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| Subject:  | IMT-2030 (6G) Spectrum needs and candidate bands |
| Group membership required to read? (Y/N)N |
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| Summary:  |
| IMT-2030/6G is expected to become the primary mobile technology in the 2030s and will offer an enhanced user experience compared to previous generations. 6G promises ultra-fast data rates with lower latency, significant energy efficiency, and greater reliability besides sensing connectivity, immersive communications and communications empowered by artificial intelligence.ITU-R Working Party 5D has developed a work plan, timeline, process and all the required deliverables for the future development of IMT that are necessary to be provided by the 2030 timeframe. The expected ITU-R outcome of this evolved IMT has now been agreed to be named “IMT-2030” by the responsible ITU-R WP 5D.Moreover, in the recent CPM-23-2 discussions, suggestions for an IMT agenda item, to cater for IMT-2030/6G spectrum need and use, are currently under consideration for inclusion on the agenda for WRC-27 and were contributed to the doc CPM23-2/221 and referenced in the summary document CPM23-2/247r1. Noting the development and discussions in ECC CPG PTA meetings with respect to proposals on AI10, there is a need to explore additional spectrum bands for IMT and for the mobile industry stakeholders to provide a list of additional frequency bands to be studied for the development and realisation of IMT-2030/6G. This contribution proposes specific frequency sub-bands from within 7.125-15.35 GHz, noting the current status of some Common Security and Defence Policy (CSDP) bands in this range in Europe and the need to consider coexistence with co-primary services.Nevertheless, ECC CPG PTA is invited to consider what studies/measures that need to be taken into account in order for the proposal not to jeopardise usages relevant to the CSDP or to the European space policy. This may as well lead to the exclusion of some of the proposed bands in CEPT, while still being relevant/important in other Regions (similar to the approach taken for the 37-43.5 GHz band; while the band was harmonised for IMT at WRC-19, the scope for Region 1 was limited to 40.5-43.5 GHz). |
| Proposal: |
| ECC PTA is invited to:* consider this contribution in relation to addressing a WRC-27 agenda item for possible IMT identification of frequency bands from within the frequency range 7.125-15.35 GHz and, if necessary, to allocate frequency range(s) to the Mobile Service on a primary basis.

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# introduction

6G will serve a wide range of use cases. Clearly, mobile broadband use cases will continue to be important. The November 2022 issue of the Ericsson Mobility Report [1] indicated that mobile network data traffic doubled in the preceding two years. Traffic is expected to significantly grow for many years to come, and cost-efficient support of this traffic increase is therefore of uttermost importance for 6G networks, translating into the need for additional spectrum even without considering new 6G use cases.

When it comes to new IMT-2030/6G use cases, a previous GSA contribution “CPG PTA(22)064” provided details on specific 6G use cases which are expected to drive the spectrum needs in the 6G era. The set of use cases was obviously not exhaustive but provided some insight into the future development of IMT.

In another GSA document on IMT-2030 (6G) spectrum needs analysis, submitted as APG23-5/INF-26 in February 2023 to the 5th Meeting of the APT Conference Preparatory (see Annex 1 for an extract), use cases such as XR, holographic communications and Joint communication and sensing were highlighted as drivers for additional wide-area spectrum in the 6G timeframe. The analysis is based on assessment methods that are straight-forward, and not over-complicated technically and creates a link between the most relevant use cases and their spectrum implications/needs. According to the analysis, the estimated additional wide-area spectrum need per network would be ~500 to ~750 MHz depending on the existing mid bands spectrum available for IMT and on the number of networks in a specific country.

In another study, part of a recent 6G white paper [2], quite similar spectrum needs results were found. The amount and exact spectrum available in each country that allows for the best balance between coverage and capacity differs largely across the world, but even when considering the most optimistic assumptions in terms of spectrum availability by 2030 in the mid-band range (including the availability of the upper 6 GHz band for IMT), a total spectrum shortfall of ~1.5 to 2.2 GHz is found.

In order to close this gap/shortfall, suitable spectrum must be considered in the closest proximity to mid-bands. This is where the 7.125–15.35 GHz range enters the picture, noting that there are propagation differences within this range, the closer to the mid-band range (below 7 GHz), the greater the possibility of reusing the existing base station grids and the lower the number of required new sites, costs, and power consumption for the delivery of services.

As previously mentioned, the additional spectrum from within the 7.125–15.35 GHz range is necessary to realize the capacity-demanding use cases in future 6G networks and is key to enabling mobility for many of these use cases. Any mobility and coverage restrictions would deprive such use cases of their full potential and value to society.

Considering the ongoing IMT-2030 and 6G research and flagship initiatives, there are several 6G-activities in various countries around Europe and worldwide. Also, in the EC funded Hexa-X and Hexa-X-II research projects, various industry players and several universities are participating from the following European counties: Finland, France, Germany, Greece, Hungary, Italy, Spain, Sweden, Türkiye (see more from <https://hexa-x.eu/members/>). Spectrum remains a critical enabler, hence it is important for the ongoing European wide research initiatives that CEPT supports studies for IMT-2030/6G spectrum within the 7.125–15.35 GHz range.

To realize the future network vision enabled by 6G and to deliver its full potential, there is a need to secure timely spectrum availability. Given the time it takes to secure additional spectrum through regulatory deliberations in ITU and/or regional groups and to avoid delaying initial IMT-2030/6G commercial deployments starting around 2030, it is now the time to start the process to ensure timely availability of IMT-2030/6G spectrum. PTA is invited to consider the need for a WRC-27 agenda item to address the additional spectrum needs of IMT-2030/6G.

Specific frequency sub-bands from within the 7.125-15.35 GHz are proposed in this contribution in order to initiate a discussion on potential bands to be studied for WRC-27.

# Candidate bands for studies

It is to be noted that harmonized global bands for IMT are highly desirable in order to achieve the benefits of economies of scale and facilitate global roaming. While not all these bands may become globally harmonized, harmonization of spectrum bands and technical conditions remains at the core of a healthy product ecosystem. We invite PTA to consider supporting studies for the following frequency bands as part of a new agenda item for IMT at WRC-27:

* 7.125-8.5 GHz
* 10.7-11.7 GHz
* 11.7-12.75 GHz
* 12.75-13.25 GHz
* 14-14.5 GHz
* 14.5-15.35 GHz

We recognize that Administrations may propose other bands to be studied and that some (or parts) of the proposed sub-bands may not be considered to be studied for IMT in some countries and regions. For instance, we are aware of the current status of some NATO bands in this range in Europe, however they are not precluded from the list above due to their relevance and availability in other regions and due to the global aspect of this proposed IMT Agenda item.

ECC CPG PTA is invited to consider what studies/measures that need to be taken into account in order for the proposal not to jeopardise usages relevant to the Common Security and Defence Policy (CSDP) or to the European space policy. This may as well lead to the exclusion of some of the proposed bands in CEPT, while still being relevant/important in other Regions (similar to the approach taken for the 37-43.5 GHz band; while the band was harmonised for IMT at WRC-19, the scope for Region 1 was limited to 40.5-43.5 GHz).

# sharing considerations with co-primary services

We recognise that it is becoming increasingly difficult to find “clean” spectrum and that, even though primary allocations to the Mobile and Fixed Services in the 7.125-15.35 GHz range exist today in the International Telecommunication Union Radio Regulations (ITU-RR), this frequency range also accommodates other primary services that need to be considered. Given the early stage of 6G development there is a window of opportunity to consider coexistence needs with some co-primary services in the design of 6G from the very outset. A WRC-27 agenda item would allow to perform the needed studies in this respect, noting that some co-primary services have a global nature and would best be studied in an international forum such as ITU-R.

# Global activities

Figure 1 depicts existing information on already ongoing national considerations in the US [3], [4], [5], [6].



It is also noted that APT is considering the range 7-24 GHz in its questionnaire and efforts to narrow down this range are expected.

# References

[1] [Ericsson Mobility Report - November 2022](https://www.ericsson.com/4ae28d/assets/local/reports-papers/mobility-report/documents/2022/ericsson-mobility-report-november-2022.pdf)

[2] [Ericsson white paper: 6G spectrum - enabling the future mobile life beyond 2030](https://www.ericsson.com/assets/local/reports-papers/white-papers/6g-spectrum.pdf)

[3] [Keynote remarks of FCC Commissioner Brendan Carr - extending America’s 5G leadership](https://docs.fcc.gov/public/attachments/DOC-370781A1.pdf)

[4] Expanding Flexible Use of the 12.2–12.7 GHz Band, et al., WT Docket No. 20–443, Notice of Proposed Rulemaking, 36 FCC Rcd 606 (2021) (NPRM).

[5] Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use, GN Docket No. 22-352.

[6] [WAC recommendations - FCC - April 2023](https://docs.fcc.gov/public/attachments/DA-23-296A1.pdf), [Qualcomm comments](https://www.fcc.gov/ecfs/search/search-filings/filing/10421133611609), [CTIA comments](https://www.fcc.gov/ecfs/document/10421150562546/1), [Ericsson comments](https://www.fcc.gov/ecfs/document/10421103325993/1)

# Annex 1 (extract from GSA input APG23-5/INF-26 ”IMT-2030 (6G) SPECTRUM NEEDS ANALYSIS”)

In the following calculations, the cell-edge Spectral Efficiency (SE) of IMT-2030/6G is assumed to be twice that of IMT-2020/5G, which is a forward-looking assumption with the consideration that IMT-2030/6G will have advanced development of its air-interface technology compared to IMT-2020/5G. For several use-cases such as immersive XR, we also assume advanced video codec, VVC (Versatile Video Coding), along with an optimistic assumption on the compression ratio (e.g., 800:1).

## Spectrum Needs Estimation Methods

There is a need to consider different methods for estimating spectrum needs for IMT-2030. This is due to the fact that the requirements of the different IMT-2030/6G use cases can be very divergent. Also, for IMT-2020 [1], there were various methods: traffic forecast-based approach, application-based approach and technical performance-based approach.

Both methods adopted in this document are technical performance based. In addition, the approach considers various data-rate requirements of different IMT-2030/6G use cases. Hence, this approach would provide a preliminary analysis of the spectrum needs for each application with straight-forward, not overly complicated technical assessment methods. More accurate spectrum needs calculations would require many assumptions including country/deployment dependent (density of population, IMT-2030/6G penetration, etc.) data.

The methods used in this document are presented in the following sub-sections.

### Method 1: Data rate and spectral efficiency based method [1]

$$B=D/S$$

where:

* One active user is assumed at the cell edge in a cell requiring a data rate $D$.
* $B$ is the amount of spectrum (Hz) required to support a certain data rate $D$.
* $D$ is the required data rate (bit/s) by a user/device.
* $S$ is the 5th percentile spectral efficiency (bit/s/Hz/cell), namely, the cell-edge spectral efficiency (a.k.a, cell-edge SE).

As mentioned earlier, the cell-edge SE of IMT-2030 is assumed to be *twice* that of IMT-2020, the latter is specified in ITU-R M.2410. In ITU-R M.2412, which contains the assumptions and evaluation methodology that led to the spectral efficiency figures of M.2410, 10 active users were assumed in a cell. Hence, by using the IMT-2020 SE (and the methodologies described in M.2412, M.2410) as a baseline for estimating the SE of IMT-2030, this calculation method implicitly assumes 10 active users in the entire cell, of which 1 user is located at the cell edge. While multiple users are served in the same cell, it is expected that the cell-edge user dominates the spectrum needs due to reduced spectral efficiency.

### Method 2: High accuracy sensing/positioning based method [2]

This method is suitable for use cases where high accuracy sensing and positioning is needed.

$$B=\frac{c}{2∆r}$$

where:

*  is the required bandwidth (Hz).
* $c$ is the speed of light (m/s).$∆r$ is the range resolution (m).

## Spectrum needs estimation of some IMT-2030/6G use cases

### XR

Extended Reality (XR) is an umbrella term encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). In conventional XR, the data processing required to present immersive experiences are carried out by the user devices themselves, thereby contributing to the size/weight, complexity, cost and energy consumption of the user devices. To mitigate this, cloud-based technologies and XR will be brought together to deliver superior experiences via cloud-based platforms, i.e. Cloud XR [3].

In Cloud XR, content will be stored, rendered and computed in the cloud, i.e. in the network. This will greatly reduce the computing load and energy consumption of XR devices. As such, lightweight devices and network communication are combined to provide ubiquitous XR services across the network [4].

IMT-2020 Cloud XR [4] currently supports a motion-to-photon (MTP) latency of less than 20 ms and end-to-end latency of up to 70 ms. Towards 2030 and beyond, the end-to-end latency of cloud XR is expected to be further reduced to below 10 ms through the use of IMT-2030 technology. A fully immersive XR experience requires 16K×16K resolution, a frame rate of at least 60 Hz (for single eye), and each pixel being represented by 12 bits. To reduce motion sickness, the required throughput will approximate be 0.45 Gbit/s[[1]](#footnote-2), given a 800:1 compression ratio.

Table 4 shows the required bandwidths for Cloud XR, derived based on Method 1 ($B={D}/{S}$), assuming a cell-edge SE of 0.45 bits/s/Hz/cell for outdoor and 0.6 bits/s/Hz/cell for Indoor, and a link throughput $D$ of 450 Mbit/s.

The resulting B (in MHz) is as follows assuming a dense-urban eMBB scenario in the calculation.

Table 4: DL Spectrum needs to support Cloud XR

|  |
| --- |
| DL spectrum needs for Cloud XR (GHz per Network) |
| Indoor | Outdoor |
| **0.75** | **1** |

### Holographic communications

Holographic communications are expected to be widely used, e.g. for social communication, work and training, healthcare, education, retail and shopping, entertainment, and in industry production facilities. This use case may start indoors but expand to outdoor environments shortly after its adoption, similar to voice and video applications in previous mobile generations. This will bring a fully immersive experience to users without the restrictions of time, space, and the boundary between the real and virtual worlds. It will require future IMT-2030 networks to provide information exchange capabilities supporting real-time 3D display and fast transfer of holographic images.

Holograms are mainly generated with image- and volumetric-based method [5]. Image-based holograms (e.g. Light Field Video) have the characteristics of high-fidelity image and are conceptually simple, but requires significant storage and transmission bandwidth. It is expected to require up to 1 Tbit/s bandwidth [4, 6]. Another way is to base holographic representation on volumetric media (e.g. point clouds). The objects are represented as sets of 3D volume pixels (i.e., voxels). The actual image is then dynamically rendered from any viewing angle at the local endpoint, which will greatly reduce the requirement of bandwidth.

As shown in the figure below, networks are required to support a throughput of approximately over 500 Mbps, if based on the volumetric-method (e.g. point clouds). Note that this figure is just an illustrative indication of data rates required and does not present any typical outdoor use case of holographic communications.



Figure 1. Data-rate requirement evolution for Holographic communications [5]

Considering such a required data rate of 500 Mbps, and using Method 1 with a cell-edge spectral efficiency of $S$ = 0.45 bit/s/Hz for outdoor and $S$ = 0.6 bit/s/Hz for indoor, the DL spectrum needs for Holographic communications can be estimated as shown below:

Table 5. DL spectrum needs for Holographic communications

|  |
| --- |
| DL spectrum needs for Holographic communications (GHz per Network) |
| Indoor | Outdoor |
| **0.83** | **1.1** |

On the other hand, if using image-based holograms (e.g. Light Field Video) to achieve hologram images, it is expected to require between 100 Gbit/s and 1 Tbit/s data-rate [5, 6] for the transmission of these images, which implies a huge amount of spectrum (approximately above tens of GHz) needed to realize this holographic experience, in addition to the need, e.g., for either a high resolution LCD panel with optics or a projector array system.

### Integrated sensing and communication (ISAC)/Joint communication and sensing

Integrated sensing and communication (ISAC) or Joint communication and sensing (JCS), is a new use case envisioned for IMT-2030/6G [4]. It will include various applications such as object positioning and monitoring, real-time wireless map construction, and will also help to improve the performance and efficiency of the communication system itself, by optimizing the utilization of radio resources when sensing information are taken into account.

The sensing resolution, $∆r$, is defined as the resolution with which the location of objects can be determined and is one of the key technical performance indicators for sensing applications. Different applications have various requirements on the sensing range resolution. For example, sensing range resolution can be in the order of tens of cm or dm levels for traffic management/collision avoidance etc. in the outdoor environment, but may need to be at cm or sub-cm level in smart factory or automatic assembly line applications [4] in the indoor environment.

Sensing the locations of objects by directly using the reference signals transmitted in radio communication systems is a typical feature of ISAC systems [4]. With this, the spectrum required to satisfy the sensing performance is to a large extent the same spectrum that is used by the communication system.

By using Method 2 as introduced in the previous section, Table 7 below shows the bandwidths required for different values of sensing range resolution, considering that in outdoor scenarios such as outdoor traffic management/collision avoidance, more relaxed accuracies, e.g., dm levels may be sufficient. Such outdoor scenarios are of high relevance in the context of this document since these are the ones that would be adding to the mobile network traffic; hence Table 7 represents the relevant figures for outdoor applications.

Table 7. Required contiguous bandwidth – applicable for outdoor applications

|  |  |  |
| --- | --- | --- |
| Sensing range resolution $∆r$ (in cm) | 50 | 20 |
| Required bandwidth *B* (GHz) | **0.3** | **0.75** |

On the other hand, certain industrial use cases, mostly in the local-area and indoor environment, may require mm or cm level range resolution, thus corresponding to the spectrum needs shown in Table 8:

Table 8. Required bandwidth – applicable for certain industrial applications

|  |  |  |
| --- | --- | --- |
| Sensing range resolution $∆r$ (in cm) | 1 | < 1 |
| Required contiguous bandwidth *B* (GHz) | **15** | **>15** |

In addition, it must be noted that due to the feature of integrated/joint sensing and communication, sensing can be done in a time-division manner or directly using the reference signals, together with communication. Therefore, the spectrum needs of integrated/joint sensing and communication is not expected to increase the overall spectrum needs resulting from other IMT-2030/6G use cases (e.g., XR and holographic communications).

# The summary of spectrum needs for some IMT-2030 / 6G use cases

In this contribution, examples of preliminary calculations of spectrum needs for some specific use cases relevant for IMT-2030/6G are provided. This set of use cases is not exhaustive but should provide some insight into the future development of IMT and to the corresponding spectrum implications by using straight-forward, not overly complicated technical assessment methods. Spectrum needs results estimated from each considered use case are summarized in the table below:

Table 9. Estimated required spectrum needs per network to support

the studied IMT-2030/6G use cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Unit: GHz** | XR | Holographic communications | ISAC/JCS |
| Wide area use cases  | **1** | **1.1** | **0.3 - 0.75** |
| Local area use cases  |  | **> 10s of GHz** | **> 15** |

In this summary Table, the split is done to differentiate between cases where usage of IMT-2030/6G use cases is required for wide-area outdoors and/or with supported mobility versus the case where usage of IMT-2030/6G is for local-area/indoors.

Each expected IMT-2030/6G use case will have different spectrum bandwidth needs due to different bit rate requirements, etc. The overall spectrum needs of IMT-2030/6G will need to correspond to the aggregated spectrum needs of the different IMT-2030/6G use cases.

However, some of the considered use cases are mutually exclusive, for instance XR and holographic communication would not be used at the same time by the same user, but in a given cell there could be a mixture of those use cases, by different users. On the other hand, some use cases could be realized at the same time by the same user. In this latter case, the spectrum needs of these use cases should be added up.

With that, from the summary table, the aggregated spectrum needs required to enable mobility and outdoor application of the analyzed IMT-2030/6G use cases are estimated to be in the order of 1 GHz per network. If assuming typically 3-4 networks in a country, and that in the long term, existing mid bands spectrum will be re-used for IMT-2030/6G wide area use cases, the overall additional spectrum needs will approximately be 2 to 3 GHz for the analyzed wide-area use cases (corresponding respectively to the cases of 3 and 4 operators in a country). This estimation is based on the simplistic assumption that all existing mid bands spectrum available for IMT (roughly ~1GHz) will solely be used to address the analyzed IMT-2030/6G wide area use cases, i.e., not considering existing MBB usage. So based on above, the estimated additional wide-area spectrum need per network can be rounded to ~500 - 750 MHz depending on the existing mid bands spectrum available for IMT and on the number of networks in a specific country. It should be noted that the lower the frequency range the better from coverage and mobility perspectives as spectrum bands do not have the same propagation characteristics. On the other hand, the estimated spectrum needs of the local-area, indoor use cases are around tens of GHz, suitable for short range type of usage in extremely high frequencies.

Since no single frequency range satisfies all the criteria required to deploy IMT systems, the type of deployment scenario (e.g., urban, sub-urban, local area/indoors, etc) and propagation characteristics of the different frequency bands will have a direct impact on which spectrum ranges the specific use case can be deployed in (e.g., existing IMT spectrum, potential new spectrum which could be identified at WRC-23, and/or potential new spectrum at WRC-27).

Further work is on-going to analyse the spectrum needs of a number of IMT-2030/6G use-cases as well as adequate and suitable spectrum ranges for implementation of those use cases, to be provided to future meetings.

# References

1. ITU-R Document 5-1/36, “spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz”.
2. G. R. Curry, Radar System Performance Modeling, Artech House, 2005.
3. GSMA Online Document: Cloud AR/VR Whitepaper, April 2019.
4. IMT-2030 (6G) Promotion Group, White paper on 6G vision and candidate technologies, June 2021.
5. A. Clemm, M. T. Vega, H. K. Ravuri, T. Wauters and F. D. Turck, "Toward Truly Immersive Holographic-Type Communication: Challenges and Solutions," in *IEEE Communications Magazine*, vol. 58, no. 1, pp. 93-99, January 2020.
6. J. Karafin and B. Bevensee, “25-2: On the Support of Light Field and Holographic Video Display Technology,” SID Symp. Dig. Tech. Pap., vol. 49, no. 1, 2018, p. 318–21.
1. Assumptions:

16K×16K resolution

Raw data: 16384 (pixels width) × 16384 (pixels height) × 12 (bits/pixel, assuming YUV420 for RGB) × 60 (frames/s) /1024 /1024 /1024 = 180 Gbit/s (scaling from bit/s to Gbit/s)

VVC (H.266): Raw data / 800 = 0.225 Gbit/s

For stereo (two eyes): 0.225 Gbit/s × 2=0.45 Gbit/s (compressed by VVC) [↑](#footnote-ref-2)