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RADIO SPECTRUM POLICY GROUP

6G Strategic vision

RSPG Report

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1 Executive summary

1.1 Scope

The RSPG work programme 2024-2025 recognises that a proactive position is essential for supporting the development and deployment of 6G in Europe. Early recognition of spectrum needs will facilitate the initial launch and operation of 6G networks/services from 2030.

The work is based on a proper evaluation of coverage and capacity needs for 6G use cases and usages scenarios, taking into account the ITU-R IMT-2030 framework. Also, non-terrestrial networks and licence-exempt use are considered. It addresses the long-term spectrum availability and the implementation strategies for 6G. The work continues the further investigations identified in the first RSPG Opinion on 6G.[1]

1.2 Input from stakeholders

The RSPG has taken into account input from active stakeholders, such as research institutes, manufacturers, mobile network operators (MNOs) and satellite operators. For this a hearing with stakeholders was held in September 2024. The topics discussed in the hearing were:

1. Future rollouts of 5G until 2030
2. Use cases for future spectrum needs
3. Readiness for a launch of 6G in 2030 for mass market for services and equipment
4. Role of private networks in 6G
5. Role of license exempt spectrum
6. Role of Non Terrestrial Networks (NTN)
7. Sustainability and Security

A public consultation on the draft version of this RSPG report was held between 16 November and 27 December 2024. All non-confidential responses are published on the RSPG website[2]. 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 list of the stakeholders that responded to the public consultation can be found in Annex I.

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.

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[1] RSPG23-040: 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks: https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[2] https://radio-spectrum-policy-group.ec.europa.eu/document/download/55451aa3-680c-43bd-92b7-a91bca60b091_en?filename=PC-6G-2024-responses.zip

This Report takes into account the views of stakeholders. The discussion on possible new spectrum for 6G and the implications it may have on existing services is under the scope of other activities of the RSPG, e.g. WRC, Long-term vision for the upper 6 GHz band, Assessment of future usage of the frequency band 470-694 MHz within the EU, Strategic Spectrum Matters, Peer review and Member States cooperation.[3] Deployments of use cases within specific frequency ranges depend on technical and non-technical aspects such as license availability.

According to some stakeholders

- to achieve reliable nationwide-area coverage low-band spectrum (below 1 GHz) is essential. This can be supplemented in the future by non-terrestrial networks (NTN);
- higher frequency bands in sub-7 GHz will be needed, including the upper 6 GHz band, as well as new bands in the 7-15 GHz range, which would supplement low band deployments to achieve the needed capacity for both existing and new use cases, for instance in urban and sub-urban environments;
- for use cases in confined areas like cooperating mobile robots and human-centric services, small-cell deployments could be used. Additionally, the millimeter-wave bands or local sub-THz deployments, which is still being researched, can be used to meet even higher data rate and capacity requirements, however with limited coverage.

Some stakeholders stated a need of additional 200 MHz for each MNO in mid band spectrum with conditions that allow the use in macro base stations without undue power restrictions. This would enable implementation of 6G use cases that require more capacity than 5G services and provide reasonable coverage in suburban/urban areas utilising the same base station towers as for 3.6 GHz. Further, operators have expressed their need for more spectrum to provide increased network capacity in the coming years.

Researchers propose that spectrum sharing between 6G networks and incumbent spectrum users and spectrum sharing between MNOs and local/private networks need to be incorporated into 6G spectrum discussions from the beginning of the technology development phase and not be a restriction posed afterwards.

Manufacturers and reaserchers indicated that there is a clear need for a 6G spectrum roadmap for Europe.

The RSPG intends to consider as appropriate the input from stakeholders also in coming 6G work.

1.3 Conclusions

In this report the RSPG has studied the spectrum and network implications for the implementation of the six different usage scenarios defined by the ITU-R. The RSPG

[3] RSPG24-008: Work Programme for 2024 and beyond (https://radio-spectrum-policy-group.ec.europa.eu/document/download/d4e46670-313b-4bac-8d8d-760d92f4649b_en?filename=RSPG24-008final-RSPG_WP24_and_beyond_0.pdf)

has also indicated the possible frequency bands for 6G in Europe to be further investigated in preparation of the 6G spectrum roadmap.

The RSPG has also reflected on densification of mobile networks, network integration between mobile networks and fixed broadband networks to which WAS/RLAN provides wireless access.

The RSPG recognises that 6G should build on joint evolution and interoperability of terrestrial and non-terrestrial networks to leverage the most advantageous characteristics of satellite and terrestrial systems.

To create a common market for network and terminal equipment, the EU needs to indicate in which spectrum band(s) the first launches of 6G are planned. Therefore, the RSPG intends to develop a 6G spectrum roadmap further to the publication of this report in order to identify which frequency band(s) should be made available for the launch of 6G mass market but also to support development of various vertical markets. The MS who wants to take 6G into use after 2030 should be able to do so.

This report also investigates solutions for spectrum sharing. The emphasis lies on *inter-service spectrum sharing* which involves sharing between different radiocommunication applications. With the growing pressure on spectrum, inter-service sharing is becoming increasingly important. Policymakers, spectrum managers, spectrum users, and industry should shift their mindset on inter-service spectrum sharing. The research community is urged to explore spectrum sharing solutions that support European goals for the next decade. When developing the 6G spectrum roadmap, the RSPG will investigate possible actions for the introduction of innovative spectrum sharing solutions without losing sight of the technology neutrality principle.

2 5G development and lessons learnt[4]

5G implementation is largely ongoing in the primary 5G band (3.6 GHz) as well as in other bands harmonised for ECS, such as 700 MHz and the paired terrestrial 2 GHz band in France and Germany, depending on the national circumstances.

The 3.6 GHz band is the primary mid-band spectrum currently providing high-speed connections, particularly in urban areas where capacity demands are highest. It also addresses coverage-capacity requirements by offering contiguous blocks of spectrum, preferably 80-100 MHz, as outlined in the current EU framework[5]. As the primary band, this band has been targeted for the launch of 5G by many operators in the world[6]. In some Member States (MS) even more spectrum has been allocated per operator, up to 130 MHz.

The 5G pioneer band at 700 MHz supports rapid 5G roll-out, extending coverage to rural areas, and ensures building penetration together with other bands. The 700 MHz band provides coverage and has been used by some operators to introduce 5G. However, operating in narrower block sizes (5-10 MHz) than those available at 3.6 GHz provides limited capacity and user experience. In this case, the initial 5G deployment focused on the non-standalone (NSA) version, based on the 4G LTE core, thus limiting 5G performance. An increasing number ofoperators are currently launching 5G Stand-Alone (SA) in the 700 MHz band, which is well-suited for massive machine-type communication (mMTC) and ultra-reliable low-latency communication (URLLC) services due to its low latency and limited bandwidth.

The 5G pioneer band in the millimetre-wave (mmW) band 26 GHz is still under an early deployment phase[3]. Lessons to be learnt from 26 GHz could help to support further developments in 42 GHz which has been recently harmonised[7]. The mmW bands can address very high-capacity use cases and in areas with many users. However, seamless connectivity across a wide-area is not feasible due to propagation characteristics (high loss not favouring multipath: diffraction, scattering). Additionally, the availability of mobile terminals and equipment in the 26 GHz and 42 GHz band remains limited and costly, as the necessary ecosystem is still in development. At this stage, only a few mass-market 5G devices, such as smartphones, are able to operate in the mmW band. However, Fixed Wireless Access (FWA) equipment for the 26 GHz band is available and this band is already used for FWA in some countries.

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[4] This section covers mainly the mass market 5G developments.

[5] Decision (EU) 2019/235 on amending Decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3 400-3 800 MHz frequency band https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D0235

[6] RSPG23-040 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks: https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[7] Decision (EU) 2024/1983 on the harmonisation of the 40,5-43,5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401983

5G deployments in harmonised wireless broadband electronic communication services (WBB ECS[8]) bands other than 3.6 GHz are mainly on the basis of current authorisations which have supported the development of previous generations of mobile systems[9], such as in 700 MHz or the paired terrestrial 2 GHz band.

Spectrum sharing between different mobile technology generations enables MNOs to dynamically allocate and share the same frequency spectrum between 4G and 5G. This has enabled MNOs to facilitate a faster roll-out of new technologies without the need for complex refarming of frequencies, allowing for an optimised utilisation of spectrum resources during the migration phase. Intra MNO sharing is a spectrum access method that allows maximising spectrum use by dividing access, where a base station equipped with this method is capable of supporting multiple technologies at the same time, through the same antenna. The other feature of this method is dynamic re-farming that allows the base station to dedicate capacity according to traffic loads, dynamically adjusting spectrum allocation between technologies. Intra MNO sharing is a very effective tool for a smooth migration from 4G to 5G, as it allows 4G to coexist with 5G, without discontinuation of the 4G service. However, coexistence of 4G and 5G in the same band has a negative impact on peak transfer rates.

2.1 The transition from 5G Non-Stand-Alone to 5G Stand-Alone

The key standardised features of 5G including concepts like mobile edge computing and slicing required a new core network architecture based on state-of-the art computing principles. This involved virtualisation (fully cloud-based implementation), a fully software services-based architecture and a high degree of automation of signalling functions. The associated initial 3rd Generation Partnership Program (3GPP) standards for 5G in Release 15 were written based on this paradigm shift. The change from a 4G to a 5G core network implementation in the early twenties was a big and risky step for MNOs to take, without very clear return on investment (ROI) prospects at that time. The 5G NSA option was introduced to facilitate operators in an evolutionary approach. It allowed them to first deploy 5G New Radio (NR) while maintaining the 4G core network. The RSPG highlights some main differences between 5G NSA and 5G SA in terms of performance and possibilities for offering specialised or targeted services, since most of the technological evolution provided with 5G is enabled by 5G SA. Currently, there are still a significant number of European MNOs in an intermediate stage of 5G adoption, as they maintain the massive use of 5G NSA without a clear perspective for adopting 5G SA. This implies relevant limitations, innovative features of 5G, including network slicing based on the 5G SA version, preventing the efficient deployment of a set of relevant use cases. A critical point in this scenario lies in business models, notably regarding network monetisation and the ROI, which directly impacts operators' investment plans.

The low demand for differentiated services best expresses this issue. Such differentiated services require very low latency or address the massive connection of IoT devices, as well as the search for services from specialised dedicated subnets (based on network slicing). Also, European operators had been relatively hesitant in

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[8] WBB ECS in this document means the harmonised bands that can be used for IMT in Europe

[9] ECO Report 03, The Licensing of "Mobile Bands" in CEPT: https://docdb.cept.org/document/939

making the transformation to 5G SA compared to the US and Asia due to system complexity and a limited SA supporting device ecosystem.

Additionally, some aspects regarding future migration to 6G and the 5G SA must be considered. Preliminary information about the new features, called Multi-Radio Spectrum Sharing (MRSS), for coexistence of 5G and 6G are being developed by standardisation bodies (such as 3GPP). MRSS involves the use of a 6G RAN on the 5G core (5G SA) with some updates.

Other points of attention to be mentioned refer to:

- The migration of the user terminal base from 4G to 5G is still under progress. Migration of user terminal base is currently less dependent on mobile operators' strategy due to a decrease in their subsidy of terminals.
- The need to launch fibre backhaul to connect radio stations and the 5G core
- Existence of commitment clauses for the adoption of the SA version in 5G authorisations.

Therefore, for the above reasons RSPG recalled that the adoption of 5G SA is occurring slowly and unevenly among European MNOs. However, the expectation is that in the coming few years Europe will catch up with the other major regions regarding 5G SA, motivated by improved technology maturity, a better developed device ecosystem and a growing demand among enterprises for more advanced use cases requiring 5G SA.

2.2 Compliance to policy goals

According to the EU Digital Decade report (July 2024)[10], the EU will achieve its goal for 5G basic coverage by 2025. The goal of covering all populated areas with high-speed 5G networks by 2030 has been monitored for the first time in the 2024 report. This indicator measures the residential coverage of 5G networks in the 3.6 GHz band. The results indicate that EU is lagging behind its schedule to be able to reach this goal by 2030 but there are big variations between MSs. It is also recognised that a common EU-level monitoring methodology of 5G performance is needed as MS have used different approaches[11].

National coverage, including of main roads and rail tracks, is provided by using various bands and using various mobile network technologies, including 5G. These national coverage requirements in national authorisations could differ from country to country due to national context, needs and policies (see some national examples in Annex II). Some data from Member states illustrate the rapid take off of 5G in 3.6 GHz. The European 5G Observatory[12] provides an overview of the state of 5G developments in the European Union.

[10] State of the digital decade report: https://digital-strategy.ec.europa.eu/en/factpages/state-digital-decade-2024-report

[11] Draft BEREC Work Programme 2025: https://www.berec.europa.eu/system/files/2024-10/BoR%20%2824%29%20148%20Draft%20BEREC%20Work%20Programme%202025.pdf

[12] European 5G scoreboard: https://5gobservatory.eu/observatory-overview/eu-scoreboard/

2.3 The satellite component of 5G

Report ITU-R M.2514-0[13], adopted in 2022 describes the vision, requirements and evaluation guidelines for IMT-2020 satellite radio interfaces. The addition of a satellite component to IMT-2020 could extend the coverage of the IMT-2020 service in under and unserved areas where supplementing the terrestrial component is most relevant.

The satellite component of IMT-2020 covers three usage scenarios of which the enhanced mobile broadband satellite (eMBB-s) usage scenario and the massive machine type communications satellite (mMTC-s) usage scenario are satellite variants of eMBB and mMTC defined in Recommendation ITU-R M.2083-0[14]. The satellite component does not address the URLLC scenario, but covers a satellite specific high reliability communications usage scenario (HRC-s). The satellite IMT-2020 usage scenarios with associated use cases are illustrated in Figure 1.

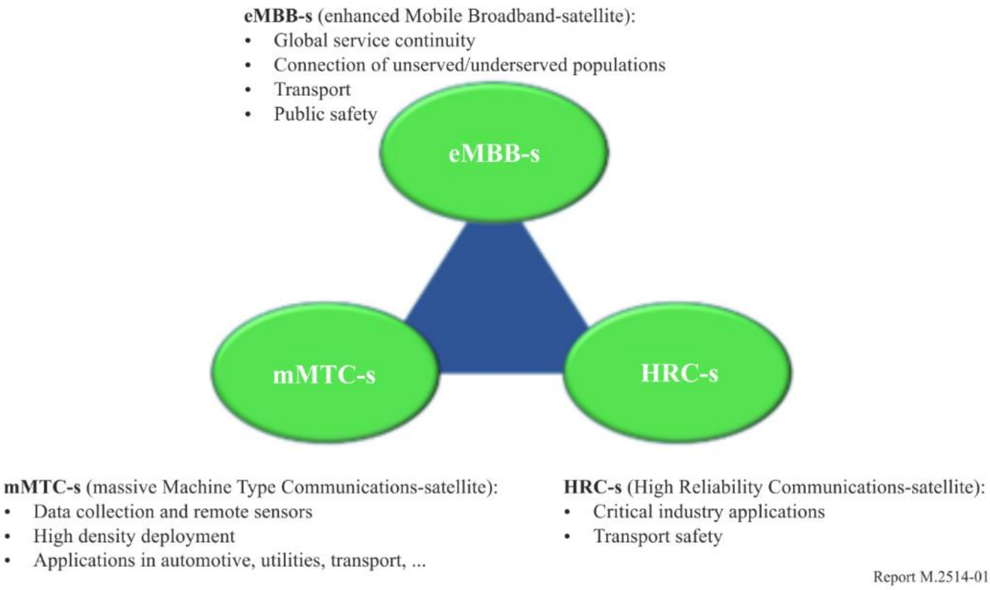

Figure 1: Satellite IMT-2020 usage scenarios with associated use cases

It is planned that ITU-R will complete the development of satellite IMT-2020 radio interface specification Recommendation(s) in May 2025.

Traditionally, mobile satellite services (MSS) have been delivered by systems based on proprietary standards and on frequency band allocated to MSS. However, the convergence between MSS and mobile services has been supported by standardisation activities.

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[13] Report ITU-R M.2514-0: Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2514-2022-PDF-E.pdf

[14] Recommendation ITU-R M.2083-0, IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

RSPG is investigating new challenges raised by direct-to-device (D2D) satellites systems operating in WBB ECS and MSS bands including access to EU markets. RSPG published an Opinion on MSS 2GHz[15] in February 2024.

2.4 Local and vertical use cases

The increasing need for spectrum for verticals and local networks has already been recognised in earlier RSPG Opinions, such as the RSPG Opinion on 5G developments and possible implications for 6G[16], RSPG Opinion on Additional Spectrum needs[17] and the RSPG Opinion on Radio Spectrum Policy Programme RSPP[18].

Currently, the availability of dedicated spectrum for local networks varies between countries. However, the harmonisation of the band 3.8-4.2 GHz for low and medium power terrestrial wireless broadband (WBB LMP) will improve the situation and provide better possibilities to fulfil the specific requirements of verticals and local use in certain use cases.

The spectrum needs for local and vertical use could still increase, which needs to be taken into account in future spectrum strategies, considering also relevant developments and timing of harmonisation in bands recommended for verticals. There is an expressed need for private networks with wide or national coverage. These can be met by different means, such as network virtualisation or slicing in MNOs networks or building their own private network.

The current harmonisation initiative in 3.8-4.2 GHz supporting low medium power wireless broadband network will enable the development of new 5G industrial use cases and improve European competitiveness. This will facilitate the continued evolution of vertical's use cases, and will further support the needs of vertical industries in the 6G era.

The evolution towards 5G SA, including network slicing, is currently underway, as an increasing number of mobile operators are migrating their core networks to 5G SA. This will enable MNOs to provide local or wide area private networks for verticals utilising network slicing.

Spectrum is also available for local 5G networks in the 26 GHz band in some MSs. This band can provide very high capacity for local networks bringing possibilities for

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[15] RSPG24-007, RSPG Opinion on assessment of different possible scenarios for the use of the frequency bands 1980-2010 MHz and 2170-2200 MHz by the Mobile Satellite Services beyond 2027: https://radio-spectrum-policy-group.ec.europa.eu/document/download/b1f597f2-d6b5-44e5-878d-ea09bdd8a1d7_en?filename=RSPG24-007final-RSPG-Opinion-MSS-public_version.pdf

[16] RSPG23-040 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks: https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[17] RSPG21-024, RSPG Opinion on Additional spectrum needs and guidance on the fast rollout of future wireless broadband networks https://radio-spectrum-policy-group.ec.europa.eu/document/download/efbe8bbd-9625-4080-8ccc-088a44a5d6bc_en?filename=RSPG21-024final_RSPG_Opinion_Additional_Spectrum_Needs.pdf

[18] RSPG21-033, RSPG Opinion on a Radio Spectrum Policy Programme (RSPP): https://radio-spectrum-policy-group.ec.europa.eu/document/download/00cfd520-efa9-48a1-bfec-d2980f511c3c_en?filename=RSPG21-033final-RSPG_Opinion_on_RSPP.pdf

new types of services. Currently this band is still lightly utilised, but is expected to increase as equipment availability improves in the coming years. The 42 GHz band was recently harmonised in Europe and it remains to be seen how it will be used in the future.

Among verticals there is a need for increasing awareness regarding the potential of 5G. The demand from enterprises may increase, when they are better informed about the benefits and capacities of 5G. The telecommunications industry is working on 'plug and play'concepts which hide many of the complexities in 5G. It is also expected that solution providers will emerge in the market which are specialized in specific verticals.

2.5 Network integration

In recent years, there has been a growing demand for high-speed and reliable connectivity leading to a significant progress in deployment of mobile networks and fixed broadband access networks, to which WAS/RLAN provides wireless access.

The interoperability with non-3GPP networks has been established by some mobile operators for certain use cases. One example is VoWiFi, which uses the 4G core element ePDG[19] (evolved Packet Data Gateway) to seamlessly carry voice calls over WiFi.

The evolution to 5G Core by deploying functionalities[20] such as the Non-3GPP Inter-Working Function (N3IWF) and the Trusted Non-3GPP Gateway Function (TNGF), has the potential to create a more efficient, sustainable and user-centric network, leveraging the strengths of non-3GPP and IMT technologies.

WAS/RLAN and mobile networks, including 6G, will converge to deliver seamless, high-performance connectivity in diverse environments. WAS/RLAN provides connectivity in indoor settings while 6G can provide wide-area coverage. Emerging use cases like AR/VR, automated transport and IoT, and emerging IT technologies like AI and cloud computing rely on both local connectivity (e.g., WAS/RLAN) and wide-area (e.g., 6G) connectivity for scalability and flexibility. WAS/RLAN alleviates congestion on cellular networks (6G) by offloading data traffic, especially in high-density areas such as cities and venues.

[19] ETSI TS 123 402 V16.0.0 (2020-11), Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for non-3GPP accesses (3GPP TS 23.402 version 16.0.0 Release 16): https://www.etsi.org/deliver/etsi_ts/123400_123499/123402/16.00.00_60/ts_123402v160000p.pdf

[20] ETSI TS 123 501 V16.6.0 (2020-10) 5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 version 16.6.0 Release 16): https://www.etsi.org/deliver/etsi_ts/123500_123599/123501/16.06.00_60/ts_123501v160600p.pdf

3 Early policy initiatives on 6G

When drafting this Report, RSPG identified number of drivers triggering the development of 6G in Europe such as:

- Policy initiatives:
  - Council Conclusions on the future of the "EU Digital Policy" (§18, §25)[21]
  - Report from Enrico Letta "Much more than a market" in support of future 6G development in Europe"[22]
  - Report from Mario Draghi "The future of European competitiveness"[23]
  - Council Conclusions on The White paper on "How to master Europe's digital infrastructure needs?"[24]
- Initiatives supporting 6G research and EU sovereignty:
  - The Council Regulation 2021/2085 established the Smart Networks and Services Joint Undertaking (SNS JU) as a legal and funding entity in order to foster Europe's technology sovereignty in 6G[25]
  - EU Member States, with the support of the European Commission and ENISA, the EU Agency for Cybersecurity, are engaged on the implementation of the EU Toolbox on 5G cybersecurity. Security and Cybersecurity are parts of the Conclusions of the Council on the future of the "EU Digital Policy "[19]
  - The NIS 2 Directive (Directive (EU) 2022/2555)[26] is a legislative act that aims to achieve a high common level of cybersecurity across the European Union.

The EU Council adopting in May 2024 conclusions on the "Future of EU Digital Policy" already expressed views on 6G recognising the importance of a common and strategic European Approach to 6G technology as enablers for the technological development and competitiveness of the EU at a global level, as well as for sustainable development (§18), encouragement to continue and strengthen efforts to establish an attractive policy framework for 6G research and development as well as for 6G deployment on the basis of an appropriate 6G strategic vision that takes into account the early recognition of spectrum needs based on the assessment of coverage and capacity requirements for 6G use cases and its environmental impact (§25).

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[21] The Future of EU Digital Policy - Council Conclusions (21 May 2024): https://data.consilium.europa.eu/doc/document/ST-9957-2024-INIT/en/pdf

[22] Much more than a market: https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf

[23]The future of European competitiveness, Part A, A competitiveness strategy for Europe : https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en

[24] Expected to be adopted by December 2024

[25] The Smart Networks and Services Joint Undertaking: https://digital-strategy.ec.europa.eu/en/policies/smart-networks-and-services-joint-undertaking

[26] Network and Information Systems 2 (NIS 2) Directive: https://www.nis-2-directive.com/

Europe needs to be active in its actions towards 6G and contribute to the international harmonisation initiatives and promote the European interests. With 5G the early identification by the RSPG of the need for low (coverage in 700 MHz), mid (capacity in 3.6 GHz) and high (pioneering and innovation in 26 GHz) bands for 5G proved to be the right recipe[27]. Also, other harmonised bands for WBB ECS have been used for 5G implementations. Taking into account the need for a clear target for initial 6G investments, a similar kind of approach could be considered for 6G to meet future needs in the EU and to support the development of European competitiveness. Stakeholders are requesting clear guidance on which frequency bands to focus on for 6G.

It should also be noted that 6G is more than just a new generation for higher data speeds - it is expected to bring possibilities for new innovations and services compared to 4G/5G. 5G SA networks are currently under development in a large number of EU MSs in various harmonised bands depending on mobile operator's strategy (services, network migration, CAPEX, operational expense (OPEX), etc.) and available spectrum resources.

RSPG identified the limited new resources that could be made available to support the launch of 6G. For example, even if WRC-23 identified 6425-7125 MHz for IMT, the upper 6 GHz band is subject to another RSPG Opinion. Except for 7125-7250 MHz, the European position at WRC-23 was to oppose studying additional IMT identifications in frequency bands where IMT would have the potential to jeopardise strategic and important European spectrum use with international footprint (satellite, maritime, aeronautical).In addition, reuse of current harmonised WBB ECS spectrum may be considered depending on further broad implementation of 5G SA by MNOs and features under standardisation for intra-MNO coexistence (see also RSPG's first Opinion on 6G[28]).

Europe is also actively engaged in cooperation in 6G research: 6G SNS with others regions[29].

Working in collaboration to influence international 6G policy is important and as an example of the co-operation the United States and a number of European countries have signed a joint-statement laying down the guiding principles for the development of 6G[30].

Examples of developments outside Europe

- In the US the Next G Alliance is an initiative to advance North American wireless technology leadership over the next decade through private-sector-led

[27] RSPG24-019: Opinion on How to master Europe's digital infrastructure needs?, https://radio-spectrum-policy-group.ec.europa.eu/document/download/15789389-828c-4a55-a397-f2338fa2125b_en?filename=RSPG24-019final-RSPG_Opinion_on_how_to_master_Europes_digital_infrastructure_needs.pdf

[28] RSPG23-040 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks: https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[29] SNS JU missions and objectives: https://smart-networks.europa.eu/missions-and-objectives/

[30] Joint Statement EU-US Trade and Technology Council of 4-5 April 2024: https://ec.europa.eu/commission/presscorner/detail/en/statement_24_1828

efforts. With a strong emphasis on technology commercialisation, the work will encompass the full lifecycle of research and development, manufacturing, standardisation and market readiness[31].

- In South Korea the Ministry of Science and ICT (MSIT) has launched the K-Network 2030 Strategy to discuss mutually beneficial cooperation between the public and private sector, and between large businesses, SMEs, and micro-businesses to become an exemplary country for next-generation networks[32].

[31] Next G Alliance: https://nextgalliance.org/

[32] Ministry of Science and ICT, Korea: MSIT Launches the K-Network 2030 Strategy: https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&bbsSeqNo=42&nttSeqNo=783

4 Drivers and enablers for 6G

4.1 Recent technology trends

In 2022 ITU-R published a report "Future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 and beyond" [33].

In December 2023 3GPP commits to develop 6G Specifications. The follow up in early 5G systems targeting vertical services could appear as a direct competitor of vertical services provided by mobile operators using 5G slicing and stimulate further development towards 6G supporting verticals needs.

Also, 3GPP is developing specifications for 5G non-terrestrial networks (NTN), including satellite. Furthermore, there are developments in co-operation between satellite and mobile operators.

4.2 6G usage scenarios and their implications on spectrum

The ITU-R IMT-2030 framework[34] and timeline outlines the 6G development on an international level. The usage scenarios and overarching aspects presented in the framework are depicted in Figure 2.

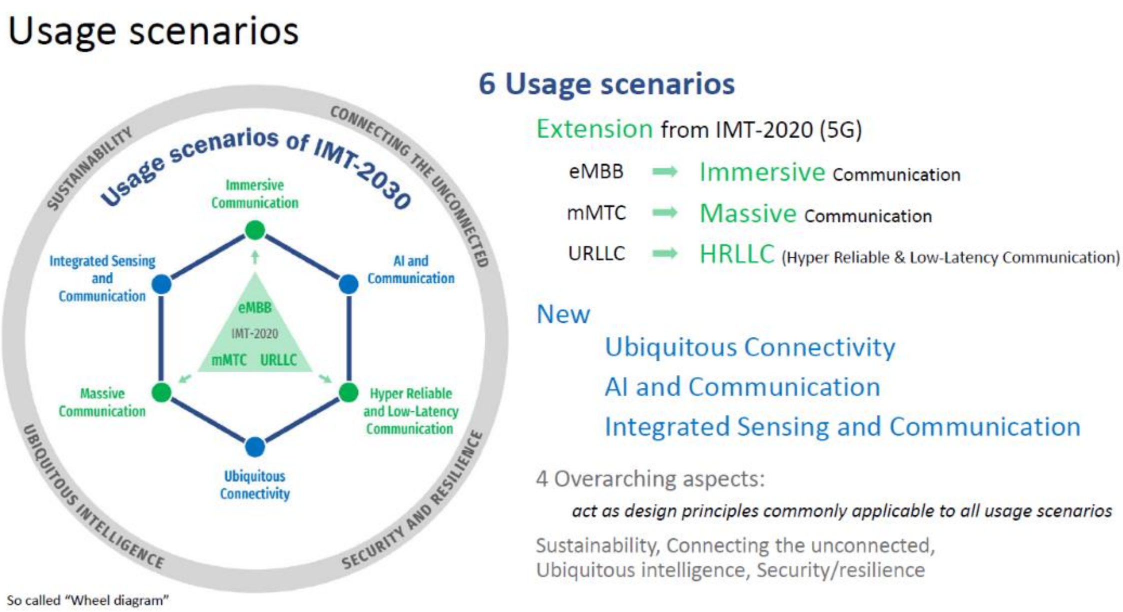

Figure 2: Usage scenarios and overarching aspects in the ITU-R IMT-2030 framework

[33] Report ITU-R M.2516-0 Future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 and beyond: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2516-2022-PDF-E.pdf

[34] Rec. ITU-R M.2160, Framework and overall objectives of the future development of IMT for 2030 and beyond: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

According to ITU, various usage scenarios of 6G are envisaged to expand on those of 5G (i.e. eMBB, URLLC, and mMTC) into broader use requiring evolved and new capabilities. In addition to expanded 5G usage scenarios, 6G is envisaged to enable new usage scenarios arising from capabilities, such as artificial intelligence and sensing, which previous generations were not designed to support. Also, various targets for 6G include new and enhanced capabilities compared to 5G (Figure 3).

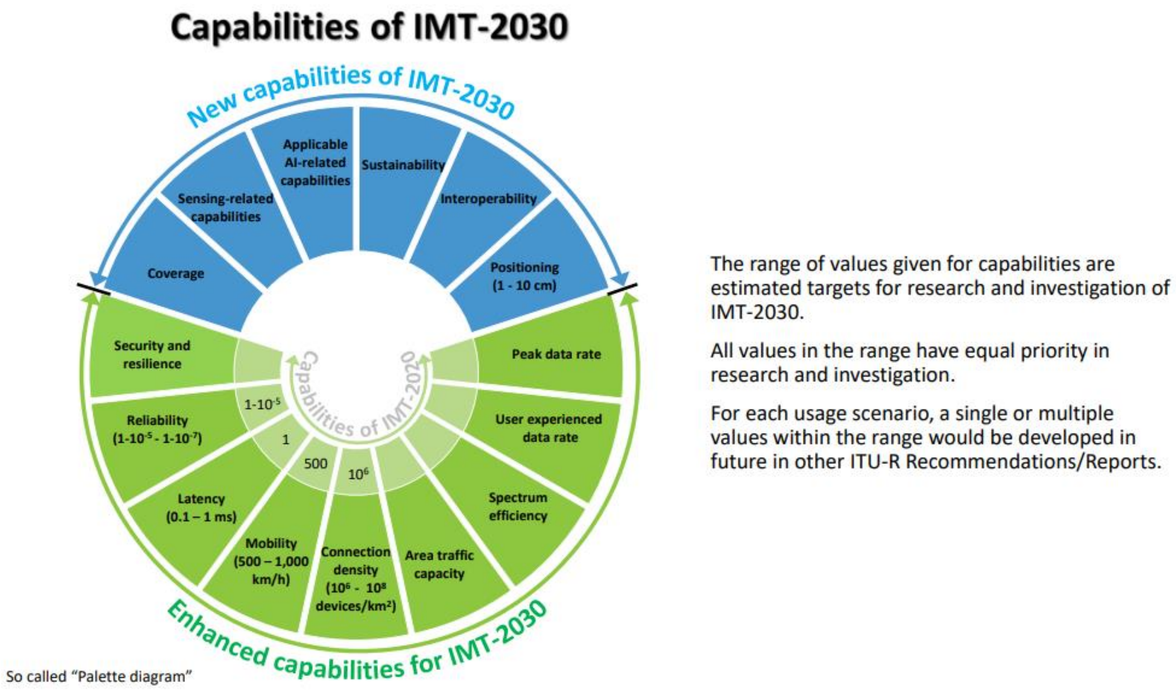

Figure 3: Capabilities of IMT-2030

The following early spectrum implications might be expected based on the IMT-2030 usage scenarios:

- Immersive communication covers use cases which provide a rich and interactive video (immersive) experience to users, including the interactions with machine interfaces. This usage scenario is relevant to the EU work on virtual worlds[35]. Balance between higher data rates and increased mobility in various environments are essential. Cost-efficient urban coverage and capacity for immersive communication enabling reuse of current base station sites will require mid band spectrum due to the need for spectrum suitable for larger bandwidth and with similar radio properties as 3.4-3.8 GHz (coverage/capacity performance) ensuring also possible reuse of base stations sites. There are technical and economic limitations on the amount of densification that is feasible. Some use cases, depending on population density or areas of interest, can be also served by 6G networks providing high speed

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[35] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023DC0442 describes virtual worlds as *"persistent, immersive environments, based on technologies including 3D and extended reality (XR), which make it possible to blend physical and digital worlds in real-time, for a variety of purposes such as designing, making simulations, collaborating, learning, socialising, carrying out transactions or providing entertainment*"

data, e.g., in the high bands, but then coverage will be limited. Virtual worlds for homes and consumer use could be served by unlicensed bands.

- Massive Communication: This usage scenario is related to connect a very large amount of IoT devices, including those with very low power consumption, requiring low or moderate bit rates in a large coverage area. The usage scenario could best be supported by networks utilising low and mid bands. Non-terrestrial networks are needed to provide global coverage. There is spectrum already available for IoT, including MNO's frequency bands that could also support 6G technology. Comparing with 5G, 6G intends to increase the number and density of connected devices.
- Hyper Reliable and Low-Latency Communications: Typical use cases include communications in an industrial environment for full automation, control and operation. This usage scenario is expected to be served by extreme performance specialised networks. The first network implementations are expected to be local and tailored e.g., for industry. URLCC does not in all use cases require high capacity and large bandwidth. In consequence. current harmonised band (frequency bands with narrow and reduced block sizes) could respond to some of the demand.
- Ubiquitous connectivity is expected to provide affordable connectivity and, at minimum, basic broadband services with extended coverage, including sparsely populated areas. Typical use cases include, but not limited to, IoT and mobile broadband communication. Networks to serve this usage scenario could be built in the low bands (preferably with carrier aggregation of networks < 1 GHz). Connectivity could be enhanced through interworking with other systems, e.g., non-terrestrial networks.
- AI and Communication would require support of high area traffic capacity and user experienced data rates, as well as low latency and high reliability, depending on the specific use case. Typical use cases include assisted automated driving, autonomous collaboration between devices for medical assistance applications and creation of and prediction with digital twins. The usage scenario could be served by 6G networks in the mid bands providing capacity and coverage. AI and communication use cases are in early stage and part of research and development activities.
- Integrated Sensing and Communication (ISAC) provides spatial information about unconnected objects as well as connected devices and their movements and surroundings. Early research and development activities have presented two different network implementation approaches: 1) utilising some subcarriers of 6G networks in low and mid bands for sensing, which will slightly decrease the capacity of the network, 2) specialised networks for ISAC in very high spectrum (e.g. mmWave or sub-THz).

4.3 Sustainability

As a first step, RSPG may consider addressing a state of the art on how sustainability considerations are taken into account in current 6G roadmaps and flagship projects by providing an overview of enabling green features and functionalities, envisioned KPIs and targets etc. and identify how these considerations relate to spectrum policy.

Recent 6G statements emphasise sustainability as a guiding principle, including e.g. EU-US Trade and Technology Council's (TTC) 6G Outlook[36], which states that *"6G technologies must also be an enabler for sustainability, considering environmental, social, and economic perspectives. A reduced carbon footprint 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."* These high-level policy objectives are triggering relevant investment in 6G research and developments.

With its requirement for technology neutrality and the implementation of least restrictive technical conditions ECS spectrum policy supports the idea of sustainable spectrum use. New technologies with higher efficiency can easily be implemented with no need to make or wait for changes to the regulatory requirements. In addition, national administrations support the testing of new sustainability approaches in the research and development phase by issuing test licenses for new technologies before they are made available on the market. This helps to evaluate also if the expected behaviour of new developments is met in real environments.

Recommendations to support sustainability are given in the Industry 6G roadmap[37] of the EU-US TCC. Sustainability is also further discussed in Chapter 8 of this report.

The non-terrestrial components of 6G could contribute to both handprint and footprint of the 6G system. On the other hand, NTN could possibly contribute to the sustainability of 6G networks. Reducing the need for terrestrial infrastructure can be a benefit of NTN in some parts of Europe, as they provide global coverage with much fewer installations on Earth.

[36] Shaping Europe's digital future: 6G outlook:https://digital-strategy.ec.europa.eu/en/library/6g-outlook

[37] EU-US, Beyond 5G/6G Roadmap: https://6g-ia.eu/wp-content/uploads/2024/01/eu-us-aligned-6g-roadmap-joint-paper.pdf?x44222

5 Spectrum sharing solutions

Spectrum sharing is a strategic pillar of spectrum management. To that end, RSPG published various documents to discuss spectrum sharing approaches and providing recommendations for increasing sharing practices and their dissemination. Previous Opinions[38] [39] [40] remain valid for 6G and could pave the way for future development of 6G. This Report particularly emphasises spectrum sharing between different radiocommunication applications, either within one radio service (e.g. FIXED, MOBILE) or between different radio services. The latter is referred to as inter service spectrum sharing. This Report includes recommendations to increase spectrum sharing with preliminary analysis on possible actions to favour the introduction of innovative and more dynamic spectrum sharing solutions and proposals for coordinated actions. These spectrum sharing approaches should be carefully assessed by RSPG when investigating possible frequency bands targeted for 6G. Strategic goal of this particular Report is also to change the mindset on this topic among policy makers, spectrum managers, users and industry. The research community is urged to explore spectrum sharing solutions that support European goals for the next decade.

5.1 Inter service sharing becoming more essential

There is an ever-increasing interest in the use of mobile networks (WBB ECS), fixed links supporting the development of WBB ECS, wireless local area networks (WBB LMP), satellite services, and commercial and governmental services (e.g. scientific, defence, etc.) all of which could target the same frequency bands. Some applications are subject to the same radio service such as IMT and WAS/RLAN as part of MOBILE service. Increasing demand for spectrum in the future, sharing of the same spectrum band between different users will become more and more essential when developing 6G.

There is a very clear signal from administrations to stakeholders that interservice spectrum sharing is becoming more and more an essential topic. Given the spectrum requirements for 6G in 2030 and beyond including spectrum sharing requirements, it is of a pivotal importance that the ecosystems involved, including mobile industry, play also their part in contributing to this long-term strategic evolution in spectrum management.

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[38] RSPG21-016, RSPG Report on Spectrum Sharing, A forward-looking survey: https://radio-spectrum-policy-group.ec.europa.eu/document/download/aee201a0-06e3-494f-b7f7-36ec3b723291_en?filename=RSPG21-016final_RSPG_Report_on_Spectrum_Sharing.pdf

[39] RSPG21-022, RSPG Opinion on Spectrum Sharing – Pioneer initiatives and bands: https://radio-spectrum-policy-group.ec.europa.eu/document/download/0e3df317-dbc6-49ee-9d15-ef47ccd9db0d_en?filename=RSPG21-022final_RSPG_Opinion_Spectrum_Sharing.pdf

[40] RSPG21-033, RSPG Opinion on a Radio Spectrum Policy Programme (RSPP): https://radio-spectrum-policy-group.ec.europa.eu/document/download/00cfd520-efa9-48a1-bfec-d2980f511c3c_en?filename=RSPG21-033final-RSPG_Opinion_on_RSPP.pdf

5.2 Trends in Spectrum sharing

5.2.1 Different levels to establish spectrum sharing

The RSPG recognises that already today a large amount of radio spectrum is used on a shared basis, involving WBB ECS. For example, sharing conditions could be established at:

- International level (One example is the decision of WRC-23 establishing sharing conditions to operate IMT systems in upper 6 GHz while protecting satellite reception (protection of the fixed satellite service FSS (Earth-to-space)[41])
- European level with harmonised conditions (for example mobile communications on-board aircraft, MCA, services sharing the band with commercial 5G mobile networks)
- National level (such as national technical conditions to be developed in order to protect operation of earth stations or fixed service in 26 GHz in case of WBB ECS roll-out).

5.2.2 Intra MNO Sharing

Moreover, Spectrum sharing is also being practised by industry itself with intra MNO spectrum sharing. Spectrum sharing between different technologies has enabled MNOs to utilise the same frequency band between different mobile technology generations to enable smooth evolutions to newer technologies. Due to the ability to share spectrum resources on demand in real-time, complex refarming of frequencies is no longer necessary. While allowing a faster roll out of new technologies for customers with user equipment (UE) supporting the latest generation of mobile technologies, customers with legacy UE can still be served. This optimised utilisation of spectrum resources leads to a better overall user experience. It is relevant to collect the experiences of MNO’s with intra MNO sharing.

The RSPG observes that the mobile industry’s focus to date has been predominantly on intra technology spectrum sharing. For example, MNOs could have business incentives (e.g. reduction of capital expenditure, CAPEX) and are therefore proactively engaged in the standardisation of intra technology spectrum sharing solutions which target an evolutionary development of the mobile network architecture and equipment. These standardisation efforts which provide also opportunities for economies of scale are expected to continue in the future.

It is expected that multi radio access technology spectrum sharing (MRSS) could become a built-in capability of 6G. Such an approach relies on the identification of sharing condition at the intra MNO network level, with standardised conditions supported by the MNO. This avoids major changes in its mobile network architecture

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[41] ITU-R agreed on a level of expected e.i.r.p. spectral density emitted by an IMT base station as a function of vertical angle above the horizon the solution for protecting satellite reception in the upper 6 GHz band, decided on in WRC-23, was an example of a new and innovative way to enable introduction of terrestrial mobile applications in this band.

and network equipment while providing economies of scale. MRSS is under standardisation for coexistence of 5G SA and 6G.

5.2.3 Inter service sharing

Recognising the principle of technology neutrality in spectrum management, requirements stemming from a harmonised framework could also result in the need for sharing between technologies. For example, sharing of WBB ECS bands between different local networks or sharing between MNOs and local or private networks could further enhance the efficient use of these bands, while allowing access to spectrum for a variety of users[42]. With 6G, further advances in spectrum utilisation and sharing can be expected. However, interservice or cross technology spectrum sharing might not be only triggered by mobile industry in response to business requirements.

Inter service spectrum sharing does require dedicated studies and intensive cross sector collaboration. Frequency bands already used by incumbent services could be targeted by services that need new additional spectrum opportunities. Sharing of those bands is not always possible due to the strategic nature of incumbent usage as well as technical issues. The nature of applications and services as well as the characteristics of the spectrum band in question should be taken into account in sharing considerations. These issues are addressed on a case-by-case basis, band by band, including if appropriate relevant synergies between these services with commercial perspectives (such as D2D and mobile services). In some cases, national reorganisation of spectrum use is needed such as, as an example from the past, the migration of fixed links to other frequency bands in order to introduce 5G mobile supplementary downlink (SDL) in L-band. This implies long-term spectrum planning by national administrations.

Spectrum management will face challenges to accommodate 6G due to extensive use of existing services and applications within the bands considered. European harmonisation policy could support 6G standardisation activities promoting interservice as well as cross technology sharing, as appropriate. This should be carefully assessed by RSPG when developing the 6G spectrum roadmap as this is not a business requirement, taking into account the principle of technology neutrality and spectrum needs.

In conclusion

- Sharing issues are addressed on a case-by-case basis, band by band
- Sharing solutions triggered by spectrum management requirements e.g. in 6G to accommodate interservice spectrum sharing could be also needed in addition to sharing concepts already triggered by mobile industry business incentives.

[42] RSPG21-022, RSPG Opinion on Spectrum Sharing – Pioneer initiatives and bands: https://radio-spectrum-policy-group.ec.europa.eu/document/download/0e3df317-dbc6-49ee-9d15-ef47ccd9db0d_en?filename=RSPG21-022final_RSPG_Opinion_Spectrum_Sharing.pdf

- Innovative sharing solutions and initiatives could be based also on improving the authorisation process and on defining and implementing advanced technical sharing conditions.
- In support of efficient use of spectrum and in line with the objectives of EU policy, inter-service spectrum sharing mechanisms should be further studied and standardised, not restricted to 6G only, to help accelerating this process. This should be also promoted in research, CEPT, ETSI, 3GPP and IEEE and possibly through an EU legal act.

5.3 Towards advanced sharing solutions involving 6G

5.3.1 Lessons learnt

RSPG explored and recommended a dynamic approach to share spectrum between different usages with the licensed shared access (LSA) approach[43]. Such approach has even been standardised. Also, White Spaces utilisation, citizens broadband radio service (CBRS) and more recently automated frequency coordination (AFC) in the United States (US), based on sensing and/or database principles are mentioned. CBRS in the 3.5 GHz band in the US, relating to the protection of incumbent governmental usages reveals a complexity to access to spectrum.

It is important to understand and assess all practical performances and shortcomings of various sharing concepts and approaches, and what is required for their generalisation in order to assess any opportunity to apply these solutions in frequencybands targeted for 6G in the future. Lesson learnt from sharing concepts and approaches will be part of the analysis when developing the 6G spectrum roadmap.

5.3.2 Use case requirements in relation to spectrum sharing

With the prospect of various advanced, bandwidth demanding and quality of service (QoS) critical use cases accommodated by 6G technology, it is also important to better understand their locality and geographical focus in order to assess on case-by-case basis the potential of smart/dynamic geographical sharing with other services and applications, taking into account both nationwide and local needs including to support various policies. This is especially relevant for frequency bands with propagation characteristics favouring the coverage of large areas.

Artificial Intelligence technologies may prove beneficial in this respect, by learning usage patterns to accommodate and manage context dependent sharing of spectrum based on situational, temporal circumstances, and actual demand, which in turn would optimise spectrum utilisation.

[43] RSPG13-538, RSPG Opinion on Licensed Shared Access: https://radio-spectrum-policy-group.ec.europa.eu/document/download/a0f71cd0-35e3-4f09-acf0-bf47bb3ebee7_en?filename=RSPG13-538_RSPG-Opinion-on-LSA%20.pdf

5.3.3 Supporting and driving innovation in sharing to support 6G, promoting European sovereignty

As highlighted by the previous Opinion[44], practical implementation of dynamic spectrum sharing remains dependent of various components such as: characteristics of the spectrum band under consideration, incumbent users and newcomers, compatibility of technologies, technical feasibility, security, confidentiality for certain use, willingness of various components of the industry to contribute to a sharing approach, sharing conditions/access and algorithms. Even for 6G, those issues remain valid. Therefore, such advanced approaches to sharing should be seen as preliminary guidance for possible evolutionary steps to be considered in the 6G era, rather than as a long-term vision. Nevertheless, in the context of 6G and to enhance spectrum sharing, RSPG considers that 6G should include native features/enablers to assist in sharing with other spectrum usages, since new spectrum for mobile networks are expected not to be on an exclusive basis. For example, the possibility for active antenna system to reduce the transmission in a fixed direction, through zero-forcing algorithm, would facilitate the coordination with other stations such as fixed service, radio astronomy service or fixed satellite service earth stations.

When developing the 6G spectrum roadmap, such evolutionary steps could be investigated, when appropriate, for specific frequency bands initially as long as emerging solutions have a potential for commoditisation / generalisation and without losing sight of the technology neutrality principle.

The importance of two different but inter related European work streams should also be mentioned, both supporting European sovereignty.

- Firstly, the support of European Research & Development (R&D) activities is required. It is key that publicly financed European R&D projects on 6G are incentivised to incorporate possible interservice spectrum management in their project scope (see for example Hexa-X project).
- Secondly, European radio spectrum policy (RSPG) and technical harmonisation, supported by CEPT[45] and standardisation work done by ETSI are of pivotal importance. It may however not be enough to only foster work by CEPT and ETSI to support the implementation of such harmonised spectrum sharing approaches. Their relevant implementation supported by European Policy and technical harmonisation should also be promoted, as appropriate, in the International standardisation, such as within the 3GPP specification process.

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[44] RSPG23-040 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks: https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[45] DECISION No 676/2002/EC on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002D0676&qid=1730232945967

6 Strategic Role of Non-Terrestrial Networks in 6G

RSPG noted the various components that may be part of non-terrestrial networks (NTN).

Satellites networks: Networks or segments of networks that use station(s) on objects at an altitude exceeding 50 km.

High Altitude Platform Station (HAPS): A station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth.

High Altitude International Mobile Telecommunications (IMT) base stations (HIBS): HAPS stations with IMT base stations (with possibility to operate from 18 km and others altitude of HAPS).

Those components do not typically provide the same service quality as terrestrial cellular networks. Nevertheless, they could provide enhanced coverage and resilience, or be used as fall-back or complementary networks in emergency and disaster relief situations, for example.

The role of NTN, HAPS/HIBS could be, for example, to serve the ubiquitous connectivity usage scenario and 'connecting the unconnected' overarching design principle. Further, as 6G is envisaged to provide connectivity on land, at sea, in the air and in space, NTN, HAPS/HIBS could be needed to complement terrestrial networks. To make this target a reality, 6G should be designed to interwork with NTN, HAPS/HIBS.

Those systems operate mainly according to an international technology neutral spectrum regulation. Relevant frameworks are already in place for HAPS, HIBS and various satellites networks.

Recent development in satellite domains have triggered investments and innovations towards D2D in MSS bands and D2D in mobile bands where WBB ECS networks are in operation. NTN D2D could be provided either with satellite D2D or HIBS.

As for ITU conditions to HAPS and HIBS, 6G in the satellite environment will soon benefit from future updates to the international regulatory framework in particular to protect mobile networks from D2D satellites emissions over neighbouring countries.

In addition, the European Commission has requested RSPG to form an opinion on the EU-level policy approach to the use of satellite Direct-to-Device connectivity and related Single Market issues. The opinion is requested to assess different policy approaches covering both MSS and ECS (mobile) bands. RSPG is requested to deliver the final opinion on this matter in June 2025.

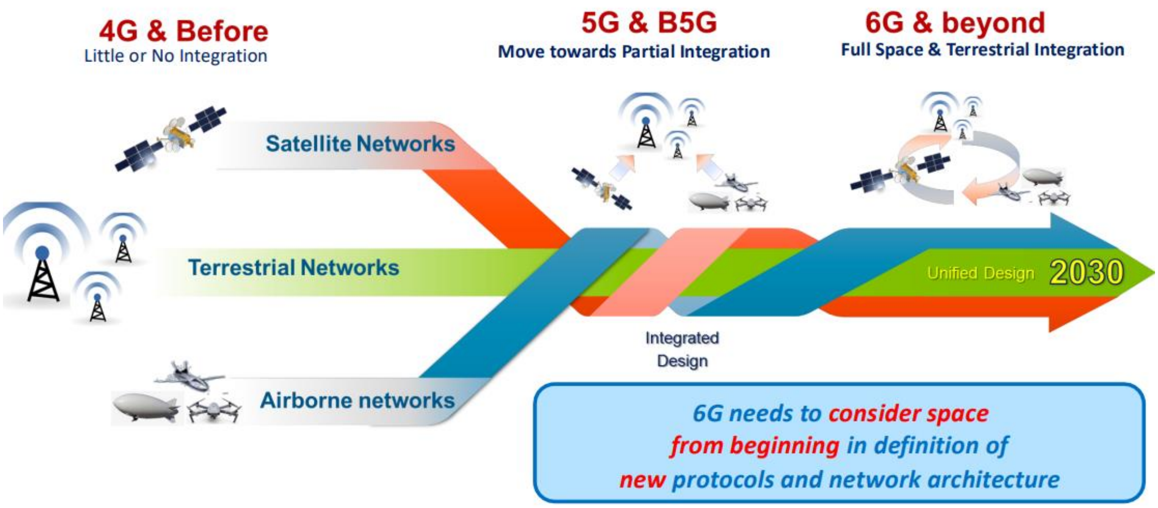

Figure 4: 6G: Towards a fully integrated ecosystem (source: GSOA)

The NTN satellite component of 6G will rely on a large variety of satellite solutions, operating not only in Low Earth Orbit (LEO) constellations, but also at Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO), as stand-alone platforms or in concert. Multi-orbit combinations, inter-satellite links, the integration of AI and quantum technology and other advanced features will equip next generation satellite (ground and space) systems to further contribute to the massive and secure distribution of data globally, and also respond to time-sensitive 6G applications like autonomous vehicles, industrial automation, and other immersive services, as identified for IMT-2030[46].

6G should build on joint evolution/interoperability of 5G NTN and terrestrial networks to leverage the most advantageous characteristics of satellite and terrestrial systems. 6G could support and combine terrestrial networks and NTN-components as depicted in Figure 4. 6G networks could support dynamic reconfiguration to adapt to traffic load/distribution and operational conditions. The satellite component can increase coverage, reliability and resilience. Table 1 compares possible D2D services based on MSS or terrestrial bands[47].

[46] Additional details can be found in the GSOA whitepaper on New Satellite Technologies for Transformative Connectivity, https://gsoasatellite.com/reports_and_studies/new-satellite-technologies-for-transformative-connectivity/

[47] The RSPG is preparing an opinion on the EU-level policy approach to the use of satellite Direct-to-Device connectivity and related Single Market issues.

Table 1: D2D in MSS and Terrestrial bands (source: GSOA[48])

D2D in MSS bands	**D2D in Terrestrial bands**
• Uses spectrum allocated to Mobile Satellite Service • Leverages 3GPP Release 17 NTN specifications • Requires no additional regulatory action if MSS authorised • Support L- and S-Band, and Ka- Ku in future release • Additional MSS spectrum allocations studies in WRC-27 agenda items 1.12 and 1.14 Challenges: • Needs mobile chipset vendors to include those 3GPP bands	• Uses terrestrial spectrum (IMT bands) • Requires partnerships with MNOs • Complements existing mobile coverage • Can use off-the-shelf mobile handsets • IMT bands <3GHz Challenges: • Interference management between MNO and satellite operator • Regulatory hurdles (ITU RR 4.4) • Coexistence being studied under WRC-27 agenda item 1.13

[48] The future of satellite connectivity: Various approaches to Direct-to-Device services: https://gsoasatellite.com/wp-content/uploads/GSOA-D2D-Paper-Aug-24.pdf

7 Role of authorisation regime

7.1 Technology neutrality

Technology neutrality remains key also for future access to ECS spectrum. In Europe this approach formed the regulatory basis for the implementation of intra MNO sharing and led to 5G being the fastest deployed new generation of mobile networks. Existing network structures could easily be upgraded to the new generation with no or little restriction on the existing coverage and uses. For the 6G vision a technology neutral approach which allows the MNOs to quickly satisfy the market demand within the public networks and the upgrade of uses in the markets for verticals are essential.

7.2 National authorisation

A harmonised approach for spectrum access is the basis for an attractive market environment. Authorisation within the current European framework is a national domain since the needs and required solutions are different and there is no "one size fits all" strategy for all EU Member States.

7.3 Single-market dimension

As mentioned in the RSPG Opinion on How to master Europe's digital infrastructure needs?[49], EU spectrum harmonisation is the key enabler of the Single Market enabling market entry and proliferation of different market strategies. It is also mentioned that when drafting future plans for the rollout of 6G in EU, expected to be launched around 2030, flexibility should be preserved. Due consideration has to be taken to maximise the benefit of the measures. Such measures include assessing and adjusting to national demands, drive competition and align to specificities of national markets such as the geographic and demographic landscape. All while keeping focus on making spectrum available in due time to meet future needs in the EU and to support the development of European competitiveness.

Harmonised spectrum also supports the Single Market by creating basis for mass market of network and terminal equipment.

National frequency and licence policy has a key impact on the price, quality and availability of communications services. It is important that decisions on the rights of use of frequencies and their detailed terms and conditions, such as licence processes and terms and conditions of network licences, continue to be made at the national level. Given the differences in the Member States' market situations, geographic locations and social structures, national authorities have the best competence and expertise regarding the needs, potential problems, and possible solutions in each market. Rather than introduce more stringent regulation on radio frequencies, the aim

[49] RSPG24-019: Opinion on How to master Europe's digital infrastructure needs?, https://radio-spectrum-policy-group.ec.europa.eu/document/download/15789389-828c-4a55-a397-f2338fa2125b_en?filename=RSPG24-019final-RSPG_Opinion_on_how_to_master_Europes_digital_infrastructure_needs.pdf

in the EU should be to focus on more efficient frequency use within the framework of the existing regulatory instruments and structures.

7.4 Licence-exempt use

Depending on the used frequency range, the use case and other requirements license-exempt use can be the first choice and/or a complementary solution to the licensed use of spectrum.

According to R&D efforts, overall, unlicensed use of spectrum presents a lower hurdle for operations by end users and small or private networks. The higher the frequency range, the more bandwidth is usually available and can reach up to multiple contiguous GHz at sub-THz frequencies. However, due to the physical constraints in radio frequency propagation, sub-THz will target highly localised use cases. As a result, this minimises the need to license spectrum nationwide in the sub-THz range. A license-exempt regulatory framework may be more appropriate in the sub-THz range.

Licence-exempt technologies continue to evolve and will play multiple important 6G roles. Offloading 6G mobile traffic to licence-exempt networks (e.g., Wi-Fi) is one important use case. Licence-exempt spectrum supports a variety of use cases, like wireless broadband and IoT applications.

The report “The future of European competitiveness” (a.k.a. the “Draghi report”) suggestes to assess the needs for licence-exempt spectrum. This could include promoting the convergence of different networks using different frequency bands, with a particular focus on integrating solutions to deliver seamless connectivity across mobile and fixed networks.

8 Input from Research and Development

The inputs from R&D come mainly from EU 6G Flagship project Hexa-X II and the Finnish 6G Flagship.

8.1 Input on spectrum challenges anticipated for 6G use cases

Market structures are evolving, and local 5G networks have become a reality.

Competition for the scarce spectrum resource remains intensive among various wireless services, and there are no “clean” frequency bands available for 6G. Spectrum sharing is a necessity in the 6G era even more than in the 5G era.

Traditional spectrum requirement estimations have primarily provided high-level totals of spectrum needed for mobile communication systems, aiming justify new spectrum allocations based on assumed services, technology and deployments. However, these estimates fail to accurately reflect the anticipated spectrum needs of actual stakeholders in the future.

With 5G, the complexity of spectrum management has grown, encompassing a diverse range of frequency bands and access models. Administrative allocation, market-based mechanisms, and the unlicensed commons all coexist. The same will continue in 6G. Different technologies, spectrum access models and use cases will remain better suited to specific frequency bands.

8.2 Input on 6G goals for spectrum use[50]

The goals for 6G spectrum use are the following:

- Provide additional capacity: Enhance current mobile communication by providing more capacity while re-using existing base station grid, reducing the cost of identifying, acquiring, and deploying additional base station sites by operators.
- Support high data rate services: New services, such as extended reality (XR) and holographic presence, require larger bandwidths, which are typically easier to find in mid and high frequency ranges.
- Support mobility: Most applications of mobile communications need mobility. Mobility requirements may be combined with requirements for high data rates. Consequently, spectrum needs to support high data rates and continuous coverage required for mobility.
- Support wide area coverage: Making 6G inclusive implies that 6G is available everywhere. For wide area coverage, lower frequency ranges are more suitable. In addition, non-terrestrial networks might be a supplement to wide area coverage provided by terrestrial networks in sparsely populated and underpopulated areas.

[50] Hexa-X-II, D1.1, Environmental, social, and economic drivers and goals for 6G: https://hexa-x-ii.eu/wp-content/uploads/2023/07/Hexa-X-II_D1.1_final-website.pdf

- Provide indoor coverage: Increasing volumes of indoor mobile data can be supported by 1) outdoor to indoor coverage from outdoor base stations in low and mid frequency ranges and/or 2) Indoor to indoor coverage with indoor radio solutions in higher frequency ranges, noting the propagation limitations of higher frequencies.
- Service continuity: Seamless continuation of connectivity travelling across e.g., outdoor-indoor, urban-rural, private-public situations.
- Enable positioning and sensing: In general, higher frequency ranges imply more accurate positioning and sensing.

The frequency ranges currently under discussion at the international level for 6G are depicted in Figure 5.

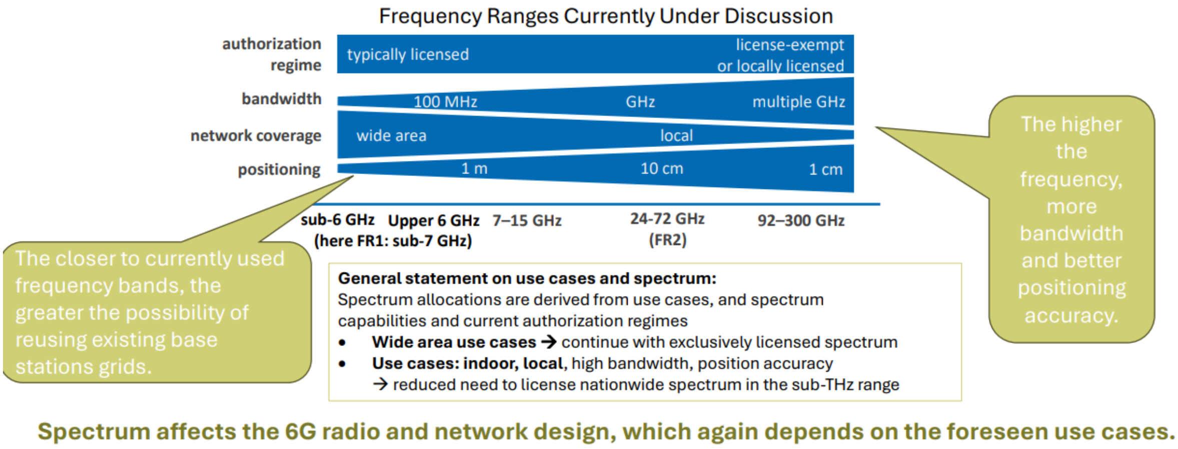

Figure 5: Frequency Ranges Currently Under Discussion at the international level [51]

8.3 *Input on use cases for 6G*

Local 6G networks will be an important deployment model, relying on access to spectrum. Local 6G networks can be public or private, and deployed by different stakeholders using different spectrum access options, whose availability varies between countries.

Networks for vertical applications may or may not be local. There is not enough spectrum for everybody to build separate vertical specific systems for all verticals, which calls for sharing in multiple fronts including virtual networks via network slicing.

Serving the unconnected is still a challenge. Making spectrum available where and when it is not used by existing holders of spectrum usage rights is still not a reality widely.

[51] An earlier version is presented in Hexa-X-II, D1.1, Environmental, social, and economic drivers and goals for 6G: https://hexa-x-ii.eu/wp-content/uploads/2023/07/Hexa-X-II_D1.1_final-website.pdf

8.4 Input on Spectrum implications of use cases

Deployments of use cases within specific frequency ranges depend on technical and non-technical aspects such as license availability. To achieve reliable nationwide-area coverage, which is specifically important for representative network-assisted mobility and ubiquitous network use cases, low-band spectrum is essential, preferably below 1 GHz. This can be supplemented by non-terrestrial network (NTN) systems in sparsely and underpopulated areas.

Since achievable data rate and capacity in low frequency band deployments is limited, higher frequency bands (sub-7 GHz) are claimed to be needed by stakeholders, including the upper 6 GHz band, as well as new bands in the 7-15 GHz range, which would achieve the needed capacity for both existing and new use cases, for instance in urban and sub-urban environments. The lower the frequency within 7-15 GHz, the better (e.g., 7/8 GHz). For use cases in confined areas like cooperating mobile robots and human-centric services, small-cell deployments could be used. Additionally, spectrum within the 24-72 GHz range or local sub-THz deployments, which is still being researched, can be used to meet even higher data rate and capacity requirements, however with limited coverage.

8.5 Input on 6G spectrum ecosystem stakeholders, roles and motivations

The 6G ecosystem may include the following stakeholders.

- MNOs: 6G is expected to be deployed in the same frequency bands as earlier generations complemented by additional spectrum. Nationwide area coverage can be achieved using preferable sub-GHz (below 1 GHz) spectrum while spectrum in the 1-6 GHz range as well as additional bands (e.g., Upper 6 GHz and 7/8 GHz (or parts thereof)) can be used for coverage and capacity and can re-use existing base station grids.
- Stakeholders deploying private networks and specific purpose networks: Public-network-integrated non-public-networks (PNI-NPN) might share radio access network (RAN) and spectrum with the public network. Stand-alone non-public networks (S-NPN) are often deployed in dedicated spectrum (e.g. 3.8-4.2 GHz).
- Network vendors, software vendors and/or system integrators: Expected to meet different network deployments (e.g., "global” or local) and the variety of operator models that can emerge.
- End user equipment manufacturers: Devices are likely to include a multitude of wireless technologies. Regional and global harmonisation will benefit the 6G ecosystem as scale will be bigger, bringing costs down.
- Incumbent users: There is a variety of primary incumbent services, in the potential new frequency bands envisaged for 6G and will need to be considered accordingly.
- Regulators: Enablers of 6G market emergence by making spectrum available for 6G and assigning spectrum access rights.

- Building owners: Drivers for indoor coverage demands and potential investors for indoor network solutions, which in turn are linked to deployed frequency ranges and spectrum access mechanisms.
- Neutral hosts: Build and operate (indoor) radio networks and rent capacity to network operators. Deployment choices affect spectrum use.

8.6 Input on spectrum access options for stakeholders to establish local 5G/6G networks

For stakeholders that wish to use spectrum to establish local networks, various solutions can be envisaged:

- Local networks can be deployed by an MNO in the MNO's frequency bands: The stakeholders are clients of the MNOs and can ask the provision of services in local areas from the MNOs according to their needs.
- Local spectrum licenses from the national regulatory authority (NRA) to different stakeholders (incl. MNOs): Depending on the availability of spectrum in a local environment, the NRA can issue spectrum licenses directly to stakeholders that are interested to establish local networks or MNOs that can undertake the task of establishing local networks according to the needs of the stakeholders. Rights of use can be assigned by the NRA in frequency bands that are cleared from incumbent use as well as in frequency bands that are in use by MNOs or by other incumbent spectrum users where additional licenses can be awarded by the NRA locally.
- Local spectrum access rights acquired from incumbent spectrum user(s): Stakeholders can obtain or gain access to spectrum in existing (or potentially new) bands, where MNOs or other incumbent users hold spectrum access rights.
- Local spectrum access rights granted by a third party: Stakeholders can use frequency bands with or without existing incumbent spectrum users using a spectrum broker functionality[52].
- Unlicensed access: Stakeholders can use existing unlicensed bands (e.g., 2.4 GHz, 5 GHz, 6 GHz, 60 GHz) or possible new unlicensed bands in the 6G era to build their networks.

For the realisation of the scenarios above, the following cases can be identified:

- the stakeholder that operates as an MNO client can benefit from the MNOs' know how without the need to have expertise for building, tuning and operating a 5G/6G network as they can rely on the services offered by the MNO. In areas where 5G SA has been deployed, the stakeholder can negotiate certain QoS values with the MNO according to their operational needs
- the stakeholder that acquires access to local spectrum and does not have personnel that is trained to build and operate a 5G/6G network must turn to a

[52] Spectrum brokers do not have their own spectrum resources, but pools of unused spectrum from operators or incumbent users

third party with the appropriate expertise (could be a manufacturer, systems integrator or MNO).

- the stakeholder that acquires access to local spectrum and has personnel that is trained to build and operate a 5G/6G network can do so without the aid of a third party

A lot of fragmentation exists between MSs' approaches to making different spectrum access options available.

8.7 Input on launch readiness for 6G in 2030 for mass market for services and equipment

Coverage is crucial. Indoor coverage as well as remote and rural area coverage present challenges and should be a priority in the 6G era, as highlighted in ITU-R's IMT-2030 work. They benefit from different technology and regulatory solutions.

There is a lot of uncertainty in predicting capacity needs for 6G use cases and usage scenarios in the 2030s, given that future services and technology developments are still being studied.

Technology developments which enhance efficiency can reduce the actual capacity demands. In particular the role of edge computing and increasing processing power in end devices will reduce the amount of data that needs to be transferred. This needs to be taken into account in spectrum needs.

Different launch times in different countries are not really an issue. Announcements are often marketing. Ranking forerunner countries by the launch date, which are within weeks or months, is irrelevant. Ranking countries according to most consumed total mobile data is not relevant either (and not sustainable). What matters is making the same frequency bands available in different European countries for achieving economies of scale (e.g., in local licensing). Researchers would also need specific frequency bands to focus their research on.

Increasing role of spectrum sharing calls for understanding what spectrum sharing means and its implications on technology, regulation and markets, which is still a challenge.

8.8 Input on spectrum sharing

Spectrum sharing refers to the situation, where two or more radio systems use the same frequency band[53]. Yet, there are no commonly agreed approaches in Europe despite decades of active R&D.

Vertical spectrum sharing occurs when a radio system with a lower level of spectrum usage rights shares a spectrum band with radio system(s) having higher spectrum usage rights.

Horizontal spectrum sharing occurs between radio systems at the same level of spectrum usage rights.

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[53] ITU-R M.2330-0 report. Cognitive radio systems in theland mobile service: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2330-2014-PDF-E.pdf

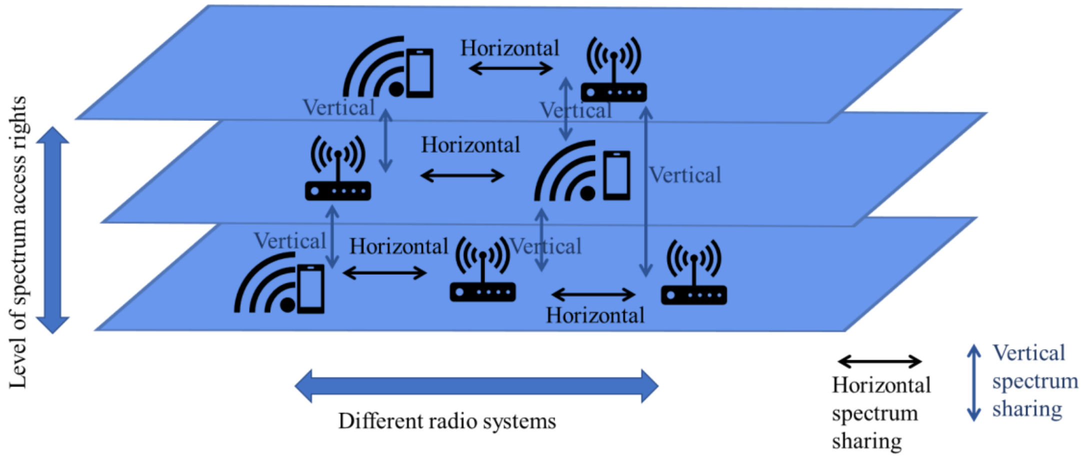

Figure 6: Vertical and horizontal spectrum sharing

Vertical and horizontal spectrum sharing are not mutually exclusive and both are present in real-life sharing situations (see Figure 6)[54].

Spectrum sharing including both vertical sharing between entrant 6G and other incumbents as well as horizontal sharing between several local network deployments will play a key role in 6G development. Spectrum sharing, considering the specifics of wireless technologies and system deployments in the bands can make local sharing particularly feasible with advanced capabilities to manage interference.

Technological innovations for spectrum sharing will rapidly improve with the introduction of AI driven interference management techniques and increasing processing capabilities. The impact of AI on spectrum management in the 2030s is not taken into account in the existing regulatory framework. The flexibility provided by AI to balance the needs and supply of spectrum resources across multiple systems at the local level cannot be exploited under the current static regulatory framework.

8.9 Input on the role of license exempt spectrum

Wireless technologies operating in the license exempt spectrum have been a playground for innovation and experiments for decades. The role of technologies operating under a license-exempt spectrum access regime is significant in delivering indoor broadband connectivity.

Understanding and accepting the roles of different wireless technologies without biases, especially in the context of indoor usage, is important. End users use a variety of wireless technologies in a variety of frequency bands under different spectrum access models without noticing it or the need to notice it. Unnecessary confrontations focusing on WiFi/3GPP/satellite interests are not helpful in promoting digitalisation of societies but instead have created barriers.

Principles of license-exempt spectrum use are open to different technologies, including 5G/6G.

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[54] Marja Matinmikko-Blue, Seppo Yrjölä, and Petri Ahokangas: Spectrum Management for Local Mobile Communication Networks, IEEE Communications Magazine • July 2023: https://ieeexplore.ieee.org/document/10049305

8.10 Input on the role of Non-Terrestrial Networks (NTN)

The interworking of terrestrial IMT-2030 (6G) network with non-terrestrial networks (NTN), including satellite communications, high altitude platform stations as 6G base stations (HIBS), is expected to enhance achieving required connectivity objective[55].

IMT-2030 (6G) is expected to support service continuity and provide flexibility to users via close interworking with non-terrestrial network implementations, existing IMT systems and other non-IMT access systems[49].

Deployment scenarios, where end user or base station equipment is mounted on objects moving above ground level, results in different and challenging interference scenarios, depending on the wireless systems using the specific band. The sharing studies and techniques required to manage the resulting interference are studied in the research community.

8.11 Input on the role of network convergence

Recognising the future strain on spectrum resources from various systems, the high proportion of data traffic consumed indoors and taking into consideration that indoor building penetration losses increase with the use of higher frequency, significantly diminishing spectral efficiency, it is essential for 6G to explore further mechanisms that reduce the outdoor macro network's reliance on spectrum for indoor traffic.

The convergence of non-3GPP and 3GPP networks presents a compelling opportunity to weight up the strengths of different technologies and, by combining the best of their characteristics, will potentially create a unified network that delivers a superior user experience.

8.12 Input on the sustainability

Sustainable development refers to “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland report 1987[56]).

It is important to understand different sustainability perspectives, which are interrelated, and state the limitations when focusing on a specific perspective:

- Environmental, social and economic sustainability perspectives
- Sustainable ICT and ICT for sustainability
- Positive and negative impacts / handprint and footprint / benefits and costs
- Life cycle approach; end to end system approach

Overall goal is to maximise positive sustainability impacts and minimise negative impacts.

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[55] Rec. ITU-R M.2160, Framework and overall objectives of the future development of IMT for 2030 and beyond: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

[56]Report of the World Commission on Environment and Development: note / by the Secretary-General https://digitallibrary.un.org/record/139811?v=pdf

Today's sustainability discussions are focusing on energy efficiency, which is an environmental sustainability indicator of sustainable ICT and a ratio of output and input. It is not an absolute measure. Improved energy efficiency does not directly lead to reduced energy consumption. Reduced energy consumption is an environmental sustainability target for sustainable ICT.

Sustainability is a cross-cutting priority that needs to enter different thematic topics, including spectrum management, considering environmental, social and economic sustainability perspectives.

Environmental sustainability examples:

- The capabilities of devices increase, impacting spectrum use. Processing of data locally in end user device or network edge changes how data flows occur in the future. With sustainability thinking, the goal is to minimise transmitted data and only transfer what is needed. Total amount of consumed data is not sustainable.
- High energy efficiency per bit can be achieved only when data rates are extremely high requiring wide bandwidths. Only use cases that will need it and can utilise it should be promoted.
- Selection of communication solutions which cause the lowest environmental impact once this info is available.

Social sustainability: Digital inclusion – affordable access to digital services.

Economic sustainability: reasonable auction prices that allow investment in the networks.

Academic question for regulators: How does long-term exclusive spectrum licenses without obligations to share unused spectrum fit in the new sustainable spectrum management framework?

8.13 Implications on Security and resilience

Spectrum policy is a tool for governments to safeguard national security, protect consumer data and ensure resilience against cyberattacks by posing restrictions and requirements on stakeholders to address security, when they award spectrum access rights to deploy the systems. These include banning technology originating from some countries, security audits, certifications, standardised approaches, mandatory security updates, etc. [57]

Local 5G/6G networks are a new deployment model that introduces security challenges, such as trusting that all emerging local operators are legitimate players. Spectrum policy through local licensing conditions can address this.

Security technologies should not considerably affect the transmission spectral efficiency. However, serious denial of service attacks can momentarily impact network performance and decrease spectral efficiency.

[57] M. Ylianttila, R. Kantola, A. Gurtov, L. Mucchi & I Oppermann (Eds.). (2020). 6G White Paper: Research Challenges For Trust, Security And Privacy. (6G Research Visions, No. 9). University of Oulu. http://urn.fi/urn:isbn:9789526226804

Some European countries plan to phase out the Terrestrial Trunked Radio (TETRA) system for user organizations such as the police, rescue services, government, border control, and military. Instead, they will either rely on a combined approach using Public Protection and Disaster Relief (PPDR) and commercial networks or exclusively on commercial 4G and 5G networks. Consequently, it is crucial to implement measures that extend beyond the capabilities of current mobile networks to ensure the security and reliability of communications for critical services. In this development, security build-in and the openness of security design principles are crucial as well as taking into account already known vulnerabilities. This transition calls for new design paradigms aimed at resilient-by-design frameworks for 6G and beyond. Such planning must address multiple time scales, focusing on both immediate needs and long-term strategies.

Resilience in the 6G real-time economy is critical cross-cutting theme for maintaining uninterrupted operations, mitigating risks, and adapting to disruptions and requires building measures using redundancy, fault-tolerance and impact mitigation. Many of the topics discussed earlier (NTN, remote area connectivity, etc.) are relevant for resilience. Spectrum policy is a tool to pose requirements in licensing conditions.

9 Input from equipment manufacturers, operators and vertical markets

9.1 Key points from equipment manufacturers

The following key points were received from the Global mobile Suppliers Association (GSA):

- Research and deployments: 6G research is globally accelerating. IMT-2030/6G specifications to be completed by 2030 (ITU-R Working Party 5D in cooperation with external organisations such as 3GPP). Commercialisation target of around year 2030 is expected for initial 6G deployments
- Spectrum needs: 6G will need the combination of various frequency ranges to meet coverage and enhanced capacity requirements as well serve new emerging use cases. GSA estimates an additional 500-750 MHz of wide-area spectrum per network is needed to implement the anticipated 6G use cases. A smaller amount of spectrum, but at least 200 MHz of the needed additional wide-area spectrum per network, would be needed for the initial 6G deployments. Wide-area spectrum will continue to be the focus in the 6G era, enabling the 6G use cases indoors, outdoors and on-the-move by cost-effective deployments re-using the existing grid. RSPG should facilitate full power macro base station deployments in the upper 6 GHz band (6425-7125 MHz) for 5GA and future 6G, as well as to include spectrum within 7125-8400 MHz (further than 7125-7250 MHz) as part of the 6G roadmap. GSA also suggests including UHF to provide ubiquitous coverage and digital equality.
- Harmonisation and licensing: Licensed spectrum is required for ensuring reliability, security, and quality of service in 6G, including critical communications such as autonomous systems, AI, and digital twins. 6G will require higher capacity, ultra-low latency, and seamless global interoperability, which can only be achieved with adequate access to harmonized licensed spectrum.
- Timing: GSA would urge the RSPG to promote similar timeframes for spectrum availability across EU member states to avoid spectrum fragmentation and ensure a single market for 6G technologies and would like to emphasize that such harmonization is essential for economies of scale, cross-border interoperability, and the competitiveness of European industries.

Standardisation, harmonisation and regulation: As research and standardisation of IMT-2030/6G is still ongoing, sharing and coexistence with other Radio Services could be reflected in that process. Global/regional harmonisation (spectrum, standards, timing, etc.) remains critical. New bands for 6G will be needed and would be beneficial.

9.2 Key points from operators

The following key points vere received from MNOs:

- Mobile bradband demand is recognised in policy but so far, no clear commitment for making spectrum available. Europe is aiming for best-in-class mobile networks, appropriate mid band spectrum is key to achieve this goal. Europe has not clearly positioned to use the upper 6 GHz for WBB ECS. Europe has positioned against further IMT spectrum at WRC-27. This risks a timely availability of appropriate resources for 5G and risks 6G introduction.

- Operators indicate that the spectrum need in upper 6 GHz band would be 200 MHz for each operator with conditions that allow deployment with standard macro base station power levels. Mid band spectrum providing wider channels of at least 200 MHz per operator, e.g. in 6 GHz, is key to provide full blown 5G SA as a basis to implement 6G, and to achieve national and international digitisation goals.
- 6G will come more as an evolution than a revolution. The generation-based terminology fosters misconceptions and may be less relevant in the future for users.
- Future use cases should be driven by value and sustainability. There is a strong value on empowering other sectors to meet their own environmental, societal and economic targets. The networks should support traffic growth and coverage at minumum cost, under energy and environmental contraints.
- Work will thus begin, both in 3GPP and in broader planning, on the use of wider channels for 6G. 200 MHz and possibly up to 400 MHz channels are anticipated. The development path into 400 MHz channels may come in the form of using 2x200 MHz aggregated channels or one 400 MHz channel, but initially the focus will be on 200 MHz in Europe and elsewhere for 6G launch deployments.
- As the only feasible spectrum opportunity to launch 6G in Europe at the end of this decade it is crucial for the EU to make available full-power use of the upper 6 GHz band. In the longer term, some of the adjoining spectrum in 7-8 GHz (under study for WRC-27) could be considered for evolved 6G requirements.
- While the upper 6 GHz mid-band spectrum will be key to cost-effectively address network capacity and the deployment of 6G service capabilities in urban and high demand areas, spectrum in low band ranges will also play a role in 6G. The band (470-698 MHz) will be important for delivering 6G to wider and more sparsely populated areas supporting digital equality.
- Spectrum in mmWave bands cannot substitute mid-bands for cost-efficient delivery of wide-area coverage and capacity across cities and other areas, but can serve very high capacity needs in localised areas (e.g. smart factories, very high speed Fixed Wireless Access, stadiums).

9.3 Key points from vertical markets

Operators generate their revenue from the sale of telecommunications services, whereas verticals derive their revenue from the sale of non-telecommunications products and services – such as energy, water, transportation, industrial products etc. Non-commercial vertical sectors, such as Public Safety, use telecommunications to deliver essential services to the public.

These ‘vertical’ markets have different motivations for their telecommunications investments compared to mobile operators. Vertical players can therefore bring much needed capital investment to the 6G market to supplement investment by MNOs. This will help to plug the investment gap which has been a significant challenge for the rollout of 5G.

9.4 Key points from other organisations

Various key points from other organisations (eg. WiFi and satellite sectors) are reflected throughout the rest of this report.

10 Spectrum for launching 6G in EU and paving its initial development

The global timeline for 6G development is set by ITU-R (Figure 7)[58]. The target for technology development and spectrum implementation is set to enable network launch in 2030. This timeline should also be supported by EU spectrum policy to enable the first launches of 6G networks and services in 2030 in the EU, based on national needs.

To establish a unified market for network and terminal equipment, the EU needs to indicate the spectrum band(s) planned for the launch of 6G, drawing lessons from the 5G primary and pioneer bands strategy. Therefore, the RSPG intends to develop a 6G spectrum roadmap during its next working period (2026-2027) in order to identify which frequency band(s) should be made available for the launch of 6G, while also to supporting the growth of various vertical markets.

RSPG identifies the following possible frequency bands as suitable candidates for 6G to be further investigated when developing the 6G spectrum roadmap, including relevant bands suitable for the launch of 6G and supporting the growth of various vertical markets:

- Frequency bands already harmonised for ECS (WBB) under EU Spectrum Decisions
  - Low bands: 700 MHz, 800 MHz, 900 MHz
  - Mid bands: 1500 MHz[59] [60], 1800 MHz, paired terrestrial 2 GHz, 2.6 GHz, 3.6 GHz
  - High bands: 26 GHz, 42 GHz
- Frequency band 3.8-4.2 GHz for low/medium power local area networks (under harmonisation)
- 6425-7125 MHz is already identified for IMT at international level and also used for the implementation of wireless access systems (WAS), including radio local area networks (RLANs). This band is subject to RSPG investigation on its long-term use[61].

RSPG noted that the following frequency bands on the WRCs agenda (WRC-27 or WRC-31) are subject to many uncertainties.

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[58] Rec. ITU-R M.2160, Framework and overall objectives of the future development of IMT for 2030 and beyond: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

[59] DECISION (EU) 2015/750 on the harmonisation of the 1 452-1 492 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Union: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015D0750

[60] DECISION (EU) 2018/661 amending Implementing Decision (EU) 2015/750 on the harmonisation of the 1 452-1 492 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Union as regards its extension in the harmonised 1 427-1 452 MHz and 1 492-1 517 MHz frequency bands: https://eur-lex.europa.eu/eli/dec_impl/2018/661/oj/eng

[61] RSPG Opinion on Long-term vision for the upper 6 GHz band, expected in June 2025 https://radio-spectrum-policy-group.ec.europa.eu/document/download/d4e46670-313b-4bac-8d8d-760d92f4649b_en?filename=RSPG24-008final-RSPG_WP24_and_beyond_0.pdf

- Frequency bands to be studied in Region 1 at WRC-27: 4400-4800 MHz, 7125-7250 MHz and 7750-8400 MHz (or parts thereof), 14.8-15.35 GHz. However, due to European strategic usages, CEPT opposed at WRC-23 to study frequency bands listed in WRC-27 AI 1.7 except 7125-7250 MHz. This position and European strategic usages that remain valid will impact any future positions to be developed for WRC-27.
- High bands, e.g. sub-THz bands, are subject to long term studies at international level (WRC-31)
- Low bands 470-698 MHz are under study for WRC-31. However, the current EU framework in UHF band[62] remains applicable.

In addition to the RSPG activities on WRC-27 including number of agenda items on satellites, RSPG engaged an analysis on satellite usages including D2D. Future work of RSPG on Satellite and 6G to be addressed in 6G spectrum roadmap will benefit from this analysis in response to request for Opinion from European Commission.

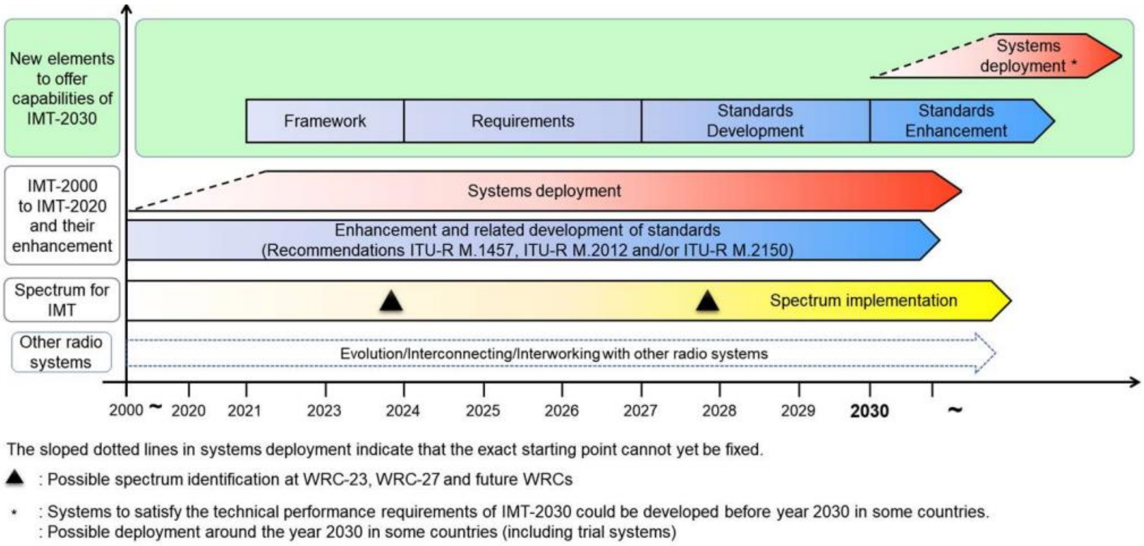

Figure 7: Anticipated perspective of the timelines for IMT-2030

10.1 Densification of public mobile networks

At this stage, no additional harmonised frequency bands are foreseen to become available for use before 2030. To cope with the growth of 5G data traffic, some mobile operators mainly in the most densely populated European countries will need to densify their 5G network across various harmonised bands. It is essential to assess the impact of this spectrum usage densification during the decade until 2030, taking into account the growth of 5G market until 2030 but also its implication for economic and environmental sustainability.

Network densification requires additional base station sites and passive infrastructure, which may impose difficulties or delays, e.g. related to building permission process. More attention should also be paid to climate and environmental effects. Introducing

[62] Decision (EU) 2017/899 on the use of the 470-790 MHz frequency band in the Union: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017D0899

new frequency bands to existing base stations has a smaller environmental impact than densifying networks by building additional base station locations.

10.2 Spectrum for 6G for launching phase

There will probably be a need for 6G to offer coverage and capacity in mid-bands noting that 6G requires larger bandwidths than 5G. This need is based on the requirements of 6G in general and 6G use cases (see ITU-R Recommendation M.2160). Thus, there is a need to assess spectrum requirements for an introduction of 6G mass market in EU due to capacity and coverage needs, as well as equipment eco-systems, etc.

10.2.1 How to respond to 6G spectrum needs

The switch-off of 2G or 3G in frequency bands such as 900 MHz and 1800 MHz could create opportunities for 6G use cases that require limited bandwidth, such as massive IoT communications.

Mid band spectrum responds to capacity and coverage needs for 6G immersive communications usage scenarios. Immersive communication is an enhancement of eMBB supporting the ongoing development of 5G mobile operator’s business model. Additionally, mid band spectrum helps reducing CapEx by enabling the reuse of existing base stations sites.

Compared to mid band spectrum, the millimeter-wave bands can address very high-capacity use cases in very dense local areas. Due to the propagation characteristics, wide area coverage using millimeter-wave bands is not economically feasible. Achieving seamless connectivity over a large area with millimeter-wave bands would require a significant number of base stations, especially in urban or suburban regions. RSPG has recommended that millimeter-wave bands could respond to specific needs of vertical industries (such as providing reliable indoor coverage).

It is essential to recognise that the spectrum refarming process must consider the specific needs of end users, particularly in the M2M/IoT sectors. In these areas, replacing devices may present more significant challenges, especially for applications such as metering, where the continuous and reliable operation of existing devices is crucial. This could lead to delays in the availability of spectrum for refarming.

10.2.2 A need for coordinated timing and additional band(s)

Coordinated timing for a launch of 6G services does not appear practical at EU level in the current harmonised bands due to technology neutrality and operators' migration plans for switching to enhanched technologies. Timing of 6G launch will depend on mobile operator’s strategy, availability of spectrum resources and expiration dates of existing authorisations. Therefore, additional spectrum band(s) in EU could facilitate coordinated timing for 6G launch. This issue will be carefully addressed by RSPG when developing its 6G spectrum roadmap and considering the 2030 target date.

10.2.3 Creating a 6G eco-system supported by policy initiatives

To create common equipment ecosystems in EU, RSPG recognises the need to give a positive signal to equipment manufacturers to focus on certain frequency bands for 6G. In its future 6G Spectrum Roadmap RSPG intends to recommend to the European Commission the frequency bands to enable a launch of 6G technology in 2030.

RSPG recognises that in the past new bands had been identified for each new mobile generation[63]. Whether this should continue in the future needs further investigation.

The approach, aimed at supporting the rapid introduction of a new mobile generation in Europe has proven to be a strategic policy decision for a number of reasons, e.g.:

- RSPG notes the complexity for MNOs to repurspose spectrum for existing networks to launch a new generation, reducing the capacity-of their existing networks, which at the beginning has limited number of customers and compatible terminals.
- It incentivises and provides clear guidance to the mobile industry (both for network infrastructure and terminal manufacturers) to implement the appropriate frequency bands.
- It reduces the technical complexity of equipment variants, thereby, improve the business opportunities in a competitive market.
- It minimises negative impact on existing services, customer satisfaction and operators.
- It allows the gradual migration of terminals, enables early adopters to benefit from new technology.
- It provides sufficient spectrum bandwidth required by a new generation of mobile networks.

The adoption of primary or pioneer bands has demonstrated some potential and interests from mobile operators, helping to address some of the challenges highlighted above. This approach also meets capacity and services requirements supported by new technologies including to trigger rapid development of terminals and investments in common targeted bands in Europe. The European spectrum policy and legislation has supported such an approach through several decisions related to 2G-5G (such as EU

[63] RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G) https://radio-spectrum-policy-group.ec.europa.eu/document/download/7664730c-c5e6-45d1-8fb6-3244c6034a1b_en?filename=RSPG16-032-Opinion_5G.pdf

Directives[64] (2G), Council and Parliament Decision[65] (3G), RSPP[66] (4G), EECC[67] (5G)).

In addition to providing market visibility and enabling economy of scale, a primary 6G band could facilitate larger blocks sizes compared to those available in current harmonised bands. This would be particularly beneficial for targeted new 6G services that require larger bandwidth and there are coverage and capacity requirements. Furthermore, on the basis of harmonised spectrum being made available, new usages not initially targeted when developing the technology roadmap could emerge triggered either by new technology opportunities or by evolving MNOs' strategies .

[64] Council Directive 87/372/EEC on the frequency bands to be reserved for the coordinated introduction of public pan-European cellular digital land-based mobile communications in the Community: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01987L0372-20091109&qid=1730300721405

[65] Decision No 128/1999/EC on the coordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999D0128

[66] Decision No 243/2012/EU on establishing a multiannual radio spectrum policy programme: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012D0243

[67] Directive (EU) 2018/1972 establishing the European Electronic Communications Code (Recast): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972

ANNEX I

The following respondents provided comments during the public consultation:

01	University of Oulu	19	Vodafone
02	AIRBUS	20	CRTV
03	Aerospacelab	21	Multi-company (Amazon Inc., Apple Inc., Broadcom Inc., Cisco Systems Inc., Hewlett Packard Enterprise, Meta Platforms Ireland Limited)
04	ecta	22	UWB Alliance
05	Ericsson	23	FNS6G
06	ARD	24	Telia
07	Elisa Finland	25	Leaf Space
08	Thales	26	CSSMA
09	GSA	27	Deutsche Telekom
10	GSOA	28	GIFAS
11	Wi Fi Alliance	29	BTG
12	APWPT	30	Fastweb *(CONFIDENTIAL)*
13	GSMA and Connect Europe	31	Nokia
14	EUTC	32	Intel
15	Cisco	33	HUAWEI
16	Mobile Network Operators (BT Group, Deutsche Telekom, KPN, Odido, Orange, SFR, TIM, Telefónica, Telia Company and Vodafone)	34	DSA
17	EOLO	35	Qualcomm
18	ASTRON	36	SCF Associates

ANNEX II

National coverage including main roads, rail tracks are provided with various bands using various mobile network technologies, including 5G. These national coverage requirements are parts of national authorisations and could differ from country to country due to national context, needs and policies. Some data from Member states illustrate the rapid take off of 5G in 3.6 GHz.

Finland

Mobile communication networks' basic coverage is available to > 99% of the population (94 % of land area covered by 4G) and the entire road and rail network in accordance with the network licenses. However, basic coverage does not guarantee any specific data rate for the user.

Nationwide 4G/5G network licences in the frequency bands from 700 MHz up to 2100 MHz include coverage requirements, which are for population, not for geographical coverage. The requirement is [typically] that the network shall cover 99 % of the population. In addition, [in most of the network licences] there is a requirement to cover also the main roads and railroads.

There are no coverage requirements in the 3.6 GHz and 26 GHz network licences. Fast mobile broadband (> 100 Mbit/s) is, however, available already for 91% of households in the 3.6 GHz band with 5G.[68]

France

ANFR observatory provides on a monthly basis relevant information of the 5G roll out. Any base station Installations (except SAWAP) require an agreement from ANFR. SAWAP with eirp above 1 W also need to be declared.

See last published ANFR observatory[69] More than 29k 5G BS are authorised by ANFR in the 3.6 GHz band (near 23 k are technically operational), this band being the most used by all 4 operators. Two operators are also using the paired terrestrial 2 GHz band with more than 19k BS in this band (14k operational), and one operator has also deployed near 24k BS in 700 MHz (more than 19 k operational). Except for one mobile operator, the number of 5G BS in 3.6 GHz (launched in 2020) is approaching the number of 4G BS in 2.6 GHz (launched around 2008) – This is evidence of the rapid 5G take off in 3.6 GHz.

Authorisations granted to mobile operators includes 5G roll out obligations in number of sites per year including with % sites focusing on low density areas and supporting economic development; obligation to provide coverage on all highways and major roads with 100 Mbit/s

Germany

On a regular basis, the Federal Network Agency (BNetzA) publishes results of its mobile networks monitoring which includes an interactive map and statistical evaluation of mobile coverage by the public MNOs within the framework of the

[68] Coverage of mobile broadband services: https://tieto.traficom.fi/en/statistics/coverage-mobile-broadband-services

[69] Observatoire mensuel: https://www.anfr.fr/gestion-des-frequences-sites/lobservatoire/

Gigabit land register (Gigabit Grundbuch)[70]. The map shows the current mobile networks coverage in Germany from a consumer perspective. The information for the coverage map is provided by the four MNOs in accordance with BNetzA's specifications. The data is checked for plausibility and comparability using, among other things, the results of the Funkloch-App"[71]. In addition, random measurements from BNetzA's testing and measuring service help to verify the data. The result is a transparent picture of the area coverage of mobile networks in Germany including 2G, 4G and 5G networks. If all kinds of technical implementation of 5G (5G NSA and 5G SA) are considered, around 92 percent of Germany are already covered by this mobile communications standard (as of April 2024). 4G data coverage is available in >97 % and basic 2G voice services in 99.8 % of the area.

In general coverage obligations are technology neutral and no use of a specific frequency band is required. However, the obligations contain, amongst others, requirements for data throughput and latency. In deviation, the obligations of the 2019 award also include the deployment of 1000 5G base stations.

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[70] Mobilfunk-Monitoring: https://gigabitgrundbuch.bund.de/GIGA/DE/MobilfunkMonitoring/start.html (German language only)

[71] Mobil testen: https://breitbandmessung.de/mobil-testen (German language only)