5G key technology enableRs for Emerging media COntent pRoDuction services

Deliverable D2.2

Regulatory framework and business models for 5G content production

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Editor(s):	Darko Ratkaj (EBU)
Authors:	Antonio Garcia (ACC), Simon Eley, Ian Wagdin (BBC), Mika Skarp (CMC), Paola Sunna, Darko Ratkaj (EBU), Thorsten Lohmar (Ericsson), Manuel Fuentes, Héctor J. Donat (5CMM), Baruch Altman (LU), Pablo Perez (Nokia), Luca Vignaroli (RAI), Pierre-Jean Muller, Meryem Messaoudi, Christophe Le Thierry d'Ennequin (RED), Maria Perez, Jan Dürre, Norbert Werner (SENN), Rocio Ortiz (TID), Cristina Avellan, Irene Alepuz, Adrián Rodrigo (UPV).
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[1] CO = Confidential, only members of the consortium (including the Commission Services)
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Abstract

This deliverable describes the ecosystem for using 5G in professional content production, provides elements for a business validation and identifies the regulatory framework.

Within the ecosystem the main actors and their roles have been defined. 5G-RECORDS partners were situated within the ecosystem while their exploitation plans define their respective roles, in particular with regard to 5G components developed within the project.

In the business validation framework the emphasis was put on the value that 5G might bring to different actors in the ecosystem. It was noted that 5G as a technology allows for flexible implementation in networks and devices. Different network configurations have been examined with respect to their ability to meet the technical requirements and business objectives of different actors in the production workflows. Furthermore, there are substantial differences between different actors such as MNOs and content producers with regard to their incentives to implement particular functionalities in the networks. Some technical solutions are already commercially available, while others are not.

The currently available data does not allow a quantitative business analysis to be carried out.

In professional production workflows 5G would provide advanced connectivity and would be used alongside other wireless technologies as well as cloud and MEC solutions. Therefore, interoperability will be very important.

The regulatory framework includes a number of different kinds of regulation such as spectrum access and licensing, network-related regulation (e.g. roaming between networks, numbering, traffic prioritisation and network neutrality, and planning permissions requirements), privacy and data protection, security, and EMF exposure limits. Not all regulation is equally important for all production use cases.

Spectrum access and licensing options for 5G NPNs were discussed in greater detail. This includes novel approaches to spectrum sharing such as secondary licensing and eLSA. Furthermore, key requirements for NPNs intended for PMSE use have been identified, resulting in a set of recommendations to the European regulators.

Keywords

5G, content production, regulation, business models

Executive Summary

5G has the potential to play a role as a wireless component in IP-based content production workflows. As a technology, 5G can be deployed in different ways and tailored to different technical and operation requirements. This is an important factor as there are many different types of production and the flexibility of 5G enables support of different production use cases. The three use cases described in the deliverable D2.1[2] are good examples but there are many more.

In professional production workflows 5G is expected to provide advanced connectivity. Furthermore, interoperability between 5G and other technologies, such as cloud or MEC, is crucial as 5G alone cannot support the entire workflow.

The use of 5G in content production would need to create value for all stakeholders in the ecosystem. Benefits for content producers and broadcasters may come not only from the expected costs savings but also from new opportunities that 5G may provide. This could include the ability to produce a wider range of content in an innovative way.

Both 5G PLMNs and NPNs are important in content production. Different network configurations are used for different purposes as no single solution can support all production use cases.

At present, some network configurations and capabilities are already commercially available while others are not, despite being standardised. One reason for this is that a particular solution may be more or less attractive to different stakeholders depending on their business objectives. For example, with regard to QoS-enabled networks, the MNOs' perspective may be different from the broadcasters' or content producers' perspectives.

This leads to a conclusion that besides technology maturity, viable business cases are essential to facilitate the use of 5G in content production.

Furthermore, the adoption of 5G in content production is dependent on the regulatory conditions. There are many different areas of regulation that may be relevant, including spectrum access and licensing, the rules governing network roll-out and service provision, network neutrality and traffic prioritisation, numbering, privacy and data protection, security, and EMF exposure limits. The relevance and impact of a particular area of regulation depends on the type of production use case and the type of 5G deployment. For example, some regulatory issues such as access to spectrum are relevant in all cases while others, such as numbering or roaming regulation will only apply to the interconnected 5G networks.

Some regulation may need to be further developed to be better suited for the production requirements, in particular with regard to spectrum access for 5G NPNs. Beyond the specific technical and operational requirements, regulators and policy makers should also consider the long-term viability of the frequency bands, the availability of 5G hardware, and any constraints inherent in the technical conditions within the band (e.g. duplex arrangements).

The regulators are also encouraged to consider novel approaches to spectrum licensing, such as secondary licensing and eLSA in order to improve the availability of spectrum for 5G NPNs, including for temporary and ad-hoc production use cases.

[2] Deliverable D2.1: Use cases, requirements and KPIs, https://www.5g-records.eu/Deliverables/5G-RECORDS_D2.1_v1.0_web.pdf

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List of Acronyms and Abbreviations

Acronym	Definition
5G NR	5G New Radio
ARPU	Average Revenue Per User
AV	Audio and Video
BEM	Block Edge Mask
BMC	Business Model Canvas
CEPT	European Conference of Postal and Telecommunications Administrations
CBRS	Citizen Broadcast Radio Service
DTT	Digital Terrestrial Television
EC	European Commission
ECC	Electronic Communications Committee of CEPT
eLC	eLSA Controller
eLR	eLSA Repository
eLSA	evolved Licensed Shared Access
eMBB	enhanced Mobile Broadband
EMF	Electromagnetic field
ENG	Electronic News Gathering
ESC	Environmental Sensing Capabilities
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FVV	Free Viewpoint Video
GAA	General Authorization Access
ICT	Information and Communications Technology
IMT	International Mobile Telecommunication
ISM	Industrial Scientific and Medical (frequency bands)
IoT	Internet of Things
KPI	Key Performance Indicator
LSA	Licensed Shared Access
LTE	Long Term Evolution
MEC	Multi-access Edge Compute
MNO	Mobile Network Operator
NPN	Non-Public Network
NRA	National Regulatory Authority
O-RAN	O-RAN Alliance is a specification group defining next generation RAN infrastructures
OAI	Outgoing Access, implicit outgoing access for all communications
OB	Outside Broadcast
OSA	Open Service Access
PAL	Priority Access Licence
PLMN	Public Land Mobile Network
PMSE	Programme Making and Special Events
PNI-NPN	Public Network Integrated Non-Public Network
PPDR	Public Protection and Disaster Relief
PTP	Precision Time Protocol
RAN	Radio Access Network
RF	Radio frequency
SAS	Spectrum Access System
SATCOM	Satellite Communications
SDL	Supplementary Downlink
SDN	Software Defined Network
SDO	Standard Developing Organisation
SMPTE	Society of Motion Picture & Television Engineers
SNPN	Stand-alone Non-Public Network

SRD	Short Range Device
SUL	Supplementary Uplink
SLA	Service Level Agreement
SWOT	Strength, Weakness, Opportunity and Threat
TDD	Time Division Duplex
UHF	Ultra High Frequency
URLLC	Ultra Reliable and Low Latency Communications
VNF	Virtual Network Functions
vRAN	virtual Radio Access Network
MFCN	Mobile/Fixed Communication Networks

1 Introduction

Content production and creative industries have been using wireless technology for decades, in particular relying on wireless microphones and cameras to enable unrestricted mobility. Sports broadcasting is also increasingly using wireless tools for high-value productions.

Wireless production tools have enabled a lot of flexibility for theatres and television production. As the Programme Making and Special Events (PMSE) equipment evolved, it became increasingly capable of supporting complex production workflows, including not only audio and video signals but also different controls, telemetry, and other data. At the same time professional production companies developed their in-house competence in setting-up and operating the network infrastructure designed to meet the production requirements. This includes licensing and managing the radio spectrum for PMSE. The network infrastructure would typically be a mix of different technologies (wired and wireless, terrestrial and satellite) and in some cases would also rely on public telecommunications networks.

However, while the state-of-the art PMSE equipment meets the most demanding production requirements, it also has its limitations. Links tend to be unidirectional and carry only one type of signal. This means that dedicated links may be needed for audio, video, data, as well as for the reverse control, internal communications, and status feedback. These different radio links operate across different frequency ranges. Integration between wired and wireless components can also be a challenge, which adds complexity and latency. All this may also result in increased production costs.

In the wired domain, content production is increasingly adopting IP-based solutions that offer greater flexibility (e.g., a single connection can carry a diverse range of bidirectional signals that do not need a dedicated connection for every signal type) and enable software-based engineering solutions. This is coupled with the adoption of cloud-based workflows. Instead of relying on dedicated and permanent resources, content producers obtain part-time access to compute resources in the cloud, provided on demand only where and when needed. It is also possible to scale up or down the cloud resource, in line with the needs of the production. Conventional wireless PMSE equipment is not easily integrated in the newer IP-based workflows. Furthermore, the available frequency spectrum for PMSE has been significantly reduced in the recent years and this trend might continue in the future.

As a result of these challenges, the professional production industry is looking for potential new technological solutions that would facilitate the transition to IP-based workflows and ensure access to the radio spectrum in the long term. 5G is a candidate technology to be used in professional content production. However, it has initially been developed for different purposes and is targeting different use cases. There are on-going R&D and standardisation efforts to identify and accommodate the technical and operational requirements that 5G would need to meet in content production. There are also numerous tests and trials to determine where the practical opportunities and limits are. These are collaborative efforts between the telecommunications industry and the content production industry.

It can be expected that, over time, 5G systems will be increasingly capable of meeting the demanding production requirements. However, it will be essential to implement the necessary features in 5G networks and equipment. For this to happen, the incentives across the content production value chain need to be aligned.

At this stage it is not possible to quantify the full business potential of using 5G in professional content production. Nevertheless, it can be anticipated that, in addition to new technical solutions, new business models will be needed and they will include stakeholders from both the telecommunications and the content production industries. Furthermore, innovative models for access to radio spectrum may also be needed. This deliverable seeks to elaborate on two different issues: (1) identify the relevant regulatory framework, and (2) gather the necessary elements for business analysis of 5G-based content production. The actual business analysis will take place on a later deliverable (D2.3).

2 Definitions

Term	Definition
Best-effort service	A connectivity service without guarantees that any quality assurance requirements (e.g. those concerning throughput, latency, jitter, error rate) will be met.
Over-the-top (OTT)	Provision of content or services over the Internet directly to consumers without a commercial arrangement between the service provider and the internet service provider (i.e. 'over-the top of the ISP's infrastructure and the internet access'. OTT services are provided on a best-effort basis.
Quality of Service (QoS)	Network technologies that aim to ensure that certain quality assurance requirements will be fulfilled, e.g. minimum throughput, maximum latency, jitter and error rate. This is achieved by differentiating between multiple traffic flows and prioritising certain traffic flows over the others in terms of capacity allocations and the order in which packets are handled by the network.
Fronthaul	The transport network at that connects Radio Units to Distributed Units located at a remote side or edge sites in a disaggregated RAN to balance the latency, reliability and throughput demands of the mobile network. (see Figure 1)
Backhaul	The transport network that connects the RAN part of a network (namely the Centralised Unit) to the Core. (see Figure 1)
Midhaul	The transport network that connects the Centralised Unit with the Distributed Units in a disaggregated RAN network. (see Figure 1)
Spectrum lease	An arrangement between the lessor and the lessee for using parts of the spectrum in a particular geographical area over a period of time. It is identified by: • A duration in time • A geographical contour • Its associated lessor
Spectrum licence holder (lessor)	An entity holding individual rights of use (licence) a certain spectrum resource, which leases out parts of his licence to a lessee under a lease, it can be either a local licensee or an MNO who has available spectrum at the time and location of the event.
Spectrum lease holder (lessee)	An entity which holds right of use to a certain spectrum resource from a lessor under a lease, it can be the production event organizer (e.g. a festival).
OB van	A vehicle used in 'outside broadcast' that serves as a mobile remote broadcast television gallery. Signals from camera and microphones come into the OB van for processing, recording and possibly transmission to the studio or other production facilities.

The figure below clarifies the relation between front, mid and backhaul definitions.

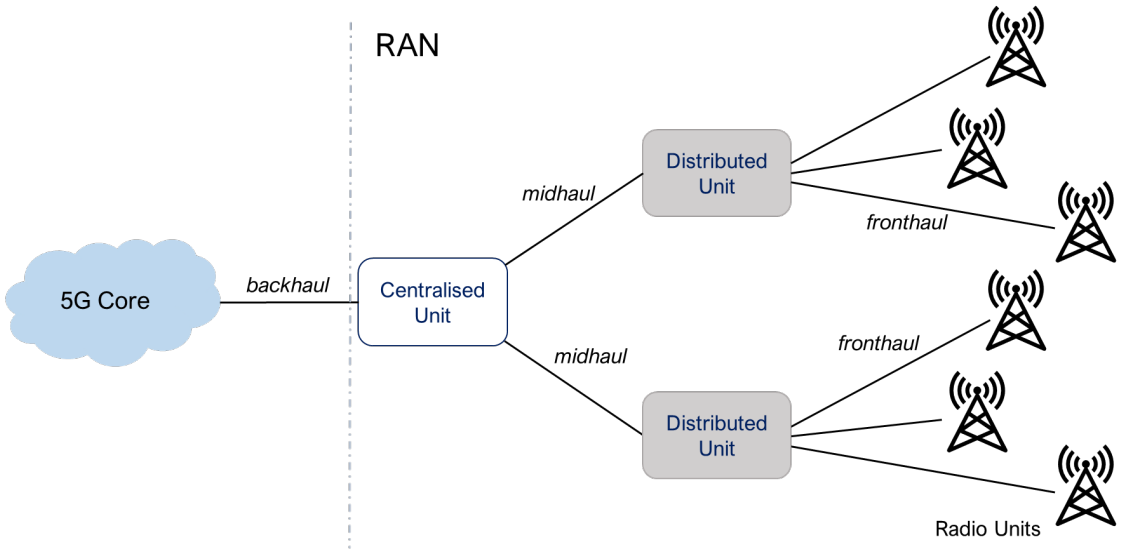

Figure 1: Disaggregated RAN

3 5G-RECORDS ecosystem

3.1 The 5G-RECORDS ecosystem

The value creation in the telecommunications market is no longer limited to a few players in a closed market. New actors, roles and relationships have evolved and become part of the ecosystem. This process is further facilitated by the introduction of 5G and the wider availability of advanced technologies, such as cloud, MEC, and IoT. Each actor must understand its position and its role in the ecosystem in order to be able to increase its value and maximize the potential revenues and/or benefits.

Professional content production is a complex vertical sector where the roles can be distributed among actors in many different ways.

Some roles are closely associated with a particular actor (e.g. equipment development and manufacturing) whereas other roles can be associated with different actors (e.g. spectrum may be licensed to the venue owner, or to the network operator, or to content producer).

At the same time, some actors can take on different roles. For example, a telecom network operator can provide both PLMN as well as NPN or can lease the spectrum to a third party NPN provider. Broadcasters may commission content from content producers or in some cases produce content themselves. It is also possible that NPNs are self-provided by broadcasters or content producers, or by a third party which then acts as a network provider. These networks may be deployed on the infrastructure owned by the venue owner which may be different from the producer, or the broadcaster.

Public networks may also be used where an NPN cannot be set up or too expensive to do so. LTE/4G networks have had their performance limitations. 5G networks, including public ones, will extend the envelope and hence enhance the support for remote production over cellular.

Such different arrangements are quite common in the current content production sector and it is expected that additional flexibility will be obtained by the adoption of 5G.

This section describes the main actors considered in the 5G-RECORDS project in the context of how content production should scale out as 5G becomes more widely adopted.

Equipment manufacturers / vendors

This actor includes the entities that provide the necessary equipment that make up the 5G-RECORDS technology stack, for the use of other actors involved in the 5G-RECORDS project. The equipment normally comprises hardware and its associated software. In 5G-RECORDS it may be useful to distinguish between telecommunications network equipment (e.g. ICT-related like servers, hard disk drives, RAM etc., networking equipment like routers and switches, and radio equipment like for small cells) and broadcast equipment associated with content production (e.g. cameras, lights, microphones, sensors etc.) and specialist equipment (e.g. media gateways and orchestrators). This actor further includes vendors providing devices for end users such as mobile phones, tablets, modems and wearable devices that allow the delivery of enhanced 5G services.

In a broader sense, this category also includes software developers who develop the necessary software as well as the Virtual Network Functions (VNFs) for the delivery and provision of 5G services. The VNFs can be classified as (i) those that are necessary for the delivery of the service and (ii) the ones that are complementary and are tailored to fulfil the requirements of users such as the media vertical. This type of actor also includes entities that create applications that can benefit from the 5G-RECORDS architecture, for example gateways, video analytics or camera controls.

Infrastructure Facility Providers and Venue Owners

These entities own the infrastructure that can be used for hosting the compute, storage, and passive network components. The available resources may include space in street cabinets, lamp posts or buildings along with power supply and connectivity facilities, but also dark fibre or transmitter towers. These are necessary to power and interconnect the ICT equipment.

Venue owners such as sports arenas, theatres, or festival places increasingly invest in network infrastructure and connectivity on location, often within the venue itself. These facilities are then made available to other actors in the content production workflow.

Network Operators (ICT infrastructure providers)

This category includes all types of network operators including mobile and fixed, cloud providers and data centres that own the physical resources of the network. It includes MNOs, which operate PLMNs, and SNPN operators. SNPN operators may hold a spectrum licence themselves or may use the spectrum that has been licensed to other stakeholders, such as broadcasters or other content producers, infrastructure facility providers or venue owners. Broadcasters and content producers may build and operate SNPNs themselves

Service Providers

These include entities that use network resources to create and provide their own services for content production. They may, or may not, own the network infrastructure. In the latter case they may enter into Service Level Agreements with Network Operators to get access to the physical and virtual resources. By taking advantage of the 5G-RECORDS architecture, content production service providers have a pool of different type of resources that they can select and use to develop new and innovative services. The type of services they offer can be connectivity or Internet access supporting the content production use cases or perhaps editing software hosting on MEC. Content Providers may self-provide such services (DIY Model) or commission them from the third parties ('aaS' Model).

Content Producers

These actors use the network architecture for producing audio-visual works in television, radio, music and video. Production teams consist of technical staff who are responsible for the technical aspects of creating a particular product, as well as operating user equipment, and also the editorial staff who are responsible for the creative output, including the producers, designers and directors. Typically, the workflow is dependent on a particular type of production and in some cases could be very complex.

Broadcasters and other distributors of AV services often act as content producers themselves in addition to commissioning content from independent producers. From a network perspective, content producers are also seen as End Users.

Regulators

The regulator's role is particularly important in provisioning the necessary radio spectrum and issuing authorisations for spectrum use. They are also in charge of applying other relevant regulation, as described in chapter 5.

End Users

This term covers a wide range of users in particular the users of equipment and services across the 5G-RECORDS ecosystem. In professional content production the end-users are, ultimately, the content producers and broadcasters.

Some of the main business relationships in the 5G-based content production ecosystem are illustrated in Figure 2.

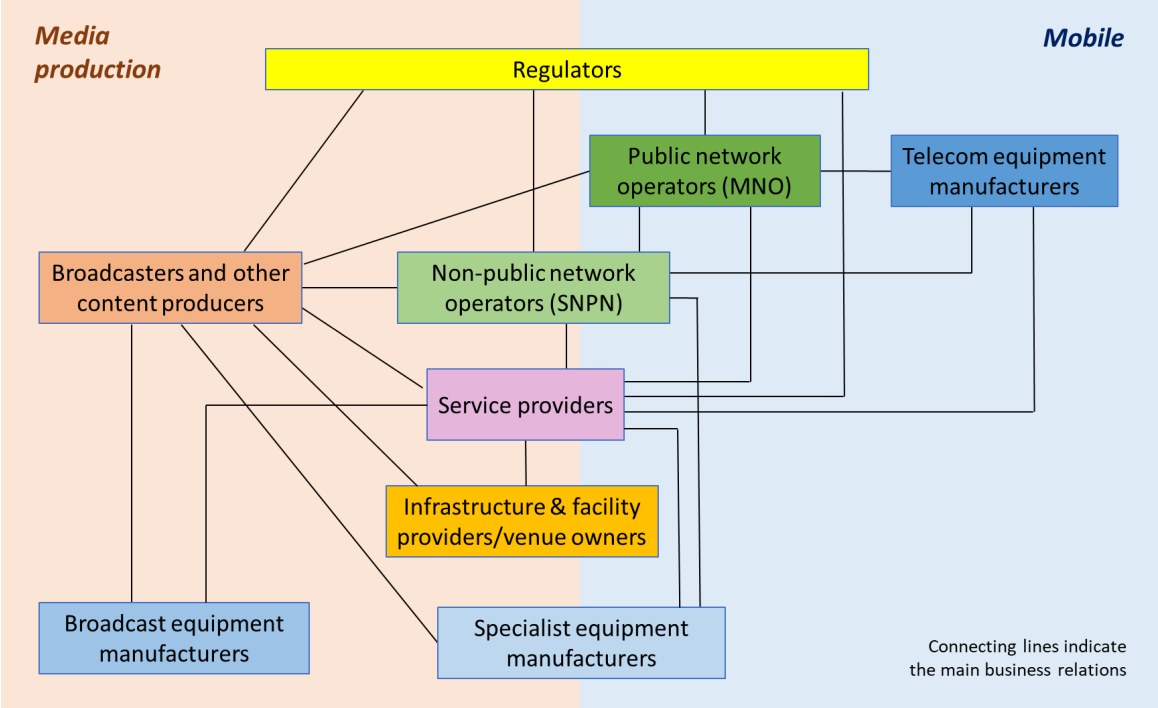

Figure 2: Business relationships in the 5G-based content production ecosystem

3.2 5G-RECORDS partners' roles in the ecosystem

The table above present the roles of 5G-RECORDS partners in the ecosystem.

Role	Partners
Equipment manufacturers / vendors (including providers of software solutions)	Aelleran, bisect, EURECOM, Cumucore, ERICSSON, image matters, Fivecomm, LiveU, NOKIA, RED TECHNOLOGIES, SENNHEISER, POLITÉCNICA, UNIVERSITAT POLITÈCNICA DE VALÈNCIA
Infrastructure and facility providers and venue owners	

Network operators (ICT infrastructure providers)	Telefónica
Service providers	BBC EBU Rai TV2
Content producers	BBC EBU Rai RED BEE TV2
Regulators	
End users	

3.3 Project partners' exploitation plans

SMEs providing 5G components

Accelleran

Accelleran is interested in extending and updating their dRAX cloud native RAN platform based on a 5G-SA Release 15 eMBB baseline towards the support of the low latency services required by the audio content production use case while leveraging a disaggregated open RAN aligned O-RAN Alliance architecture. 5G-RECORDS will enhance that opportunity whilst also developing market specific experience and credibility in the AV content production vertical. The stringent requirements and KPIs of the use case are expected to be directly applicable to the needs of additional verticals, expanding the market addressability of future commercial offerings of Accelleran. As shown in other H2020 projects, the networking and joint exploitation opportunities with other 5G-RECORDS consortium partners is expected to benefit Accelleran in growth to scale-up the business and revenues.

Cumucore

Cumucore will provide 5G SA to be used in non-public network use cases. These use cases are very demanding from latency or capacity perspective. Dynamic Network Slicing functionality will be implemented in a micro 5G environment together with MEC functionality. MEC together with dynamic Network Slicing will provide best possible latency performance together with high and predictable Quality of Service data flows. Cumucore intends to strengthen its role as provider of micro-mobile packet core, targeted to industrial deployments, private networks, small or medium MNOs. The project will help Cumucore to extend its current expertise on SDN networking and mobile core into the radio interface and cooperate with other partners to deliver end-to-end systems.

Fivecomm

Fivecomm will expand its portfolio thanks to 5G-RECORDS, helping its customers in selecting the optimum media solutions for their needs. During the project, Fivecomm will develop, integrate, and validate, in the context of the wireless studio use case, a compact and flexible 5G modem that provides wireless connectivity to the professional cameras via its integrated or external antennas. The 5G modem is NSA and SA compatible, while working in mid-band frequencies. The objective is to provide a commercial solution that connects via Ethernet to the video encoding/decoding modules, so professional cameras have real-time access to 5G. This enables new business models that will permit Fivecomm to compete in the professional content production industry.

Image Matters

Image Matters, thanks to the 5G-RECORDS project, aims at developing the OAK module and integrating it into the 5G infrastructures provided by other partners in order to validate it. The solution to develop also includes SDR equipment. The validation during the 5G test beds will enable IM to provide a commercial version of the module to camera manufacturers.

LiveU

LiveU is the pioneer and global leader in live video delivery over bonded cellular connections, revolutionizing news gathering from traditional SATCOM. LiveU intends to exploit the tests and experiences that will be achieved in this project to enhance the performance of its video transmission products, bonding and single modem, of its “at home” and “Remote production” solutions, and the remote control of studio equipment. Integration with leading broadcasters in such NPN and cloud production are also important for our solutions improvements.

RED Technologies

RED Technologies will explore new approaches to spectrum sharing, in particular based on leases, and will identify which ones best answer the needs of different actors (in particular PMSE and verticals) and which ones are the most realistic both technically and in terms of business models.

RED Technologies wish to promote the most relevant approaches within regulation organizations, standardization, and the industry.

Cellular network infrastructure providers

Ericsson

Ericsson is a world leader in mobile communications technology and services with headquarters in Sweden. Ericsson Research provides system concepts, technology and methodology to secure long-term competitive product provisioning, having a long-standing contribution to 3GPP. Ericsson Aachen is the largest Ericsson R&D site in Germany and hosts more than 100 workshops per year with network operators, vertical industries, and academia.

Ericsson will provide their end-to-end network infrastructure, contribute to concept development in 5G-RECORDS and exploit their technical solutions. Insights will be presented to the business units and will thereby have an impact on future product decisions that target the vertical use cases. Further, promising concepts and solutions will be contributed to relevant standardisation bodies such as 3GPP or others. As part of the external dissemination, Ericsson plans to feed results and findings of the 5G RECORDS project into the on-going 3GPP Release 17 standardisation work. Other research results will be published via scientific conferences.

Nokia

Nokia is interested in exploiting the general results of the project to improve existing business solutions and to reduce CAPEX and OPEX of production labs, providing potential for more economically efficient 5G solutions, services and products to customers. In 5G-RECORDS, Nokia is pioneering the experimentation with millimetre wave 5G, building a novel design which combines high-throughput RAN, Fixed Wireless Access CPEs and GPU-powered MECs. The resulting blueprint design will support high throughput (with special focus in the uplink), low latency and high processing power, as well as flexibility for the deployment. This design is suitable for several use cases which include real-time video capture and processing workloads, such as smart venues, and it can be applied both to MNOs and NPNs. The results of the project, particularly in terms of the relationship between the network design and the Quality of Experience perceived by the users, will be contributed to SDOs such as the Video Quality Experts Group (VQEG) and ITU-T.

Mobile network operators

Telefonica

Telefonica, the leading Spanish MNO, recognizes the opportunity in 5G-RECORDS to improve and develop their 5G connectivity and edge computing solution. Telefonica foresees 5G being the enabler for flexible deployments on affordable infrastructure and open source solutions and also a key enabler of new services and revenue streams.

PMSE industry

Sennheiser

Sennheiser will focus on technical and practical feasibility of integrating audio PMSE applications into the 5G ecosystem. The results of 5G RECORDS will strengthen Sennheiser's understanding of the 5G standard, of possibilities, implications and trends. Sennheiser aims at integrating first audio PMSE applications into a 5G system and testing its performance under lab and real-life conditions. Key issues are latency and reliability concerning the wireless connections. Test results will influence the development of future technology roadmaps of audio PMSE. Understanding the possibilities given by the 5G technology will trigger new developments of business models in the PMSE industry. Moreover, this project allows Sennheiser to reach out to other stakeholders from content production and distribution as well as cellular, getting more understanding of future business arrangement, role models and use case requirements. Within the project, Sennheiser targets to expand its wireless microphones and audio applications and to challenge 5G technology with new URLLC applications.

Broadcasters and content producers

BBC

BBC R&D has a strong record of exploitation of research results and development of open standards and research activities conducted in co-operation with university departments and industry. It is expected that the work conducted in the context of the project will enable the BBC's planning of services related to content production. They also recognise that spectrum currently allocated for PMSE use is under threat as we move to an IP distribution model, so we need to explore alternative ways of producing content that compliments existing workflows. BBC will also have a direct exploitation route within 5G-RECORDS by means of contribution to standards, providing a voice for public and private sector media production companies to ensure that content production can remain world class as we move to an IP based world. It will strengthen the competitiveness of the European media sector, ensuring that the results of European leading researchers and innovators in the 5G community can reach end users. As an end user of production technology, the BBC is particularly interested in how we can harmonise our IP based wired production solutions with emerging wireless technologies. This will enable us to deploy infrastructure on demand and offer more flexible, reliable and mobile production workflows.

RAI

RAI will leverage the 5G-RECORDS project to gain knowledge about new features offered by 5G technology in the areas of the television production, using the 5G network and features to implement remote and distributed production, in particular: (i) knowledge in IP-end-to-end highly distributed broadcast production workflow, cloud/edge-based video and audio encoding, in the 5G era; (ii) integration of the media company production workflow with new distributed edge network and computing technologies.

For RAI 5G technology is expected to build on and integrate the previous generations of wireless networks supporting the expected broadcasters' mobile data growth, and at the same time will allow new services for final users and advertisers. 5G will bring network performance enhancements and agility in the network characteristics, and with that, will play an important role in supporting the growth and development of many industries, the broadcasting and media factories included. More in general, RAI will leverage the 5G-RECORDS project to gain knowledge about the 5G service layer, that will be precious also for future works (research and industrial) in the environment of new generation networks and to study the impact of these technologies in the broadcaster production workflow.

EBU

The EBU is an association of public service media providers and it facilitates collaboration between its members as well as with wider industry, SDOs and academia. The use cases related to content production are well aligned with a number of ongoing EBU activities such as the 5G for Content Production evaluation group and the work conducted on IP studios, including PTP for synchronisation and in particular the definition of a media services orchestration layer.

Technical results and the experience gained from this project will also be used to assist its members in their strategic decisions for the adoption of 5G and the interaction with SMPTE 2110 IP based implementation projects. 5G-RECORDS will help to develop innovative 5G-enabled use cases and applications, to identify priorities for further R&D and standardisation efforts and to assist in engaging with the industry partners and the regulators on issues beyond the technical aspects, i.e., 5G deployment models, business arrangements and regulatory conditions.

5G will serve a large portfolio of vertical markets with different requirements ranging from high reliability to ultra-low latency. The EBU participation in the project ensures that the editorial and corresponding technical requirements for multi-camera production scenarios will be taken into account and measured through specific KPIs.

TV2

TV2 looks to the outcomes of the 5G-RECORDS project to improve their operation and broadcast production. In addition, 5G-RECORDS outputs are expected to have significant impacts for TV2, as live events are more easily, sustainably and efficiently enabled, invigorating linear schedules and supporting small niche output. In this sense, the 5G-RECORDS project will help TV2 to increase their knowledge on 5G components for multiple cameras and remote production.

Research and academia

EURECOM

The equipment and software developed by EURECOM in the context of the 5G-RECORDS project will be made available in the public-domain for future use in collective initiatives. In particular, the software generated during the project will be contributed to the OSA to allow for its use in future collaborative projects and by industry and academia around the world. EURECOM will participate to the 3GPP RAN meeting and plenaries, contribute to the 3GPP Rel-17 and -18 Study and Work Items and submit patent applications related to the UC1. EURECOM will also publicize the development through official communications in the context of OSA events and publications as well as industry-driven events (Mobile World Congress, NGMN Conference and Exhibition, ETSI-sponsored events, ITU conferences). Moreover, developments in the context of 5G-RECORDS will be followed as official projects within the OSA and regularly communicated on the OAI developer meetings and mailing lists.

UPM

As well as teaching, Universidad Politécnica de Madrid is highly interested in participating in the exploitation of the outcomes of R&D projects in which it is involved. UPM expects to further improve its understanding of the new possibilities that 5G offers to alleviate deployment, interconnection and transmission challenges associated with the stringent latency and data rate requirements of FVV systems. UPM will also exploit the experience obtained during the deployment and operation of the FVV system in actual scenarios with a twofold objective of improving the performance and quality of the FVV system and widen its portfolio of scenarios where FVV broadcasting is of interest to final users. These results and knowhow will be adapted and included to enhance its research activities and used as background knowledge for new project proposals, copyright and patent issues.

UPV

Universitat Politècnica de València will exploit the results and experience gained from the project in further expanding their knowledge base in the field and staying competitive for future wireless research initiatives. This will be through enhancing their teaching scope and quality by introducing new project findings and cutting-edge technologies into the teaching and research syllabus at undergraduate and, postgraduate teaching and research. UPV plays a central role in expanding the knowledge and, teaching and training future engineers working in the fields of telecommunications.

They also have the leading role in disseminating research results in major scientific venues. To remain competitive for future research project calls, universities also to expand their circle of competence and deepen their understanding of future broadcast and multimedia challenges.

4 Business validation framework

The purpose of business validation is to assess whether a certain system design is appropriate for the purpose and meets the business requirements within given constraints.

Professional content production is a well-established sector where business relationships can be rather complex. 5G has the potential to impact the business aspects in different ways, for example by changing the economics of some production scenarios, increasing flexibility, or by providing new production opportunities. 5G is also well-placed to support some of the main ongoing trends in content production such as the shift towards IP-based production, adoption of cloud-based solutions, and remote production workflows.

For 5G to be widely adopted in content production it will be essential to show its potential and to create value for all stakeholders. This will require not only technical innovation but also innovative business models.

The constraints are the factors that impact and limit system design and, as a consequence, the possibility to meet the business requirements. These can be technical, commercial or regulatory in nature.

In 5G-RECORDS the system design is represented by the three use cases and the customers, the corresponding end-users or vertical customers of the use case. The business validation framework described below seeks to be more general than these three use cases. In particular it seeks to identify how using 5G could create value for different stakeholders and describe advantages and disadvantages of different 5G deployment options.

4.1 Business analysis options for actors in the 5G-RECORDS ecosystem

The literature provides a wide range of approaches to carrying out a business analysis. For the purpose of defining a business validation framework for 5G-RECORDS the following approaches have been considered:

- Business Model Canvas
- Value Chain
- SWOT Analysis

Theoretical aspects of these approaches are briefly described in Annex A.

The above-mentioned methods are well suited to analyse business aspects of a particular product or a business model. However, 5G-RECORDS is not aiming at developing a specific product or a business model. The project is primarily concerned with the technical merits of using 5G in professional content production. The three use cases described in the deliverable D2.1 are a means to that end, but it is out of scope of the project to validate the solutions in a commercial environment.

For this reason and taking into account that 5G may have an impact on content production industry beyond the three use cases, it was decided not to apply any of the above-mentioned approaches. Instead, the emphasis is put on the value that could be created for different stakeholders if 5G were to be used in professional content production. The value proposition for different actors is described in section 4.2.

Furthermore, 5G can be used in different ways, ranging from best-effort PLMNs, through SLA based PLMNs to stand-alone NPNs and in their various combinations of. The advantages and disadvantages of different implementation models have been evaluated in section 4.4.

4.2 Value proposition for actors in the 5G-RECORDS ecosystem

Broadcasters and other providers of audio-visual services

There is significant change in the traditional broadcast value chain on-going with various actors competing for television audiences, talent and a share of revenue that are based on very aggressive and world-wide business models. The role of the traditional public service broadcaster is changing to meet competition from large internet streaming companies as well as direct to consumer models where anyone can have access directly to an audience via social media.

This challenge is not only based on new technologies but on offering attractive content to draw in their customers. The outcome of this competition between the various actors is marked by huge investments in the creation of television and cinematographic content.

One area that requires specialist expertise and technology is the production of live content such as news, sports or events coverage. This can attract very large, world-wide audiences with broadcasters investing large sums of money to secure the rights to distribute content. These rights are often granted alongside guarantees as to the quality of the output so the technology to support live productions needs to be robust and reliable and be able to be deployed in a flexible, cost-effective way. In some cases where broadcasters own the content rights, they have more flexibility in managing the production quality.

The sourcing model for live content has also changed significantly over the past few years. Broadcasters no longer have significant in-house resources to produce live content as such a large number of programmes are supplied by independent production companies. In turn these production companies use facility providers to provide technical resources and expertise. For some events, such as major sporting events, the rights holders supply content from their own facilities and broadcasters then supplement this content with their own presentation coverage.

One exception to this model is news, the majority of news production is still ‘in-house’. The reasons behind this are that resources are required every day, and the peaks and troughs are a lot lower than in event or sport productions. It is therefore more sensible for business models to be based on the daily needs of production with external resources being added as required. This model also means that there is a large number of freelance owner operators of technology seeking to support multiple news operations. This means that there needs to be a common set of tools and workflows where possible to support the demand of the news broadcasters without needing to own a different set of technology for each operation.

The cost of production has a direct impact on the broadcasters' business models, the broadcasters know how important is to optimize the process of content production that can compete on the current market. In this direction the 5G-RECORDS project tries to exploit the latest network technologies to obtain new flexible and efficient production models. By reducing production costs broadcasters can choose to either provide more coverage and content or improve the quality of existing services.

There are significant similarities between the broadcasters' and content producers' perspectives on using 5G in content production.

Content producers

With the introduction of IP, cloud and remote production techniques exploiting 5G networks for content production can have a significant impact on the typical workflow of media production and technical facility providers. Remote and distributed production is extremely challenging, and requires very low and stable latency, ultra-reliable connectivity and very large bandwidth capacity to match their existing capabilities.

5G, used in conjunction with network slicing and NPN technologies, could provide enough network capacity for the audio and video production workflow. There is a promise of guaranteeing network capacity in an economically viable way. To support the economic viability there are dependencies on the regulator, the local mobile network operator strategies as well as the competitive landscape. Additionally, content producers may be able to build and operate their own small scale 5G NPN networks that support different production scenarios.

Implementing a clear 5G strategy in professional content production would not only allow higher flexibility, reliability and mobility, but enable production of a wider range and a higher volume of content. Managed correctly this would enable an increased value for money proposition and the subsequent cost saving can enable content producers to cover events that are beyond their current economic reach. The four major drivers for cost savings are:

- **Personnel costs:** Lower staff cost due to a reduction in down time brought about by remote production, such as much less travel time. More efficient workflows, including set-up of more wireless production, perhaps also remotely. Staff can work on more than a single event over a weekend.
- **OB van**: Reduced on-site requirements due to higher use of remote IP production.
- **Travel costs**: Lower travel costs due to lower head count, a smaller number of staff on location.
- **Equipment**: Lower equipment costs due to lower technical complexity or on-demand usage of needed equipment/resources - only one common connectivity layer is required, with a lower material cost - no cabling. Economies of scale if off-the-shelf 5G equipment and standardised 5G solutions could be used
- **Sustainability**: Less travel for staff and increase in the availability of function so no need to deploy multiple instances of the same technologies.

In order to make best use of the technology as soon as it becomes widely available, content providers must proactively start to identify relevant use cases, evaluate the financial and qualitative impact of those use cases on their business and define a clear overall roadmap for 5G.

Broadcast equipment manufacturers

It is initially necessary to draw a distinction has to be made in the analysis between manufacturers of content acquisition equipment, commonly known as PMSE manufacturers, and manufacturers of connectivity solutions for content contribution.

For the latter, the use of cellular technology for live coverage is already well-established and has enabled taking market share from satellite and fibre providers and creating new markets and revenues not available before. For PMSE equipment manufacturers however, the adoption of cellular 5G technology represents a paradigm change compared with the status quo of the industry, where the majority of PMSE equipment relies on proprietary radio technologies.

Overall, the value proposition of 5G technology for broadcast equipment manufacturers is to be framed in a context where the main driving force is the migration path of content producers to (wireless) IP-workflows. This general trend towards IP-based production is motivated by IP being an established, flexible, and robust interfacing layer to local or wide area networks and software processing systems. This allows productive deployment of services such as remote control, algorithmic enhancement, or cloud storage in media production scenarios.

5G natively inherits compatibility to the IP interfacing layer, supporting bi-directional communication. As such, the use of 5G technology could lower the barriers of implementing native support for IP-based services into media devices. In that way, 5G could act as a catalyst for broadcast equipment manufacturers to explore and establish new service-based business opportunities.

More technically, the use of cellular technology for live contribution has been, up until now, limited to best-effort, non-latency critical use cases and focussed on the benefit of a nation- or world-wide availability of mobile internet access. In the future, some concepts introduced with the fifth cellular generation (e.g. URLLC, NPN, Slicing) could potentially allow the new implementation of use cases that rely on quality of service and local deployments. These developments open new opportunities for PMSE manufacturers.

In certain terms, the adoption of 5G technology by PMSE equipment manufacturers can be associated with the following value propositions:

- **Improvement of interoperability through technological convergence**

In today's broadcast productions different PMSE services (i.e. audio, video, intercom) use their own wireless communication technologies. A technological convergence through the use of 5G, would simplify the integration of PMSE equipment into (wireless) IP-workflows from the perspective of RF planning through to the monitoring and control of PMSE devices and services.

This could mean, for instance that device and service configuration (e.g. battery status, mute/unmute, etc.) could be transferred via a common standardized connectivity solution. Furthermore, using a standardized transmission technology could even simplify the integration of personalized user equipment, such as that preferred by an artist or sound engineer, into any available production infrastructure. This interoperability could also drive a disaggregation of legacy PMSE infrastructure and end devices (wireless microphones, cameras, etc.) towards a "bring-your-own-device" model where venue owners own the radio and network infrastructure and PMSE users only need to bring their - preferred - wireless equipment (UEs).

- **Move towards universal suitability of PMSE equipment**

Potentially, the same PMSE equipment could be used interchangeably for different use cases, from live audio events (requiring private network deployments and strict low latency) to broadcast audio contribution use cases in public networks (e.g. ENG), simply by adjusting the device configuration to the network performance. To enable this, the network exposure and QoS framework of 5G would play a key enabling role.

- **Cost reduction and faster time to market thanks to economies of scale**

The development of custom RF equipment is a complex and costly process. The usage of 5G technology will hopefully reduce this effort and accelerate time to market and reduce costs. This would entail 5G mass-market chips integrating the features and capabilities required by the PMSE industry use cases.

Considering the small size of the PMSE industry compared with the conventional cellular mobile broadband business, it is expected that the PMSE industry alone could not motivate the implementation of URLLC and TSC features, as required by PMSE, in 5G mass market chips. Therefore, synergies with other verticals industries are of paramount importance. However, even with sufficient market weight, many required advanced 5G features, such as those mentioned above, will not be available everywhere at the same time but will evolve gradually depending on the economic viability perceived by the stakeholders.

- **Additional access to local 5G Spectrum**

In general, content production requires access to spectrum in localized areas for short period of times, often in an unplanned ad-hoc way. This has traditionally been possible as a consequence of the long-standing spectrum sharing ecosystem between PMSE and broadcasting. In the last decade, however, almost half of the available spectrum resources for broadcasting have been transferred to the cellular mobile industry (Digital Dividend 1 -800 MHz band and Digital Dividend 2 -700 MHz band) to satisfy the increased demands by consumers / Mobile Broadband. Consequently, it has become increasingly difficult to find enough suitable

frequencies for PMSE applications and to manage those to support demanding production requirements.

Direct access to local 5G spectrum (e.g. through local licensing or leasing agreements) would open additional spectrum access possibilities for PMSE manufacturers. This is predicated on regulators setting the right regulatory framework and, in the case of spectrum leasing, the right economic incentives to incumbents. For instance, MNOs will always measure the value created from this vertical use against the value that would be created if the same resources were to be used for their conventional eMBB business.

To conclude, the potential of the 5G technology for broadcast equipment manufacturers is promising and it is worthwhile to investigate and develop appropriate concepts and solutions that leverage that potential.

Telecom equipment manufacturers

5G is playing a key role in the global market growth of the mobile communication sector, but also in enabling new verticals such as professional content production. With the arrival of 5G, telecom manufacturers and providers have increased their interest to expand their offering in this sector. The key driver is the growth of the potential user base of telecom equipment. This will be achieved by using existing public (e.g. through Network Slicing) or new dedicated networks. Technologies currently developed and deployed for specific consumer needs will be extended and re-purposed to fit media production needs. Telecom manufacturers will hence lower market-entry barriers for customised communication services and open the door to innovative business models.

On the network side, the specific content production needs, namely very stringent requirements for latency and throughput, can be served thanks to the use of private networks also known as NPNs. This type of network can be assigned in different forms and for different purposes, either re-using common functions between different networks or as a dedicated standalone network.

Additionally, network capacity can be provided by deploying dedicated Virtual Network Functions, the reconfiguration of existing radio access nodes or the deployment of temporary new ones. This makes it possible to provide 5G connectivity in massive events such as sports matches or concerts, both to producers and to end users.

On the device side, consumer devices such as smartphones or tablets can be extended to fit the media producers' needs. In the simplest case, additional software packages and applications are needed to use existing devices for media production. Alternatively, and most importantly, 5G modems together with audio/video encoding/decoding solutions could be integrated into existing and evolved broadcast equipment vendor devices, such as wireless microphones, cameras or displays. This will enable new business models for device equipment manufacturers and introduce new actors in the content production value chain.

5G technologies developed by manufacturers will be introduced into the content production market by following four steps. The first and natural step is standardisation, being 5G Release-15 the current specification to be implemented. The second step is the infrastructure development and deployment. With 5G, infrastructure owners can provide customised services to the media production sector, with a large degree of freedom to manage their own private resources and adapt them to the services needed. The third step is the device availability, which is key for enabling the end-to-end business. The fourth and last step towards commercialisation is to make technology scalable and accessible (plug-and-play).

The use of 5G infrastructures and devices in content production scenarios could be translated into operational savings in terms of deployment costs, time, and resources. Telecom manufacturers could also benefit from a more flexible and reliable solution that could enable new forms of production and therefore a lower barrier to entry for media production businesses.

5G could help to simplify, digitize, and democratise the 5G production and distribution (streaming) business. It might also enable new applications and products that attract new clients and reach new business areas.

Public Network operators

Mobile Network operator business has been based on volume charging for a long time. Standardization has enabled large volumes and thus low service prices, but it has also standardized services. The service that mobile operators have provided has been the same for all users and has now saturated because all potential customers are connected. Because of competition between mobile network operators price levels for the service is fairly stable even though the capacity provided is increasing due to the technical evolution of the radio interface.

Mobile Network operators are looking for new paths to growth, but because of regulation opportunities are limited and consolidation has not been possible in Europe. When considering new opportunities there are several aspects to be considered, technology, commercials, competition and regulation.

New applications especially from Industry 4.0 and its digital transformation technologies require new and more predictable communication services. This provides new opportunities for a growth, but it will require a new business model or models. Technology has developed to the point where the price of small networks is affordable for any company, frequency assignment can be done dynamically, and physical general-purpose networks can be divided into many logical networks.

Regulators

While regulation is an essential element in any business analysis, regulators themselves are not considered to be commercial actors in the 5G-RECORDS ecosystem. Instead, the value for the regulators in supporting 5G for professional content production will be to satisfy the demand for advanced connectivity in this sector while also ensuring the efficient use of spectrum allocations for PMSE services and applications.

4.3 Application of a SWOT analysis to the 5G-RECORDS use cases

The SWOT analysis is a useful framework for analysing four main aspects (Strengths, Weaknesses, Opportunities and Threats) of an organization or a given service and concept within a project. It helps companies to build on what they do well, to address what they are lacking, to minimize risks, and to take the greatest possible advantage of chances for success. Having agreed that the SWOT analysis is a helpful method for business analysis, it has been considered during the elaboration of this deliverable as an element of the business evaluation framework. In a preliminary discussion the following issues have been identified:

- Business analysis should be based on the assumption that 5G technology is or will be mature enough to support the KPIs and functionalities of the three 5G-RECORDS use cases and that the technology is readily available in the market. At this point in time, these aspects are still uncertain until more tests and validations are made.
- A SWOT analysis is useful when it focuses on a particular product, service, or a business model. 5G-RECORDS does not aim at developing either of these. Instead. the project focuses on the three use cases which were defined to derive the challenging technical and operational requirements and KPIs.
- If carried out from the use case perspective, 3 separate SWOT analyses would be necessary. Although the use cases share some similarities that could be summarised in common SWOT elements, they also have other major differences that are not compatible as common items. Furthermore, these use cases, as defined in the project, are not

necessarily intended to be commercially deployed. Therefore, conducting a SWOT analysis for the use cases may not result in meaningful conclusions.

- There are multiple actors involved in each use case and this leads to different analysis perspectives. As an example, a SWOT analysis could be carried out from the perspective of a PMSE vendor, a MNO, a content producer, or a final user. Every actor targets different market segments and thus supposes very distinct strengths, weaknesses, opportunities, and threats.

For the reasons outlined above it was concluded that SWOT analysis is not an appropriate tool for business analysis at this stage of the project.

4.4 5G Network configurations for different QoS levels

There is a large, and growing, number of different radiocommunications services and applications and they all require access to radio spectrum. The number of users of many of these services and applications is also continuously increasing, resulting in an increasing demand for capacity and, consequently, for more spectrum. It is not possible to allocate exclusive spectrum to all services and applications and therefore the regulators and the industry are looking for new ways of accommodating the growing demand. One option is to improve the possibility of spectrum sharing. Another option could be for some of the use cases to be served by a public general-purpose network rather than by a dedicated network. 5G deployed in public mobile networks (PLMN) has the potential to facilitate the latter option, in particular for the vertical users.

Using the same frequency ranges for several purposes is expected to increase the frequency utilization rate. Using the same network technology also drives down equipment cost (User Equipment and Network) that will make it possible to use 5G networks for even more applications. Higher volumes will accelerate technology development.

The benefits could be significant for both the vertical users and the 5G network operators. The key prerequisite is that 5G networks are capable of meeting the Quality of Service (QoS) requirements in a technically and commercially efficient way.

4.4.1 Public networks

Today's public mobile broadband networks are capable of serving different use cases and applications on a best-effort basis as well as providing Quality of Service (QoS). For those applications and users that can tolerate capacity fluctuations best-effort level of service is sufficient. However, there are many vertical use cases, such as professional content production, that require guaranteed QoS and capacity. 5G provides the tools for the network operators and the vertical users to accommodate some of these demanding use cases.

To some extent such QoS requirements may be met by PLMNs through service-level agreements which may in the future also include network slicing. By using QoS technologies it is possible for PLMNs to serve certain applications that previously required specific purpose-built technologies and dedicated spectrum. This is expected to improve frequency utilization and provide lower cost and more flexibility for QoS sensitive applications.

Best-effort

Best-effort is one way of using a PLMN. It is good for use cases where mobile network performance is not driven to its limits by a small number of users. As performance parameters and QoS are not tuned for the needs of specific use cases, nor can they be controlled, best effort networks may not be suitable for the more demanding use cases. However, where a particular production or contribution use case permits the use of best-effort networks this can lower the costs of the production.

Best-effort networking suits use cases where you can buffer traffic (often to a large extent) to increase average capacity by increasing delay. Buffering also removes jitter. Note, small buffers are also needed for QoS-enabled networks. Another aspect is that a best-effort network is vulnerable to network congestion. To mitigate issues related to congestion, coverage, bandwidth and QoS several service providers and technologies may be combined to provide more capacity and coverage by using bonding which provides a good balance of performance against cost, availability and complexity. Bonding in best-effort networks adds delay and might not sufficiently improve capacity if all networks are fully congested.

From a mobile operator perspective using bonding is business as usual and adds to the same revenue stream as any other customer. A mobile operator can use traffic shaping features in congested situation and can also limit through put if fair usage of network is considered to be jeopardized. All these measures are used to protect mobile operator reputation and are fully controlled by the mobile operator.

Using general purpose networks means that data will be carried on the public network and this can be considered to be security threat even though mobile networks can be very secure.

Best effort suits very well for news gathering and streaming services from temporary locations. Best effort cellular service might encounter challenges to support high-capacity productions where there is the expectation of a guaranteed Quality of Service (QoS) for video resolutions such as 4K HDR and above.

QoS enabled networks

QoS technologies have been developed to be able to provide guaranteed minimum service levels for the applications that require them. The agreed QoS level is normally defined in a Service Level Agreement (SLA) between the service provider and the network operator.

The existing QoS tools are powerful and feature-rich which enable modern PLMNs to provide different QoS classes. By using modern QoS tools the overall network throughput can be increased if RF conditions are set for a SLA service. At the same time an end user can enjoy a stable data stream if the number of SLA agreements is limited and well managed in a given area.

QoS parameters defined in SLA may include minimum throughput, capacity allocation in uplink or downlink, or maximum acceptable latency, jitter, or error rate.

Net neutrality regulation allows for, under certain conditions, using QoS for those applications that need different network settings to work as required.

Using general purpose networks, even with QoS tools, means that data will be carried on the public networks which can be considered to be a potential security threat even though mobile networks can generally be considered very secure and reliable.

QoS could improve provisions for news gathering and coverage of smaller production events when networks are crowded. QoS could also significantly improve bonding functionality and reduce the need for buffering.

Some use cases cannot be supported by QoS tools. These include critical audio productions with stringent latency requirements, and high bandwidth use cases which may not be feasible because the bandwidth available for other applications would be reduced which could negatively impact other consumers. This may be seen as a risk to the MNO's reputation and, therefore, needs to be managed appropriately. So even without an additional technical cost to an MNO of selling QoS enabled services, such services cannot be marketed without due regard to existing services.

Network slicing

Network slicing in public networks requires a segregation between the resources allocated to best-effort users and the network slice users. Note that an SLA is a pre-requisite when using a network slice on a PLMN. Similar to using QoS, Network Slicing allows a content producer to manage available resources.

Many potential users of network slicing currently use dedicated non-public networks which require strict control of spectrum use and their own network hardware and software investment in order to ensure the service performance. Network slicing enables a business model where, instead of investing in a dedicated non-public network, the user buys capacity from a multipurpose PLMN. In this model PLMN spectrum and network resources are seen as a raw material that can be used to generate different kinds of capacity products (uplink, downlink, jitter and delay) for services and applications based on their requirements. In this model we can also have a broker that is buying different capacity products from several connectivity providers and sells them on to service and application providers.

Network slicing means that there are multiple virtual networks inside one physical network. Adding a virtual network layer does not have significant additional cost, because it can run on the same hardware. This is enabled by network function virtualisation which allows resource allocation to be fine-tuned for a use case or for a particular user. Network slicing can be used in public and non-public networks.

Commercially, selling a network slice is similar to selling capacity in fixed infrastructure, but it is more complex than selling subscriptions to consumers. Network slicing provides higher revenue per bit to a mobile operator because the alternative cost reference for the business users is a proprietary network that is either more expensive or not possible because of the current regulation. For those MNOs that also have a fixed network business, moving to network slices means that there may need to be a new corporate structure in place. There is also the same reputation risk as in selling QoS, especially if network slices are fixed in size.

It is still unclear as to busines models that will provide slicing. A media production company may choose to contract a permanent slice with a specific MNO or choose to follow a ‘slice as a service’ model once it becomes commercially available.

Using network slices means that data does not necessarily have to leave to go to the public networks, but it can have additional security measures even when leaving operator premises.

Network slicing could solve contribution issues and it could be used to cover at least smaller and medium size productions even when networks are crowded.

Using network slicing for specialist audio productions in public networks is theoretically possible but will require MEC or a local breakout functionality close to the base station.

Generally, Network slicing with 5G is not suitable for the use cases that require the majority of the capacity available in a limited service area.

4.4.2 Stand-alone Non-public networks[3]

Non-public 5G networks (NPNs) are configured according to the requirements of a particular organisation and are intended to be used only by the terminals authorised by that organisation. NPNs may be deployed in a variety of configurations, including PNI-NPN which implies different degrees of integration with a PLMN (e.g. sharing virtual and physical elements,

[3] A stand-alone NPN (or SNPN) is defined in 3GPP as a network 'operated by an NPN operator and not relying on network functions provided by a PLMN' - see https://www.3gpp.org/news-events/2122-tsn_v_lan. This must be distinguished from a 5G standalone network which consists of both 5G Core and 5G NR, as opposed to 5G non-standalone where 5G NR is connected to EPC (LTE core) - see https://www.ericsson.com/en/blog/2019/7/standalone-and-non-standalone-5g-nr-two-5g-tracks

leveraging Network Slicing or QoS) and a completely standalone NPN (or SNPN).[4] Network slicing could also be implemented in SNPNs.

Spectrum access and licensing options for 5G SNPNs are covered in section 5.1 below.

Because SNPNs may use different frequencies than the PLMNs it means that investment is required in hardware capable of operating in the bands available for SNPNs. The required investment level has decreased over the years and most likely will continue on that trend, meaning more and more use case can benefit from stand-alone non-public networks.

SNPNs may be provided in different ways and by utilising a variety of business models. They could be self-provided by content producers and broadcasters, or commissioned by venue owners, third parties, or from mobile operators.

Mobile operators can see non-public networks as competitors especially if mobile operators do not have fibre networks in their portfolio.

Operating non-public networks is quite different from operating public networks. A non-public network can be considered as part of a separate IT infrastructure meaning that network planning (not RF planning) challenges are quite different from those related to PLMN planning. The required capabilities are more familiar to IT management companies than mobile operators.

For a mobile operator providing stand-alone non-public networks may not include any reputational risk and can be added to a product portfolio in the same ways as a fixed business line.

For broadcasters and other content producers using non-public networks means that data does not need to move to the public networks, which can be seen as an additional security improvement.

Non-public networks can be finetuned to utilize the full potential of the network to meet requirements of various use cases. This enables the use of these non-public networks for the demanding production use cases and can optimise uplink and downlink speed.

We are also seeing media production teams exploring the provision of their own NPN facilities. They are generally very small-scale networks limited to a small number of radio units. These very low power networks can enable short range wireless production and be connected into other infrastructure to provide backhaul capabilities.

4.4.3 Discussion on 5G Network configurations for different QoS levels

From a content producers' perspective both PLMNs and NPNs are relevant for the production use cases, in particular remote production. PLMN provide wide-are coverage and with the deployment of 5G will be capable of supporting higher QoS. NPNs can be tailored to the specific production requirements but may not be available in all locations, times and events, due to various deployment complexities and costs.

The business advantages of different network configurations are already listed above. It should also be noted that PLMNs and NPNs could be used in a complementary way, i.e. a PLMN to complement the NPN by providing additional bandwidth and reliability or provide additional coverage outside the NPN area. PLMNs will be a preferred choice also in areas and times where an NPN would be too costly or too complex or otherwise inappropriate. Depending on the specific capabilities of the PLMN, the specific deployment in the area of interest, the potential designated agreements between the MNO and end-users or other service providers

[4] Further information 5G NPNs for content production use cases is provided in 5G-MAG publications, https://www.5g-mag.com/explainers

A detailed treatment of NPNs for industrial scenarios is available in the 5GACIA White paper: https://5g-acia.org/wp-content/uploads/2021/04/WP_5G_NPN_2019_01.pdf.

such as to make available designated slices per-use, the use case may enjoy high performance of the public network at a fraction of the cost and complexity.

Some capabilities may be harder to achieve in PLMNs such as local 'walled-garden', a very low latency 'private-like' networks, although with technological evolution their capabilities may continue to improve, possibly improving the economics of some of the use cases. This may also be dependent on the commercial offering of local MNOs.

There is also a strong dependency on scale. Small-scale NPNs may be inexpensive but limited in terms of coverage and capabilities. Large-scale NPNs may be complex and costly in particular when large coverage is required. Most production models operate within a relatively small, highly controlled environment with limited UE access requirements. This means there is less reliance on universal access and networks can be tuned to deliver against a limited set of requirements.[5]

The content producers' perspective on different network configurations is shown in Figure 3:

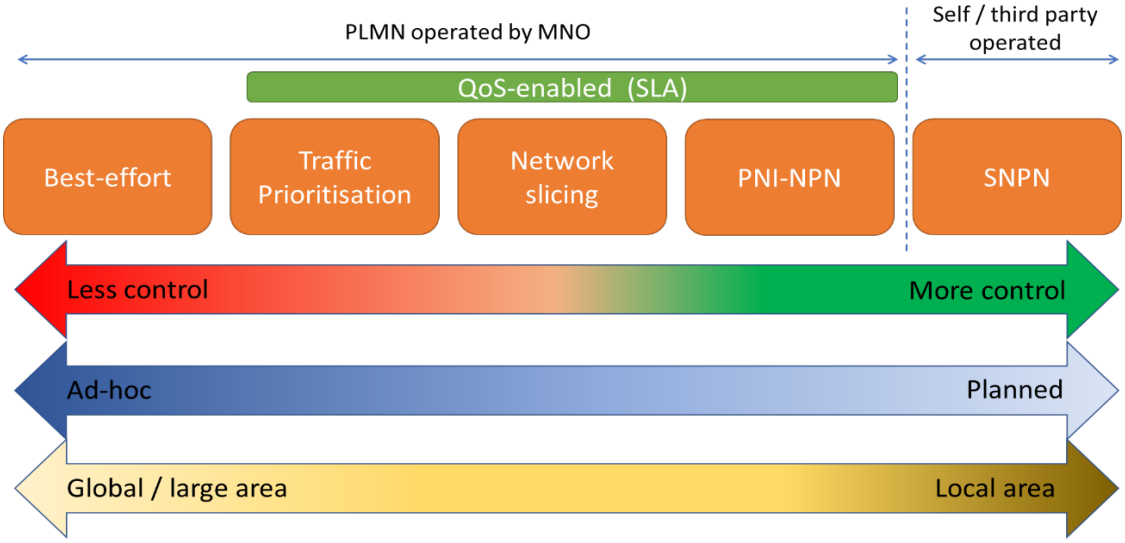

Figure 3: Content producers' perspective on different network configurations

From the mobile operator's perspective, the main business is streamlined to support high volume business. Mobile operators are among the largest companies in any country, it is a big business. Providing consumers wireless internet means that business is driven by ARPU and churn. A mobile operator organization tries to increase ARPU and reduce churn. In given geographical area this is a zero-sum game between three to five mobile operators. This is largely because the market has saturated. In general, it is understood that innovations are needed for a growth, but at the same time it is not wise to risk your current market share and revenue.

Among business customers there is an increasing demand for wireless connectivity that is more stable and reliable than what mobile operator best-effort service can provide. There are a number of different use cases where service providers would be prepared to pay more to a mobile operator if an easily understood SLA could be negotiated. For example, media production companies may be interested in using QoS enabled networks on the basis of SLAs. There are also companies who would like to use 5G instead of existing WiFi or fixed Ethernet networks.

[5] Opportunities and challenges of using 5G in content production are further described in https://www.svgeurope.org/blog/headlines/trials-and-challenges-unlocking-the-potential-of-5g-for-sports-broadcast-production/.

The challenge is that every use case is slightly different, and every use case has a very limited number of users compared with a mobile operator's main line of business. Even though mobile networks could provide QoS-enabled connectivity mobile operators have been reluctant to offer it. These kinds of special services usually require specific skillset to sell, install, operate and maintain which may not be available within MNO organisations. They have different life cycles and tolerance for errors which are incompatible with the main MNO business models.

Moreover, none of the 'verticals' are even close to the size of MNOs' consumer business. It is estimated that all verticals combined have a potential to generate about 30% additional revenue for an MNO on top of the consumer business today[6]. Furthermore, in order to be able to meet verticals' technical and operational requirements MNOs need to make significant investments in network capabilities above and beyond what is required for consumer-focused services. For this to happen viable business cases are needed.

The following two charts illustrate the main differences between the media producers' perspectives and MNO's perspectives on business aspects of different PLMN configurations. While there are a number of different issues to be considered in any business analysis, the diagrams show only the three main drivers: cost, coverage and reliability for content producers and costs, revenue and reputational risks for MNOs.

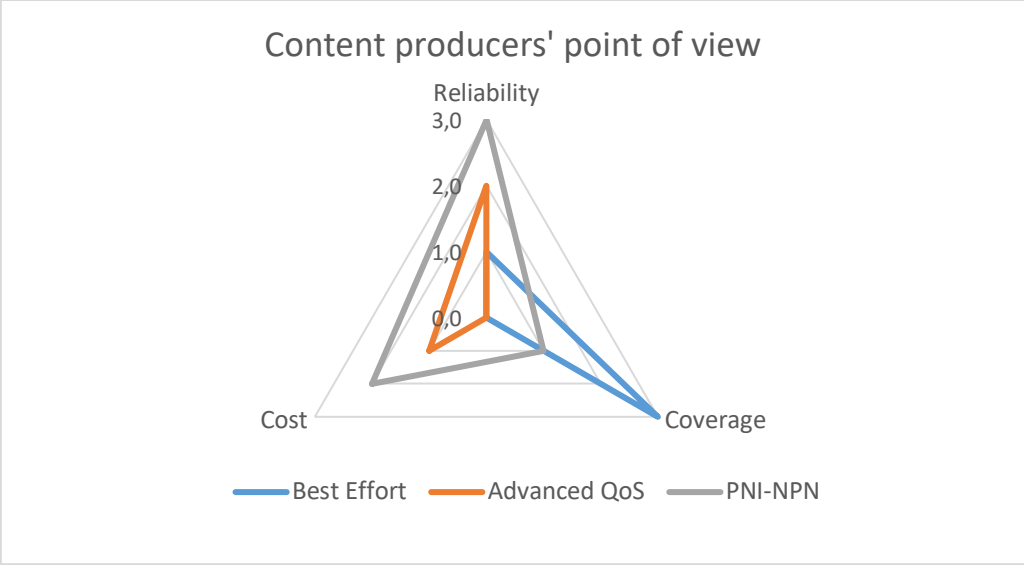

Figure 4: Content producers' perspective on different PLMN configurations

[6] See https://www.ericsson.com/en/blog/2021/5/network-slicing-a-usd-200-billion-opportunity-for-csps

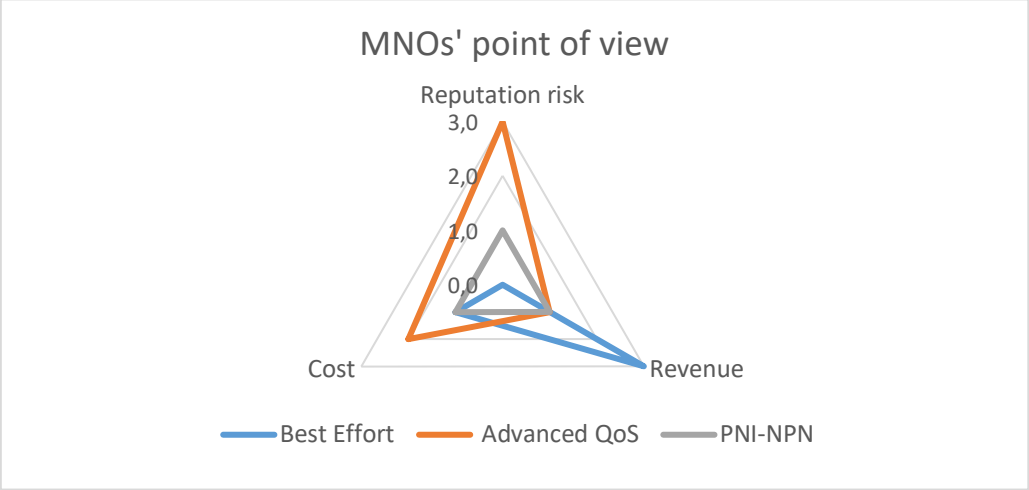

Figure 5: MNO's perspective on different network PLMN configurations

Numbers are relative using a scale from 0 to 3, where 3 means highest reliability, coverage, cost, revenue, and risk. Each network configuration is ranked in each category related to each other using the same relative scale.

Costs covers SW and HW investments into network as well as the network running cost.

NPNs can be deployed in different ways, depending on regulation and the market situation in the country. They can be managed by MNOs, media production companies or broadcasters who have decades of experience using private RF networks, or by third parties.

4.5 Spectrum as a service

With the introduction of 5G it may also be possible to decouple the ownership of network infrastructure from the rights of use of frequency spectrum, in particular for 5G SNPNs. This decoupling may open the possibility for new business models. For example, it might be possible that a 5G SNPN operator owns the network infrastructure while accessing spectrum dynamically according to its varying needs from an independent spectrum supplier (e.g. an MNO).

Where the regulation allows, such a spectrum supplier (the holder of spectrum licence) may develop a business model based on spectrum leasing to business users. This may enable access to spectrum for those business users that cannot obtain the spectrum from the regulator, for business or regulatory reasons.

In content production the 'spectrum as a service' model could be suitable for temporary or nomadic access to spectrum. In some cases, this may be a content producers' preferred option, particularly when they need the spectrum urgently and either have no time or no possibility to secure it in another way.

The regulatory aspects of spectrum leasing are described in detail in Annex C below.

Spectrum holder's business motivation is to generate revenues from leasing any unused capacity in their licensed geographic area. For the business users, this model could reduce the spectrum costs as they only pay for the quantity of spectrum used in a certain area for a certain amount of time. The user of the spectrum does not bear the costs of obtaining and holding the spectrum licence.

4.6 Summary on business validation framework

5G has a potential to play a role as a wireless component in the IP-based content production workflows. As a technology, 5G can be deployed in different ways and tailored to different technical and operation requirements, hence being able to support different production use cases. This is important as there are many different types of production. The three use cases described in the deliverable D2.1 are good examples but there are many more.

In professional production workflows 5G is expected to provide advanced connectivity. Furthermore, interoperability between 5G and other technologies such as cloud or MEC is of the essence as 5G alone cannot support the entire workflow. Both 5G PLMNs and NPNs are important in content production. Different network configurations are used for different purposes as no single solution can support all production use cases.

From a commercial point of view the attractiveness of a particular solutions may depend on the business model and business objectives of a particular stakeholder. For example, with regard to QoS-enabled networks the MNOs' perspective may be different from the broadcasters' or content producers' perspectives.

Some network configurations and capabilities are already commercially available while others are not. For example, 5G network slicing is not yet commercially available. A reason for that may be the lack of incentives for MNOs to invest in the required network capabilities. Besides technology maturity, viable business cases are essential to facilitate the necessary investments in 5G networks, whether PLMNs or NPNs.

The use of 5G in content production would need to create value for all stakeholders in the ecosystem. Benefits for content producers and broadcasters may come not only from the expected costs savings but also from new opportunities that 5G may provide, such as the ability to produce a wider range of content in an innovative way.

In practice, the currently available data is insufficient for a quantitative business analysis to be carried out. The scope of the benefits for different stakeholders will become evident over time as the availability of 5G gradually increases and the network capabilities to improve, and as suitable business models are developed.

5 Regulatory framework

Suitable regulatory conditions are essential for wireless content production, whether using conventional or 5G-based solutions. In the case of conventional PMSE the most important regulation covers access to radio spectrum. However, when 5G is used for content production there will be other areas of the applicable regulation in particular if PLMNs are used.

Telecommunications and information systems are subject to different types of regulation that influences how the networks are designed and operated. In the EU the main legislative text that regulates electronic communications networks and services is the European Electronic Communications Code (EECC). Furthermore, there are a number of other relevant legal and regulatory texts that govern provision of services, access to the radio spectrum, numbering, network operation, security, EMF limits, network neutrality, data protection and consumer protection as well as commercial relations between stakeholders. BEREC has carried out a study on what the impact of 5G deployment and development may be on the regulatory environment[7].

With the deployment of 5G it is expected that new business models will be developed focusing on B2B services and specific vertical sectors. In many vertical sectors there is specific regulation which is likely to remain in place even though 5G may enable new workflows and business practices. Some of the new business models are possible within the existing regulation while others may require further clarification on how the current rules are to be applied. In some cases, the rules may need to be changed or new rules adopted to allow development of 5G-based business models.

Further regulation may come in the future in areas such as environmental impact or some new, 5G-specific issues such as network slicing or roaming between NPNs and public networks.

It is beyond the scope of this deliverable to provide a comprehensive legal analysis of the regulatory framework applicable to the use cases considered by the project. Instead, it outlines some of the issues identified in the course of the project where the stakeholders must be conscious of the existing rules that may affect the use cases, and business aspects of 5G-based content production.

5.1 Spectrum access and licensing for non-public 5G networks

Radio spectrum is, necessarily, a highly regulated area. In the international context (ITU-R), radio applications for the transmission of audio and video related to the professional production of audio and video content are classed under "Programme Making and Special Events" (PMSE). Examples where PMSE applications are used include broadcasting, cultural, musical and theatrical performances, and social and sporting events.

The media industry has extensive expertise and experience in deploying dedicated wireless networks for PMSE applications, including not only local area network for wireless production but also fixed and satellite contribution links.

Spectrum availability remains essential for conventional wireless production equipment as well as for 5G-based solutions. Certain spectrum bands are more technically suitable for specific PMSE applications. Different propagation characteristics may suit obstructed or unobstructed signal paths. The availability of sufficient bandwidth will achieve the desired throughput, or the limitation of external interference in a given band may be a factor.

In this section the focus is on spectrum regulation and licensing for 5G SNPNs as it assumed that the spectrum regulation and licensing for public 5G networks are outside the scope of 5G-RECORDS.

[7] See: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8910-report-on-the-impact-of-5g-on-regulation-and-the-role-of-regulation-in-enabling-the-5g-ecosystem

To accommodate different PMSE applications cases, such as audio, video, fronthaul, backhaul, it may be necessary to consider low, mid, and high '5G' spectrum bands. Furthermore, licensing models should be suitable for different operational needs, including permanent and temporary, stationary and nomadic production use cases.

Spectrum licensing can take a number of different forms. It might aim to achieve an efficient use of the spectrum, i.e. the maximum capacity, perhaps through spectrum sharing and reuse, or maximum protection from interference, or maximum economic and social benefit.

PMSE services can be licensed in different ways according to the particular application and user. Some possibilities include:

- **Long term fixed site licensing**

For a location where productions are continuous and can demonstrate regular demand, perhaps a film or TV production centre with multiple stages or studios, it may be appropriate to authorise long-term spectrum access. Often these instances will be indoor facilities where building shielding will be favourable to incoming and outgoing interference, maximising the potential for spectrum sharing and spectrum re-use.

- **Short-term temporary licensing**

As much of PMSE production is for short-term events there is a requirement for temporary spectrum access in some specific locations (e.g. sports venues, festivals and other outdoors events) over flexible periods of time, which could be as short as few hours or as long as several weeks. Licensing spectrum in this way maximises spectral reuse and geographical availability. The amount of spectrum required can vary depending on the nature of the production; the duration for which it is needed can be from a few hours to many days, or permanently.

In contrast, the way spectrum is currently allocated to 5G services means that access is provided on a long-term basis (e.g. several years) in specific permanent locations (e.g. a factory or a studio) but the options suitable for temporary deployments are limited. This is not optimal for those PMSE applications that require spectrum only temporarily over short periods of time and at non-permanent locations.

For the content production sector, it is important that spectrum access for PMSE services, whether conventional or 5G-based, remains easy, affordable and timely. Another important requirement is long term access to internationally harmonised spectrum bands.

Furthermore, spectrum allocations for NPNs ideally should be defined in such a way as to allow the same hardware to operate in both public and non-public 5G networks.

It is important that NRAs are aware of these requirements and take them into account when allocating spectrum for PMSE services

5.1.1 The current regulatory framework for PMSE spectrum licensing in Europe

When considering spectrum access for 5G NPNs for the purpose of professional content production it may be instructive to draw a comparison with the licensing regime for conventional PMSE services. These methodologies have evolved over time and in line with the technical and operational requirements.

PMSE services are licensed on a national basis whereas CEPT provides a harmonised European framework. The ERC Recommendation 25-10 [2] provides a list of tuning ranges that CEPT administrations may consider for audio and video PMSE applications. Harmonisation of spectrum use is not common for PMSE services and national frequency plans rarely match. This recommendation therefore uses the concept of ‘tuning ranges’ which are frequency ranges over which PMSE equipment is envisaged to operate.

The term “tuning range” for PMSE means a range of frequencies over which radio equipment is envisaged to be capable of operating. Within this tuning range, the use in any one country of radio equipment will be limited to the range of frequencies identified nationally (if any) within that country for PMSE, and will be operated in accordance with the related national regulatory conditions and requirements. Within each tuning range national regulators may assign specific sub-bands or particular frequencies for PMSE links subject to availability, actual demand and sharing arrangements with primary services using those bands. Ideally, PMSE equipment should be capable of being operated within the whole tuning range and even beyond in order to provide flexibility for operation in different countries.

The ECC has recognised in its 2020-2025 strategic plan the need to identify the necessary spectrum for PMSE, taking into account the increase in the overall demand, recent changes in the availability of the spectrum and technological developments.

CEPT maintains a dedicated PMSE web page that contains the information on:

- PMSE contact points and regulatory processes in CEPT administrations
- Frequency ranges available for PMSE in CEPT countries
- Other ECC deliverables and activities in the PMSE area
- Information on national conditions for PMSE use in CEPT
- Links to relevant articles in the ECC newsletters

Detailed information about spectrum and conditions of use for PMSE in CEPT and at the national level can also be found in the ECO Frequency Information System - EFIS.

Particularly relevant to this document is the ECC Report 323 that examines the principal and latest changes and trends affecting PMSE's use of radio spectrum in three broad categories:

1) Changes and trends affecting PMSE demand for radio spectrum
2) Changes and trends affecting the supply of radio spectrum for PMSE
3) Mitigating factors that affect the demand and supply of radio spectrum for PMSE. [6]

5.1.1.1 Regulatory approaches to PMSE licensing

The current regulatory framework for PMSE spectrum access is not harmonised. In ITU Region 1, audio PMSE is classified within the 470-694 MHz band as an application of the land mobile service with secondary status to broadcasting. In frequencies above 695 MHz audio PMSE is either classified as a land mobile service application (e.g. 823-832 MHz, 1785-1805 MHz) or as a short-range device (SRD) application (e.g. 863-865 MHz). In ITU Regions 2 and 3, PMSE is classified as a short-range device (SRD) application.

Harmonising the spectrum used by PMSE equipment would contribute to allowing economies of scale, fostering cross-border portability of equipment and interoperability, improving the quality and efficiency of spectrum use, and providing legal certainty for access to relevant spectrum bands.

Today, in most frequency bands PMSE is a secondary service which means that access to spectrum is provided on a non-interference, non-protection basis.

The use of radio spectrum for PMSE is authorised either by granting site licences under the national regulatory framework, or by exempting the use of particular equipment from the requirement to hold an individual licence.

Spectrum sharing between PMSE and other applications is feasible only if usage by the other users is observable, traceable and predictable. This is the case, for example, with terrestrial TV services in the UHF band, where audio PMSE has been in use since the early 1960s.

5.1.1.2 Conventional PMSE frequency bands

Frequency ranges used for conventional PMSE services are listed in the ERC Recommendation 25-10 which details frequency ranges for existing PMSE applications across CEPT countries [2].

Frequency range	PMSE applications
Sub-1 GHz	• In-ear monitors and wireless microphones
1 - 6 GHz	• In-ear monitors and wireless microphones • Audio links • Cordless cameras / Portable video links • Mobile point-to-point video links (airborne and vehicular; temporary use)
mm-Wave	• Cordless cameras / Portable video links • Fixed point-to-point video links (temporary use) • Mobile point-to-point video links (airborne and vehicular; temporary use)

Table 1: Frequency ranges used for conventional PMSE services

Audio PMSE services, with a small number of exceptions, operate in sub-1GHz bands. This has been the case for many decades due to spectrum being readily available, the possibility of sharing with terrestrial broadcast television services in the UHF band, as well as the favourable propagation characteristics and low body absorption. Video PMSE services have traditionally operated above 1GHz where wider bandwidths have been available and the signal propagation, often over challenging paths, is acceptable.

5.1.2 Frequency bands for 5G SNPNs

5.1.2.1 Regulatory approaches to spectrum access for 5G SNPN

There are a growing number of verticals that will rely on non-public 5G networks and different regulatory solutions will be required to accommodate their requirements for access to radio spectrum.

In general terms, SNPNs could make use of both licensed and licence exempt spectrum bands.

Different regulatory approaches to spectrum access and licensing are possible:

- *General authorisation* - i.e. the SNPN does not require an individual licence but it can operate in specific spectrum bands (e.g. operation within ISM bands, or as a GAA user of CBRS) under rules and conditions defined by the NRA.
- *Secondary licensing* - i.e. the NRA issues a licence to the SNPN in a band already used by an incumbent user (e.g. SNPN as an LSA licensee, as a PAL user in CBRS).
- *Individual licensing* - i.e. each SNPN is authorised individually. The conditions defined in the spectrum licence are specific to the particular SNPN.
- *Local area licensing* - this is a form of individual licensing where the NRA provides a licence to the SNPN in a given frequency allocation in a defined location and for a defined period of time.
- *Spectrum leasing or trading* - i.e. incumbents including MNOs or lessors can lease out or trade part of their licensed spectrum to SNPNs Spectrum Managers (or lessees) in a defined area and for a defined period of time.

Many of the currently considered licence models tend to focus on longer time frames and the use on fixed locations. This is suitable for many but not all PMSE applications.

However, productions are often taking place on temporary locations and for a limited period of time (from a few hours to some days or weeks). 5G SNPNs for these PMSE applications will require spectrum to be available locally and often on an ad-hoc basis.

Furthermore, spectrum authorisation for content production should be technologically neutral in a regulatory sense to allow for the integration of supplementary systems with 5G, or a mixed operation of conventional and 5G-based PMSE systems.

5.1.2.2 Candidate frequency bands for 5G SNPNs

A number of different spectrum options are currently being considered for 5G NPNs, including the following:

- Dedicated frequency band 3700-3800 MHz (Germany)
- Spectrum sharing options, such as
  - CBRS in the 3500 MHz band (USA)
  - LSA and in the future eLSA models in Europe
  - Licence exempt bands
  - Shared use of the band 3800-4200 MHz (UK)
  - Spectrum leasing from MNOs

The list of 5G NR frequency bands can be found in 3GPP TS 38.101. [1]

In 3GPP, frequency bands for 5G NR are being separated into two different frequency ranges, FR1 and FR2. The Frequency Range 1 (FR1) includes sub-6 GHz frequency bands, some of which are used by previous mobile generations. The Frequency Range 2 (FR2) include new bands in the range 24.25 - 52.6 GHz.

The 3GPP list can be further classified into three groups of frequency bands:

- Frequency Division Duplex Bands (FDD),
- Time Division Duplex Bands (TDD), and
- Supplementary Downlink Bands (SDL) & Supplementary Uplink Bands (SUL).

Furthermore, some of the 3GPP frequency bands overlap with or are adjacent to the PMSE bands included in ERC Rec 25-10 as shown in the table below.

Rec 25-10 Ranges			NR Ranges	Uplink	Downlink	Duplex Mode
A3	Audio	470 - 694MHz	n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
A4/B3		733 - 758MHz	n13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
A4/B3		733 - 758MHz	n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
A4/B3		733 - 758MHz	n83	703 MHz – 748 MHz	N/A	SUL
A5		823 - 832MHz	n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
C1	Video	2010 - 2025MHz	n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
C1		2010 - 2025MHz	n95	2010 MHz – 2025 MHz	N/A	SUL
C4		2300 - 2400MHz	n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
C4		2300 - 2400MHz	n97	2300 MHz – 2400 MHz	N/A	SUL
C4		2300 - 2400MHz	n30	2305 MHz – 2315 MHz	2350 MHz – 2360 MHz	FDD
C9		21200 - 24500MHz	n258	24250 - 27500 MHz	24250 - 27500 MHz	TDD

Table 2: Overlapping frequency ranges - ERC Rec 25-10 and 3GPP NR Bands

The overlaps or close proximity between PMSE bands and 5G NR bands may present an opportunity for NPNs used for content production. This is particularly relevant because the availability of 5G hardware in given bands will be a major factor in evaluating the suitability of bands for PMSE.

TDD bands are more likely to be candidates for PMSE SNPNs while FDD bands used by MNOs will have less availability for SNPNs. It should be noted that TDD arrangements, in particular the pre-defined UL/DL ratios, may limit the flexibility for SNPNs to accommodate specific production requirements.

5.1.3 Analysis of the frequency bands and regulatory approaches

A number of different issues may need to be considered when assessing the suitability of frequency bands for PMSE use, such as the following:

- **Physical characteristics of the band**: Different frequency bands have different characteristics (e.g. distances that can be covered by radio links, available bandwidth capacity, body absorption properties, line-of-sight requirements, support for mobility) and not all frequency bands are suitable for all PMSE applications.
- **Availability of 5G hardware**: 5G equipment with the required functionality will be available only if there is a sufficient market demand. The content production sector would benefit from the economies of scale if the already-available 5G hardware could be used or easily adapted for use in production workflows.
- **Existing constraints within the band***:* Resulting, for example, from a duplex arrangement (FDD or TDD) that includes a pre-defined UL/DL ratio which cannot be adjusted to meet the requirements of a production use case.[8]
- **Availability of the band for PMSE use**: Including for temporary and nomadic NPNs. This includes a regulatory framework for access to the band, sufficient protection from interference, and affordable conditions, for example, in the case of spectrum leasing.
- ***Long-term viability***: Commitment to the band to allow investments in 5G-based technical solutions and the development of the ecosystem.

Furthermore, certain degree of harmonisation of the regulatory framework for 5G NPNs across multiple countries - ideally at the EU or CEPT level - would be desirable, in particular:

- **Harmonisation of frequency bands or tuning ranges for PMSE applications**: this would facilitate investments in the 5G equipment and potentially achieving economies of scale.
- **Harmonisation of the licensing regime**: this would be beneficial in particular for those content producers that operate in different countries.

As the demand for PMSE services is expected to continue increasing, novel regulatory approaches such as secondary licensing and dynamic spectrum access could help to ensure access to sufficient spectrum capacity for 5G NPNs.

5.1.4 Recommendations on spectrum access and licensing for 5G SNPNs

SNPNs for 5G production offer broadcasters and content producers the essential high Quality of Service (QoS) required for coverage of high profile, often live, events. They supply the flexibility to configure network architectures which provide the required professional workflows and advanced connectivity.

Delivering the highest QoS requires timely access to sufficient and suitable spectrum, determined by regulatory conditions, and how those conditions are then applied by national administrations.

[8] For example, some production use cases require very large uplink capacity and a small DL capacity. If the DL/UL ratio in a TDD band is, say, 5/1 then the spectrum will not be used efficiently. Equally, in an FDD arrangement the UL capacity may be fully used while the DL capacity would be largely unused.

The key requirements for spectrum access and licensing for 5G SNPNs in the content production sector are a sufficient amount of suitable spectrum, ease of access, international harmonisation, and support for innovation. The following points expand on these requirements.

- Sufficient suitable spectrum ranges need to be internationally harmonised by the CEPT and national implementations need to be sufficiently flexible. Opportunities for NPNs should be explored not only in the 5G NR bands and the licence-exempt spectrum but also in other bands where sharing with the incumbent users is possible. This includes the existing international PMSE spectrum 'tuning ranges' adjacent to or overlapping NR bands. In the latter bands, coexistence with conventional PMSE services needs to be ensured.
- There needs to be sufficient security of tenure for future access to spectrum for broadcasters and content producers to adopt 5G NPNs. This, together with international harmonisation would allow the content production sector to benefit from the economies of scale inherent in the broader 5G ecosystem.
- Regulation also needs to encourage future innovation in 5G NPNs and in production workflows.
- Spectrum made available for 5G NPNs that are deployed for content production needs to be of sufficient quality and geographically co-ordinated for local access with other spectrum users, including other NPNs and PMSE users.
- Access to spectrum for NPNs needs to be provided for a range of production use cases, including stationary and long term as well as temporary and of short durations and available at short notice. Licensing procedures should be in line with best current practices in the content production industry.[9]
- Authorisation to use spectrum for 5G NPNs can take many forms and a flexible approach including licensing, leasing and, if appropriate, general authorisation, need to be considered. Where appropriate, novel approaches to spectrum sharing such as secondary licensing and eLSA could be adopted.

5.2 Network regulation

Beyond access to the spectrum a number of different aspects related to 5G networks is subject to regulation. It is assumed that MNOs will be aware and will have implemented the applicable regulation as far as it relates to their operations and business models.

Non-public 5G networks may be less regulated than PLMNs. However, in some cases further clarification may be needed to determine to what extent NPNs fall within the scope of the regulation.

Due to the nature of professional content production use cases, some regulatory issues are particularly relevant. Some of these issues have been identified in the course of the project and are described below.

5.2.1 Roaming between networks

Roaming agreements between MNOs allow the users to move between networks using the same SIM card. Roaming is typical for using the mobile service abroad, i.e. when the user device is outside the coverage area of the network to which it is primarily subscribed. International roaming within the EU is regulated, in particular with regard to roaming charges.

Roaming between networks within a country is only possible in some specific cases where it is allowed by the regulation and enabled by an agreement between the MNOs. In countries

[9] Examples of existing access to PMSE spectrum via online portals are given in Annex B.

where MNOs have a nation-wide coverage (which is quite common in Europe) national roaming is usually prohibited or limited by regulation in order to preserve competition. In those countries where licenses for mobile services are issued on a regional basis, national roaming is a way of ensuring a nation-wide availability of the services. National roaming may also be a means to implement national policy, for example, to support a new market entrant, to extend the network coverage to underserved areas, to enable emergency communications, or increase the overall resilience of network infrastructure.

In some cases, MNOs may have an interest to enter into national roaming agreements to reduce network costs.

For content producers and use cases relying on public mobile networks international roaming provides an advantage as the same subscription and SIM can be used both within the countries and abroad. National roaming, where it exists, helps to ensure better network coverage (leveraging a single network subscription) and allows the producers to switch networks in case of outage or congestion.

A special case is roaming between PLMN(s) and NPNs, which may be suitable for some content production use cases, for example when a device moves out of the NPN coverage and falls back on PLMN while maintaining service continuity. It is unclear what the regulatory conditions are for such a case.

5.2.2 Access to network slicing

Network slicing allows network resources to be utilised more efficiently by creating virtual networks optimised for a specific user, service, or application. Network Slicing can be regarded as a base technology for realizing solutions such as PNI-NPNs. Multiple virtual networks are supported by the same physical and compute resources. Users have the flexibility to use the network resources tailored to their technical requirements and operational needs in a scalable way, and release them when they are no longer needed. Resource sharing results in a number of benefits to both the network operators and the users.

Network slicing is not yet available commercially. If and when it becomes available the network operators may have to prioritise between different users, in particular when the overall resources are limited. How will the network operator determine different priorities? On a commercial basis? Would some users (e.g. public services of PPDR) be designated by regulation as priority users?

For example, if content producers were to rely on a network slice they will need a guarantee of its availability, in particular for high-value productions or breaking news. If a user with a higher priority (e.g. PPDR) requires network resource, the content producer may be deprived of the access to a slice.

Further clarification by the regulators may be required for this kind of situation.

5.2.3 Network neutrality and traffic prioritisation

In the EU[10] and a number of other countries there are network neutrality rules that require public network operators providing access to the internet to treat all traffic equally, irrespective of its origin or destination, the type of service or application, the location of the provider or user, or the type of user terminal. Network neutrality rules also limit the scope for traffic management but recognise certain exceptions where it is allowed. Specifically, traffic management measures "shall be transparent, non-discriminatory and proportionate" and "shall not be based

[10] The EU network neutrality rules are included in Regulation (EU) 2015/2120. BEREC (Body of European Regulators for Electronic Communication) has issued guidelines to help inform the National Regulatory Authorities' implementation of the regulation.

on commercial considerations but on objectively different technical quality of service requirements of specific categories of traffic".

Furthermore, network operators are allowed to provide specialised services (i.e. services other than access to the Internet) which can be optimised for specific content or application "where the optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality". However specialised services "shall not be usable or offered as a replacement for internet access services, and shall not be to the detriment of the availability of general quality internet access services for end-users".

For many verticals, technical and operational requirements can be rather stringent and may require a high degree of quality assurance, network management, and traffic prioritisation. Professional content production is no exception. The question arises how these requirements can be met by 5G networks without violating the network neutrality rules.

For example, it is not clear whether traffic segmentation (e.g. treating separately video, audio, control, and data streams) and QoS differentiation fall within the exception for reasonable network management. Furthermore, it would appear that network slicing and 5G PNI-NPNs would be considered as specialized services, provided that they do not provide internet access. In practice, however, clear distinctions may not always be possible.

Resolving this question would allow MNOs and content producers to develop novel business models suitable for the professional content production use cases.

5.2.4 Numbering and Network codes for 5G NPNs

The numbering resource is limited and it is managed by the national authorities and the ITU-T. The right of use for numbering resources has traditionally been granted only to the providers of public communications networks and services. The emergence of the non-public networks raises the issue of granting the same right to other entities such as vertical users and NPN operators.

In the EU, the EECC foresees the possibility to allocate the numbering resource to NPNs but does not make it mandatory. Instead, it is left to the Member States to decide how the numbering resource shall be used.

A separate issue is a mobile network code (MNC) that is assigned for unique identification of networks within a given country and is part of the IMSI structure[11]. The IMSI structure and format are defined in the Recommendation ITU-T E.212 as follows:

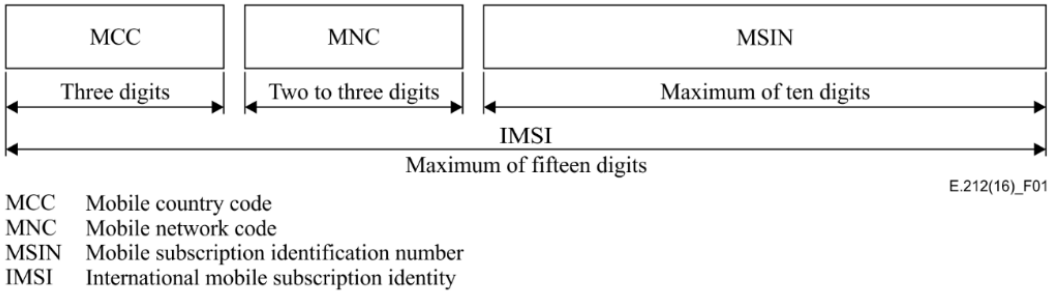

Figure 6: Structure and format of IMSI

The MNC, in combination with the MCC, provides sufficient information to identify the home network.

[11] International mobile subscription identity
See also Rec. ITU-T E.212 'The international identification plan for public networks and subscriptions', https://www.itu.int/rec/T-REC-E.212/en

The Rec. ITU-T E.212 also defines the MCC 999 for internal use within a private network. MNCs under this MCC may not be globally unique and therefore are not routable between networks. As a consequence, they are suitable for stand-alone NPNs but don't support interconnectivity and roaming.

There are ongoing consultations in some countries and at the EU level to further develop the numbering solutions and E.212 MNC use by NPNs. This is important for those vertical users and NPN operators that want to provide their own SIMs and facilitate interconnection and roaming. Further information has been provided by BEREC[12].

5.2.5 Network roll-out - Planning permission requirements

Deployment of physical network infrastructure (e.g. masts, antennas, cables, ducts, cabinets, and other elements) requires a permission from the national or local authorities. These requirements usually apply not only to RAN but also to backhaul and fronthaul.

Rules and regulations often differ between countries or regions, and there may be differences between urban and rural deployments.

For example, a deployment of a mobile network base station may require the approval of a technical project that guarantees that the radiation from the antennas comply with legal and safety requirements. Such technical project may include the following information:

- Station / location code.
- Endorsement from a certified telecommunication engineer.
- Description of existing radio technologies in the same location.
- Cartography of the location.
- Study of the radiation levels from the base station:
  - Schematic representation of the measurement points around the station
  - Measurement of the pre-existing levels of radiation in such locations
  - Computation of the reference volume for each radiation sector
  - Description of the area, including buildings and other locations frequently occupied by people.
  - Signalling and, if appropriate, fencing, to keep people away from the antenna.
- Photography of the locations of the antennas and the measurement points.
- Description of the techniques used to minimize emission levels.
- Calibration certificate of the measurement equipment.
- Other relevant information.

In some countries small installations or certain site upgrades are exempt from planning permission requirements. The European Commission has recommended such an exemption for 5G small cells which must meet certain technical and visual requirements[13]. Some provisions in the EECC (i.e. Article 57) also seek to remove planning constraints for small cell deployment.

[12] BEREC Report on the outcome of the public consultation on the draft 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, https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/9035-berec-report-on-the-outcome-of-the-public-consultation-on-the-draft-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

[13] See the Commission Implementing Regulation (EU) 2020/1070 of 20 July 2020 - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R1070&qid=1633514399742

5.3 Privacy and data protection

Privacy and data protection rules are particularly concerned with the protection of personal data. One of the most important laws in this field is the EU General Data Protection Regulation (GDPR)[14] which is concerned with the protection of natural persons with regard to the processing of personal data and on the free movement of such data.

The scope of GDPR is rather large and the stakeholders in 5G-based content production use cases need to be aware of their obligations and constraints.

5.4 Security

Telecommunications networks are generally considered to be part of national critical infrastructure. They are subject to regulation aiming to ensure a minimum level of security. Within the EU the applicable regulation is Directive on Security of Network and Information Systems ('NIS Directive)[15].

The European Commission has initiated a risk assessment on cybersecurity in 5G Networks and subsequently published a recommendation[16] and a toolbox[17] with a common set of measures for the Member States to mitigate the main cybersecurity risks. The following security challenges have been identified:

- Increasing security concerns related to the availability and integrity of the networks, in addition to the confidentiality and privacy concerns.
- Key innovations in the 5G technology (which will also bring a number of specific security improvements), in particular the increased important role of software and the wide range of services and applications enabled by 5G networks.
- The role of suppliers in building and operating 5G networks, the complexity of the interlinkages between suppliers and operators, and the degree of dependency on individual suppliers.

With respect to 5G NPNs it is not entirely clear whether and to what extent they fall within the scope of the current security regulation.

5.5 EMF exposure limits

Electromagnetic radiation from 5G networks is subject to regulation aiming to ensure that the public and workers are protected from harmful effects arising from exposure to EMF. Such regulation usually defines maximum exposure limits for two tiers of the population:

- **general public** who may not be aware of or have no control over the RF exposure;
- **occupational**, i.e. for the workers in the telecommunications industry who can exercise control over their RF exposure.

Most countries, including the majority of the EU Member states, follow the guidelines for safety limits provided by the International Commission on Non-ionizing Radiation Protection - ICNIRP[18] (also endorsed by WHO and ITU). In some countries stricter limits then those specified by ICNIRP are imposed by the national regulation.

[14] Regulation (EU) 2016/679, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0679-20160504&qid=1532348683434

[15] https://digital-strategy.ec.europa.eu/en/policies/nis-directive
Note: the NIS Directive is currently under review:

[16] Recommendation on Cybersecurity of 5G networks, https://www.europeansources.info/record/recommendation-on-cybersecurity-of-5g-networks/

[17] Cybersecurity of 5G networks: EU Toolbox of risk mitigating measures, https://digital-strategy.ec.europa.eu/en/library/cybersecurity-5g-networks-eu-toolbox-risk-mitigating-measures

[18] See https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf

Other countries follow the IEEE International Committee on Electromagnetic Safety (IEEE-ICES)[19] standards.

Further information about the EMF regulation and antenna siting policies in different countries is available on the GSMA site https://www.gsma.com/publicpolicy/emf-and-health/emf-policy.

The EMF standards and the associated regulation are not specific to 5G networks but apply to all RF equipment. Nevertheless, in order to address the public concern about 5G network deployments, BEREC and RSPG have published a position paper on spectrum-related EMF issues.[20]

Furthermore, a relevant regulation in the EU is the EMF Directive.[21]

5.6 Regulation applicable to the 5G-RECORDS use cases

The 5G-RECORDS project focuses on three distinct use cases which were selected because they represent three of the most challenging production scenarios: live audio production (use case 1), multiple camera wireless studio (use case 2), and live immersive media services (use case 3). The use cases are described in detail in the deliverable D2.1[22].

Figure 7: 5G-RECORDS use cases

The main purpose of these use cases was to derive the requirements and KPIs for the technical work in the project. However, if they were to be implemented commercially, they would be subject to regulation.

The following table shows an estimated impact of different kinds of regulation on each of the use cases, assuming usage of a SNPN with dedicated spectrum for the use case. This qualitative assessment is provided only for illustrative purposes and does not represent a competent legal analysis.

Regulatory issue	Use case 1	Use case 2	Use case 3
Spectrum access and licensing	High	High	High
Roaming between networks	Low	Low (High if the equipment moves between different networks)	Medium
Access to network slicing	Possibly high, depending on the workflow	Possibly high, depending on the workflow	High

[19] See https://www.ices-emfsafety.org/

[20] See https://berec.europa.eu/eng/document_register/subject_matter/berec/others/9462-berec-rspg-position-paper-on-spectrum-related-emf-issues

[21] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013L0035

[22] Deliverable D2.1: Use cases, requirements and KPIs, https://www.5g-records.eu/Deliverables/5G-RECORDS_D2.1_v1.0_web.pdf

Network neutrality and traffic prioritisation	Low (High, if traffic is going over the internet)	Low (High, if traffic is going over the internet)	High
Numbering and network codes	Low (High if interconnection between the local NPN and a PLMN or other NPN is required)	Low (High if interconnection between the local NPN and PLMN or other NPNS is required)	High
Network rollout - Planning permissions	Low (Possibly high, depending on the characteristics of the local NPN)	Low (Possibly high, depending on the characteristics of the local NPN)	High for PLMN rollout, not specific to the use case.
Privacy and data protection	High	Low	High
Security	Low	Low (High, for parts of the workflow going over PLMNs)	High
EMF exposure	High	High	High

Table 3: Impact of regulation on 5G-RECORDS use cases

References

[1] 3GPP TS 38.101, NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone (Release 17)

[2] ERC Recommendation 25-10 Frequency ranges for the use of terrestrial audio and video programme making and special events (PMSE) applications

[3] EBU Tech Report 056 5G for professional media production

[4] Ofcom (UK) Supporting the expanding role of wireless innovation in UK industry

[5] 5G-PPP Business Validation in 5G PPP vertical use cases, White Paper, 5G AI, June 2020.

[6] ECC Report 323 - Spectrum use and future spectrum requirements for PMSE

[7] ECC Report 205 - Licensed Shared Access (LSA)

[8] ETSI TS 103 235 V1.1.1 (2015-10): Reconfigurable Radio Systems (RRS); System architecture and high level procedures for operation of Licensed Shared Access (LSA) in the 2 300 MHz - 2 400 MHz band

[9] ETSI TR 103 588 V1.1.1 (2018-02): Reconfigurable radio systems (RRS); Feasibility study on temporary spectrum access for local high-quality wireless networks.

[10] ETSI TS 103 652-1 V1.1.1. (2019-02): Reconfigurable radio systems (RRS); evolved Licensed Shared Access (eLSA); Part 1: System requirements.

[11] ETSI TS 103 652-2 V1.1.1 (2020-01): Reconfigurable radio systems (RRS); evolved Licensed Shared Access (eLSA); Part 2: System architecture and high-level procedures.

[12] ETSI TS 103 652-3 V1.1.1 (2021-02): Reconfigurable radio systems (RRS); evolved Licensed Shared Access (eLSA); Part 3: Information elements and protocols for the interface between eLSA Controller (eLC) and eLSA Repository (eLR).

[13] Osterwalder, A. and Pignneur, Y., Business Model Generation. A Handbook for Visionaries, Game Changers, and Challengers. New Jersey: John Wiley & Sons, 2010

[14] Matinmikko-Blue, M., et. al.; Analysis of spectrum valuation approaches: The viewpoint of local 5G networks in shared spectrum bands. IEEE international symposium on dynamic spectrum access networks (DySPAN), 22–25 October 2018, Seoul.

[15] Matinmikko-Blue, M.,. Analysis of spectrum valuation elements for local 5G networks: Case study of 3.5 GHz band. IEEE Transactions on Cognitive Communications and Networking, 5, 741–753.

[16] Perez Guirao, M. D., Wilzeck, A., Schmidt, A., Septinus, K., & Thein, C. (2017). Locally and temporary shared spectrum as opportunity for vertical sectors in 5G. IEEE Network, 31, 24–31.

[17] Kour, H., et.al.. A Comprehensive survey on spectrum sharing: Architecture, energy efficiency and security issues. Network and Computer Applications, 103, 29–57.

[18] Yang, C., et al; Advanced spectrum sharing in 5G cognitive heterogeneous networks. IEEE Wireless Communications, 23, 94–101, 2016

Annexes

A Review of business analysis approaches

The literature provides a wide range of approaches to carrying out a business analysis. For the purpose of defining a business validation framework for 5G-RECORDS the following approaches have been considered: *(i)* Business Model Canvas; *(ii)* Value Chain; and *(iii)* SWOT Analysis.

Business Model Canvas (BMC)

The use of the Business Model Canvas (BMC) is recommended in order to analyse the following four aspects of the business process: [1]

- How to make the business happen (based on existing assets such as partners, existing activities and resources)
- What to propose to the customer (the value proposition)
- With whom (i.e. the customers)
- The financial structure (including inflows and outflows)

Within WP2, we could use the BMC approach to analyse the vertical market stakeholders utilisation of the 5G-RECORDS specific use cases and the value creation that the use cases bring to the stakeholders and their markets.

The BMC was developed by Alexander Osterwalder and is a visual chart with elements describing an organisation's or product's value proposition, infrastructure, customers, and finances. An example BMC template is shown in Figure 1.

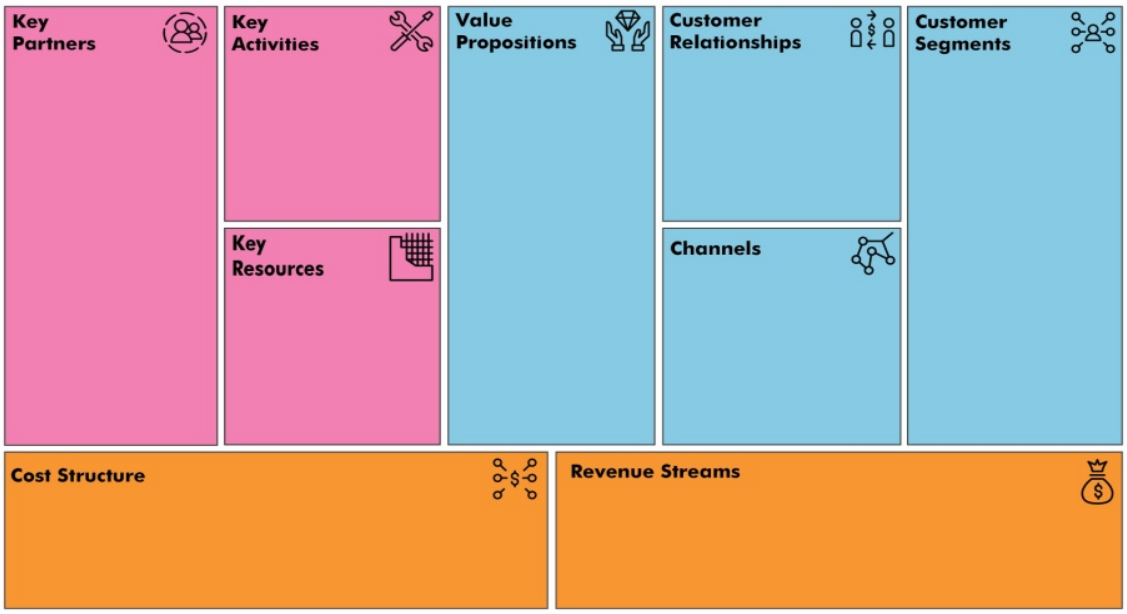

Figure A1: BMC Template

The BMC template comprises nine "building blocks" grouped by an organisation's or product's value proposition (the offering), infrastructure, customers, and finances (cost and revenue):

Offering

- Value Proposition: The collection of products and services a business offers to meet the needs of its customers.

Infrastructure

- Key Activities: The most important activities in executing a company's value proposition.
- Key Resources: The resources that are necessary to create value for the customer.
- Key Partners: The other organisations required to optimise operations and reduce risks of a business model. They can be joint ventures or strategic alliances between competitors or non-competitors.

Customers

- Customer Segments: This considers the customers that are to be served. They can be classified according to their different needs and attributes.
- Channels: An organisation can deliver its value proposition to its targeted customers through different channels such as distributors, resellers, integrators or infrastructure companies.
- Customer Relationships: Organisations must identify the type of relationship they want to create and maintain with their customer segments.

Finances

- Cost Structure: This describes the most important monetary consequences while operating under different business models. It addresses the class of business structure e.g. cost-driven versus value drive, and the cost structure characteristics e.g. fixed costs, variable costs, economies of scale and economies of scope.
- Revenue Streams: This describes the way the organisation generates income from each customer segment. It includes asset sale, subscription fees, licensing, etc…

Value Chain

The Value Chain model should also be considered because it describes the way that a company fits together its products and services to meet the specific needs of current and prospective customers. While a Business Model shows the way a business returns profit from the activities, resources, channels and partnerships that deliver the product, a Value Chain identifies the sequence of activities, from sourcing to marketing and sales, that deliver the product while returning a "Margin" to the company. Any Business Model could be best evaluated or built on the Value Chain that realises it.

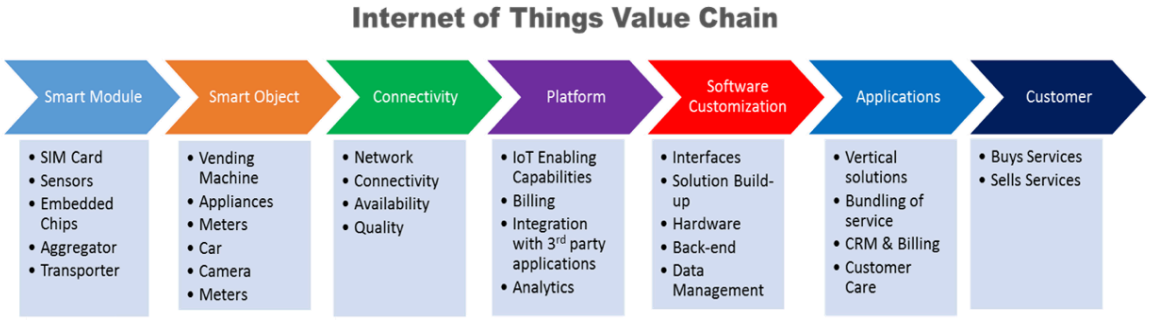

Figure A2: Example of an IoT Value chain model

SWOT Analysis

The SWOT analysis can be used in any decision-making situation when a desired objective is defined. It is a strategic planning approach used to help an organization to identify strengths, weaknesses, opportunities, and threats related to a business. It is intended to specify the objectives of a project and identify the internal and external factors that are favourable and unfavourable to achieving those objectives.

The name is an acronym for the four parameters the technique examines:

- **S**trengths: Characteristics of the business or project that give it an advantage over others.
- **W**eaknesses: Characteristics that place the business or project at a disadvantage relative to others.
- **O**pportunities: Elements in the environment that the business or project could exploit to its advantage.
- **T**hreats: Elements in the environment that could cause trouble for the business or project.

Internal factors are viewed as strengths or weaknesses depending upon their effect on the organization's objectives. What may represent strengths with respect to one objective may be weaknesses (distractions, competition) for another objective.

External factors include macroeconomics, technological change, legislation, and sociocultural changes, as well as changes in the marketplace. Results are often presented in the form of a matrix.

Figure A3: SWOT Schema

B National examples of PMSE spectrum licensing

Germany

In Germany, frequency use is possible in the form of individual licenses or general allocations. The Federal Network Agency (BNetzA) is responsible for the coordination and allocation of radio frequencies.

An individual license allows a specific frequency use at a specific time and place. An individual assignment is specifically approved and documented by a frequency assignment certificate. For individual licenses, one-off fees and annual frequency usage fees must be paid by the users.

For short-term frequency use (e.g. in the context of car races, sporting events, concerts and trade fairs) the allocation is carried out in a simplified procedure as a short-term allocation for a maximum duration of 30 days. The frequency allocation for short-term frequency use is basically event- and location-related.

General allocations, in contrast, permit the use of frequencies by the general public or a group of persons defined according to general characteristics, such as broadcasters and event technology service providers, etc. In the case of a general authorisation, no authorisation procedure is necessary for the user. Only a declaration of conformity for the devices is required here.

In general, the operation of audio PMSE transmission systems does not enjoy protection against interference from users with the same rights. The various operators of audio PMSE systems must coordinate the use of the audio transmission links on site among themselves.

Table B1 lists the frequency ranges available for audio PMSE in Germany and their basic frequency use.

Frequency band [MHz]	Frequency usage
32.475 - 34.325 and 36.610 - 38.125	General allocation limited until 31.12.2025. In case of non-use (no audio signal) the transmission signal must be switched off.
174 - 230	General allocation limited until 31.12.2025.
470 - 608 and 614 - 694	General allocation limited until 31.12.2030. In the case of major events, frequency coordination can be taken over by a central office, e.g. the organiser's organisation office or a person appointed by the organiser.
733- 758	Individual license Optional additional capacity for the use of radio microphones.
823 - 832	General allocation limited until 31.12.2025. Harmonised within the EU [ECC 2014/641/EU]
863 - 865	General allocation limited until 31.12.2028. In case of non-use (no audio signal) the transmission signal must be switched off. Harmonised within the EU [ECC 2014/641/EU].
1350 - 1400	Individual license. Subject to approval by the military requirement holder, within closed buildings for a defined area of operation.
1452 - 1492	Individual license.

	Optional additional capacity for the use of radio microphones.
1492 - 1518	Individual license. Permitted exclusively within buildings.
1785 - 1805	General allocation limited until 31.12.2025. Harmonised within the EU [ECC 2014/641/EU]

Table B1: Frequency ranges available for audio PMSE in Germany

United Kingdom

PMSE licensing and online application system

Licensing arrangements

PMSE licences are issued by Ofcom for a period of one year and are of two types:

1. A general authorisation to use specific equipment types, defining technical parameters and frequencies which may include geographical exclusions. Examples include low power wireless microphones such as the Shared UHF licence which grants uncoordinated access to Ch38 (606-614MHz), the 'duplex gap' (823-832MHz) and the 1.8 GHz band (1785-1805MHz).
2. A licence for individually co-ordinated and exclusive assignments. The applicant requests individual frequencies and channels for specific locations and time periods from 48 hours up to one year. Generally, only indoor assignments are licensed for long periods up to one year to avoid sterilising spectrum and maximise temporary availability for other indoor and outdoor users.

Co-ordination and spectrum sharing arrangements

Most PMSE spectrum use in the UK is subject to spectrum sharing arrangements with other spectrum owners, either co-channel or adjacent to PMSE. Applications for assignments in a given frequency range are first considered against the established sharing conditions with the other spectrum user. For wireless microphones in the UHF range 470-694 MHz also occupied by DTT broadcasting, the compatibility between protecting DTT reception from wireless microphones and protecting wireless microphones from excessive DTT interference determines the geographical availability of specific frequency ranges. In other cases, such as for wireless cameras, for a given frequency range there may simply be geographical exclusions in which PMSE operations are prohibited.

The compatibility of the application is also considered against other existing PMSE assignments, co-channel and adjacent. Practical operational assumptions and automated software propagation tools inform the decision and ensure reuse distances are sufficient without being excessive to maximise spectrum availability and use.

For major events when spectrum demand is greatest from multiple PMSE licensees at a single location, general planning assumptions cannot be relied upon to meet the spectrum requirements. The automated application process is temporarily suspended for the location and a more detailed manual frequency planning exercise is carried out, perhaps 20 or 30 times a year. It considers the operational factors in more detail, for example, the exact layout of an OB compound and negotiating with applicants, to understand and modify how they operate. In this way a more efficient and reliable frequency plan can be produced where automated methods would not satisfy the total spectrum demand.

All of these functions, with the exception of managing the Major Events, have been automated into an online application system for some years. It allows applicants to license frequencies

from familiar drop-down lists for all their production requirements, for specific locations and times. All the typical PMSE applications and frequency ranges are available including wireless microphones, in-ear monitors, production talkback, wireless cameras and point-to-point links. Automated co-ordination is carried out in real time licensing compatible assignments. Online payment is taken and licence documentation immediately emailed to the applicant so that PMSE licensees swiftly receive their authorisation. Late applications, changes and additions can be made at any time which is particularly valued by the PMSE industry. Past assignments can also be recalled for repeat events, pre-payment tokens can be managed and geographical availability of spectrum can be checked before applying. A list of regularly licensed locations can be accessed and custom assignment tabs can be tailored for particular users to display only their regular assignments and uses. While applications for major events can be made online, these assignment processes take place offline.

Screenshots below illustrate the process of applying for temporary assignments online:

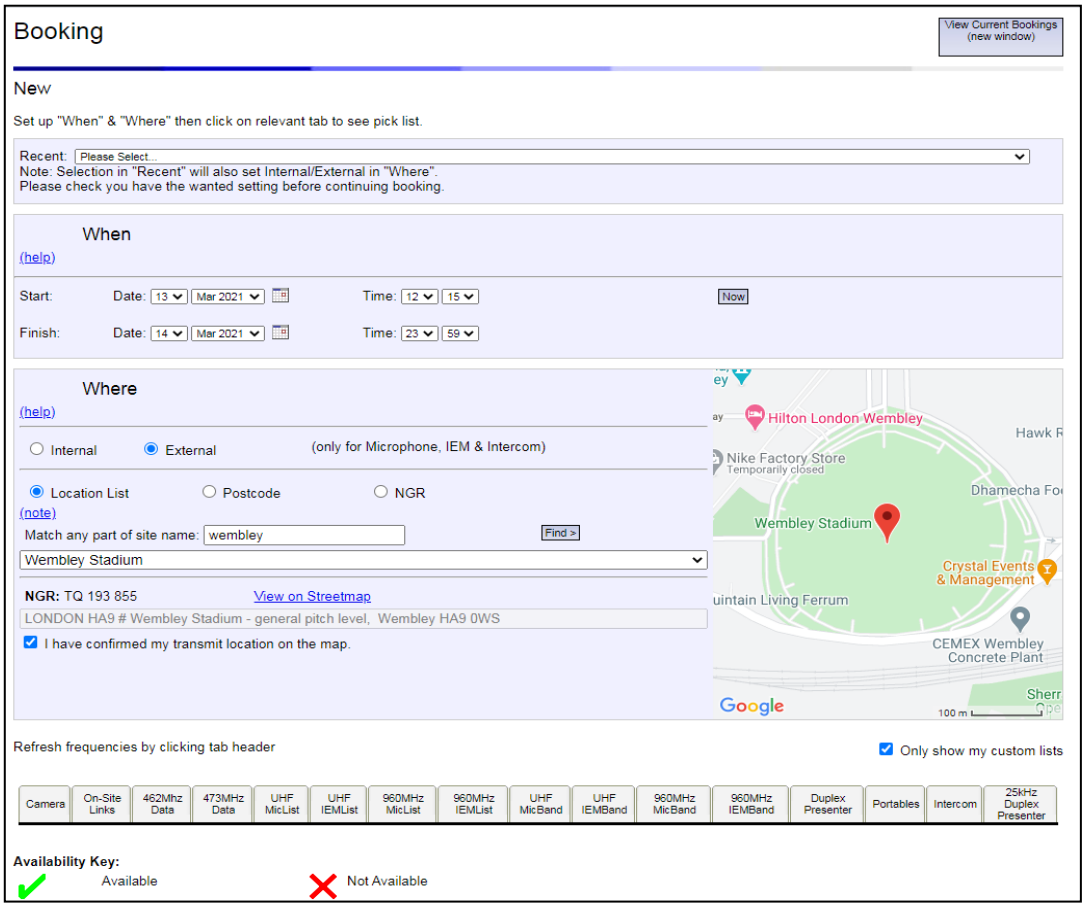

Figure B1: PMSE licensing and online application system in the UK - The initial booking page selecting start, finish and location

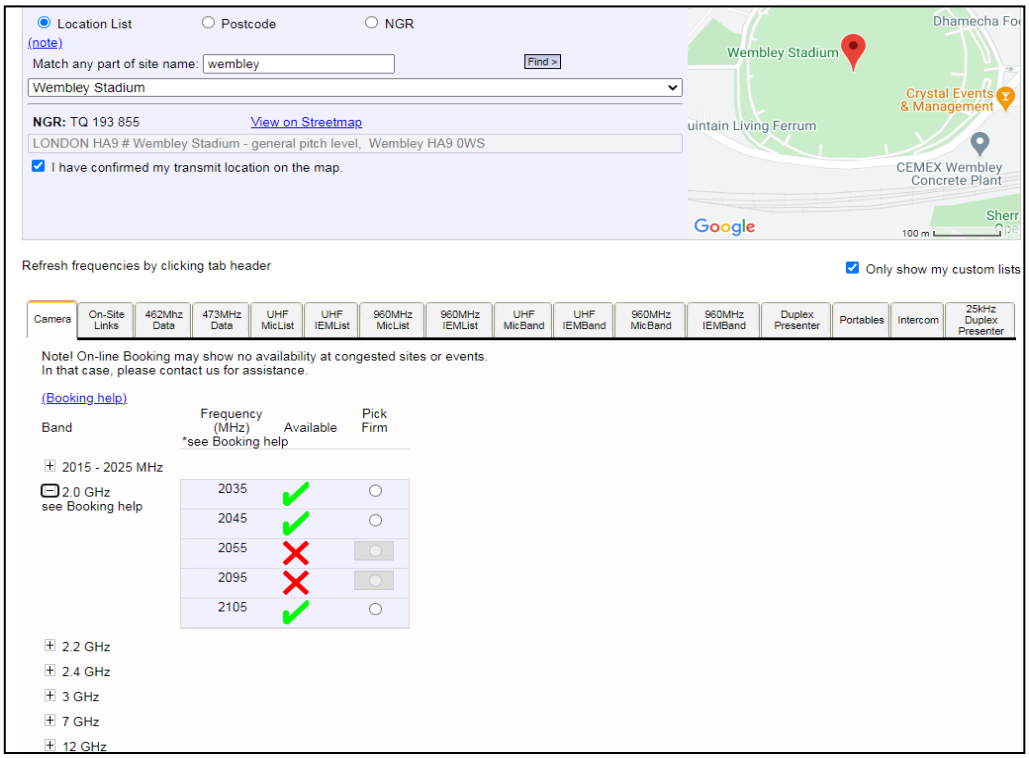

Figure B2: PMSE licensing and online application system in the UK - Frequency selection then takes place using the respective tabs – here Wireless Cameras

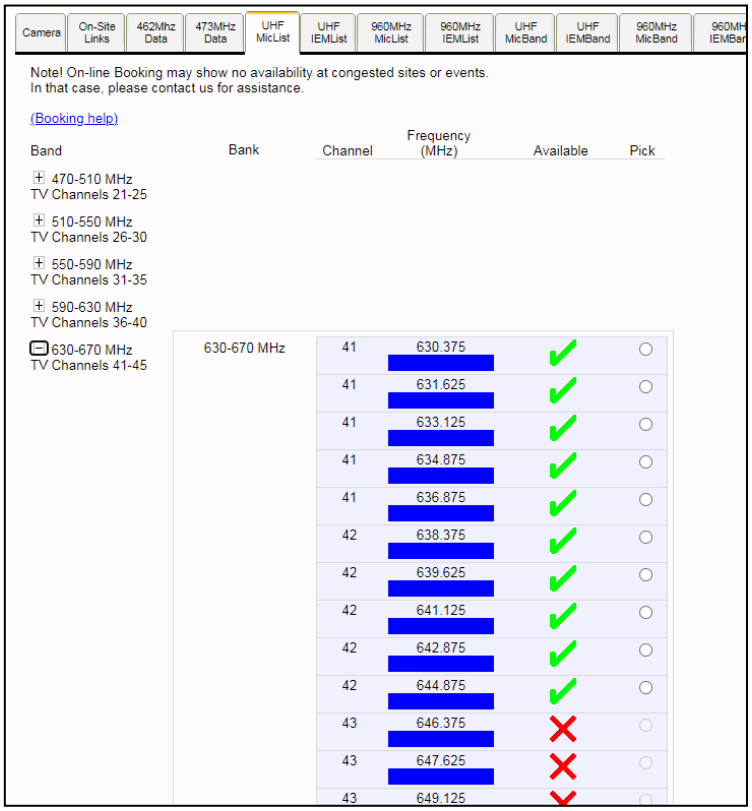

Figure B3: PMSE licensing and online application system in the UK - Frequency selection from the Wireless Microphone tab

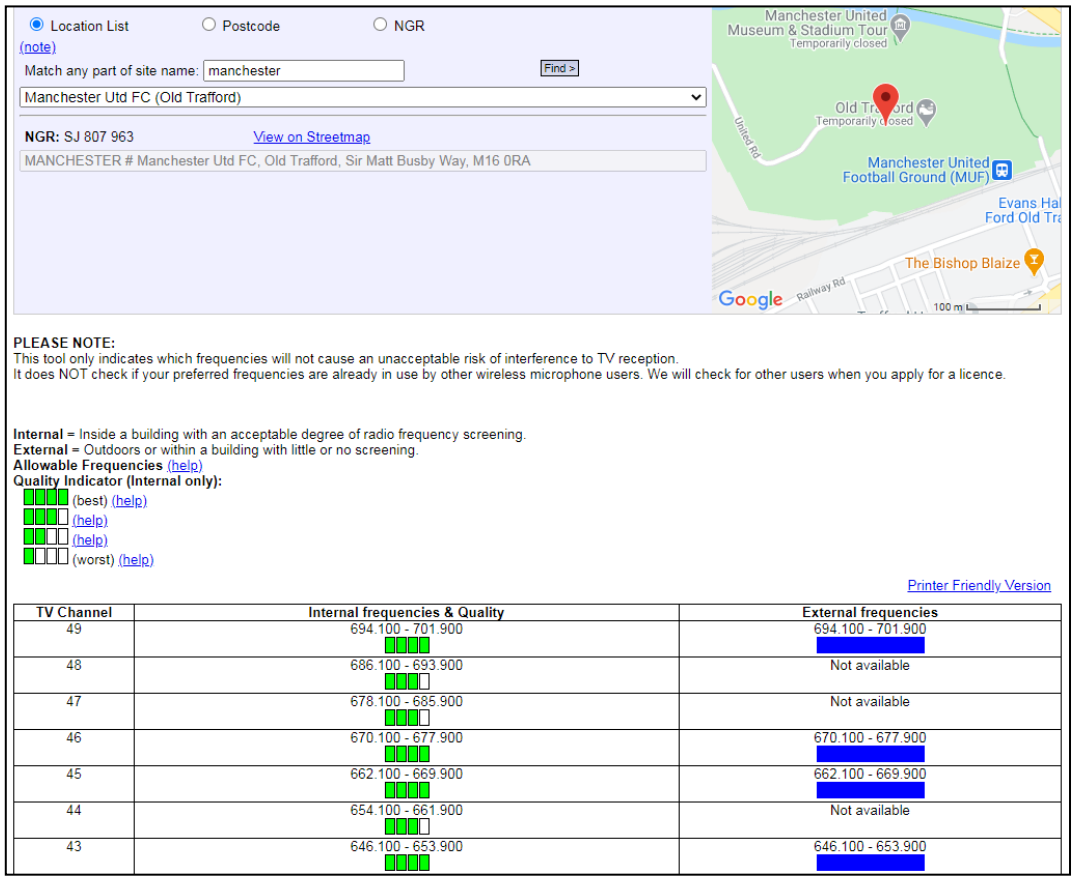

Figure B4: PMSE licensing and online application system in the UK - An extract of geographical spectrum availability planner for Wireless Microphones at Manchester United

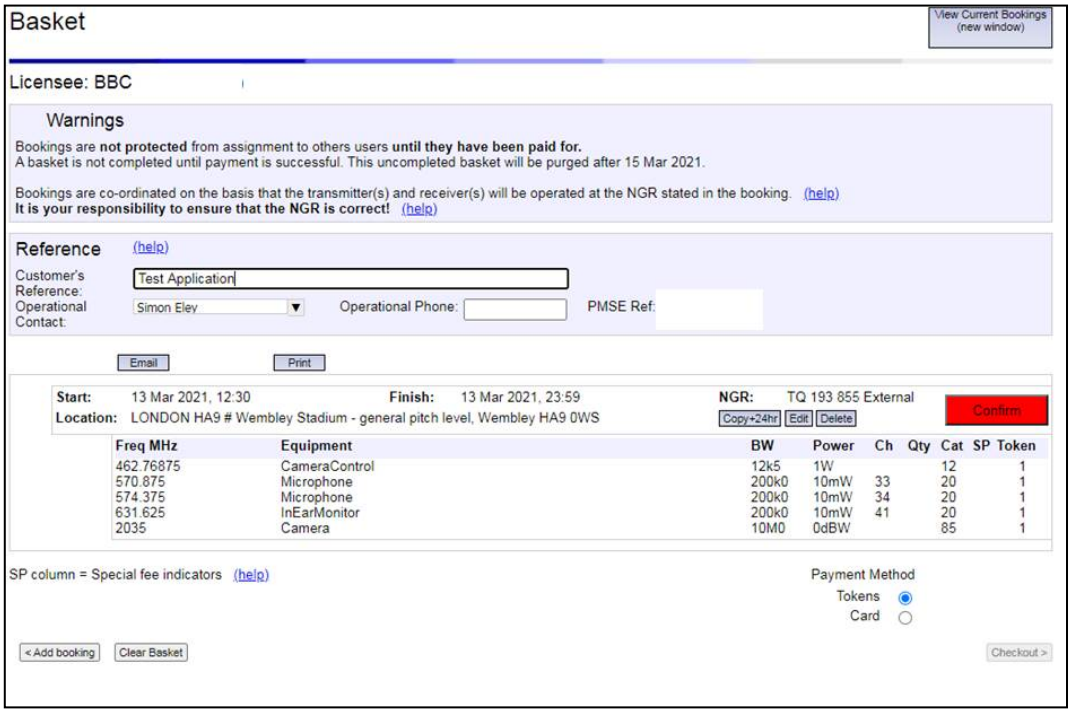

Figure B5: PMSE licensing and online application system in the UK - An example booking prior to payment with prepaid tokens

C Authorisation to use spectrum for 5G NPNs

C.1 Introduction

There are a number of authorisation options which can be used to permit access to spectrum for 5G SNPNs. These options can be divided into two broad categories: licensed access, and license-exempt access to the spectrum. Licensed spectrum access could be exclusive or shared, whereas license-exempt access is always shared[23]. A preferred option will depend upon the type of service or application and the user's requirements.

C.2 License Exempt Spectrum

Exemption from obtaining an individual license is limited to certain frequency bands for which a set of technical conditions is defined by the spectrum regulator. Provided that equipment meets these technical parameters, it can operate within these frequency ranges. The technical conditions are defined in such a way as to allow coexistence of different users in the same frequency band and the same location, without a need for coordination. Many mass-market radio devices are licence-exempt and can operate satisfactorily under these conditions.

The greatest advantages of the licence exempt use of spectrum are a low barrier for new users and a potentially high number of users in the same frequency band. For SNPNs, access to licensed exempt spectrum is the easiest and lowest-cost option.

The main limitation of license-exempt use of the spectrum is the lack of (or difficult to ensure) protection against harmful interference from other users that operate in the same frequency band. If the spectrum is heavily used in a given location this may lead to congestion, which results in unpredictable quality and service availability. These conditions are not suitable for those use cases that require consistent capacity, quality, latency and availability. This is why license-exempt spectrum access may not be a preferred option for the more demanding production use cases.

C.3 Licensed Spectrum

Licensed spectrum can be used only by authorised users. Authorisation can be secured through a national regulator or, in some countries and some frequency bands, obtained from a spectrum owner by means of a leasing agreement. Spectrum authorisations can be designated for national, regional or local coverage. They can be issued for a specific assignment or for block of frequencies. The latter allows licensees to manage their deployments within a range of frequencies. They have to respect the RF emission limits are typically defined by a spectrum mask (e.g. Block Edge Mask - BEM), that also needs to ensure protection of users in adjacent frequency blocks. IMT bands are examples where this approach is used.

The assignment of frequencies may need to be technically co-ordinated with other spectrum users to ensure that the protection requirements are met.

Assignments may alternatively be licensed without technical co-ordination between users, known as a ‘light licence’. This may be appropriate when the degree of exclusivity from technically co-ordinated assignments is not required and it can maximise spectrum re-use.

A spectrum license usually implies costs for the licensee and it guarantees access to the spectrum and protection from harmful interference. This is why the use of licensed spectrum is recommended for content production uses cases where guaranteed access and protection form interference are key requirements, and the licensee is willing to bear the costs of spectrum access rights.

[23] Spectrum sharing is treated in greater detail in annex D

For the operation of SNPNs in licensed spectrum two options are considered: secondary licensing and individual local licensing, as further described below.

C.3.1 Secondary Licensing (e.g. LSA, CBRS)

Secondary licensing refers to spectrum sharing between an incumbent spectrum user and the SNPN. Examples are the Licensed Shared Access - LSA in Europe [7] and the Citizens Broadband Radio Service - CBRS (as PAL user) in the USA [14].

In this approach, a SNPN applies to the NRA for a license to access a spectrum band already used by an incumbent user. Such an arrangement is feasible only if the incumbent user does not use the spectrum band to the full extent and sharing is technically possible. This license is called a secondary license and provides some level of certainty that the spectrum is available for the SNPN. At the same time, the SNPN has to follow the rules given in the license in order to protect incumbents from harmful interference, as well as other secondary license holders.

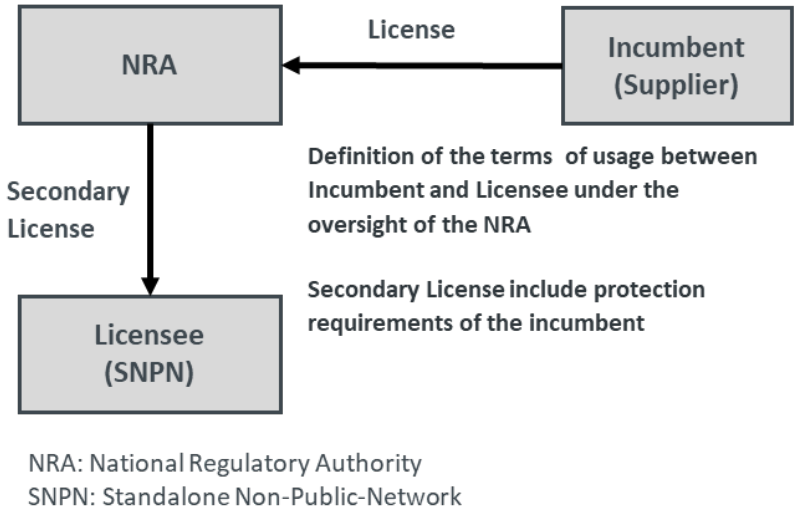

Figure C4: Operation principle of secondary licensing

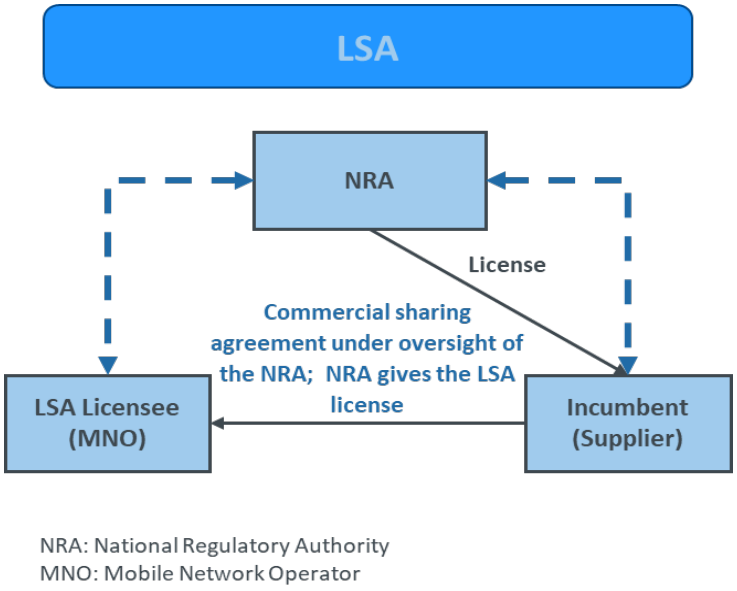

Figure C5: Secondary licensing as per Licensed Shared Access (LSA)

The costs of secondary licensing include the license costs, which depends on the 'amount of use' (measured in bandwidth, area and time), the costs for the deployment of the equipment and the infrastructure to control and monitor the spectrum access (CapEX), and the operational cost of interference management and coordination mechanisms (e.g. databases, spectrum sensing). For instance, LSA requires the deployment of an LSA controller unit on the SNPN infrastructure, and the deployment of an LSA repository unit on the NRA side. CBRS is a more dynamic approach requiring additional spectrum sensing capabilities (ESC – Environmental Sensing Capabilities) beside the repository and controller units (SAS – Spectrum Access System).

Under the secondary licensing scheme, access to the spectrum for SNPNs is not guaranteed. It depends on the characteristics of the incumbent usage and the ability of the SNPN service to tolerate interference coming from the incumbent user.

C.3.2 Local Area Licensing

The main difference between individual licensing and the secondary licensing described above is that, in this case, there may not be any incumbent users and, if they are, coexistence is ensured by the NRA. Thus, certainty of access for the licensee and predefined QoS levels can be guaranteed.

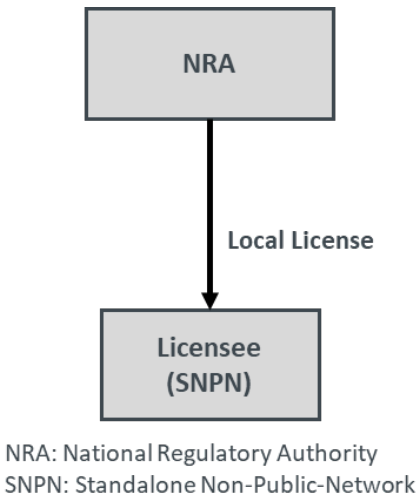

Figure C6: Operation principle of local area licensing

In general, local area licensing is suitable for those uses cases that require local coverage, certainty of access to the spectrum and high QoS levels at a reasonable cost.

This is particularly feasible at higher frequencies where the signal attenuation limits the interference among neighbouring deployments. National regulators in several European countries (Germany, UK, Sweden, The Netherlands) are currently considering local licensing for vertical-specific networks in 5G bands such as 3.7–3.8 GHz or on a shared basis, for example, in the band 3.8-4.2 GHz.

There is currently no common model for issuing local licensing to 5G SNPNs across Europe. Furthermore, the currently considered models are suitable for a long-term local use but not for a short-term, temporary use (e.g. few days, weeks or months) such as for media coverage of sports, cultural, political, events, news gathering or drama production on location.

Therefore, a certain degree of harmonisation of spectrum licensing conditions for 5G SNPNs across Europe and the models for temporary, short-term licenses would be beneficial for the content production sector. Current licensing regimes for PMSE, as described in Annex B, could serve as models for such arrangements.

C.4 Spectrum leasing or trading

C.4.1 Principle

In a general sense, spectrum trading allows the transfer of rights to use the radio spectrum from one user to another, including without the involvement of the NRA. Spectrum leasing is a process where an incumbent spectrum user, such as an MNOs (the lessor) leases out part of their licensed spectrum to another user, for example the SNPN spectrum manager (the lessee) to operate as SNPN in a defined area during a defined period of time. The incumbent and the SNPN spectrum manager conclude a leasing or trading arrangement which stipulates the rules and conditions for the use of the spectrum in accordance with the incumbent's spectrum license. The incumbent remains responsible to the NRA for the fulfilment of those rules/conditions.

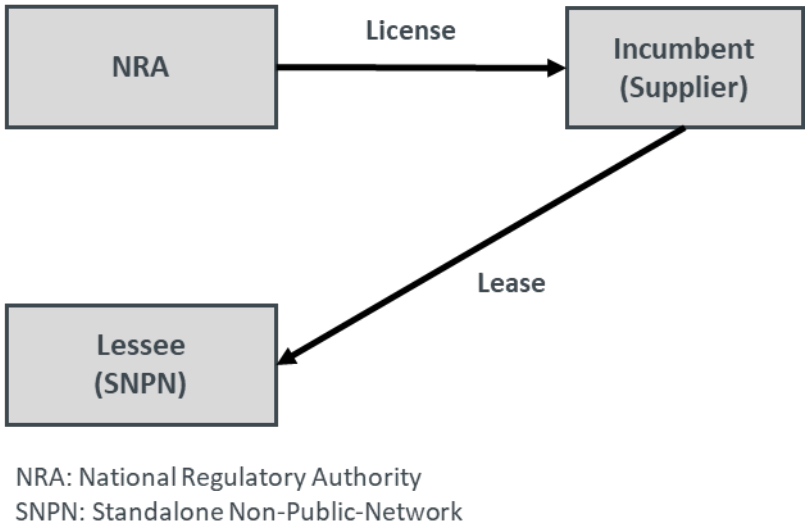

Figure C7: Operation principle of spectrum leasing

This spectrum access option is suitable for uses cases with local as well as national coverage and it provide a certain level of certainty of the spectrum availability, and the possibility to ensure high QoS levels. As the incumbent may seek a financial gain from the leasing agreement, it can be assumed that this option would result in higher costs for the lessee than in the case of local area licensing.

However, like in the local area licensing option, there is no common European framework for spectrum leasing. Thus, leasing contracts must be agreed on a national basis with the same consequences for nomadic use cases. Furthermore, NRAs must ensure transparency and fairness of the leasing and trading process.

C.4.2 Examples of leases

Possible features of leases (based on a trade-off between the level of interference protection and the flexibility of spectrum use) are summarized in the table below.

Types of Protection	Lease information	Spectrum Manager role
Guaranteed protection from interference **and guaranteed transmission power**	Contour + Interference protection threshold **within** the contour + Allowed Deployment	Determines the allowed transmission power at lease creation.
Guaranteed protection from interference (CBRS model)	Contour + Interference protection threshold **within** the contour	Adjusts the allowed transmission power at regular intervals (e.g., daily).
Moderate protection from interference	Contour + Interference limit **at** the contour	Adjusts the allowed transmission whenever a transmitter is deployed within the lease.
Manual coordination	Contour	Assistance during planning. Interference resolution.

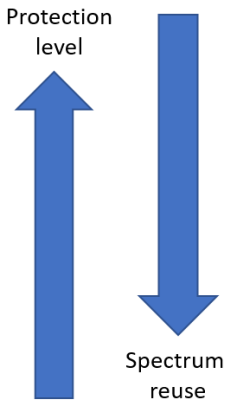

Figure C5: Features spectrum of leases

C.4.3 Lease creation process

In the context of PMSE, once a lease is created, it is critical to ensure that the PMSE user has a guaranteed protection from interference for the entire duration of the lease, regardless of other deployments in the vicinity of this lease.

One possible way to achieve this could be to accept creation of a new lease only in the case that this new lease does not impact the already operating PMSE users.

The process for creating such a lease is illustrated in the figure C6 below:

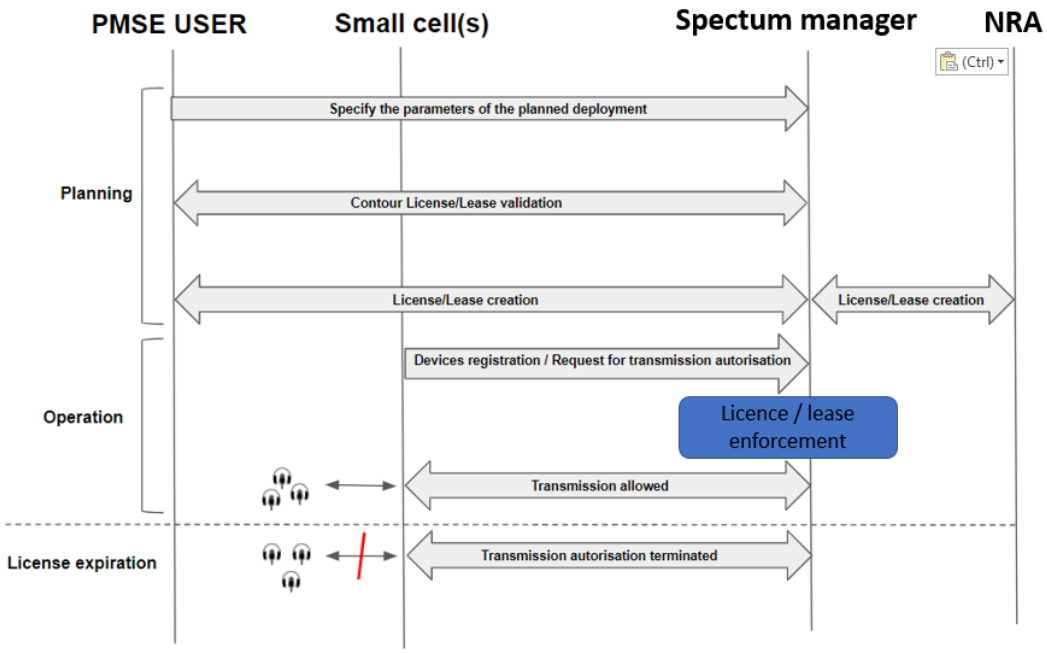

Figure C6: Example of the lease creation process

Upon the lease creation, the PMSE user provides its intended deployment and maximum transmission power for each transmitter.

Using this information, the Spectrum Manager is able to compute the interference that this new deployment would create to nearby leases, and to verify that the level of interference is below the guaranteed interference threshold associated with those existing leases.

Computation of interference on a given existing lease can be done by using a radio propagation algorithm and by performing an aggregation of the interference caused by all transmitters located outside of this lease.

C.4.4 Determination of the frequency range associated with a lease

The frequency range associated with a lease can be either:

1) Statically assigned (upon lease creation), or
2) Dynamically assigned.

The second alternative assumes that devices deployed within a lease are able to operate on different channels and can smoothly transition from one channel to another.

Based on the evolution of the radio environment, the Spectrum Manager can identify what is the most suitable frequency for each lease, so as to minimize the level of interferences among different PMSE users.

This re-allocation can be performed at regular intervals, or upon creation of a new lease in a given geographic area.

D Spectrum Sharing Approaches for 5G SNPNs

D.1 Introduction

There are two different kinds of spectrum sharing:

- Sharing among users with equal rights to spectrum access and protection from interference. Examples of this kind of spectrum sharing include license-exempt spectrum bands or spectrum under a general authorisation regime.
- Sharing between a primary user that has a priority access to spectrum and full protection from interference, and secondary users that can access the spectrum only under certain conditions, for example, in the areas where the spectrum is unused by the primary user and without the right to protection from interference caused by the primary user. Examples of this kind of sharing include sharing between terrestrial TV and audio PMSE (or white space devices) in the UHF band and the secondary licensing schemes such as LSA.

Advantages and disadvantages of different licensing options are presented in Annex C above. The following text will focus on spectrum sharing options and their suitability for 5G SNPNs.

Spectrum ranges used for 5G SNPNs may be exclusive to PMSE services or may be shared with other spectrum users, with or without technical co-ordination.

Where spectrum is shared on a technically co-ordinated basis the assignment parameters need to strike a balance between guaranteeing sufficient QoS, management of incoming and outgoing interference, and the efficient use of the spectrum, i.e. by geographical reuse of the frequencies. If re-use distances are over-cautious, spectrum requirements of other users may be denied. Conversely, if the reuse distances are over-optimistic, this may result in a degradation of QoS for the involved users.

For conventional PMSE services, technical coordination is often done on-site, in particular for large productions. However, for a large number of users that share spectrum on a dynamic basis, automated processes are key to ensure reliable technical co-ordination and swift authorisation. Where appropriate coordination and authorisation procedures exist, they ensure that content productions can be planned in advance with certainty as well as ensuring that urgent requirements and changes on a short notice can be met. Online tools are particularly suitable for this purpose. Some examples of such tools are included in Annex B above.

The heterogeneity of vertical use cases exploiting 5G NPNs anticipates diverse spectrum requirements strongly depending on the characteristic of the foreseen use cases. For example, much of PMSE production use cases, such as production at events (e.g. sports, cultural, political, community), require short-term spectrum access (i.e. a few hours, day or weeks). However, productions at permanent venues (theatres), film or TV production facilities or studios have a permanent spectrum demand and it may be appropriate to authorise spectrum access on a long-term basis.

Furthermore, most content production use cases require high, predictable, and consistent QoS levels that may be difficult to achieve in a license-exempt spectrum, hence the use of licensed spectrum is preferred. However, suitable spectrum resource for 5G SNPNs that could be licensed on an exclusive basis is rather scarce and it may be difficult to harmonise. Therefore, spectrum sharing in licensed frequency bands is considered to be one promising way to ensure that sufficient spectrum is available for 5G-based content production using SNPNs.

In recent years some spectrum sharing concepts have been proposed by regulatory bodies to improve spectrum utilization while ensuring co-existence of incumbents and additional users. For example, in the UK, Ofcom has authorised the 'white space' wireless technology (TVWS)

to operate in the interleaved channels within the TV UHF band[24]. In the USA the FCC established the Citizens Broadband Radio Service (CBRS) and created a three-tiered access and authorization framework to accommodate shared use of the 3550-3700 MHz band[25], while in Europe the CEPT recommended the Licensed Shared Access (LSA) concept [7]. These spectrum sharing models are briefly presented below. At present, only CBRS in US has reached a commercial implementation.

It is also worth noting that the research community has further studied spectrum trading and leasing approaches and the possible ways of making them commercially available [17], [18]. Spectrum sharing with a focus on private 5G networks has been studied, as examples, by [14], [15], [16], [17].

D.2 CBRS Model

(CBRS) is a spectrum sharing model developed by the FCC for the 3.5 GHz band in the USA. This model divides users into three tiers:

- Incumbent users: The first-tier users comprise military, governmental, and satellite users. This group of users enjoy protection against harmful interference and may access the spectrum band whenever required.
- Priority Access License (PAL) users: The second-tier users require a license petition from the national regulatory authority, i.e. have to apply for a license to access the spectrum band. The license periods hold for 10 years and should be renewable. PAL users are expected to receive protection against third-tier users.
- General Authorized Access (GAA) Users: Third-tier user's operation is similar to operation in license-exempt bands, where users share the spectrum under rules and conditions defined by the regulator. GAA users are not allowed to cause harmful interference to higher-priority (tier-2 and tier-3) users.

The operation of PAL and GAA is restricted within exclusion zones, i.e. certain geographical areas where incumbent operation is permanent. Further PAL and GAA users need to register to a control entity, Spectrum Access System (SAS), which monitor and coordinate the joint use of the spectrum. The SAS receives information about the spectrum utilization of incumbent users from an Environmental Spectrum Sensing Capability (ESC) system.

D.3 LSA Model

Licensed Shared Access (LSA) [7] is a European spectrum-sharing model that enables additional use of spectrum on bands already licensed to incumbent users. LSA focuses on nation-wide, long-term sharing arrangements between incumbents and LSA licensees. However, the operation of LSA licensees in certain geographical areas can be completely excluded (exclusion zones) or restricted (protection/restricted zones) depending on the sharing conditions imposed by the incumbent operation.

According to CEPT, a deployment of an LSA system requires the introduction of two architecture building blocks, the LSA repository and the LSA controller [7]. The LSA repository holds information such as spectrum resources for sharing, protection requirements of incumbents, LSA usage rights, and sharing conditions in general. The LSA controller is a management entity relaying this information to licensee networks to which it is connected.

CEPT proposed MNO bandwidth expansion in the 2.3–2.4 GHz band [7] as a first practical use case for LSA. Following that proposal, ETSI developed a series of technical specifications [9], [10] describing mobile broadband service in the 2.3–2.4 GHz band under the LSA concept.

[24] https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2015/tvws-statement

[25] https://www.fcc.gov/35-ghz-band-overview

For the 3600–3800 MHz range, ECC Report 254 [8] provides operational guidelines for national regulatory administrations (NRAs) on the implementation of LSA.

LSA trials in several European countries (Italy, Spain, Portugal) have focused on the bandwidth expansion of MNOs at a national level. However, so far, no commercial LSA implementation exists.

D.4 eLSA Model

Evolved LSA (eLSA) relies on the existing European regulatory framework for licensed-shared access (LSA) [7] while it extends the existing LSA standardization work within ETSI [9], [12] to support spectrum access demands of local private networks requiring predictable levels of QoS [13]. Figure D1 depicts the eLSA reference architecture [15], which is kept as close as possible to the LSA reference architecture [11] to maximize synergies.

eLSA supports geographically and temporarily flexible sharing arrangements – both secondary licensing and leasing - between incumbents and eLSA licensees. It also introduces a generic technical framework for a dynamic allocation and coordination of local area licenses/leases. Figure D1 also illustrates the spectrum access options supported by eLSA. Most importantly, eLSA extends the role of the Licensee/Lessee beyond MNOs to include vertical service providers.

eLSA supports the existence of *exclusion, restriction* and *protection zones* (as in LSA) to protect incumbent usage by constraining the spectrum access rights of eLSA licensees. Additionally, eLSA introduces the concept of *allowance zone* to define the geographical area within which an eLSA Licensee is allowed to operate radio transmitters on its assigned spectrum resources. Allowance zones can be defined in a flexible way on the area (from local to national), time (e.g. from short-term to long-term, periodic vs. sporadic) and frequency dimensions.

Thanks to its flexible definition of *allowance zones* together with the dynamic request/relinquishment procedure for the allocation of local area licenses/leases, eLSA enables spectrum access for nomadic, local, private networks, such as those required by many PMSE use cases.

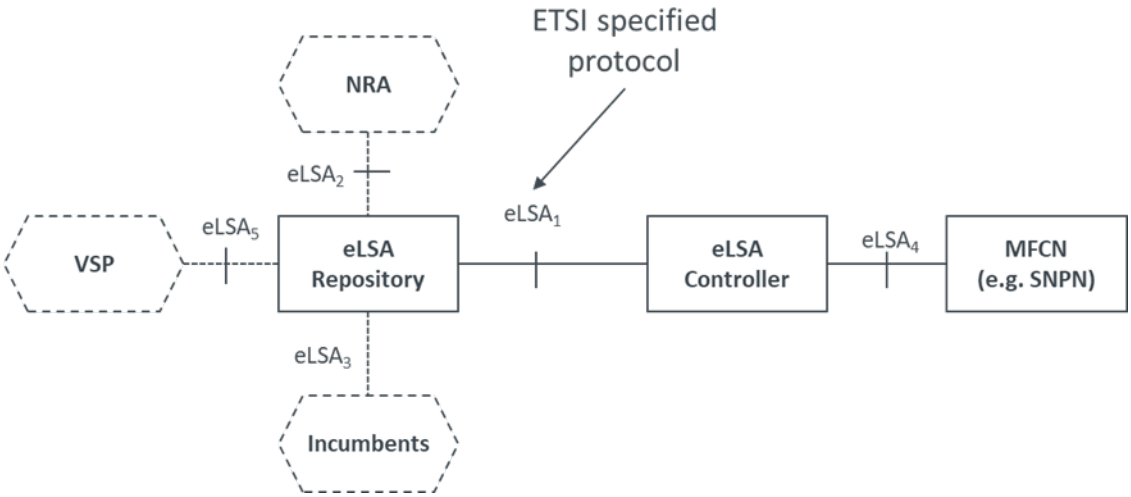

Figure D1: eLSA reference architecture

The objective of evolving the LSA model towards an eLSA (evolved LSA) is to provide a flexible and generic framework for enabling demand-driven spectrum access in Europe.

The eLSA model aims to become a reference model for CEPT regulators allowing vertical industries such as PMSE to derive maximum benefit from local private networks. Therefore, the concept is agnostic with respect to frequency bands and radio access technologies. In that sense, the implementation of the eLSA model can be adapted to any European national regulatory framework.

D.4.1 Discussion on the applicability of eLSA for typical PMSE Use Cases

D.4.1.1 Studio Production – Stationary/Fixed Operation

For stationary/fixed PMSE operation, e.g. studio production, the studio owner may deploy a permanent local private network (e.g. 5G SNPN) on premises. That local private network requires access to spectrum for operation. In the context of eLSA, the studio owner may decide to include the eLSA Controller (eLC) functionality within its network infrastructure.

D.4.1.2 Special Event Production – Nomadic Operation

Typically, for the production at events, production companies deploy the network infrastructure at the venue. For nomadic use cases the same network equipment is transported from one venue to another. For each venue, the production company has to apply to the responsible NRA for a license to obtain local spectrum rights for the duration of the event.

Usually, co-located production companies at the same event need to coordinate their frequency use on site. For very large events the NRA may be involved in on-site coordination.

In the context of eLSA, event production companies would most probably implement an eLC in their portable network infrastructure (e.g. SNPN) since they cannot assume that every location owner has deployed a fixed network infrastructure and an eLC for requesting local spectrum access on its premises.

Note that in some countries the location/venue owner may be the only stakeholder entitled to obtain a local spectrum license for its property. This is the case in Germany in the 3.7 -3.8 GHz band. This means that the actual spectrum user, which may be only temporary, is not eligible to apply for a spectrum license. Nevertheless, this kind of spectrum regulation may enable some interesting deployment scenarios, such as the following:

- The venue owner (local license holder) deploys a neutral host network using her local spectrum resources. The neutral host network can provide support for one or more vertical users (e.g. content production companies), neither of which owns the spectrum access rights nor network infrastructure, but pays for the access to network services.
- The local private network (NPN) could be provided by an MNO or a third party while using the local spectrum resources licensed to the venue owner (local license holder).
- The venue owner (local license holder) / lessor may trade / lease the spectrum to other network operators / lessees, such as production companies, deploying their networks on-demand at the venue.