequency Agency (ANFR) manages all radio frequencies in France. This rare and strategic resource, used for all wireless communications, belongs to the public domain of the State which entrusted the management to ANFR. As such, its mission is to negotiate, at the international level, the future uses of the frequency bands and defend French positions. It also authorizes all implantations of emission sites (> 5 watts) on the territory and ensures compliance with the limits of public exposure to the airwaves. Finally, it controls the use of frequencies and ensures a good coexistence of their uses by all users.

In the framework of an agreement that has been renewed every year since 1998, the ANFR prepares the frequency use authorisations (AUF) issued by the ARCEP (France's Electronic Communications, Postal and Print media distribution Regulatory Authority). In this matter, it manages some parts of the spectrum assigned to the ARCEP and examines, prepares and sends the authorisations that are under ARCEP jurisdiction in specific bands. Depending on the network type and frequency band, this activity covers frequency assignments, their coordination with other assignees, the initialisation of the border coordination procedures, registration in the CAF and the application of the COMSIS procedure.

ARCEP is an independent administrative authority (IAA). It is responsible for regulating the electronic communications and postal sectors, on behalf of the State, but entirely independently of any political power or economic stakeholder. In the electronic communications sector, ARCEP duties include, among other:

- Define the regulation that applies to all or some of the operators. Under this "asymmetric" regulation, ARCEP issues a market analysis decision that sets out the obligations imposed on one or all of the operators that are deemed to enjoy significant power in the relevant market, and so referred to as the SMP operator(s), in accordance with Article L. 37-1 et seq. of the French Postal and Electronic Communications Code (CPCE). For the purposes of "symmetric" regulation, ARCEP defines the general obligations that apply equally to all operators (CPCE Art. L. 36-6 and L. 36-7);

- Allocate frequency and numbering resources, through individual decisions (CPCE Art. L. 42-1 et seq. and Art. L. 44) and define the national numbering plan (CPCE Art. L. 44);

After having published a 5G roadmap in 2018, the year 2019 was devoted to releasing the "core" 5G band (3.4 – 3.8 GHz), and to listening to stakeholders and European counterparts on how to design an

unprecedented, two-part spectrum award mechanism for the 310 MHz. In Part 1, operators were awarded a block of 50 MHz in exchange for making a series of optional commitments, prior to the auction, i.e. Part 2, during which the candidates will be able to obtain additional frequencies, up to a maximum 100 MHz. Although initially scheduled for April 2020, the COVID-19 public health crisis prevented the auction from taking place and postponed it to September 2020.

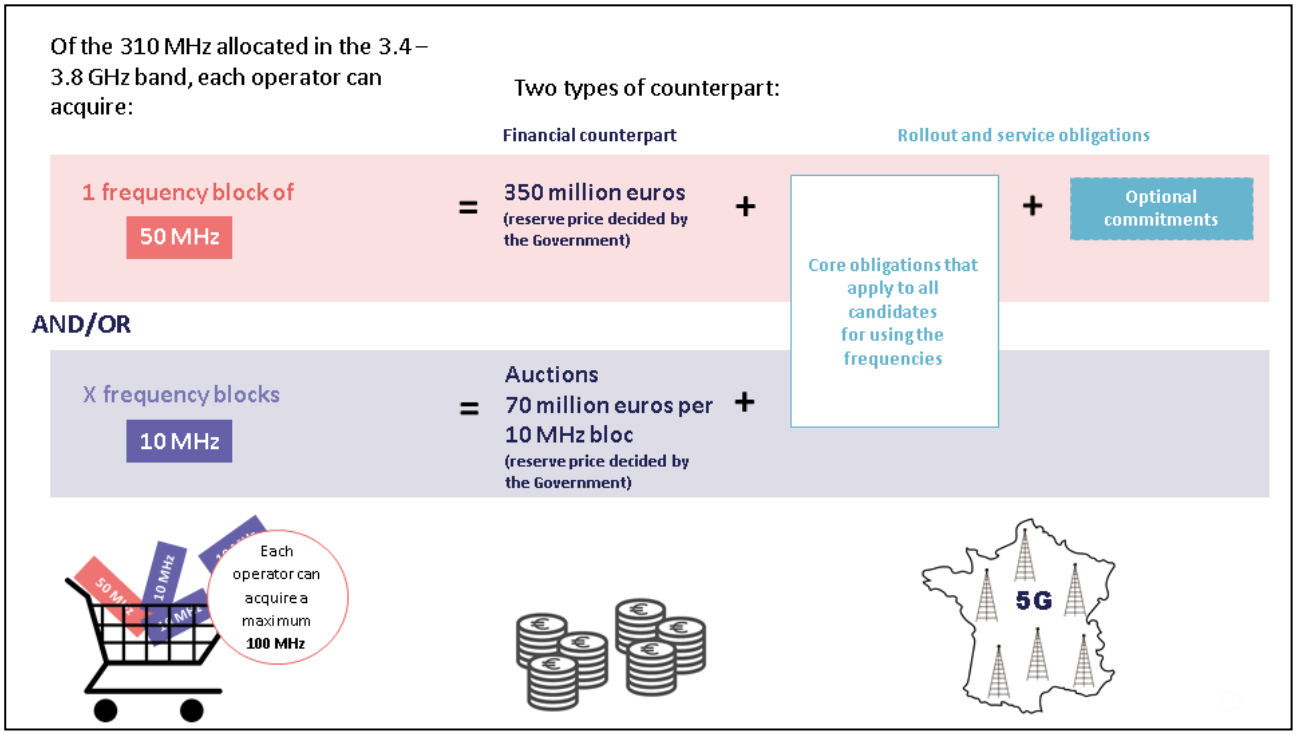


Figure 19. The 5G spectrum auction rules in France

On 2 April 2020, ARCEP announced that France's four mobile network operators – Bouygues Telecom, Free Mobile, Orange and SFR – had qualified to participate in the 3.4 – 3.8 GHz band frequency awards. Each had made the commitments that enabled them to obtain a block of 50 MHz for the sum of €350M. Since then, ARCEP has been preparing for the main auction to award the remaining 11 blocks of 10 MHz in the 3.4 – 3.8 GHz band. The auction, which was initially scheduled for April, was completed on 1st of October after three days of bidding. At the close of the main auction, local operators Orange, SFR, Bouygues Telecom and Iliad committed to pay a total of 2.8 billion euros for the 310 MHz of spectrum to be awarded. In fact, according to ARCEP, Orange bid €854 million for a total of 90 megahertz; SFR €728 million for 80 megahertz, while Bouygues Telecom and Free Mobile (Iliad) each offered €602 million for 70 megahertz. Upon completion of this main auction, a positioning auction will be held in October to determine the winning candidates' position on the band, followed by the award of the licences.

The commercial launch of 5G will then be performed on operators' initiative. Here, ARCEP is lifting the obligation listed in the specifications for each operator to deploy 5G services in at least two cities before the end of 2020.

ARCEP has also developed a pro-innovative regulation for start-ups and small enterprises. Among the initiatives put into place, the ARCEP is providing companies wanting to test a technology or an innovative service with a regulatory "sandbox", with more relaxed obligations than usual, which allows them to have a rapid, simple and temporary access to frequencies or to the status of network operator, for a duration no longer than two years. Other frequencies are very regularly attributed by ARCEP for experimentations out of the sandbox process in different areas such as C-ITS, airport network migrations, 4G and 5G trials.

After a joint call by ARCEP and the government in January 2019, ARCEP has authorized the first actors to exploit 5G experimental platforms open on 26GHz. This long-term use authorization is conditioned by the engagement of these actors to allow other third parties to use their pilot networks to test their own 5G use cases.

Nowadays, only the 26.5 – 27.5 GHz is available and can be used since 2020. After that, the whole band should become progressively available, provided that the coexistence conditions with other services such as radio-astronomy and satellite communications (25.5 - 27 GHz) are respected.

4.4.7. The Netherlands

Currently in the Netherlands frequencies in the lower and mid-band are available for mobile communication. The first 5G frequencies in the 700MHz band have been auctioned in July 2020 [16], where Figure 20 gives an overview of the current frequency allocations. In 2022 and 2026, the 5G frequencies in the 3.5GHz band are planned to be auctioned. In each auction, 200MHz will be auctioned, totalling to 400MHz. For the mmWave frequencies no auctions are planned yet. Discussions are currently ongoing on the health impact and the "gezondheidsraad" has advised to do more research on the impact of mmWave frequencies on health [17].

The licenses in the Netherlands are not bound to a specific technology, this way also the previously auctioned spectrum can be used to provide 5G coverage. With the auctioning of the 700MHz band, extra rules have been imposed on the providers acquiring at least 2x10MHz of spectrum in that band [18]. These rules impose that:

- Every municipality in the Netherlands needs to be covered for 98% (two years from acquiring the spectrum). The coverage can also be provided with previously acquired spectrum. Natura 2000 areas are excluded from this.
- A minimum speed of 8 Mbps needs to be available. Also for this the previously acquired spectrum is included.
- A minimum area needs to be covered by each band. The size of this area is different for each band and gives a minimum size to be reached in two and five years.

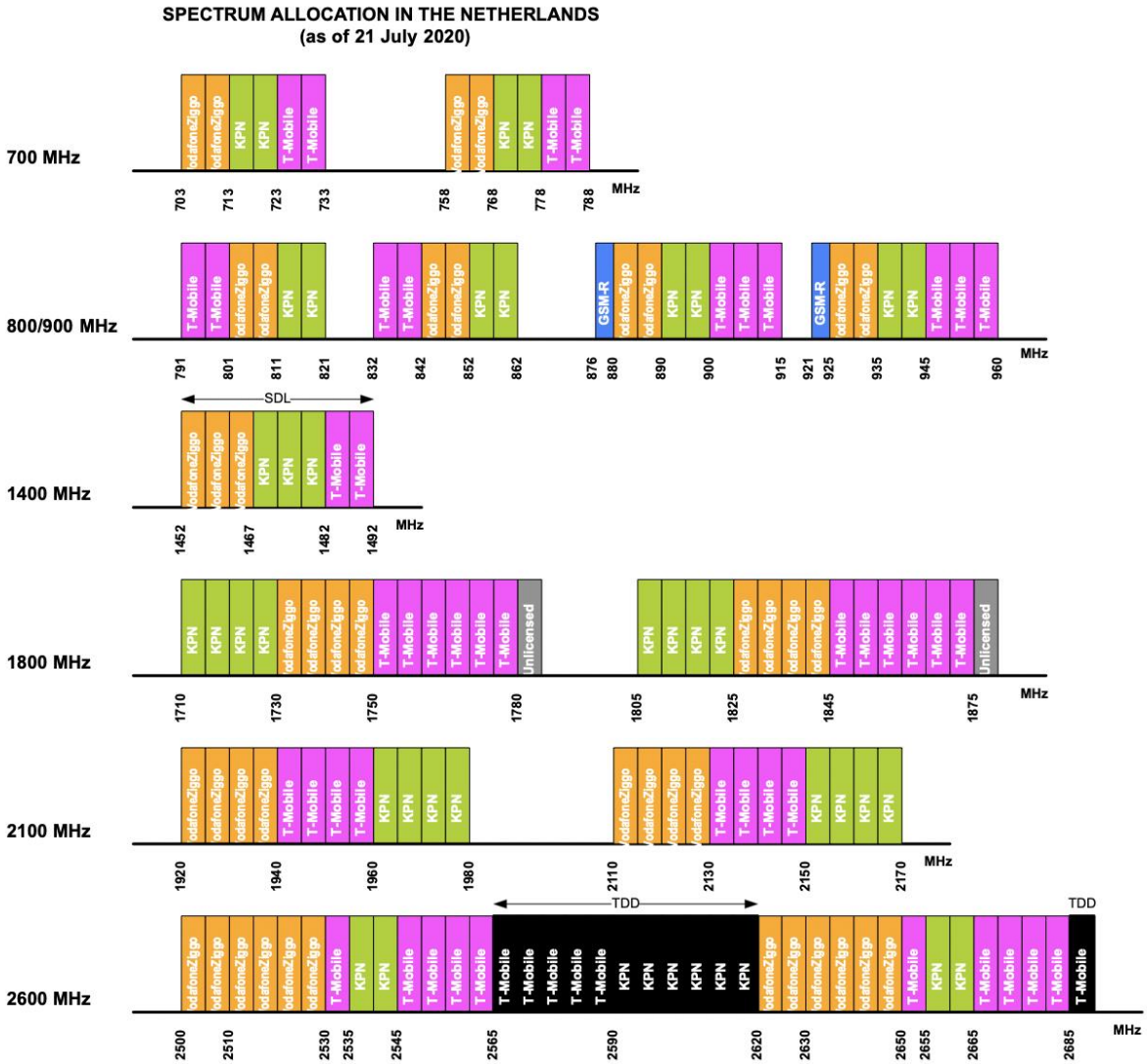


Figure 20. Spectrum allocations in the Netherlands as of July 21th

4.4.8. Finland

Finland follows the Europe's 5G Action Plan [4]. The 5G radio frequency auctions in Finland have been held as in the following:

1) The 700 MHz band was auctioned in 2016. The bands 703–733 and 758–788 were auctioned in 6 blocks. The winners were:
   - Telia finland Oyj
   - Elisa Oyj
   - DNA Oyj.

Each of them got 10 MHz band. This is one of the pilot bands for 5G. TRAFICOM, the Finnish frequency and road authority, published the news (in Finnish) [19].

2) The 3.5 GHz band was auctioned in 1.10.2018. TRAFICOM published the news [20], and the winners were:
   - 3410-3540 MH (A) Telia finland Oyj
   - 3540-3670 MHz (B) Elisa Oyj
   - 3670-3800 MHz (C) DNA Oyj.

3) The 26GHz band was auctioned in 8.6.2020 [21], and the winners were:
   - 25.1-25.9 GHz (A) Elisa Oyj
   - 25.9-26.7 GHz (B) Telia Finland Oyj
   - 26.7-27.5 GHz (C) DNA Oyj

All of the bands have been now auctioned. TRAFICOM has no information concerning operators' priorities on frequency bands or plans concerning C-V2X.

4.4.9. China

In China, on December 6,2018, 5G spectrum has been clearly allocated to MNOs as in the following:

1) China Telecom got 5G test spectrum resources with a total bandwidth of 100MHz from 3400MHz to 3500MHz frequency bands;
2) 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.
3) China Unicom got 5G test frequency resources with a total bandwidth of 100MHz from 3500MHz to 3600MHz frequency bands.
4) China Broadcast Network got 700MHz, and may get 4.9GHz.

Spectrum allocation in terms of network for three operators in China is as follows:

MNO	Network	Spectrum	Up Link	Down Link
China Telecom	5G	3.5GHz	3400-3500MHz	
China Mobile	5G	2.6GHz	2515 MHz-2675 MHz	
China Mobile	5G	4.9GHz	4800 MHz-4900 MHz	
China Unicom	5G	3.5GHz	3500-3600 MHz	
China Broadcast Network	5G	700MHz (or 4.9GHz TBD)	TBD	

4.4.10. South Korea

Ministry of Science and ICT (MSIT) is one of the ministries responsible for science, information, communication technology in South Korea. The MSIT has revealed the details of the winning bids for its sale of spectrum suitable for the planned deployment of 5G technology, with all three of the nation's incumbent MNOs walking away with new frequencies. The regulator noted that, with the auction having been conducted in two phases, the first of these determined the quantity of frequencies each operator would get, with the second determining the position of the spectrum.

SKT emerged as the biggest spender overall, bidding a total of KRW1.222 trillion (USD1.10 billion) for 100MHz in the 3.5GHz band (3600MHz-3700MHz), while it paid a further KRW207.3 billion for 800MHz of bandwidth in the 28GHz band (28.1GHz-28.9GHz). For its part, KT Corp offered a total of KRW968 billion for its 3.5GHz spectrum (3500MHz-3600MHz), although it spent the most of any operator on its 28GHz frequencies, claiming the 26.5GHz-27.3GHz block with a KRW207.8 billion bid. Rounding out the nation's cellcos, LG Uplus spent KRW809.5 billion on an 80MHz block in the 3.5GHz band (3420MHz-3500MHz), and committed a further KRW207.2 billion for its 28GHz allocation (27.3GHz-28.1GHz).

Frequency	Auction Status	Operator
3.42 - 3.5 GHz	Auctioned (2018)	LG Uplus
3.5 - 3.6 GHz	Auctioned (2018)	KT
3.6 - 3.7 GHz	Auctioned (2018)	SKT
26.5 - 27.3 GHz	Auctioned (2018)	KT
27.3 - 28.1 GHz	Auctioned (2018)	LG Uplus
28.1 - 28.9 GHz	Auctioned (2018)	SKT

As per the auction, each operator can use the sub-6 GHz frequencies for the next 10 years and mmWave frequencies for the next 5 years. By the end of January 2020, 5G carried approximately 20% of South Korea's total mobile traffic. The MSIT forecast that 30% of the country will have access to 5G services by the end of 2020 and 90% coverage by the year 2026.

SK Telecom and LG Uplus have successfully tested Standalone (SA) 5G networks and are expected to launch 5G based on SA architecture in the end of 2020.

5. ASSESSMENT OF 5G-MOBIX

The second stage of Task 6.3 is concerned with making a self-assessment of 5G-MOBIX with respect to the involvement of the partners in the relevant SDO activities and the standardisation potential of the technical issues to be encountered during the trials for the use case categories and user stories under consideration in the project. In this section, the preliminary results of this stage is presented.

5.1. Participation of 5G-MOBIX to Standardisation Activities

Following the project trials and pilots, 5G-MOBIX intends to disseminate important results to SDOs, either by the direct participation of involved partners in SDOs or through other partner activities. Table 9 provides a list of 5G-MOBIX partners that are directly involved in various SDO activities.

Table 9. 5G-MOBIX partners' participation to SDOs

Standards Organisation / Alliance	Group (home): Reference	On-going/open items	Involved Partners
3GPP	TSG - SA		
	SA2 - Architecture	Work items	FRAUNHOFER
	TSG - RAN		
	RAN1 - Radio Layer 1	Work items	FRAUNHOFER, TURKCELL
	RAN 2 - Radio Layer 2 & 3	Work items	FRAUNHOFER, AALTO, TURKCELL
	RAN 3 - Iu, Iub, Iur, S1, X2, UTRAN/E-UTRAN	Work items	FRAUNHOFER
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)	ITS Portal	VEDECOM, VTT, Siemens
	Industry Specification Group (ISG) Experiential Networked Intelligence (ENI)	ENI Portal	ICCS (Participant)

	Industry Specification Group (ISG) IPv6 Integration (IP6)	IP6 Portal	University of Luxembourg
	Industry Specification Group (ISG) on Multi-access Edge Computing (MEC)	MEC Portal	AALTO, ICCS (Participant)
	Industry Specification Group (ISG) Network Functions Virtualisation (NFV)	NFV Portal	ICCS (Participant)
	Industry Specification Group (ISG) on Non-IP Networking (NIN)	NIN Portal	ICCS (Participant)
	Industry Specification Group (ISG) Zero Touch Network and Service Management (ZSM)	ZSM Portal	ICCS (Participant)
CAR-2-CAR Communication Consortium	WG Deployment		SIEMENS

Furthermore, partners who are not directly involved in standardisation groups can also contribute through:

a) The identification of unique results stemming from the project activities. All partners involved in the cross-border corridors and trial sites may propose results to be showcased in future activities.
b) Proposing existing standards and recommendations that may impact 5G-MOBIX development.
c) The attendance of partners to workshops, fairs, congresses organised or endorsed by SDOs and the identification of possible impacts to 5G-MOBIX stemming from these events.
d) The participation of partners 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.

A list of related events where partners may participate can be found in Table 10. The list will be maintained during the project lifetime and partners are encouraged to attend or present 5G-MOBIX results.

Table 10. List of events organised or sponsored by SDOs (digital events, due to COVID-19 restrictions)

Organisation	Event
Organised by ETSI	**NG eCall Plugtests 2020 (2-6 Nov 2020)** The Remote NG eCall Plugtests 2020 event will have a specific focus on the interoperability of Next Generation eCall (NG eCall) systems or eCall over Long Term Evolution (LTE), based on the interoperability test descriptions defined in ETSI TS 103 683.
Endorsed by ETSI	**5G India 2020 Virtual Conference & Exhibition** (4 November 2020, event website)
Organised by ETSI	**oneM2M Interop 7 (Nov 16-27 2020)** The purpose of this event is to verify the primitive's interoperability as defined in the oneM2M standards and to check end-to-end functionality on oneM2M interfaces Mca and Mcc. The implementations need to support at least one of the oneM2M protocol bindings (HTTP, CoAP, MQTT or WebSocket). Interoperability test scenarios from TS-

	0013 (interoperability testing) are proposed to participants
Organised by ETSI	3rd mWT Plugtests **(17-19 November 2020)** ETSI is organising the third mWT (millimetre Wave Transmission) SDN (Software Defined Network) Plugtests™ event which will take place from 17 to 19 November 2020. This event will be held remotely. This edition of the Plugtests event will focus on proving the ability of Software Defined Network (SDN) to operate from an end to end service point of view.
Organised by ETSI	OSM-10-Hackfest **(30 Nov - 04 Dec 2020)** ETSI's Centre for Testing and Interoperability and the OSM community are organising the next OSM#10 Hackfest from 30 November to 04 December 2020. The event will be run remotely, allowing participants to join the hands-on sessions from home. The OSM#10 Hackfest will run in parallel with the OSM#10 Plenary.
Organised by ETSI	**Boosting the Impact of Research & Innovation through Standardization (24-25 Nov 2020)** Recognizing the importance of research and innovation in the domain of ICT, ETSI is excited to organize a dedicated online event that will present the latest developments and initiatives from the European Commission, leading research institutes, European Technology platforms and also showcase the tools that ETSI offers researchers to enable them to engage in standardization.
Endorsed by ETSI	**2020 IEEE Conference on Network Function Virtualization and Software Defined Networks (9-12 Nov, event website)** IEEE NFV-SDN focuses on new or novel operational results related to virtualized networks functions (VNFs) as well as designing, describing, orchestrating, and managing new applications enabled by VNF and SDN with the goal to bring improved intelligence into networks and their operation.
Endorsed by ETSI	**TU-Automotive Europe (23-26 Nov 2020, Digital Event, event website)** TU-Automotive Europe is a B2B automotive technology conference and exhibition, offering expert content and networking to 500+ virtual attendees from across the auto tech ecosystem in Europe. It is important that during this time, we continue to come together to Connect stakeholders, to Accelerate business, to Showcase new technology and to Educate each other on the future of mobility.
Organised by ETSI	**Droidcon MEC Hackathon (25-26 Nov 2020, event website)** Develop mobile applications for advanced services in MEC-enabled 5G networks. The droidcon MEC Hackathon was a cutting edge competition designed to test your skills and abilities as a Multi-Access Edge Application developer! Developers also had the chance to gain remote access in advance to real MEC platforms.
Organised by	OSM-10-Hackfest **(30 Nov - 04 Dec 2020)**

ETSI	ETSI's Centre for Testing and Interoperability and the OSM community are organising the next OSM#10 Hackfest from 30 November to 04 December 2020. The event will be run remotely, allowing participants to join the hands-on sessions from home. The OSM#10 Hackfest will run in parallel with the OSM#10 Plenary.
Organised by ETSI	**The ETSI Seminar (10 Dec 2020)** The ETSI Seminar is run twice a year, to provide an intensive course on ETSI, its organization, structure, ways of working and related subjects. It is targeted at those who are new to ETSI or those who need to develop a deeper understanding of how to work effectively in ETSI.
Organised by ETSI	**NG112 Emergency Communications Plugtests #4 (22 Feb-5 March 2021)** ETSI, in cooperation with the European Emergency Number Association (EENA) and NENA: The 9-1-1 Association, is organizing the fourth NG112 Emergency Communications Plugtests™ event to be held remotely with the support of ETSI SC EMTEL. This event will take place from 22 February to 5 March 2021.
Organised by ETSI	**ETSI IoT Week** (details TBD, April 2021)
ITU	At this time, ITU does not have any scheduled public events (Oct 2020)
IETF	At this time, IETF does not have any scheduled public events (Oct 2020)

Next, some of the technical issues that have been encountered and investigated by some of the partners during the trial preparation stage (WP2 and WP3), which are expected to be affected by the standardisation activities, are introduced. These range from multi-SIM support for ubiquitous coverage, MEC discovery services and IPv6 to satellite communications, where the latter has been the subject of "friend or foe?" discussions for some time due to its potential for rivalling/replacing MNOs for mobile broadband services.

5.2. Multi-SIM Support

The FI trial site has a user story "Remote driving in a redundant network environment" (UCC4/US2), whereby, the SAE L4 vehicle trajectory is an area covered by multiple public land mobile networks (PLMNs) or subject to transitions between two PLMN coverage areas. In the multi-PLMN scenario, the vehicle's home PLMN (original serving network) may have locations with poor or non-existent coverage, or then experience V2N connection degradation or failure due to overloading, network failure etc. To guarantee availability of V2N connectivity for remote driving, the vehicle seamlessly switches to (or simultaneously utilises) a visited PLMN, ensuring a safer operation of the vehicle regardless of the instantaneous network conditions.

Connectivity to multiple PLMNs would typically require on board units (OBUs) with multi-SIM ports (one for attaching to each PLMN). Multi-SIM devices have long been on the market, mostly using proprietary solutions from different device vendors without any support from the 3GPP. This has resulted in a variety

of implementations and UE behaviours, which would limit the use of multi-PLMN in critical vertical applications including CCAM. To that end, 3GPP has approved a work item in Release 17 to provide standardisation support for multi-SIM UEs, which can prove beneficial from a performance perspective. Specifically, in 3GPP TSG RAN and 3GPP TSG SA2 are studying the system impact of multi-SIM devices and potential enhancements required within the 3GPP Release 17 framework in "RP-193263 Support for Multi-SIM devices in Rel-17 (LTE_NR_MUSIM)" and "SP-190248 Revised SID: Study on system enablers for multi-SIM devices", respectively.

5.3. Multi-access Edge Computing (MEC) Service Discovery Protocol

Standardisation of multi-access edge computing (MEC) is positioned as an industry specification group (ISG) within ETSI. The Finnish user story on "extended sensors" use case category resorts to the MEC architecture when relaying the location-tagged HD video streams obtained from vehicle(s) to the authorised subscribers of the streams, where the video streams are the sensors extended to other vehicles. For this user story, the edge service discovery protocol runs in the 5GC to reduce latency. The sensor extension system basically follows 3GPP's design guideline for edge computing [22].

The Finnish site has sensors and computation nodes (MECs) running on the user plane and coordinators (MEC orchestrator) running on the control plane. So, the overall infrastructure should be compatible with future 3GPP releases. Although most of the modules in the sensor extension system works purely on the user plane, which will never be affected by the developments within 3GPP, there are some other modules that may be altered. For example, the Finnish partners have proposed a service discovery protocol to help a vehicle find a MEC. This protocol utilizes control plane APIs on equipment registration and requires customization on the UPF, which may be further improved on future releases (e.g., UPF will be enhanced in 3GPP Release 17 [23]). Besides, the project is looking into the opportunity of switching to a multicast-based solution for service discovery because multicast/broadcast will be addressed in 3GPP Release 17 [23].

5.4. The Effect of 3GPP Release 17 on the GR-TR Extended Sensors User Story

"The Assisted "zero-touch" Border Crossing use cases instantiated at the GR-TR CBC targets a more efficient and safe customs inspection process at European borders and customs sites. By utilizing the enhanced capabilities of 5G, the autonomous capabilities of SAE vehicles and cutting edge AI/ML techniques, the platform developed by WINGS ICT Solutions is capable of performing an initial remote inspection of incoming vehicles/trucks and issuing a threat assessment level estimation with the corresponding automated driving commands issued towards the vehicle/truck. The platform utilises information from on-board sensors, distributed heterogeneous sensors at the customs site, customs agents smartphones/tablets and mounted cameras surrounding the customs site. Based on this information and cross-checking with cloud based data bases regarding the manifest/authorizations and legal status of incoming vehicles the threat assessment is performed. Increased safety for customs agents is also delivered as their locations is always cross-checked against the trajectory of incoming vehicles and

autonomous braking/driving instructions are given to the vehicles to avoid potential accidents (URLLC services necessary). Based on this functionality, the following standardisation 3GPP Release 17 Work Items have been identified as relevant for this use case, as they have the potential to help increase the experienced performance in cross-border environments:

- **(840035/890036) Study on enhancements to application layer support for V2X services / Enhanced application layer support for V2X services** → Potential enhancements in V2X application layer support, will likely enable further functionality for this use case broadening its application spectrum.
- **(880029) Enhancement of Handover Optimization** → As this is a use case inherently applicable in cross-border/customs environments, i.e. inter-PLMN / multi-RAT environments, HO optimizations will enable faster transitions among the multiple RATs/PLMNs which will have a significant effect on the QoS provided by this use case when crossing the borders.
- **(870001) Enhancement to the 5GC Location Services-Phase 2** → Potential enhancements in 5G offered location services will enable improved custom agents safety as their location and that of incoming vehicles will be more accurately calculated.
- **(860049) Further Multi-RAT Dual-Connectivity enhancements** → Dual connectivity in cross-border multi-RAT environments is a key enabler for this use case, as service interruptions can be completely resolved or significantly mitigated, offering a much higher QoS/QoE.

5.5. Infrastructure-assisted advanced driving at the French Trial Site

This user story deals with safe lane change manoeuvre assisted by Cloud/MEC under hybrid traffic. The FR TS will demonstrate MEC assisted lane manoeuvres, which consists of two phases:

- **Phase 1:** MEC-assisted lane change manoeuvre at highway entry
- **Phase 2:** Cloud-assisted lane change manoeuvre due to traffic restrictions (prohibited to drive in an autonomous mode).

This use case presents several challenges needing both the eMBB and URLLC features of 5G technology recently defined in the 3GPP standards. eMBB is needed to collect the huge amount of vehicle's sensor data so that MECs can build sufficient extended perception to assist CAVs for safe manoeuvres. Meanwhile, manoeuvre guidance from MEC to CAVs requires URLLC to ensure perfect synchronisation between MEC and CAVs. In addition, in order to build an extended perception necessary to guide CAVs for safe lane manoeuvre, MEC will receive different types of data, particularly vehicles' status data and sensor data from CAVs and roadside sensors through CAMs and CPM messages. In this context, the FR trial site will implement the CPM message format that has recently been standardized by ETSI ITS Technical committee and to which VEDECOM (FR trial site leader) has actively contributed. Once the extended perception is built, the MEC will estimate the risk of collision between the basic vehicle trying to enter the highway and the CAV approaching in the nearby lane. If a collision risk is detected, MEC will calculate the optimal trajectory of CAV (e.g., lane-change) and provide a trajectory guidance to the CAV by sending Manoeuvre Coordination Message (MCM) with a very little latency to secure the lane change manoeuvre

using URLLC service. MCM message format is being standardized by ETSI ITS Technical committee with active contribution from VEDECOM, as well.

In line with 5G concept of network slicing and QoS to cater to different requirements and criticality of communication, the MCM messaging has stronger needs for resilience, redundancy and robustness. In the 5G architecture, this is addressed at multiple levels – including Radio and System. For the radio communication link, high QoS for resilience and redundancy will be delivered through the combined use of 5GNR, LTE and L-Band non-terrestrial bearer. The non-terrestrial (i.e., satellite) communication link will be provided through Iridium1 Next Low Earth Orbit (LEO) constellation, thus ensuring low latency and high reliability, irrespectively of the vehicle location and the coverage provided by the 5GNR and LTE radio access networks (RANs). The architecture for integration of non-terrestrial systems to 5G is being made according to the implementation requirements and access architectures presented in the 3GPP Release 16, which will further be standardized in 3GPP Release 17.

From a security perspective, the 5G communication architectures deployed in different countries could implement different authentication procedures with different security levels. This heterogeneity could lead to incompatibility problems, especially when dealing with the handover procedure at border crossing, and could even be the source of some security threats. To cope with this problem, the French trial site suggests using common trust domain EU CCMS (European Union C-ITS Security Credential Management System). Besides, several cyber-security and privacy aspects are considered such as OBU and network mutual authentication, secure short-range C-V2X PC5 connection using ETSI certificates as well as MEC protection. All these aspects make FR TS approach novel and innovative – building upon the work in progress within the research institutions, industry and standards, indicating a high potential for contribution to standards.

5.6. The Use of Non-Terrestrial Networks (NTNs) in C-V2X Applications

In 5G-MOBIX, the French trial site resorts to satellite communications that is known as non-terrestrial networks (NTN) within the telecommunications community. A closer look at the implications of this decision to tie this technology to the 5G architecture follows.

5.6.1. The need for non-3GPP access standardisation

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 CCAM 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 5GNR 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 architectural solutions and use cases for the integration of satellite and terrestrial connectivity are presented in 3GPP TR.22.822 [24] and TR.23737 [25], where among others, refer to hybrid connectivity, satellite backhauling and inter PLMN coverage. Some of these solutions are also demonstrated in [25], however the resolutions to various issues/use cases will be adapted and applied appropriately to the French trial site 5G CCAM development.

5.6.2. Hybrid Satellite-Terrestrial Connectivity on FR-TS trials

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 Rel.16 on Multi-Access PDU through support of Access Traffic Steering, Switching and Splitting (ATSSS) between 3GPP and non-3GPP access network [26].

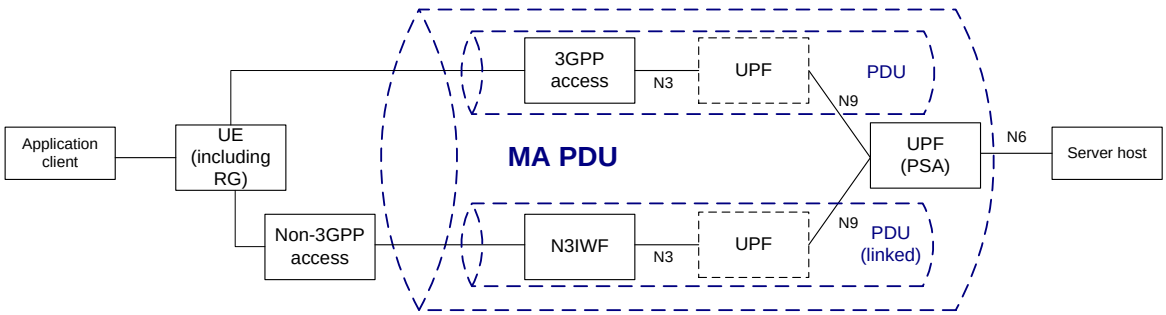


Figure 21. Multi-Access PDU

Due to the lack of N3IWF network function and the lack of support of MPTCP and 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 5GNR 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 artifact.

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 artifact. The architecture to be deployed in the FR-TS is shown in Figure 22. Further features will be added depending on the advances on 5G Core N3IWF functionality and the MPTCP support on the vehicle side.

5.6.3. 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 SSIG (Standards Special Interest Group) since 2018 [27]. The work on the CCAM 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.

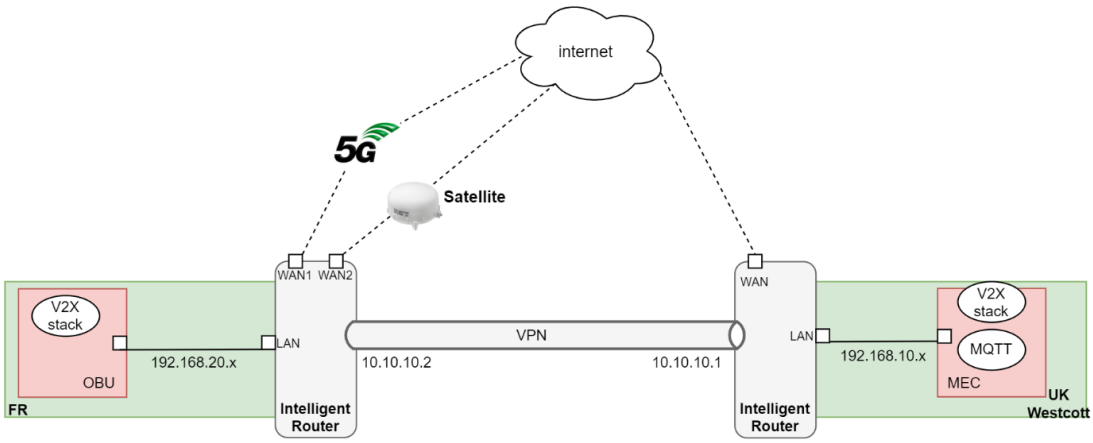


Figure 22. Hybrid 5G-satellite intelligent routing-based deployment at the French test site.

5.7. IPv6-Based Vehicular Networking

Internet protocol version 6 (IPv6) is a new version of the Internet protocol (IP) defined in IETF RFC 8200 and designed to replace Internet protocol version 4 (IPv4). IPv6 provides several advantages that cover important needs in cooperative vehicular communications, such as the large space of addressing due to the exhaustion of IPv4 address space, which impacts the growing of internet continuity. In fact, most mobile terminals will not be able to connect to IPv4 Internet without the intermediate technology called Network Address Translation (NAT), which allows one or more public addresses to serve many private IP addresses. In this context, IPv6 is particularly important because it goes from 32-bit to 128-bit addressing. In addition, IPv6 protocol also brings other numerous benefits such as the improvement of mobility and security services and mainly the addition of node auto-configuration mechanisms to facilitate the configuration of connected equipment. In fact, one of the main functions of an IPv6 node based on its

ability to be configured automatically when its connected to a network using router discovery message ICMPv6 (Internet Control Message Protocol version 6).

In this context, UL has contributed to the standardisation activities of this task by producing an ETSI group report, namely ETSI GR IP6 030 V1.1.1, on IPv6-based Vehicular Networking (V2X) [28]. This document 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.

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

6.1. 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 11) depends heavily on the M2M/IoT use case.

Table 11. Overview of related ITU international standards

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[6] 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[7] (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

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

[7] 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)

including its impact on Number Portability[8] in case of the use of Over-The-Air, i.e. in case of use of eSIM. At the moment, the EU 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.

6.2. 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.

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

- 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.

6.3. Considerations on Spectrum Auctions

During June 2020, EETT launched a public consultation "on the granting of rights of use for radio frequencies in the 700 MHz, 2 GHz, 3400 - 3800 MHz and 26 GHz frequency bands". The results of the public consultation were published in the form of comments provided by various stakeholders in the Greek market, including telco operators, municipalities, software/hardware suppliers, satellite operators and associations such as the European Competitive Telecommunications Association (ECTA) and the EMEA Satellite Operators Association. COSMOTE, a 5G-MOBIX partner was among the stakeholders that participated actively to the public consultation. The comments provide some insight on factors that could delay a spectrum auction and indicate best practices to optimise the process. The following table summarises the stakeholder opinions.

Table 12. Stakeholder comments on the GR public consultation

	Stakeholder Comments
Spectrum	In terms of spectrum, (2) participants asked that all bands be made available during 2020, (1) participant considered that the 700MHz/2.1GHZ,3.6GHz should be made available immediately, while the 26GHz band can be discussed in the future. (1) participant has suggested that the spectrum fragments to be auctioned should be as continuous as possible, while another participant suggests at least 100MHz of continuous spectrum at the 3.6 GHz band.
Satellite Communications	(1) participant has suggested that sustainable 5G with maximum coverage can only be achieved by leveraging satellite communications. (1) participant has suggested that the Hellenic State should ensure the safety and security of its satellite constellation, as defined in the contract between the satellite operator and the State.
Infrastructure	(1) participant suggested that new licenses for the deployment of antennas for telcos that are moving to new spectrum bands should not be required (1) participant suggested that the licensing process should be simplified and

	accelerated, and that new rules specific to 5G should be put in place and enacted. (1) participant suggested to review current telco limits with respect to coverage and power to ensure no unnecessary rules are applied, while another participant disagreed with the existence of any limits that affect deployment whatsoever.
Spectrum Auctions	(5) participants have commented on the spectrum pricing, its relation to the telco operators plans for future investments and the terms of the payment. Specifically, they have suggested: • A long-term plan for payment incentivises telco operators to make investments on infrastructure and equipment. • Pricing that is competitive in terms of the international benchmarks. • Fair and balanced assignment of spectrum, particularly in the 700MHz and 2.1 GHz bands (1) participant has suggested that spectrum auctions should be optimised and the process should be re-examined. The State should create the appropriate conditions for: • the existence of a new telco provider by reserving spectrum, • Ensuring international cooperation to enable roaming agreements, • Ensuring the viability for the creation of 5G Mobile Virtual Network Operators (MVNOs) through capacity sharing or wholesale-only models, • Ensuring additional spectrum/frequencies can be made available or leased in the future. (3) participants have suggested that the State should provide a clear and binding plan regarding spectrum availability, clarification of the process for gaining access to new spectrum, and a timeline to solve current issues (co-existence with other services like digital broadcasting, re-farming/defragmentation etc.). (1) participant considers that up to 3-4 years might be required to move existing services away from the 26GHz band, before licensing the 26GHz band.
Other	5G Security needs to be addressed. The European 5G Security Toolbox[9] should be taken into account. Discussion on verticals is considered premature at this stage.

[9] Q&A on the European 5G Security Toolbox: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_127 (Accessed August 2020)

The document proceeds with posing specific questions to be elaborated by the related stakeholders. The stakeholder inputs have revealed some common barriers with the potential to cause delays in 5G deployments and proposed some high-level actions to alleviate those barriers:

- The need for spectrum **defragmentation/re-farming** could delay spectrum auctions.
    - A **specific plan** needs to be in place from any member state prior to the spectrum auctions to enable telco operators to make appropriate plans for 5G deployments.
- The process for **spectrum auctions should be optimised and a flexible mechanism** should be in place to enable leasing of additional frequencies.
- **Simplified and accelerated licensing processes** for the development of infrastructure (e.g. antenna placement etc.)
- **Cross-border harmonisation** issues may arise in cases of countries that do not implement the ECC/DEC/(15)01 decision on "Harmonised technical conditions for mobile/fixed communications networks (MFCN) in the band 694-790 MHz including a paired frequency arrangement (Frequency Division Duplex 2x30 MHz) and an optional unpaired frequency arrangement (Supplemental Downlink)" e.g. Bulgaria.
- Coexistence with other services like **digital television and PPDR** should be taken into account.
- **Coexistence** of 5G base stations with satellite ground control stations should be taken into account, to ensure that no harmful interference is present. For example, a base station for 2.1GHz should not be placed near a ground control station operating on the S-band.

7. CONCLUSION

This document introduces the plan and preliminary report for the standardisation and spectrum allocation needs of the 5G-enabled CCAM 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 early-to-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 CCAM 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
2. Self-assessment of 5G-MOBIX partners, trials and user stories
3. Development of recommendations based on 5G-MOBIX outcomes
4. Validation and exchange of views 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.

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 CCAM 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.

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. This stage will necessitate extensive work to investigate what has already been done by the organisations, as well. The project will ensure that this stage is executed with the involvement of a large number of partners from the project that will continue with developing recommendations and requirements.

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