EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR COMMUNICATIONS NETWORKS, CONTENT AND TECHNOLOGY

Digital Decade and Connectivity
Radio Spectrum Policy Group
RSPG Secretariat

Brussels, 25 October 2023

RSPG23-040 FINAL

RADIO SPECTRUM POLICY GROUP

Opinion

5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks

RSPG Secretariat, office L-51 05/DCS,
Commission européenne/Europese Commissie, 1049 Bruxelles/Brussel, BELGIQUE/BELGIË
Telephone: direct line (+32-2)29.21.261, switchboard 299.11.11;
E-mail: cnect-rspg@ec.europa.eu
Website CIRCABC: https://circabc.europa.eu/w/browse/f5b44016-a8c5-4ef6-a0bf-bc8d357debcb
Website : https://radio-spectrum-policy-group.ec.europa.eu/index_en

1 Introduction

Further to its Opinion on Additional spectrum needs[1], the RSPG has conducted an additional evaluation of 5G in Europe (licensing strategies, auction design, deployment progress, etc.) with the aim to gain knowledge around what has been successful and what still needs to be addressed, thus providing valuable input when designing future 6G strategies.

Regarding the pivotal role of wireless broadband, the RSPG considers early signals of demand for additional spectrum as well as the necessity to make a certain amount of harmonised spectrum for 6G available in a timely manner also in spectrum bands initially targeted for 5G including low, mid and high bands. This may involve continuing the move further up to higher bands, thus enabling early exploratory work in the sub-THz bands.

The RSPG continues to engage in the sharing of information and experience in support of a successful development and future roll-out of 6G in the EU and will provide targeted guidance on authorisation and implementation issues, if such a need is identified. This activity has included inviting presentations and/or organising stakeholders' workshop, also to address the issue of spectrum demand for unlicensed devices, including WAS/RLAN, and of non-terrestrial networks to maximise 6G coverage.

This work may form the basis for and may lead to future 6G spectrum roadmaps of the RSPG later on (beyond 2023). This activity does not address WRC-23 agenda item 10, which has been addressed solely under the activity regarding the preparation of EU position for WRC-23.

[1] RSPG Opinion on Additional spectrum needs and guidance on the fast rollout of future wireless broadband networks, Document RSPG21-024

2 RSPG Opinion

The RSPG:

1. Recognises that 5G implementation is ongoing in the primary and pioneer bands identified for 5G.

    a. The 700 MHz band was harmonised in the EU in 2016. It was initially planned and used for 4G in some Member States (MS) and has now started to be used for 5G. The band provides excellent coverage but offers lower bit rates than the 3.6 GHz, 26 GHz and 42 GHz bands due to its bandwidth.

    b. The 3.6 GHz band[2] is the primary band for implementation of 5G networks in Europe with a harmonised spectrum of 400 MHz. The initial roll-out of 5G in this band benefits from the reuse of 4G network architectures and sites with 5G Non-Stand-Alone (NSA) deployment. Today mobile network operators (MNOs) have also deployed 5G Stand-Alone (SA) networks in this band. The band offers both good coverage and capacity. The roll-out in this band is still ongoing.

    c. The 26 GHz band[3] is subject to different timings and implementations in MS. The roll-out of 5G has been slow even in those MS that have made this band available to the market. Millimetre-wave bands can address very high-capacity use cases in dense areas bringing possibilities for new types of networks, services, service providers, users (verticals) and business models, but at the same time this band does not provide good coverage due to its different propagation characteristics compared to the other bands used since the launch of mobile technology.

    However, this pioneer band in millimetre-waves range remains a suitable band to conduct trials, develop services and explore new opportunities for mobile networks in the millimetre-wave spectrum bands. The learning phase is still on going, noting that initial commercial use (including by verticals) has started and is expected to increase as equipment availability improves in the coming years and MNOs are willing to densify their networks (e.g. in hot-spot areas) where user demand increases or for implementing fixed wireless access solutions. MS should be encouraged to proceed in the harmonised way in making the band available for 5G according to the EC Decision and taking into account the RSPG Opinions and their recommendations.

2. Recognises that new solutions for more dynamic and shared use of spectrum have been introduced with the uptake of 5G. This need is expected to increase with 5G development and the uptake of 6G and could require more flexibility in spectrum access.

---

[2] In this document 3.6 GHz refers to the 3.4-3.8 GHz (3400-3800 MHz) frequency band

[3] In this document 26 GHz refers to the 24.25-27.5 GHz frequency band

a. Intra-operator Dynamic Spectrum Sharing enables an MNO to share its spectrum resources on demand in real-time between 4G and 5G (later expected for 6G) technologies within their spectrum blocks. This approach has already been widely implemented. MNOs took the opportunity to quickly roll out and make available 5G services to their customers in large areas without the need to completely phase out a legacy technology.

b. Beyond voluntary initiatives, some MS have also introduced leasing obligation models (mainly in the 3.6 GHz band) that encourage the provision of MNOs bands to third parties as well as sharing models between MNOs (mainly in the 26 GHz band).

c. Mechanisms emerge to share spectrum dynamically between different terrestrial mobile broadband networks and other types of networks in a flexible and effective way, e.g. for events and other temporary needs, and should be further developed more broadly for 6G.

3. Recognises the increasing needs for spectrum for verticals and local networks.

a. Some MS have already assigned spectrum for local and vertical applications and the spectrum needs for these are still increasing. Current national implementations include dedicated spectrum, e.g. in the 400 MHz, 2.3 GHz and in harmonised bands 2.6 GHz, 3.6 GHz and, as recommended by the RSPG, 26 GHz.

b. In some MS, voluntary harmonisation in 410-430 and 450-470 MHz bands responds to user demands, in particular from utilities.

c. In addition, and in response to the strong demand for mid-band spectrum for vertical and local use and to address the RSPG Opinion 21-024 for harmonised spectrum for vertical needs the Commission issued a Mandate to CEPT “on technical conditions regarding the shared use of the 3.8-4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity in the Union”. Beyond national initiatives, work will continue to define harmonised technical conditions for low and medium power terrestrial wireless broadband (WBB LMP).

d. As part of the second stage mmWave bands, the 42 GHz band will be a possible extension to the 26 GHz band, and will be available as needed in the MS. The 42 GHz and 26 GHz bands, as recommended in RSPG Opinion 21-024, can enable local access to spectrum including for verticals with market demands expected to increase in the future.

e. There is a benefit in and increased need for common European approaches for spectrum access for verticals with options for enabling local access to spectrum (See RSPG Opinion 21-024).

4. Recognises, further to RSPG Opinion 21-024, that, prior to the introduction of 6G, additional capacity needs for mobile networks may arise on the national level during this decade. These do not require additional EU harmonisation and can be met at a national level either by firstly using the current spectrum more efficiently (e.g. by densifying the network) or introducing additional spectrum for terrestrial mobile broadband.

5. Recognises that technology neutrality[4] and spectrum sharing[5] are applicable and the existing harmonised bands for ECS will be also made available for 6G. Further, there is a need to assess the suitability of harmonised technical conditions to support the long-term development of 6G in the bands as it has been done for 5G.

6. Recognises, as for 5G, the role and need of license exempt or light-licensed spectrum for offloading some of the 6G traffic and to provide private and personal networks. License exempt spectrum supports improved end-user connectivity, machine-to-machine and other applications, but is shared between many users, therefore predictable quality of service is not typically guaranteed so far.

7. Recognises the role of and need for non-terrestrial networks to support 6G development further current initiatives on 5G. Non-terrestrial networks could become an important connectivity layer to terrestrial connectivity services, e.g. to provide coverage in underserved areas, provide global connectivity to logistics and transport, support disaster relief and serve as a fallback layer or backhaul for terrestrial networks. The currently emerging non-terrestrial networks offer a third dimension to terrestrial connectivity.

8. Recognises that a proactive position is essential for supporting the development and deployment of 6G. This includes further work by RSPG on early recognition of spectrum needs, so that the initial launch and operation of 6G networks/services can start in 2030[6]. In due time, this early recognition of spectrum needs should be based on a proper evaluation of coverage and capacity needs for 6G use cases and usages scenarios, also considering non-terrestrial networks and licence exempt use, and of the challenge of launching 6G at a time where most terminals do not yet support 6G, taking into account, among others, the results of projects in 6G Research and Development. RSPG will consider in 2024 or later a 6G spectrum roadmap.

9. Recommends to the European Commission, taking into account RSPG recommendations, with the help of Member States, to work towards a strategy, involving all active stakeholders (research institutes, manufacturers, MNOs,

---

[4] Technology neutrality means that an operator chooses what technology generation to use in their spectrum bands

[5] see RSPG deliverables on spectrum sharing: RSPG Opinion on Spectrum Sharing – Pioneer initiatives and bands – Document RSPG21-022; RSPG Report on Spectrum Sharing – A forward-looking survey – Document RSPG21-016

[6] 2030 is the current target date planned by international standardisation bodies for the availability of 6G specifications

spectrum users' associations, end-users, etc.), to facilitate the timely launch of 6G services across the EU and supporting various EU policies.

The focus of the RSPG is to provide the necessary strategic spectrum guidance to facilitate the future roll-out of 6G services across the EU, which is expected at the beginning of the next decade.

~.~

Informative Annex 1: Background to the opinion

1 Working methods

A questionnaire was issued to RSPG member and observer countries in relation to development of 6G and possible implications for spectrum needs. Twenty-one Member States responded to the questionnaire. This RSPG opinion takes into account those responses.

A workshop with stakeholders was held in September 2022. The purpose of the workshop was to:

- Provide input for evaluation of 5G in Europe (licensing strategies, auction design, deployment progress, etc.) with the aim to gain knowledge around what has been successful and what still needs to be addressed, thus providing valuable input when designing future 6G strategies.
- Understand the use cases for 6G and how they deviate from the use cases of 5G
- Understand the expectations for 6G related to regulation, spectrum demand, licensing, sustainability, energy efficiency.
- Provide additional information to the questionnaire answers from member states.

A summary of messages from those presentations are included in Annex II.

A public consultation on the draft version of this RSPG opinion was held between 16 June 2023 and 25 August 2023. All non-confidential responses are published on the RSPG website[7]. The RSPG appreciated all comments received. The RSPG considered them carefully and improved the draft opinion as appropriate.

The following respondents provided comments:

1	ecta
2	EOLO SpA
3	Wi-Fi Alliance
4	CRTV
5	University of Oulu
6	EUTC
7	ETNO
8	Bitkom
9	Vodafone
10	SCF
11	Multi company (Amazon Inc., Broadcom Inc., Cisco Systems Inc., Hewlett Packard Enterprise (HPE), Meta Platforms Ireland Limited)
12	German Center for Satellite Communications
13	GSA
14	Deutsche Telekom
15	Liberty Global

[7] https://radio-spectrum-policy-group.ec.europa.eu/document/download/069f2c87-03d4-4964-a016-1158795c48b2_en?filename=Responses_PC-6G.zip

16	IEEE 802 LANMAN
17	GSOA
18	Cisco
19	GSMA
20	Elisa
21	6G-NTN
22	Nokia
23	DSA
24	Qualcomm
25	Viasat

The RSPG welcomes the number of responses received from a diverse range of stake holders representing the majority of the services with an interest in the development of 6G networks.

The wide support for this Opinion from stakeholders was clear.

As expected many of the individual comments reflect self-interest and as a consequence polar-opposite views on the same topic are presented by different parties.

Finally, the RSPG intends to consider as appropriate those comments in the next (2024-2025) RSPG work.

This Annex is intended only for informative purpose, in order to provide a general background to the opinion, based on the responses to questionnaire, the results of the workshop with stakeholders and the comments received during the public consultation of the draft Opinion.

2 Review of 5G development in Europe

Further to the initial 5G RSPG Opinion, EC launched harmonisation initiatives for the 3.6 GHz and 26 GHz frequency bands (700 MHz has been harmonised in early 2016) under the Radio Spectrum Decision[8], which has been confirmed by the EECC. Council/EP adopted ambitious objectives for harmonisation implementation of 3.6 GHz and 26 GHz (EECC – European Electronic Communications Code DIRECTIVE (EU) 2018/1972, article 54º) and reorganisation of the UHF band in order to make available 700 MHz to IMT. This Opinion shares RSPG reflections on primary / pioneer bands to 5G in Europe, lessons learnt from 5G development in Europe (including on Dynamic Spectrum Sharing (DSS) between 4G and 5G as well some reflections on new regulatory practices), the impact of small cells regulation, Connectivity Toolbox and connectivity goals set by EU for 2025 and how to address potential capacity needs by 2025.

2.1 Reflections on primary / pioneer bands to 5G in Europe

The RSPG noted that primary and pioneer bands have been identified in order to support the launch of 5G in Europe.

[8] Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community

The RSPG in its first Opinion on 5G (RSPG16-032)[9] in November 2016 recommended:

- the frequency band 3400-3800 MHz as primary band for introduction of 5G-based services in Europe even before 2020 in order to put Europe at the fore front of 5G development and to Member States to consider appropriate measures to defragment this band in time for authorizing sufficiently large blocks. This band has been subject to harmonised technical conditions under spectrum Decision adopted in 2008, 2014, with low market demand, and then in 2019 for 5G (Decision (EU) 2019/235).
- the band 24.25-27.5 GHz as a pioneer band for 5G above 24 GHz (mmWave). In order to support development of the broadband market, RSPG recommended also to harmonise this frequency band before 2020 and to make part of the available bands. RSPG noted that roll-out of 5G in this band was expected to be progressive, starting in major urban centres according to some business models, without excluding other areas (i.e. rural areas) based on other business models. RSPG also noted that in some MS mobile network operators are the main users of this frequency band for fixed service.

The RSPG also recognised that 5G will need to be deployed also in frequency bands below 1 GHz including, in particular, the 700 MHz in order to enable nationwide and indoor coverage.

In addition, the EECC - European Electronic Communications Code DIRECTIVE (EU) 2018/1972 (CODE) mandated a coordinated timing by end of 2020 for assignments of these two specific 5G bands (art.54) and implementation of the harmonised technical conditions under the Radio Spectrum Decision.
The following sections are assessing these three frequency bands: 700 MHz, 3.6 GHz and 26 GHz.

2.1.1 State of Play of the 700 MHz band

This frequency band benefits from EU harmonisation and synergies with other regions including economies of scale. As the band was harmonised in the EU in 2016 before the availability of 5G equipment in 2020, it has been initially used by 4G in some EU Member States and later started to be used by 5G. However, due to the size of the frequency band (small bandwidth), the some of 5G performances (bitrate/speed) are lower than in the higher bands (e.g. 3.6 GHz) although operators can use carrier aggregation with other bands (e.g. 800 MHz), within technology neutrality framework. The advantage of the 700 MHz band is the good propagation characteristics, which enable larger coverage areas than the higher bands.

2.1.2 State of Play of the 3.6 GHz band

This frequency band has been subject to ambitious harmonisation initiative in order to make available 400 MHz of harmonised spectrum for mobile broadband (at least 80 MHz per operator) supporting development of 5G in Europe. It should be noted that two harmonisation initiatives took place in this frequency band in previous decades

[9] RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G), Document RSPG16-032 FINAL (09 November 2016)

(2008, 2014) without meeting the market demand. The last initiative in 2019 took place at the same time as 5G standard equipment became available and the introduction of new technology innovations such as Active Antenna Systems (AAS).

The initial 5G roll out in this frequency band benefited from the reuse of 4G network architectures and sites with Non-Stand Alone (NSA) deployment. NSA has been a welcomed standardisation initiative as for the first time in the mobile industry a new radio technology has been introduced with the existing core network, mainly due to the technology evolution (network *softwarisation*). This offered an opportunity for an early launch of 5G Radio Access Network (RAN) in this primary 5G frequency band, which was connected to a 4G core network. NSA cannot provide genuine 5G features such as low-latency communications that require 5G core.

Member States were also engaged to reorganise some of the frequency bands, in order to make available wide contiguous spectrum band.

In the future designation of new frequency bands, there should be sufficient possibilities and/or time for Member States to take existing use into account when implementing future spectrum decisions. As an example, the Netherlands were at the forefront of the implementation of the initial EU spectrum decision for the 3.6 GHz band (2008) with the issue of local licenses (e.g. for use in the port of Rotterdam and for FWA in rural area). The last EC decision for 5G in the 3.6 GHz band forced NL to refarm this use, resulting in a significant migration challenge.

This frequency band has been largely assigned in EU Member States, as recognised by the European Commission, and benefits from large economies of scale (given that it is the 5G worldwide core band) including with some possible synergy with the 700 MHz band.

RSPG noted that outside Europe, 5G development has benefitted from the availability of some mid bands, such as 3.3-3.4 GHz and 4.8-4.99 GHz, which are not available in Europe (and will not be made available due to other strategic usages supporting various European interests and Common Security and Defence Policy (CSDP)).

2.1.3 State of Play of the 26 GHz band

Despite harmonisation (EC Decision) and Policy initiative (EECC), RSPG noted that mmWave 5G bands have not been authorised in many Member States. In 2022, there is no clear indication of the market demand in some Member States. Nevertheless, some other MS, in public consultation, have verified the presence of market demand and have already assigned or planned to assign the 5G band in accordance with the harmonised technical conditions laid down in the EC Decision. MS where the band has been assigned reported that actual use in some cases is limited but it is spreading with the launch of commercial services. In particular, some MS reported that there are interesting expectations from various operators for the use of the 26 GHz band for 5G, to meet both the needs of mobile connectivity and/or FWA; the latter, for example, in typical sub-urban and rural scenarios.

A "club use" mechanism has been also adopted in that band by Italy and the implementation details have almost been finalised by the operators in order to initiate the mechanism.

Some MS have already assigned at least 1 GHz in this band for 5G and plan to make the whole 24.25-27.5 GHz frequency band available for terrestrial systems capable of providing wireless broadband electronic communications services, in compliance with the harmonised technical conditions set out in the EC Decision.

In order to implement the EC Decision and make the band available for 5G, some MS have also studied conditions for the protection of incumbent services and have decided to migrate existing fixed links.

Some MS, based on the interest shown by several operators in the use of the 26 GHz frequency band for 5G, believe that the boost from EU as well as national digital development and transformation policies can reasonably lead to a rapid growth of the 5G ecosystem also in this band. In this regard, it has been expressed confidence that technologies will be able to better support the development of 5G services based on a compact position of MS in making the band available according to the harmonised technical conditions set out in the EC Decision. On the contrary, investments made or planned in these Member States to support the development of 5G services in the 26 GHz band could be jeopardised without a homogeneous implementation of the EC decision that could pave the way for the mass market.

In order to support industry and market development in this frequency band, multiple trials initiatives including inter-sectorial have been launched in number of EU Member States.

See examples of trials

- In France, part of the 26 GHz band (26.5-27.5 GHz) is authorised for trials since 2019 and there are still 13 innovation platforms currently under a 3-year authorisation licence. At this stage, the development of solutions in this band is still slow, mainly due to limited equipment availability and lack of strong business models, among other things. Some trials include a multi stakeholder approach including either verticals or local authorities. Some are just starting to yield some actual demonstrations of usage for crowded public places or venues.
- In Finland, MNOs have brought 26 GHz spectrum into use at some sites for trials and testing. There are also local research, development and test networks (of vendors and research organisations for instance) using this band. Part of the frequency band is also assigned for private and local networks. The 26 GHz band has also been used in live demonstrations and is in operational use in a sports arena[10].
- In the Czech Republic one MNO had a successful trial in July 2022. This MNO has a plan to use mmWave spectrum in future private networks. Both non-standalone and standalone modes can be used.

[10] Nokia and Elisa achieve over 2 Gbps 5G uplink speeds on mmWave with Qualcomm solutions

The mmWave bands can address very high-capacity use cases and especially in very dense areas. However, compared to 3.4-3.8 GHz, densification of networks to achieve seamless connectivity across large areas is not economically realistic. Due to propagation characteristic (high loss not favouring multipath: diffraction, scattering), mmWaves would require a very high number of base stations. There is also a lack of mass market in EU compared to what was initially planned (2020). Sharing of small cells is also at an early phase of deployments.

Heterogenic EMF limits across the EU are also impairing the assignment and usage of mmWave bands. RSPG and BEREC adopted in 2020 a position paper on spectrum-related EMF issues. BEREC members are sharing information about the different levels of cooperation between competent bodies in countries and about national policies around monitoring, communicating and implementing EMF-related issues[11]. RSPG noted the recent update of the ICNIRP 2020[12] guidelines on the EMF exposure limits. During the public consultation some respondents expressed an interest for EU harmonisation. However, EMF exposure limits are not in the pureview of RSPG and RSPG will not examine this further.

RSPG noted that mmW equipment availability is still limited compared to mid band devices, the strategies of some countries on mobile bands or of mobile operators outside Europe are focusing on either 5G development without mmW bands or on more investments in mid-band compare to mmW. There are some initiatives on FWA in mmW.

2.2 Lessons learnt from 5G development in Europe

RSPG summarises the above analysis with the following lessons learnt:

- There is a need for long term strategic spectrum planning supported by RSPG Opinions (see RSPG 21-024)[13] in order to bring about EU harmonisation and regulatory initiatives. Policy/regulatory initiatives are necessary (5G Action plan, EECC) to give visibility for investment and provide legal certainties. Based on demand from major mobile operators, equipment vendors make investments and undertake technology developments, which generate economies of scale.
- The launch of 5G in Europe has benefitted from the availability of large contiguous blocks of harmonised spectrum in the 3.4-3.8 GHz band at the right time along with technology development, market demand and existing network grids and architecture which are suitable for this band (more so than the mmWave bands).
- Such policies and strategies have not been sufficient, in case of mmWave, due to specific requirements for devices and network deployment/roll out: this frequency range has different characteristics compared to the spectrum bands which have been used since the launch of mobile technology.

[11] BEREC: Electromagnetic Fields
[12] The main ocjective of this document is to establish guidelines for limiting exposure to EMFs.
[13] RSPG Opinion on Additional spectrum needs and guidance on the fast rollout of future wireless broadband networks, Document RSPG21-024

- The pioneer 26 GHz band remains, however, a suitable band to conduct trials, develop services and explore new opportunity for mobile network. The learning phase is still on going, noting that commercial use started and is expected to grow eventually as the device availability is improving.

While spectrum demands may differ among MS and is already recognised by EECC, innovation of mobile industry towards higher frequencies may require long term investment and could suffer from a lack of market demand. Spectrum harmonisation remains one pillar to create confidence in future market giving visibility for long term investment, economies of scale, efficient use of spectrum and better cross border condition. RSPG intends in its future analysis to consider also new approaches for spectrum licensing for future mobile networks supporting networks investments and competition. Taking into account also lessons learnt from 5G, any future spectrum harmonisation initiative under the Radio Spectrum Decision should be developed on the basis of RSPG spectrum roadmap involving all MS.

2.3 Impact and lessons learnt on Dynamic Spectrum Sharing (DSS) between 4G and 5G

Dynamic Spectrum Sharing (DSS) is a solution that enables parallel use of 4G and 5G in the same frequency band by an MNO. This solution allocates spectrum resources for 5G and 4G in real-time. The MNO network then divides the available bandwidth independently and decides dynamically the most suitable mobile communications standard to use the available frequencies.

The RSPG Opinion/Report on spectrum sharing (2021) identified technology evolution allowing mobile operators to realise dynamic allocation of frequency resources among devices with different radio access technologies, based on real-time conditions and network loads (e.g. Dynamic Spectrum Sharing, DSS). This is in effect an intra-operator spectrum sharing technique, which is currently proposed and implemented by many MNOs and vendors.

Dynamic Spectrum Sharing has been standardised to enable a smooth migration of the already existing bands from one technology (4G) to a newer compatible mobile technology (5G NR), relying on the compatibility between the OFDM structure of 4G and 5G NR. It is a way for mobile operators to cope with the intrinsic dynamic behaviour of a new technology introduction and adapt the spectrum dedicated to the new terminal penetration as the demand grows. Standardisation has extended the capability of the DSS features and it is expected future releases may continue this work, however, this is dependent upon the mobile operator's strategy to reduce the capacity of their 4G network in favour of 5G, taking into account the evolution of 5G devices and their footprint in the market.

It could be assumed that 5G and 6G will continue using DSS-like techniques in the early stages of 6G. However, sharing of existing bands alone may not be sufficient for providing expected 6G services and additional bands as close as possible in frequency to mid-bands and with adequate bandwidth could be required. RSPG intends to further address this issue when developing its 6G spectrum roadmap.

2.4 Reflections from Member States on new regulatory practices related to 5G development in Europe

One of the objectives of encouraging the allocation of bands for use by third parties is the efficient use of the spectrum through the flexibility of the spectrum rights. The ECC report 287/2018 - "Guidance on defragmentation of the 3400-3800 MHz frequency band" proposed it, which also opened up new possibilities for MNOs' business models for verticals. To better illustrate the following cases can be cited:

- Denmark: The allocation of a 60 MHz block (at 3740–3800 MHz) in the 3.6 GHz band to TT-Network (a joint venture of Telenor and Telia in Denmark) with the obligation to rent locally to companies and public institutions (for the exclusive use of companies and institutions). A standard contract has been prepared, which makes it easy to enter into these agreements for leasing the spectrum from the operator. It is also the idea that documentation provided to the private networks should appear to act as if it were the ADSI (Agency of Data Supply and Infrastructure) that issued the licences. The private networks must meet the same technical requirements as the licence holders of the spectrum to ensure that the private networks can coexist with the public mobile network. In addition, a maximum leasing price has been set, which includes a spectrum fee, permit price and an administration fee.

- Czech Republic: The allocation of 20 MHz blocks (at 3400–3600 MHz) acquired by O2 and CentroNet containing an obligation to lease those blocks to support Industry 4.0.

- Finland: The 3.6 GHz spectrum band is assigned to three MNOs in 130 MHz blocks. There is a particular network licence obligation on the operators to use it or lease it: If, despite the request for tenders, the licence holder does not offer a network service in the 3.6 GHz spectrum band that takes into account a customer's special needs in a port, industrial plant, hospital, shopping centre or a similar entity within a limited geographical area, the licence holder is obliged to lease the right to use the 3.6 GHz frequency to the aforementioned customer or its representative on reasonable and non-discriminatory terms in order to provide service in the aforementioned geographical area. There have not been any cases, where the regulator Traficom has made administrative decisions based on this licence obligation. However, it seems that the requirement encourages operators to find solutions to meet specific vertical needs in geographically limited areas.

- France: The NRA (Arcep) promotes secondary uses and has included in recent frequency licences (e.g. 3.6 GHz band licences) the obligation for MNOs to commit to granting reasonable requests from economic actors (enterprises, local authorities, administrations …) by providing them with tailored solutions with set coverage and performance levels or, if the operator prefers, by granting them local access to its frequencies, via “secondary” licences. This obligation will take effect by 2024 and will be complemented by a roll-out obligation in rural and industrial areas at the end of 2024. Some initiatives are also supporting development of verticals (i.e. reduced spectrum fees in 2.6 GHz TDD) and roll out of networks with improved rules for sharing of sites (including passive).

- Italy: in auctioning the 3.6-3.8 GHz band for 5G systems, Italy introduced a use-it or lease-it obligation. To encourage competition and promote the coverage of 5G services on a large number of Italian municipalities, operators without frequencies in bands up to 3.6-3.8 GHz (or with frequencies covering less than 40% of the national population) and service providers have the right to use the frequencies in the 3.6-3.8 GHz band not used by the licensees in any communes in a “Free list” (all the communes with less than 5,000 inhabitants that are not included in the mandatory lists of all the licensee constitute a "Free list") against the payment of a fee to the successful tenderer.

- Italy: "club use framework" (use other MNO's spectrum if they don't use it): in auctioning the 26 GHz band for 5G systems, Italy adopted a spectrum sharing approach to promote competition. An access obligation was introduced in the form of “Club use” (frequency pooling): each licensee can use all the awarded spectrum in this band (up to 1 GHz) in areas where frequencies are not used by other licensees; however, each licence holder has a pre-emptive right on its assigned lot. For this purpose, licensees can stipulate reasonable and non-discriminatory commercial agreements, proportionally sharing the costs; licensees can assign to a trusted third party the task of managing the uses to avoid harmful interference as well as the access scheduling.

- Ireland was an early mover in auctioning the 3.6 GHz band in June 2017. The 350 MHz of available spectrum was offered in 594 lots spread over nine regions (four rural and five urban) and assigned on a contiguous basis.
  The Auction resulted in five Winning Bidders consisting of three MNOs, one WISP/FWA operator and one wholesale operator. Winning bidders paid an upfront fee determined by what they bid in the auction and pay yearly usage fees over the 15 year duration of the licences which are linked to consumer price index (CPI) to maintain their value.
  The main licence conditions included:
    - Achieving and maintaining the rollout of a minimum number of base stations per region within 3 years of Licence issue. This ranges from 2 to 15 base stations depending on the size of the region. A higher rollout obligation is imposed on licensees holding more than 100 MHz of spectrum rights in a region and this ranges from 4 to 25 base stations.
    - minimum Quality of Service conditions including network unavailability, a minimum voice call quality as well as appropriate standards of speech transmission; and
    - compliance with the Inter Licensee Synchronisation procedure that builds on the technical conditions set out in the 3.6 GHz EC Decision to facilitate the co-existence of services in the 3.6 GHz band with services in the same band or in adjacent spectrum bands.

  Trading of spectrum rights attached to the 3.6 GHz Band Licences is permitted.
- Germany: While the lower 300 MHz in the 3.4-3.8 GHz range were auctioned to three existing network operators and one newcomer for nationwide licenses in 2019,

the upper 100 MHz were reserved for local coverage by interested vertical users. Until August 2023, more than 340 licenses were granted for local use and the demand is still increasing. A use-it-or-loose-it approach was also implemented in the local licenses.
The 26 GHz band was made available for local area coverage to be used by public mobile network operators as well as interested vertical users.

TDD use imposes restrictions and large separation distance in case of unsynchronised networks (or limited operational conditions) because of the need of synchronisation with neighbouring networks (local, regional and cross-border). Solutions to limit the impact of lack of synchronisation have been developed as appropriate by CEPT for 5G commercial networks in 3.4-3.8 GHz. This could be further investigated in 3.8-4.2 GHz within CEPT if needed for Wireless Broadband Low and Medium Power networks, especially for unsynchronised operation.
Adoption of light licensing regulation for Base Stations / Small Cells is very important for facilitating faster deployment of new / dense networks. Light licensing can make spectrum assignment easier and faster especially where there is no scarcity.

2.5 Impact of small cells regulation, Connectivity Toolbox and connectivity goals set by EU for 2025

Limited use of the regulation in the MS markets does not allow for conclusive results. Some positive views are expressed but there is no real feedback by the MS or the MNOs.

A number of MS had already implemented regulations permitting the installation of small cells. It is therefore too early to assess the effects of the small-area wireless access points regulation[14] compared with the previous situation.

In the case of MS that had already auctioned 5G spectrum before the introduction of the Connectivity Toolbox[15], the measures concerning spectrum issues were already in place. For this reason, the national implementation roadmap of the Toolbox contained no new measures for the best practices concerning spectrum issues.

Most MS have not identified major risks in meeting the connectivity goals for 2025, however for some MS it might be challenging to meet the connectivity goals (e.g. 5G coverage along major transport paths) to the full extent in areas bordering with non-EU countries due to coordination difficulties and different use of the bands (e.g. 700 MHz and 3.6 GHz). Some concerns are expressed about high investment to reach the deployment needed and the lengthy procedures for obtaining permissions for new sites.

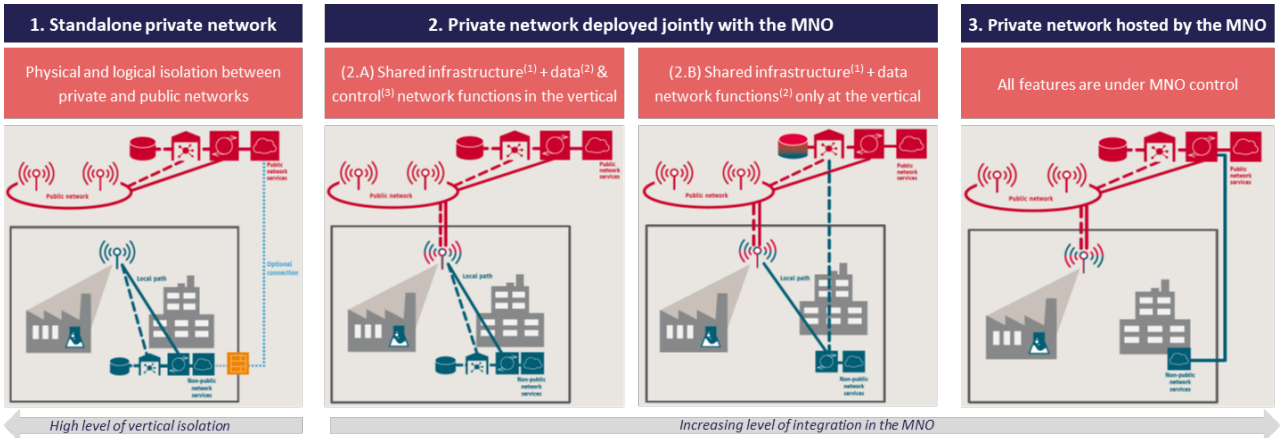
[14] Commission Implementing Regulation (EU) 2020/1070 of 20 July 2020 on specifying the characteristics of small-area wireless access points pursuant to Article 57 paragraph 2 of Directive (EU) 2018/1972 of the European Parliament and the Council establishing the European Electronic Communications Code

[15] The Connectivity Toolbox

3 Spectrum for verticals and local networks

With 4G and 5G, mobile network technology has started to be used by industry stakeholders, also known as "verticals", for their own professional use and requirements with private mobile networks. Use cases generally target local coverage of the enterprise premises (e.g. warehouses, plants, campuses) and can be served by local area network deployment on limited area (few km² or less) at limited power. Some needs for wider area network solution e.g. for the utilities or transportation sector (for example see harmonisation initiative to support RMR).

Therefore, such needs can be characterised according to the different levels of integration with the MNO[16]:



(1) Examples: Sites or any passive infrastructure (GC, pylon, technical room etc.) or active (servers, DC etc.). Dedicated spectrum
(2) Network functionalities in charge of traffic forwarding, stream transcoding and application services. Dedicated vertical spectrum and MNO spectrum
(3) Network functionalities in charge of access policy control and QoS, signaling and subscriber profiles. MNO spectrum

Figure 1. Options for implementations of private networks (source: Arcep)

National initiatives took place in order to cope with various demands (see hereafter). Various RSPG deliverables addressed verticals and also recommended frequency bands (see Opinion on "additional spectrum needs (Document RSPG21-024), Opinion to help Climate change (Document RSPG21-041)) guiding towards benefit from harmonised spectrum.

3.1 National initiatives for local spectrum

- In Finland frequency bands 2300–2320 MHz and 24.25–25.1 GHz are available to local 4G/5G networks with Traficom's (NRA) radio license. Local 4G/5G networks are intended for local use, for example, at factories, ports, airports, shopping centres, power plants and mines for their own activities. Under certain conditions, these networks can also enable minor public telecommunications operations or fixed wireless access (FWA) connections.

[16] Analysis of interviews and auditions on industrial applications for mobile networks and private networks aimed to verticals – Operators, research groups, manufacturers, utilities and interest groups (Arcep -July 2022).

- In France, the 2.6 GHz TDD band (2575-2615 MHz) has been locally allocated since 2019 to verticals, and approximately 30 networks are now deployed or being deployed, using both 4G and 5G. In 2022, Arcep allowed the use of 3.8 - 4.0 GHz for industrial/vertical trials as well.

- In the Netherlands, private networks have been active with local licenses in the 3.6 GHz band for several years. The 3.6 GHz regulation and auction to come will award 300 MHz (out of the 400 MHz in the 3.6 GHz band) for national use. The other 100 MHz will remain available for private networks. The licenses are technology neutral but given that networks must be synchronised to prevent harmful interference to other users in the band, the used technology is expected to be 5G.

- In Norway, the 3.8-4.2 GHz band was launched in 2021 for local area mobile networks, specifically for vertical and industrial usage. This was an initiative when the whole 3.6 GHz band was allocated and awarded to nationwide licenses and not partly reserved for local verticals. Regulation of the 3.8-4.2 GHz use is based on the Shared Access License regime of Ofcom UK. In developing the final conditions of the 3.8-4.2 GHz regulation in Norway, pilots have been granted access to low power usage in several locations in early 2022. This involves setting appropriate limitations on power levels, synchronisation requirements, frequency separation etc. So far the feedback from the pilots has indicated availability issues on equipment (currently using US originated equipment), costs of implementation and uncertainty on future spectrum availability. Progress is made on all these aspects internationally so using the 3.8-4.2 GHz for local area networks looks promising. The technology used is 5G, however this has been questioned by FWA operators using IEEE 802 equipment. Any potential synchronisation requirement challenges coexistence between 3GPP and IEEE usage in the same band.

- In Greece, most verticals implement their own private networks based on MNOs resources. Stand-alone private networks are managed by mobile operators.

- In Sweden, it is possible to apply for local licenses in the 3.6 GHz (3740-3800 MHz) and 26 GHz (24.25-25.1 GHz) since November 2021. There are currently approximately 20 licenses assigned.
  There is also the possibility to lease local spectrum from the MNOs in block licensed frequency bands, in the case where the MNO has excess spectrum in the area and agrees to such a commercial arrangement. A small number of larger leasing agreements have been approved by PTS. Smaller leasing agreements limited to a [low number of/few] base stations (10 or less) don't need approval from the regulator.
  A third possibility is local sharing in the assigned block licence. Block licences in Sweden are not exclusive assignments, all block licences include licence conditions that allow the regulator to introduce sharing users in the licensed bands as long as it doesn't interfere with the usage of the block licence holder. Possibilities for implementing sharing in these bands could for example be DSA

or secondary licenses. Even if this possibility has existed for many years, the regulator has not received a single application for sharing in block licenced bands.
Verticals have implemented their own private networks in the 3.6 GHz local spectrum band.

- In Denmark, 3400-3410 MHz and 24.25-24.65 GHz are reserved for the use of spectrum for local private networks. A licence to use the frequencies for a private network may be issued for the license holder's own use.
  Additionally, 3740-3800 MHz, which is licensed to an MNO, is subject to a leasing obligation to enterprises and public institutions that request to lease the frequencies for the purpose of establishing a private network. The leasing obligation applies in the first four years of the licence period. This obligation to lease frequencies is subject to a first come, first served principle.
- In Slovenia, AKOS has already conducted an auction to provide business critical machine-machine (M2M) communications via dedicated networks in the frequency band 733-736/788-791 MHz.
  AKOS has also published a document for conditions and requirements of a public tender for the allocation of radio frequencies for the provision of public communication services to end users in the 2300 MHz and 3600 MHz radio frequency bands for local use.
  AKOS will start preparing a public tender for the allocation of frequencies for public mobile communication services in the BWA part of the 28 GHz band for local use in campus networks.
  In case there is such interest, additional action points in Slovenia include:
    - auction 2 x 5 MHz in 410-430 MHz for business critical services
    - assigning 2 x 5 MHz in 450-470 MHz for mission critical services (PPDR)
    - auction or assign locally parts of 3800-4200 MHz for verticals - service/technology neutral (BWA) – protection of incumbent services
- In Spain, 20 MHz in the 2.3 GHz band are available for verticals with preferential use of 10 MHz for utilities, the technology used is LTE. For the moment a number of verticals have applied for spectrum. Some inputs have indicated that at least 20 MHz without other preferential uses is needed.
  For the 26 GHz band, 450 MHz will also be available for verticals in the lower part of the band. MNOs consider that this approach produces a fragmentation of the band and other mechanisms such as the secondary market are more efficient solution to allow access to verticals. They stated as well that spectrum reservations for this use have had very limited success and have come at the cost of the capability of public nationwide networks (3.6 GHz case band).
- In Germany, two frequency bands were opened for vertical use. The band 3.7-3.8 GHz was made available on a priority basis and more than 340 licenses have been granted to vertical users since June 2022. The 26 GHz band is also available for vertical use. Private networks for vertical applications may also be operated in frequency bands subject to general licences (e.g. based on SRD or RLAN regulation).

- In Ireland, in 2008 a national TETRA network was established in Ireland for the use of the emergency and other blue light services. The move of these service to TETRA away from legacy analogue equipment released spectrum in the 420 MHz band. The move of private users from PMR to GSM, EDGE and 3G in the following decade released further spectrum in the same band.
  Following consultation ComReg determined that the empty spectrum would be awarded through an auction as one 2x3 MHz lot (410-413 MHz / 420-423 MHz) for the provision of wireless communications for Smart Grids. Smart Grids have been identified as a key enabler in the reduction of climate emissions and to reduce the effects of climate change by international bodies such as the United Nations and the International Telecommunications Union.
  In addition, a further 2x1 MHz (in ten 100 kHz lots) would be auctioned on a technology and service neutral basis and that these lots may be used to support Smart Grid, or for a range of other uses including Business Radio type applications (PMR).
  Following the auction in 2019 all the spectrum was won by a utility operator that generates, supplies and distributes electricity across the island of Ireland. In terms of rollout the licensee is required to connect 50% of its utility network, within 7 years of the commencement date of the licence.

- In Poland, the 3800-4200 MHz band was launched in 2023 for private and local mobile networks. The 3800-4200 MHz Band Allotment Plan issued by the President of the Electronic Communications Office (UKE) lays down the rules regarding networks operating in enterprises or local governments. The 3800-3900 MHz band is reserved for local governments while the rest may be granted to other entities. The maximum spectrum to be granted cannot exceed 100 MHz. One entity may apply for the band in the area consisting up to 20 communes (unit of local government) – to provide telecommunications services. This limit does not apply for networks being used for private needs. Due to the presence of radio altimeters in the band above 4200 MHz, medium-power devices cannot be used outdoors in the 4000–4200 MHz range.

3.2 EU harmonisation of spectrum for local networks

In response to strong demand for mid band from verticals, the RSPG recommended EU harmonisation in 3800-4200 MHz for low or medium power local vertical applications and activities are on-going in order to harmonise technical conditions and studies are ongoing in order to respond to an EC mandate under Spectrum Decision[17]. An implementation has already been done in Norway based on the framework of Ofcom, UK.

RSPG also recommended the bands 26 GHz and 42 GHz to cope to some verticals needs.

[17] Mandate to CEPT on technical conditions regarding the shared use of the 3.8-4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity in the Union

Technology- and service-neutral licensing conditions for local use of spectrum could allow for their upgrade to the newest and more efficient technology over time, including to 6G and beyond. Access to spectrum for local area use should not be limited to specific groups of potential licensees, but open to primarly all interested parties in the country, including mobile network operators considering also national licensing policies.

Based on the current trend and interests of verticals to build their own local networks, it is expected that new features enabled with emerging technologies will also be of interest for verticals. Hence the evolution of 6G based local and private networks should be considered for any future spectrum strategic analysis.

3.3 How operators address vertical needs

RSPG also noted that the role the mobile operators engaged in addressing the connectivity needs of vertical industries (through network slicing and non-public as well as hybrid networks that use currently available spectrum) should also be considered. Development of initiatives based on network slicing are currently at an early stage/initial phase.

Examples of how operators address particular needs of vertical sectors can be found in Finland:

- In Kittilä gold mine, the largest primary gold producer in Europe, a 5G network has been built by Agnico Eagle in cooperation with Telia (MNO), Digita (private network operator) and Nokia (network equipment provider)[18].
- In Kokkola Industrial Park, an area with large-scale industry, Elisa (MNO) has established a private 5G network to develop tailored solutions for the needs of 19 chemical industry plants, 60 service companies and Finland's largest bulk port[19].
- Kalmar, part of Cargotec, together with Telia and Telia's partners Digita and Nokia, has implemented a new stand-alone 5G network for its Technology and Competence Centre in Tampere, Finland. In Tampere, Kalmar has the industry's largest port automation test field and world-class facilities and laboratories for prototyping, simulation, testing, monitoring and optimisation. Thanks to the private network, Kalmar is now able to develop new integrated solutions for the product development of communication and cargo handling technologies[20].

In France, Alcatel Submarine Network, part of Nokia and world leader in the submarine cable manufacturing sector, has deployed a 5G private network on its production facility in Calais. Some initial use cases were implemented such as real time monitoring of the cable tank fill level or remote maintenance. One licensed mobile operator is partner of this initiative. This ASN network operates in part of Iliad licensed spectrum.

[18] Kittilä Mine makes the first underground 5G call
[19] Privaattiverkko Digitalisoi Teollisuutta Kokkolan Suurteollisuusalueella (In Finnish)
[20] Kalmar accelerates its product development with cutting edge 5G private network

4 6G research and development

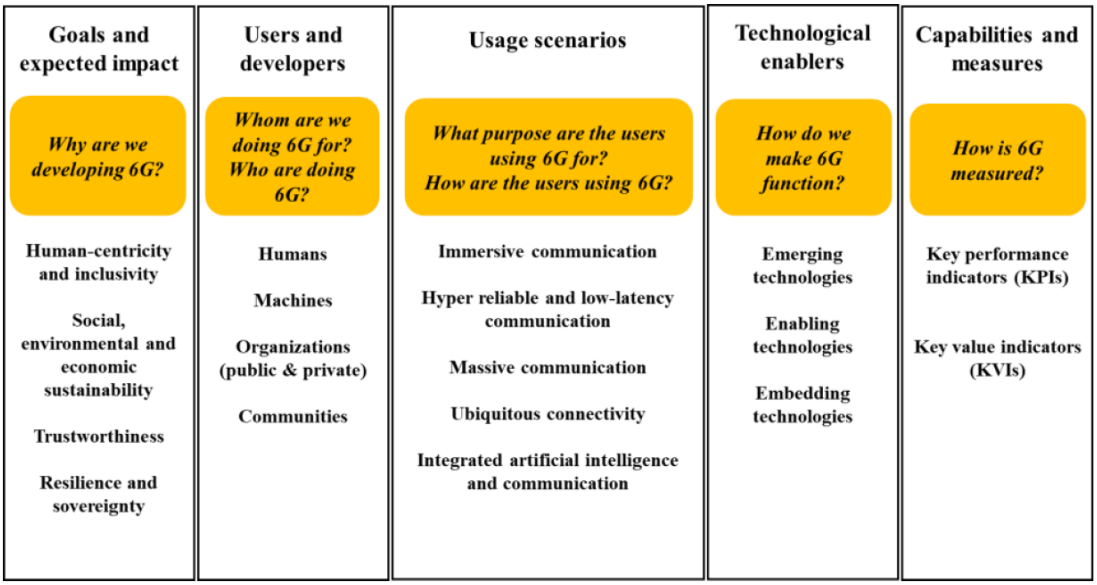


Figure 2. Motivation, usage scenarios, technology enablers and capabilities for 6G development

While 5G deployments are anticipated to continue to expand over the rest of this decade, 6G is expected to be the innovation platform for the next decade, for example, by integrating communications, artificial intelligence, machine learning, and sensing to create a new type of more energy efficient network architecture. In particular, some of 6G's use of advanced sensing is intended to provide spatial perception to further improve spectral efficiency and communications applications providing highly immersive experiences. Some 6G uses cases are expected to drive productivity, such as advanced XR and holographic communication, will rely on extremely high capacity that is not currently deployed.

4.1 Main research projects

In some MS, various institutions/companies are participating in European research projects:

- Hexa-X is the European flagship research initiative to develop the foundation and contribute to industry consensus leading to 6G. The focus is on structuring, framing, and developing technology for connectivity needs in the 2030 timeframe. The 25 partners with funding from EU represent network vendors, operators, industry, small and medium-sized companies and academia. While Hexa-X focuses on a common European 6G vision and possible use cases and technology enablers, Hexa-X-II, starting in January 2023 with a duration of 2.5 years, will expand the Hexa-X partner list to 44 organisations that are tasked with creating the pre-standardised platform and system view that will form the basis for many inputs into future 6G standardisation. It forms a holistic flagship towards the 6G platform and system to inspire digital transformation for the world to act together in meeting needs in society and ecosystems with novel 6G services.

- 6G Flagship (2018-2026) started global 6G vision building. The mission is to envision and define the 6G-enabled digital world as we move towards the 2030s. United Nations Sustainable Development Goals guide the work where the physical and virtual worlds meet and wireless connectivity expands to all areas of life. 6G Flagship's joint 6G vision was built via 6G Summits and 13 multi-disciplinary White Papers since 2018 including 300 experts from 100 organisations in 30 countries through multi-stakeholder collaboration including academia, industry and the public sector.
- One6G is an open technical organisation, where incumbent as well as emerging industry players or academic institutions can join. It is a global initiative with several European members, including the European Space Agency, companies and academia. One6G aims to evolve, test and promote next generation cellular and wireless technology-based communications solutions. By supporting global 6G research and standardisation efforts, the goal is to accelerate its adoption and overall market penetration, while addressing societal and industry-driven needs for enhanced connected mobility. This with the ambition to speed up the development of new services and applications in domains such as advanced autonomous driving, advanced manufacturing, advanced wireless e-health, remote education etc.

Research activities have also been in place in various MS:

- In the Netherlands, a broad consortium of businesses and research organisations aims to strengthen R&D&I of future mobile networks. The Ministry of Economic Affairs and Climate Policy supports this initiative[21]. Currently, the focus is on a proposal to the national growth fund, to invest in a six year public-private research programme. The goal is to build a Dutch position in specific parts of 6G: smart components, smart networks and leading applications in key sectors. This would also contribute to the EU Smart Networks and Services (SNS) joint undertaking. 6G developments are expected to involve questions for spectrum policy such as the use of sub-THz spectrum (>100 GHz), use cases combining mobile and radar (joint communication and sensing), and dynamic spectrum management and sharing.
- In Denmark, Aalborg University has some ongoing research projects on 6G[22]
- Two important research projects can be identified in this respect in the Czech Republic.
    - Most importantly, a 6Gmobile research lab is operating at the Czech Technical University on Prague, Faculty of Electrical Engineering. It focuses on key aspects and challenges related to the future mobile networks and emerging wireless technologies. This covers mobility and radio resource management for self-organizing and energy efficient networks. Furthermore, we address network architecture including Mobile Edge Computing (MEC), Cloud-Radio Access Netwok (C-

[21] Future Network Services | TNO
[22] 6G Wireless

RAN) and drones/UAVs. From a perspective of scenarios, the 6Gmobile research is oriented mainly on scenarios encompassing device-to-device communication, heterogeneous networks, IoT, and vehicular communications.

  - At the same time, the Czech Technological Agency evaluated a public call for funding of research projects. The evaluation concerned 13 project proposals in which a range of 5G related topics were tackled. This includes 5G platform for precision agriculture, industrial card for the 57-66 GHz band for 5G networks, multichannel connection of photonic chips for high-speed optical 5G+ networks, EMIR – inbuilt intelligence with the 5G support for robots' autonomy and application for smart city monitoring and others.

- In Austria, SAL (Silicon Austria Labs) drives tasks in the 5G & 6G as well as RLAN-Technology mainly for M2M sensor networks, using mainly Wi-Fi spectrum.
- In Sweden, PTS is currently participating in a CELTIC NEXT project called 6G-SKY which focuses on multilayer, terrestrial/NTN networks, supporting 3d coverage for terrestrial, UAV and aeronautical use cases. A main goal for this project is to identify if there is a need for new concepts and/or changes to existing spectrum regulation. The results from the project are expected in the 2023-2024 timeframe.
- In Switzerland, there are research projects on digital circuits and components, algorithms and architectures enabling 6G technology, not related to a particular spectrum band:
  - Integrated Information Processing | ETH Zurich[23]
  - Digital Circuits and Systems Group – Integrated Systems Laboratory | ETH Zurich[24].

  In addition, there are also projects on high frequencies, up to terahertz range, such as:
  - Research on sensors enabling electromagnetic field detection at frequencies up to 300 GHz, for spectrum monitoring and for verifying compliance with electromagnetic and safety regulation (5&6-GEARS – Institute of Electromagnetic Fields (IEF) | ETH Zurich)[25].
  - Research on terahertz technologies for very highspeed data transfer: Terahertz RAdio communication using high ANistropy SPIn-torque Resonators (TRANSPIRE)[26]

[23] Integrated Information Processing | ETH Zurich
[24] Digital Circuits and Systems Group – Integrated Systems Laboratory | ETH Zurich
[25] 5&6-GEARS – Institute of Electromagnetic Fields (IEF) | ETH Zurich
[26] Terahertz RAdio communication using high ANistropy SPIn torque REsonators

- In Germany, 6G Platform Germany ("The 6G Platform for Future Communication Technologies and 6G")[27] coordinates, among other things, frequency regulation issues. 6G-Research Hubs: 6GEM (www.6gem.de, RWTH Aachen), 6G-life (6g-life.de, TU Dresden, TU München), 6G-RIC (6g-ric.de, HHI Berlin), Open6GHub (www.open6ghub.de, DFKI Kaiserslautern);

  Other 6G-Industry-Projects in Gemany include: 6G-ANNA (project coordinator: Nokia Solutions and Networks GmbH & Co. KG, München), 6G-Takeoff (project coordinator: Deutsche Telekom AG, Bonn), MassIMO (project coordinator: Infineon Technologies AG, Neubiberg).

- In Lithuania:
  - Research on the application of silicon electronics for THz frequencies has been carried out at the Institute of Applied Electrodynamics and Telecommunications (Noise and Terahertz Electronics Laboratory, Vilnius University, Faculty of Physics) since 2013
  - The MITA project aimed to develop a point-to-point 250 GHz radiation source corresponding to the sixth TRL stage. VU researchers are collaborating with NASA and the European Space Agency to develop equipment for the SOFIA flying observatory

- In Italy, the "B6G - 6G and Beyond - Future advances in Wireless Technologies project" issued by the CNR[28] for Sub-Terahertz/Terahertz Communication, Free-space Optical Communication and Visible Light Communication.

- In France, a research initiative investigated 6G issues in sub THz frequency band (above 90 GHz)[29], and have published deliverables addressing spectrum management issues[30].

- 6G Finland is an active coalition of Finnish 6G R&D organisations to advance the impact of Finnish 6G expertise globally, build new international partnerships, and intensify national 6G development efforts towards sustainable and data-driven society enabled by instant and unlimited wireless connectivity. Finland has a long and successful history in the field of wireless mobile technologies. Numerous successes have shown us the power of cooperation. It has – once again – led us to a global leading position, now in 6G research and development. The world's first large-scale 6G research program, 6G Flagship was launched in Finland in 2018. Currently, Finland also leads the European 6G flagship initiative, Hexa-X funded by EU and plays a significant role in other 6G measures of the EU as well. 6G Finland is a national contact point of Finnish 6G know-how, and actively participates in 6G discussion both nationally and internationally. 6G Finland operates as a network to which new members are invited on a content basis.

---

27 The German Platform for Future Communication Technologies and 6G
28 6G and Beyond - Future advances in Wireless Technologies
29 6G issues in sub THz frequency band (above 90 GHz)
30 BRAVE Project dissemination

4.2 Main research topics

6G topics studied in the research projects include:

- Channel models, spectrum bands, spectrum access models and spectrum sharing techniques for 6G
- Network Intelligence, Edge/Cloud Architectures, Transformative Computing, Massive Machine-Type Communication, Ultra-reliable Low Latency Communication, Opportunistic Sensing, Radio Vision and Holography, Sub-Terahertz/Terahertz Communication.
- Coordinated services and native slicing
- Haptic and tactile communications
- Open RAN
- C2C (customer to customer) and D2D (device to device) communication
- Point to point
- efficient and secure mobile radio systems
- human-machine collaboration
- sustainability
- secondary use of intentional transmissions e.g. for sensing/tracking objects or gestures
- open interfaces across all technology boundaries
- contributions to a global 6G harmonisation process and standard
- 5G & 6G as well as RLAN-technology mainly for M2M sensor networks
- multilayer, terrestrial / Non Terrestrial Networks (NTN networks), supporting 3D coverage for terrestrial, UAV and aeronautical use cases
- field trials in bands already assigned to ECS as well as other (non harmonised) bands
- Broadband services using optical wireless / LiFi

4.3 Sustainability

Recent 6G statements emphasize sustainability as a guiding principle, including e.g. EU-US Trade and Technology Council's (TTC) 6G Outlook, which states that *"6G technologies must also be an enabler for sustainability, considering environmental, social, and economic perspectives. A reduced carbon foot-print and energy efficiency will be important design goals for 6G networks. More broadly, 6G should allow for reduced energy consumption across all sectors of the economy and society. Ideally, 6G technologies will generate less pollution and reduce other environmental impacts to better contribute to long-term social sustainability while maintaining economic feasibility."*

RSPG intends to further investigate impact on sustainability on 6G spectrum issues. It would be important to make sustainability a key element in the European regulatory work on 6G and consequently for RSPG to consider what it means in spectrum policy making in order to develop sustainable spectrum management principles. The comments hereafter will be further addressed by RSPG.

The overriding requirement to reduce carbon emissions associated with future wireless broadband networks should not conflict with the development of 6G and associated spectrum allocations. Network densification is in some cases cost-effective but additional spectrum might remain the only way to meet demand economically, while also minimising energy requirements. Therefore, the impacts of network densification should also be considered from the perspectives of economical as well as ecological sustainability. Ever higher frequency networks imply densification of infrastructure, potentially leading to increased energy consumption. Enabling the use of additional low band spectrum and additional mid-band spectrum would lead to a substantial lesser number of antenna sites compared to mmWave antenna deployments, and thus less land occupation, less visual pollution, and lower EMF emissions as well as a more sustainable business model to the benefit of end-users. Innovative strategies may be beneficial to address this need, ranging from closer collaboration between utility energy networks and telecommunications networks, to offloading data from 6G mobile networks to RLAN networks.

Backwards compatibility for legacy equipment could ensure long life cycles of equipment, which could enhance sustainability and avoidance of stranded assets. This also enhances sustainability through minimizing waste and consumption of new raw materials.

The physical effects of climate change could to be taken into account in the construction of future wireless networks, such as the increasing potential flooding risk and higher wind loading on antenna structures. There may also be effects on radio propagation modeling and radio channels particularly due to more intense rainfall events which are especially relevant at the higher frequencies being contemplated for 6G.

4.4 6G spectrum needs

There is a need for research topics to consider and evaluate the spectrum needs for the successful initial 6G rollouts. It is important for Europe not to waste this very substantial 6G research effort, and not to fall behind in securing enough spectrum resources for 6G. Spectrum remains a critical enabler, hence it is important for the ongoing European wide research initiatives to support studies for 6G spectrum. The timing aspect is critical, given that spectrum availability and harmonisation is a long-term process. RSPG intends to further address the issue when considering the 6G spectrum roadmap.

5 Licensing and spectrum regulatory aspects

5.1 Experience with the provision of wireless broadband services using unlicensed spectrum including management of interferences

Use of unlicensed spectrum is mainly targeted towards consumers use and non-critical systems. Unlicensed spectrum is already used by the end-users, especially in indoor environments. This leads to off load of traffic from mobile networks. This could be further developed in future networks and will sustainably support local scale applications that require large capacity but might not guarantee the required quality of service.

Wireless broadband services using unlicensed spectrum are mainly limited to local coverage (e.g. WAS/RLAN). Unlicensed spectrum for outdoor and mobile use requires sharing solutions[31]. This leads to regulatory and technical complexity and additional costs. Fixed service in upper mmWave bands (such as 57-71 GHz) is, however, one example of using unlicensed bands for enterprise customers and MNOs. Unlicensed bands can be used to provide Fixed Wireless Access (FWA) to households in rural areas, but are still susceptible to interference.

- In Czech Republic, the NRA introduced light licensing for IEEE 802.11 technologies in the 5.2 GHz, 5.8 GHz, and 60 GHz bands, with the support of a registration website. In addition, in the 60 GHz band, the NRA allows sharing with Fixed-Service-similar applications based on a Coordination Calculator. Some experts believe, that (i) more advanced algorithms can allow for more flexible spectrum usage including the dynamic spectrum access, and (ii) cooperation of Member States (or third states) in projects on the development of advanced spectrum planning tolls can facilitate spectrum sharing.

  MNOs recommend conducting activities (incl. cooperation with NRA) within projects on dynamic spectrum access and/or a license-exempt usage. 6G may be a candidate for license-exempt usage (especially in mmWaves) and/or automatic (or more advanced) approaches to spectrum authorisation.

- In the Netherlands, unlicensed spectrum is complementary to licensed spectrum and will continue to play an important role e.g. in radio local area networks and for offloading of mobile traffic. Previous initiatives to use unlicensed spectrum in combination with 3GPP technology have not always proven successful, but on the other hand the unlicensed 2x5 MHz in the 1800 MHz band has been heavily used.

- In Greece there are some relatively small companies providing internet services using unlicensed spectrum. However, their customer base is small and their use cases limited. Unlicensed spectrum is used mainly for LANs, short range p2p links and non-commercial networks

- In Norway a few operators deliver FWA to a couple of thousand households in rural areas using IEEE technology in WiFi unlicensed bands, particularly the 5 GHz band. This usage has in some cases up until now been combined with licensed WiMax use in the 3.6 GHz-band. Regarding interference, the feedback is that the

[31] RSPG noted that CEPT recently launched a feasibility study including potential sharing with macro base stations.

operators would like more spectrum due to unlicensed starting to get crowded and also get access to more licensed spectrum in order to provide more reliable connections.

- In Luxembourg no overall assessment can be given. Unsurprisingly, the view of MNOs goes rather in the direction that Wi-Fi has some weaknesses that makes it unsuitable for enterprise and industrial applications and that Wi-Fi in unlicensed bands may be a sufficient solution for consumers but is less suited for enterprise customers
- In Sweden there is a limited number of end customers connected through FWA systems operating in unlicensed bands. The majority of the systems is using the 5 GHz band and connect single dwelling units in rural areas. There is also some use of systems operating in the 55-71 GHz band, offering Gbit/s connectivity to business and multi dwelling units in some urban and suburban areas.

  The 5 GHz FWA systems are normally used in areas with relatively low population density. In those areas operators have been able to handle interference planning without major problems.

  Regarding the 55-71 GHz band the extreme directionality, low overall usage of the band and the high available amount of spectrum allows for easy planning with limited risk for interference so far.

5.2 Examples of spectrum sharing in the bands that are already licensed

The following uses have been reported in the RSPG survey:

- In Italy, two operators (MNOs) asked for the authorisation for a project to set up a joint venture (JV) for the supply to them of a MOCN (Multi-Operator Core Network) service with spectrum pooling in a limited area of the national territory (so-called JV Area), in some mobile bands where the two MNOs hold the rights of use of frequencies. The areas essentially cover parts of the country that are not densely populated (including large mountainous areas). The deal was cleared after an assessment of its effects on competition, efficient use of spectrum, market development and user protection. Specific conditions were set, such as: flexibility and reversibility of the agreement; independence and impartiality of the JV with respect to the two MNOs; fulfilment by the two MNOs of all obligations and conditions related to the rights of use of frequencies.
- In the Czech Republic, due to the fragmentation in the 3.6 GHz band traditional MNOs have only 60 MHz each. MNOs believe that initiatives to share spectrum at least in the 3.6 GHz band will emerge to be able to use 100+ MHz.
- In the Netherlands, no interest has been expressed for spectrum sharing in the already licensed bands. The reason is that other potential users are put off by the fact that spectrum has been auctioned for exclusive use by the licensees over periods of 20 years. There is no real incentive for licensees to be open to spectrum sharing, as it is seen as a risk for network problems or reduced QoS, and even as a risk for an extra competitor to their services.

- In Greece, up to now there has not been any demand for licensed spectrum sharing, most probably due to the lack of appropriate business models. The required regulatory framework is in place, but there are no new market players willing to undertake initiatives in such a direction. MNOs are rather conservative with respect to this issue and prefer to keep their spectrum portfolio under their full control.
- In Finland, some local demand for spectrum sharing can be seen for research, development and innovations (RDI). We have introduced certain limited geographical areas where parts of the bands have been reserved for this purpose.
- In Sweden, PTS have had discussions with PMSE stakeholders, content creators as well as manufacturers of cordless videocameras, where they have expressed the need for this kind of opportunistic / temporary access to spectrum for major events. For PMSE, one could probably use a regulatory model similar to the temporary PMSE licenses issued today for cordless cameras and videolinks. If there is a high demand for temporary licenses also from other user groups, a more advanced model for efficient sharing of the spectrum may be needed.
- In Italy some mobile operators have requested authorisation to implement active sharing agreements with frequency pooling in the frequency bands already assigned to mobile systems at 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2600 MHz, 3400 MHz, 3600 MHz.
- In Slovenia there is permission of frequency pooling and active sharing, including dynamic spectrum sharing in challenging areas and in case network densification needs to secure very high capacity base stations offering Gigabit speeds. For the 26 GHz band, frequency pooling and active sharing, including dynamic spectrum sharing, are permitted everywhere, with a pre-emptive right in favor of the license holder on its assigned sub-band, and active sharing between all holders of license including dynamic spectrum sharing, is permitted.
- In Croatia, the NRA has received demand for 3.4-3.8 GHz for private networks which is currently not allowed. Private networks are allowed in 2.6 GHz TDD and 26 GHz.
- In Spain, MNOs consider that the exclusive license model is in principle the most efficient model for a mobile operator. In general, there is no need for spectrum sharing in the bands already licensed, noting spectrum rights may already (within the EECC regulatory framework) be subject to lease or transfer of rights in some areas, under control of existing licensed MNOs. This provides a certain flexibility in spectrum management. Nevertheless in the future there might be specific national contexts, such as Spain, where innovative spectrum sharing methods may make sense to serve some use cases such as having more efficient rural coverage solutions in order to optimise investments, provided that sharing is never regulated/imposed, only allowed to the MNOs. They also consider that the current regulation on secondary market already allows spectrum sharing.

5.3 How to address potential capacity needs by 2025 and beyond

Several Member States have indicated in the survey that a need for additional mobile spectrum resources may occur in a couple of years. This is triggered by the growth in mobile data traffic, which is still rather high (about 30% every year). Traffic forecasts and future spectrum needs indicates a need for additional spectrum ahead of 2030 to avoid congestion in dense urban areas.

Some MNOs indicate that densification of networks, use of mmWave and refarming to 5G might not be enough to cope with this growth in all locations. At this stage it is very uncertain if 6G will come in due time with enough capacity enhancement to cope with the pace of traffic increase. Hence, MNOs suggest that additional spectrum resources are required, especially in urban areas to enable the current network grid to deliver the required coverage and capacity. This may lead to some challenges in identifying the correct spectrum strategy when 6G is ready to be deployed.

Additional spectrum in the mid-band suitable for terrestrial mobile broadband may be identified in the next few years, making it available by 2025. On the other hand, if no additional harmonised resource can be made available by 2025, MNOs can densify their networks in existing harmonised bands and use additional new harmonised mmWave spectrum expected to be made available in the coming years (42 GHz).

In its future work on 6G spectrum, the RSPG needs to consider the results of WRC-23 on Agenda Items 1.2 and 10 to further determine the spectrum availability and the implementation strategies for 6G.

The RSPG recognises that there is likely to be a need for IMT to offer coverage and capacity in mid-bands. Additional mid-bands have not yet been identified. The upper 6 GHz is under consideration, noting the interest of both IMT and WAS/RLAN on this band.

In consequence, RSPG highlights that as a condition to accept an IMT identification in the band 6425-7125 MHz under Agenda Item 1.2, no candidate frequency band between 7 and 30 GHz which would jeopardise usages relevant to the Common Security and Defence Policy (CSDP) or to the space policy, should be considered for studies for IMT identification at WRC-27 (see WRC-23 Opinion on Agenda Item 10[32]).

Forecasts indicate a continuous year-by-year growth in mobile data traffic, and that this trend will continue. To effectively accommodate this traffic in the mobile networks before the end of the decade, the combination of several options is considered including technology upgrade, densification (including the use of mmWave in specific areas), etc. Technical solutions alone cannot respond to predicted growing data traffic volumes and several studies indicate that additional spectrum in mid-bands might be required before the end of the decade to support 5G and its evolution.

[32] RSPG Opinion on the ITU-R World Radiocommunication Conference 2023, Document RSPG22-040

5.4 Needs for new regulatory models for spectrum sharing in the 6G era

Given the need for large spectrum blocks to implement the next generation of wireless technology, further exploration on potential spectrum sharing between mobile network operators to allow different deployment models using spectrum sharing technologies and models will be needed. RSPG intends to address the issue when appropriate. The development of 6G should target increased flexibility and automation so that underused and unused spectrum can be put to work and to provide spectrum access to local networks. Examples include locally operated networks in remote/rural areas. Also, the use of mobile communication systems for mission critical users is expected to continue, which would require the deployment of small scale ad hoc mobile communication networks in areas that do not have coverage.

Some MS express a need for a mechanism to share spectrum for special events, temporary needs, etc. in a flexible and effective way.

Identifying the suitable spectrum for 6G in an early stage contributes also to engage analysis on right approach to spectrum management, including with contribution from research as appropriate, ensuring that requirements are considered from the early stages of standardization and regulation.

As 6G will be standardised over the next few years, there is a “window of opportunity” to influence its design to capture any co-existence / sharing requirements. It is therefore important that the co-existence studies are undertaken in a timely manner for their outcomes to be considered and incorporated in the 6G standards prior to the initial deployments.

RSPG notes that further studies are required to define regulations to meet these needs.

6 6G spectrum: preliminary analysis

Digitalisation of industries is expected to continue to grow with 5G and 5G-Advanced as new applications that use the mobile capabilities can be developed and adopted in many industrial domains, and the trend is expected to continue with 6G. With the introduction of 5G the needs for local networks have increased. Also, some indications for needs of metropolitan area networks, e.g. for smart city applications, have been seen. With 5G Advanced and 6G the needs for local and vertical use will still increase, including smaller personal area networks.

6.1 Spectrum for launching 6G mass market in EU and paving its initial development

In its future work on 6G spectrum, the RSPG needs to consider the results of WRC-23 on Agenda Items 1.2 and 10 to further determine the spectrum availability and the implementation strategies for 6G. In its opinion on WRC-23[33] RSPG recommended that no IMT candidate frequency band for WRC-27 studies between 7 GHz and 30 GHz which would jeopardise usages relevant to the Common Security and Defence Policy (CSDP) or to the space policy.

Moreover, the RSPG recognises that there is likely to be a need for 6G to offer coverage and capacity in mid-bands.

The following aspects emerged for further discussions:

- There is a need to assess spectrum requirements for an introduction of 6G mass market in EU. This should respond to capacity/coverage needs, eco-systems including for terminals, timing for making available spectrum, etc. and need for a coordinated and common timing in order to provide availability of spectrum in Europe.
- Technology neutrality allows the operator to decide the schedule according to its own strategy, for example the 2G/3G switch-off schedules differ. In consequence, under that approach, national requirements are taken into account, including competition and market demand. Timing of 6G launch will depend on national mobile operator’s strategy, availability of mobile operator's spectrum resources and expiration dates of existing authorisations (at the time of introduction of 6G).
- There is a need to assess the impact of densification of spectrum usage during the decade until 2030, including understanding its impact on economic and environmental sustainability.
- In addition, the spectrum needs for local and vertical use will still increase, which need to be taken into account in future spectrum strategies considering also relevant developments/timing of harmonisation in bands recommended for verticals.
- Although the technology neutrality principle applies, EU and national policies have encouraged the deployment of 5G, this might also be considered for 6G.

[33] RSPG Opinion on the ITU-R World Radiocommunication Conference 2023, Document RSPG22-040 (09 December 2022)

- Spectrum policy, particularly as regards spectrum allocation mechanisms, with a view to utilizing spectrum resources in an optimal way, should benefit the society as a whole.
- While technology and service neutrality will continue to be central to the European spectrum policies, spectrum refarming alone might not be sufficient to assure early deployment of 6G as refarming depends on the individual licensees' strategies and the national context. Based on prior experience with the 5G pioneer bands, similar plans could be made to analyse whether it is necessary to identify and make available primary and pioneer bands for 6G deployment in a timely manner.

In the course of developing its future work program, RSPG will consider any further developments on a 6G spectrum roadmap.

6.2 Role of non-terrestrial networks in 5G and 6G and spectrum issues

RSPG notes the following possible roles of non-terrestrial networks:

- interim or disaster relief solution, safety of life and emergency services
- for 5G and 6G specific applications with high data rates the use is limited, use as fall back to for 4G kind of applications in case of emergency may be a valid scenario
- providing coverage to isolated/underserved areas, ubiquitous coverage and deliver multi-gigabit connectivity to parts of the world which are difficult to connect such as oceans
- broadband connectivity in worldwide logistics, transport and energy sectors
- certain IoT applications
- redundancy purposes to enhance resilience
- backhauling
- 3-D coverage improvement
- support of increased driving autonomy of land vehicles as well as airborne and maritime drones
- response to complex crisis involving massive connectivity between multiple stakeholders

Non-terrestrial networks (NTN) could become an important additional connectivity layer to terrestrial connectivity services, or even competitive to terrestrial networks in some areas.

The NTN including satellite networks could have an important role in 5G and 6G in the future regarding the complementarity of the satellite with the terrestrial networks for global continuity and enhanced reliability of the service. Also terrestrial base stations on unmanned aerial vehicles (UAV) and High-Altitude Platform Stations (HAPS) should be considered in this context.

The 3rd Generation Partnership Project (3GPP) has recently developed 5G standards for the satellite and terrestrial network integration (ISTN). Thus, the first satellites have been tested and launched. The results of these testing could provide more visibility on the future of this integration.

NTN could be particularly relevant to improve the resilience of 5G/6G communication during large-scale disasters. Furthermore, they can extend network coverage in underserved areas enabling ubiquity of communications and service continuity, by complementing the terrestrial segments wherever and whenever additional coverage is needed.

For isolated/underserved areas, broadband connectivity in worldwide logistics, transport and energy sectors, certain IoT applications and for redundancy purposes, non-terrestrial networks could become an important additional connectivity layer to terrestrial connectivity services, or even competitive to terrestrial networks.

The progress of non-GSO satellites shows that non-terrestrial networks could provide coverage to unserved or underserved areas of terrestrial networks and also capacity in competitive terms. Efforts to integrate non-terrestrial components into 5G and 6G could be of great benefit.

The NTN part of 5G and 6G could add new capabilities when it comes to cost effectively add coverage in areas where the terrestrial networks dont have coverage or have poor QoS/QoE. This could have a large effect on the possibilities of utilising new innovative services as well as traditional mobile services globally, including maritime and aeronautical use cases.

BEREC has published BoR (22) 169 "Report on Satellite Connectivity for Universal Service[34]" which finds a limited role in 5G and 6G.

A difficulty currently identified regarding the suitability of internet access services via satellite communications, is the latency requirement which is a constraint in comparison to terrestrial services. Consequently, for seamless broadband mobile comparison connectivity, only LEO satellites (and in particular VLEO) should be considered where by design the latency is comparable with terrestrial networks. In such constellations, the number of satellites is high and scales with capacity requirements.

Satellite systems are a possible interim solution for re-establishing the connectivity in disaster areas, thus allowing the time needed for recovery of terrestrial systems. This can be achieved by providing satellite terminals to the public by the state, enabling future compatibility of satellite systems with the end user mobile network terminals and by using satellite systems to provide a backbone for mobile network fallback. It could be a good solution if connected to mobile operator network as redundant backhaul.

There are recent activities of satellite providers to use LEO satellites to provide "direct to device" satellite services in IMT bands (not allocated to Satellite Service) where exclusive usage rights have been granted to mobile operators. These services are intended to complement terrestrial coverage. However, the terrestrial networks are the primary usage in these harmonised mobile bands. It is important that this innovative use case ensures the protection of terrestrial services, other satellites usages and taking into consideration relevant cross border coordination issues. The usage of terrestrial bands or parts of them by satellites requires an agreement with the respective MNO.

[34] BEREC Report on satellite connectivity for universal service

National administrations are responsible for the compliance with regulatory provisions at country borders.

Further, due to the standardization initiatives, the NTN component for 5G and 6G raises more interest from stakeholders. The relevant consequences and strategic spectrum issues should be further investigated by RSPG.

6.3 Role of license exempt[35] spectrum use in 5G and 6G and spectrum issues

License exempt spectrum can be used to complement fixed networks and to complement mobile networks in individually licensed spectrum, for example:

- to offload indoor traffic through RLAN
- in ad hoc cases of massive events (e.g. concerts, festivals, sports events)
- to provide end-user connectivity, mainly fulfilling non-critical industry needs (i.e. M2M, private)

License exempt spectrum can provide additional possibilities to supplement the licensed use, easily accessible to everybody. It can be used noting the operation on a non-protected and non-interference basis. An example in Finland is a Long-Range (LoRa)-network with nationwide coverage for IoT-connections in the license exempt UHF-band[36].

New capabilities in 5G and 6G might lead to an increased usage of 5G and 6G technology in license exempt spectrum over time. In the rollout of private local area 5G networks, license exempt spectrum use can be a good alternative in comparison to individual licensed spectrum. License exempt models in mmWave bands may be one solution that gets implemented, e.g. in 66-71 GHz or higher. 5G-NRU (unlicensed) has not yet been realised, but this can hopefully mature towards 6G. Within 26 GHz and 42 GHz, sharing with other services introduced some limits in order to comply with the requirements to protect satellites receivers and earth stations.

Use of license exempt spectrum for wireless broadband services does typically not guarantee a certain QoS due the shared access to the band, noting the operation on a non-protected and non-interference basis. Licence-exempt 5G and 6G spectrum could be a solution mainly for applications that do not need their own spectrum and for which individually licensed spectrum would less appropriate.

In Spain, network operators are already broadly providing broadband services using license exempt spectrum mainly for the last few meters home connectivity as a part of their FTTH offer to the users. Low power characteristics of unlicensed spectrum and indoor usage provides a good framework for interference management.

In Norway, there have been attempts to use existing license exempt spectrum, for instance DECT NR+[37] that reuses the license exempt DECT bands of 1.9 GHz. This approach is interesting and may be a good option for many businesses needing a localised network and in many remote areas unlicensed spectrum is mostly vacant.

---

[35] This section is also covering spectrum under general authorisation

[36] IoT LoRaWAN network coverage map

[37] DECT NR+

At very high frequency bands, e.g. in the Terahertz range, the combination of potentially very wide available bandwidth and far more limited propagation combined with future interference control mechanisms could allow consideration of license exempt use (parts of) future spectrum.

6.4 Use of current harmonised mobile bands for 6G

RSPG noted that at launch, each new mobile generation has used both existing as well as new frequency bands[38] according to national and European policy initiatives.

In general, all currently EU-harmonised bands for terrestrial mobile networks could be used for 6G in the future.

Further, there is a need to assess the suitability of current harmonised technical conditions in current bands for mobile networks to support the long-term development of 6G as it has been done for 5G.

RSPG intends to further address the issue when considering the 6G spectrum roadmap taking into account also comments received during the public consultation of this Opinion.

[38] See for example for 5G: EECC article 54, EP and Council decision on UHF-band (to make available 700 MHz band under EU harmonised technical conditions)

Informative Annex 2: Summary of messages in presentations from the workshop on 6G development

These messages do not reflect the opinion of the RSPG and its members.

European 6G Flagship Hexa-X

Hexa-X is the European flagship research initiative to develop the foundation and contribute to industry consensus leading to 6G

- The focus is on structuring, framing, and developing technology for connectivity needs in the 2030 timeframe
- Funded through EU H2020 ICT-52
- 25 partners
    - NW vendors
    - Operators
    - Industry
    - Academia
    - SMEs
- Nokia is overall leader
- Ericsson is technical manager
- Horizon Europe - Smart Networks & Services

Hexa-X vision on 6G

- Connecting the physical, digital and human world
- Key values:
    - Sustainability
    - Inclusion
    - Trustworthiness
- Research challenges:
    - Connecting intelligence
    - Network of networks
    - Sustainability
    - Global service coverage
    - Extreme experience
    - Trustworthiness

6G will be much broader than the radio-access technology

A flexible platform providing connectivity, data, compute, intelligence, and sensing

- New results available at hexa-x.eu/deliverables/
    - Expanded 6G vision, use cases and societal values – including aspects of sustainability, security and spectrum
    - Targets and requirements for 6G - initial E2E architecture
    - Initial radio models and analysis towards ultra-high data rate links in 6G

- Localisation and sensing use cases and gap analysis
- AI-driven communication & computation co-design: initial solutions
- Initial 6G architectural components and enablers
- Design of service management and orchestration functionalities
- Special-purpose functionalities: intermediate solutions

6G Flagship – University of Oulu

- Sustainability as the key driver
- 6G R&D needs to translate into visible design criteria ensuring that our actions today support the range of economic, social, and environmental options open to future generations.
  - How do the long-term exclusive licenses without obligations to share unused spectrum fit in the new sustainability framework?
  - How to measure and minimise energy and other resource consumption?
- Emergence of local 5G networks by different stakeholders is already a reality globally. Europe has not taken actions to promote it, but decisions are left to national level leading to fragmented single market and competitive disadvantages.
  - How to consider new deployment models right from the beginning in 6G spectrum discussions?
- Spectrum sharing needs to be incorporated into 6G spectrum discussions from the beginning of the technology development phase and not a restriction posed afterwards.
  - Suitable spectrum regulatory enablers will be key a success factor for developing future wireless solutions via society pull with market impact to make Europe a forerunner in the global race towards 6G.

One6G

- First applications are of point-to-point nature
  - Kiosk downloading
  - Intra-device communication
  - Backhauling/Fronthauling
  - Data centre

UK Spectrum Policy Forum

- 6G will be different. It needs fresh thinking. There could well be low and mid-band 6G
- Research community/tech companies and spectrum policy makers to work close
- Set a priority on low and mid-band spectrum research projects. All research projects should encourage innovation across a range of spectrum bands

GSA – Global mobile Suppliers Association

- 5G underway with licensing and roll-outs
- 5G expansion spectrum planning underway in some countries, with a timeframe from 2023/25

- 6G early research and planning discussions commencing, targeting a timeframe from 2030

ETNO – European Telecommunications Network Operators

- Capacity demand is continuously growing in mobile networks since their introduction. This is expected to continue as people and societies are increasingly relying on mobile and broadband connectivity.
- For now, operators are fully engaged in expanding the reach of 5G to all EU citizens and businesses. We do not expect 6G to become commercial before 2030.
- 6G requirements and use cases are still under research, but the demands and harmonised spectrum for 6G should be mapped in a timely manner.
- Recognise the importance to start work on early spectrum-related considerations of 6Ggiven the long spectrum allocation cycles.

ECTA – European Competitive Telecommunications Association

- We consider that 6G will address a variety of communication profiles, from very wide-area long-range communications (via terrestrial and non terrestrial platforms) across areas of low population, to high-capacity wide-area coverage across cities, down to short-range communications and sensing.
- As such, we consider that 6G will require access to low-bands, mid-bands, and high-bands extending to sub-THz frequencies.
- Accordingly, globally harmonised spectrum is encouraged, as this facilitates the economies of scale.
- EMF issues should be anticipated with relevant studies on health impact.

GSOA – Global Satellite Operator´s Association

- 6G will need to rely on combined benefits of multiple communications technologies for 6G use cases to be meaningful for broader society
    - Satcoms will play a central role within 6G networks

DSA – Dynamic Spectrum Alliance

- All the populated areas in Europe are not covered by 4G and 5G networks
    - Use it or share it policies
    - The target for the coming years should be on providing mobile performant networks, “with all populated areas covered by 5G”
- Different stakeholders would like to deploy performant broadband networks themselves
    - Tiered Spectrum Sharing Models
    - Dynamic Spectrum Frameworks in IMT identified bands (different to DSS)
    - Enable a larger ecosystem, investment and more deployments
- An approach to connectivity that is technology neutral and promotes several advanced gigabit technologies

  - Internet traffic and internet access in Europe needs Wi-Fi as a complement to Fibre, satellite and Mobile networks
  - Not all the IMT traffic goes exclusively through the mobile network
  - Tiered Spectrum Sharing Models protecting incumbents instead of long and expensive clearance processes
- IMT identification model should be reviewed (we all know that IMT is not a service)
  - There is considerable mmWave spectrum identified for IMT at WRC-19 that is lying fallow
  - The European Observatory indicates there is a good amount of low-and mid-band spectrum that is not being assigned and utilised
  - Is there really a need for RSPG to recommend a new WRC-23 Agenda Item to Study New bands for IMT-2030?
  - DSA believes that what is needed is better sharing

Wi-Fi Alliance

- Wi-Fi is optimised for high performance indoor, and therefore delivers the bulk of the world's data traffic, including most data traffic on mobile devices.
- Demand for Wi-Fi will continue to grow with increased fibre deployments and cellular generations
- Wi-Fi 6E is a resounding success and by 2024 there will be billions of devices installed globally able to operate from 5.925 to 7.125 GHz.
- Only countries that allow Wi-Fi access to the entire 6 GHz spectrum range will get the most benefits
- Wi-Fi 7 and Wi-Fi 8 will depend on 6GHz access, and 320 MHz channels will be optimised for demanding emerging use cases
- 6 GHz is perfectly suited for Wi-Fi to continue to deliver the connectivity users need, there is no alternative spectrum for Wi-Fi, and 6 GHz is unsuitable for IMT.

~ . ~