6 GHz opportunity: licensed spectrum for mobile networks

Whitepaper
June 2022

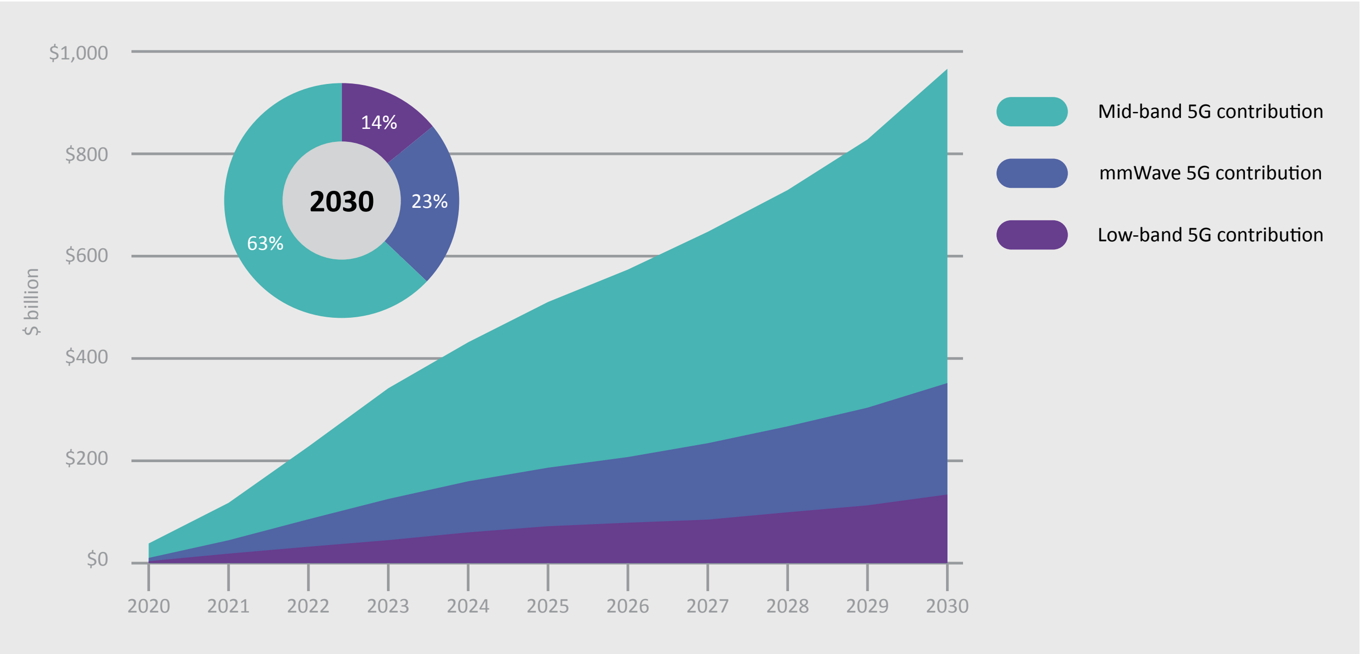
BENEFITS OF MID-BANDS TO SOCIETY

> Governments around the world recognise the importance of mobile services as an essential element in the digital transformation of their countries.

Mid-bands spectrum is currently being used in 253 5G Networks providing 5G commercial services in 60 countries.

Governments around the world recognise the importance of mobile services provided by 5G and its evolution as an essential element in the digital transformation of their countries. 5G is a key enabling platform for what has been described as the "4th industrial revolution" [1]. Providing 'anytime, anywhere' 5G connectivity necessary for Metaverse augmented/extended reality glasses, smart cities, connected vehicles, and smart deliveries with drones and robots will together generate traffic volumes far greater than today's smartphone-driven data usage rates. A recent study by GSMA Intelligence [2] concludes that 5G is expected to generate $960 billion in gross domestic product (GDP) in 2030 on a global basis, with $610 billion of this being a result of deployments in mid-bands and representing almost 65% of the overall socio-economic value generated by 5G. According to the analysis, up to 40% of the expected benefits of mid-bands 5G could be lost if no additional mid-bands spectrum is assigned to mobile services.

Exhibit 1: Annual impact of 5G on GDP, by band, 2020-2030 [2]



Source: *GSMA Intelligence*

> The need for additional mid-bands spectrum towards the end of this decade is widely recognised to realise the 5G vision. An average of 2 GHz of mid-bands spectrum will be needed in total in the 2025-2030 time frame, depending on markets.

The need for 5G spectrum is driven by the end users' traffic growth and their increasing demand for quality (e.g. lower latency and higher reliability) as set out in the ITU-R specifications for IMT-2020 [3]: "IMT-2020 is expected to provide a user experience matching, as far as possible, that of fixed networks", and are defined as 100 Mbit/s in the downlink (DL) and 50 Mbit/s in the uplink (UL). These requirements are 10 times greater than for LTE-Advanced (4G). GSMA's mid-bands spectrum demand modelling [4][5] shows that, to reliably deliver the IMT-2020 service requirements in an economically feasible manner in urban areas, on average 2 GHz of mid-bands spectrum (including the currently available mid-bands spectrum) will be required between 2025-2030. Different countries might experience slightly different timelines: for example, while European markets are expected to exhaust currently available mid-bands spectrum towards the end of the decade, other countries might reach that point earlier, closer to 2025. Beyond urban areas, this spectrum will address the digital divide, providing affordable high-speed fixed wireless access (FWA) broadband to small towns and villages, increase available capacity along major transport routes, and help address the connectivity needs of industrial use cases.

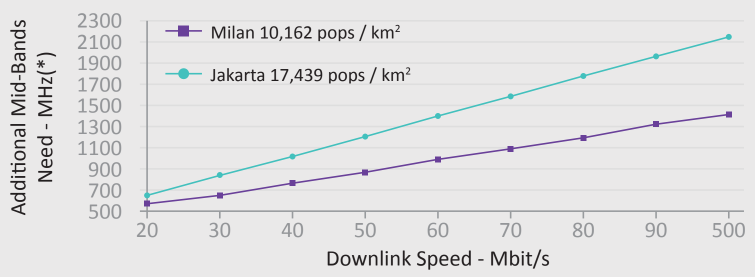
MID-BANDS SPECTRUM VS. UNFEASIBLE EXTREME NETWORK DENSIFICATION IN CITIES

Extreme network densification is not a feasible option to cope with the absence of additional mid-bands spectrum. In the absence of additional mid-bands spectrum, governments would have to accept that their nations would be unable to realise the full socio-economic benefits of 5G.

While in principle it is possible to mitigate the demand for spectrum by building additional sites (network densification), this is practically and economically unfeasible for network operators. The GSMA spectrum needs evaluation [5] estimates that if there is a deficit of 800-1000 MHz in the required mid-bands spectrum, the total cost of network ownership will be 3-5x higher over a ten year period, and the carbon footprint 1.8-2.9x greater, both as a result of the extreme densification needed to deliver the target performance levels. It is worth noting that the study does not address the practical restrictions in acquiring the additional sites required within an already dense network grid, nor the technical challenges including harmful interference management and mobility management, nor the economic feasibility in terms of both CAPEX and OPEX resulting from such extreme densification.

Accordingly, in the absence of additional mid-bands spectrum, and given the above technical and economic limits to extreme network densification, mobile network operators would not be able to deliver the user experienced data rates of 100 Mbit/s downlink and 50 Mbit/s uplink. Using Jakarta and Milan as examples, Exhibit 2 shows that user experienced speed increases in a linear fashion with the amount of available mid-bands spectrum. The higher the population density, the greater the need and hence the steeper the slope of the line. In not making additional mid-bands spectrum available, governments would have to accept that their nations will not realise the full socio-economic benefits of 5G.

Exhibit 2: Mid-bands spectrum vs speed in Jakarta and Milan



(*)Additional mid bands spectrum need to meet the DL to downlink speed from "X" axis as well as 50% UL to uplink (see table)

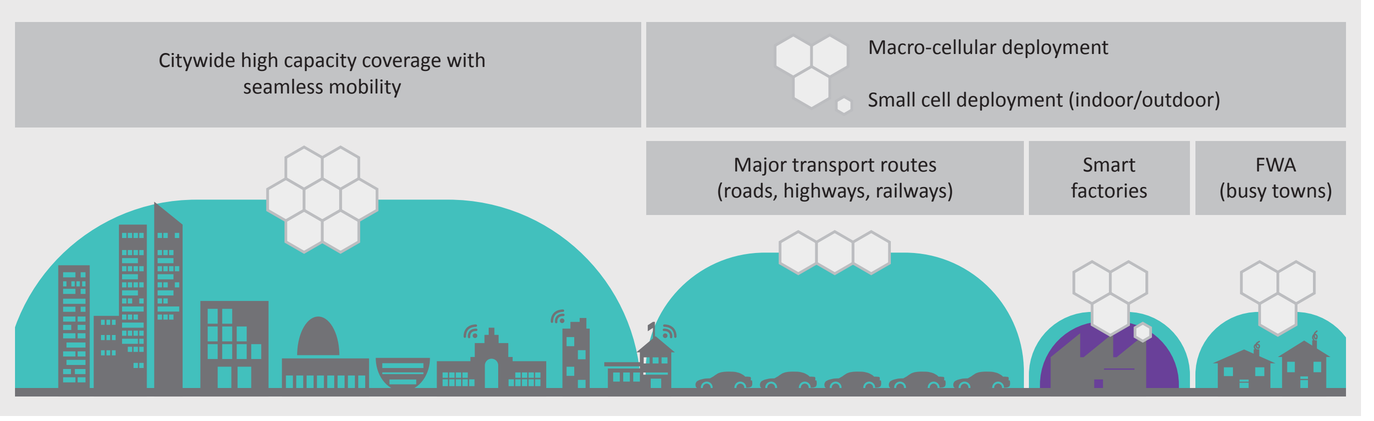
Source: *Coleago Consulting Ltd.*

BALANCE BETWEEN MACRO-CELLULAR AND LOCAL-AREA DEPLOYMENTS

The use of the 6 GHz band for macro- cellular deployments is key to ensure a balance with the spectrum assigned for local-area deployments.

Mid-bands spectrum is extremely important for mobile networks as these frequencies provide a unique combination of capacity and coverage for wide-area services, as indicated in Exhibit 3. Therefore, alternative assignment of these bands for local-area deployments must be carefully considered as no alternatives exist for wide-area mobile networks.

Exhibit 3: Mid-bands public macro-cellular networks serving multiple use cases with the same spectrum



Source: *Vendors presentation at the 2nd European 6 GHz webinar - December 2021 [6]*

However, we already see an imbalance appear in some jurisdictions – including in Europe – with large swathes of mid-bands assigned for local-area networks and short-range communications, as illustrated below.

Exhibit 4: Spectrum for macro-cellular wide-area deployments and for local-area deployments in Europe

Source: *Deutsche Telekom presentation at the 2nd European 6 GHz webinar - December 2021 [6]*

The use of the 6 GHz band for macro-cellular wide-area network deployments is key to ensure a suitable balance with spectrum assigned for local deployments.

THE 6 GHZ OPPORTUNITY

> The 6 GHz band represents a unique opportunity to meet the mid-bands spectrum needs.

Considering the complex and lengthy regulatory process of making spectrum available in new bands, it is vital that governments define roadmaps at an early stage to secure adequate support for the evolution of 5G. Depending on the country, at present only around 1000 MHz of mid-bands spectrum is available for macro-cellular mobile networks, and hence substantial amounts of additional mid-bands spectrum must be made available in the 2025-2030 time-frame to unlock the full potential of 5G. Network operators have also confirmed that, based on their detailed network capacity forecasts, 5G networks in cities will begin to experience service-impacting capacity limitations towards the end of the decade.

The 6 GHz band offers the opportunity to help meeting the identified need for additional mid-bands spectrum, providing wide contiguous mid-bands spectrum to enable enhanced performance and capacity in the foreseeable future.

To date, countries that have allocated spectrum in this band have taken divergent approaches: some have allocated the full 6 GHz band (5925-7125 MHz) for licence-exempt use, while others are considering the same band for licensed macro-cellular mobile networks; the largest group is considering to allocate the lower part of the band (5925/5945–6425 MHz) for licence-exempt use and the upper part (6425–7125 MHz) for licensed use.

The 6 GHz ecosystem is building up and will be ready when spectrum assignments occur.

The international interest generated by this band among industry (operators and suppliers) and administrations is driving the rapid consolidation of the equipment ecosystem. 3GPP has concluded the technical specifications of 5G NR base stations and user equipment for 6425-7125 MHz [6] in 3GPP band n104, defining the band plan, system parameters including channel bandwidth, transmitter and receiver characteristics, as well as other technical requirements. Commercial 5G NR products in the 6 GHz band – both for the radio access network and user equipment – are expected to be available when national assignments of these frequencies occur.

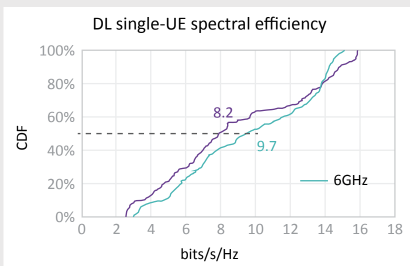
FEASIBILITY OF IMT MACRO-CELLULAR DEPLOYMENTS IN THE 6 GHZ BAND

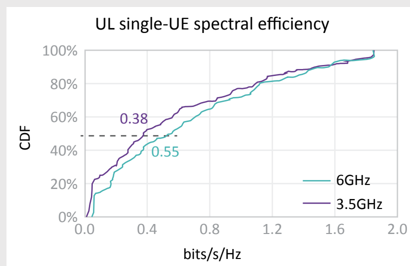
Technology advancements allow similar coverage in the 6 GHz and the 3.5 GHz bands.

Advances in radio technology allow us to achieve similar coverage with 6 GHz as with 3.5 GHz for both outdoor-to-outdoor and most outdoor-to-indoor communications. This has been confirmed by simulations and field tests with early prototype equipment. Mobile operators will therefore be able to upgrade their existing 3.5 GHz sites with 6 GHz radios without the need for additional sites.

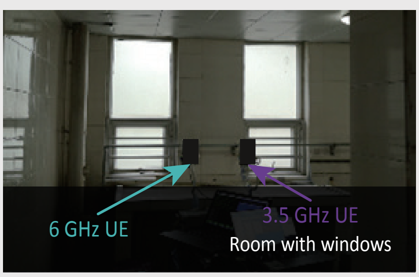
Exhibit 5: 6 GHz prototype base station field test results

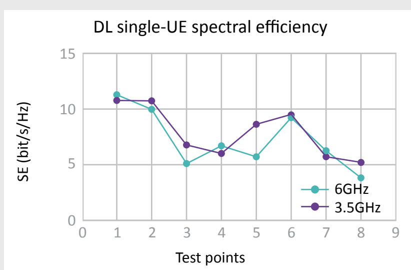
Outdoor-to-outdoor coverage tests (downlink and uplink test along the route within the cell)

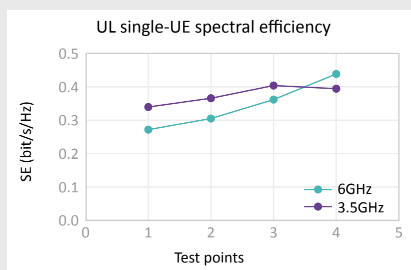




Outdoor-to-indoor coverage test (downlink and uplink test at different locations inside building, distance from base station is 150 m, non-line-of-sight)







Source: *Vendors presentation at the 2nd European 6 GHz webinar Dec. 2021 [6]*

Furthermore, the larger available bandwidth in the 6 GHz band will allow significantly greater capacity compared with what can be made available with the 3.5 GHz band. Further capacity field tests are planned, targeting the end of 2022.

UNDERSTANDING RLAN SPECTRUM NEEDS

> Co-channel operation of licenced 5G NR and licence-exempt Wi-Fi or NR-U in the same geographic area is not feasible.

Mobile networks are complemented by radio local area networks (RLANs) and we expect this trend to continue going forward with the evolutions of 5G NR mobile networks and Wi-Fi RLANs, respectively. Frequencies in mid-bands and high-bands are important for both 5G NR and Wi-Fi technologies, with mid-bands being essential for wider-area mobile use cases, whereas high-bands are more optimal where very high capacities over smaller areas are needed, such as for indoor or outdoor hotspots.

It is important to account for the fact that co-channel operation of 5G NR and Wi-Fi (or NR-U) in the same geographic area would result in harmful mutual interference, to the extent that they would not be able to perform at the levels for which they were designed: the 5G NR's protocols for scheduled access to spectrum – specified for a controlled interference environment – would be severely disrupted, while Wi-Fi's protocols for opportunistic access to spectrum – specified for managing unscheduled interference from other similar equipment – would fail to function.

Given that 5G NR and Wi-Fi must operate in different frequencies, and the criticality of mid-bands for wider-area mobile communications, the question arises as to how much additional mid-bands spectrum should be allocated for use by 5G NR and Wi-Fi, respectively.

Future availability of fixed broadband connectivity

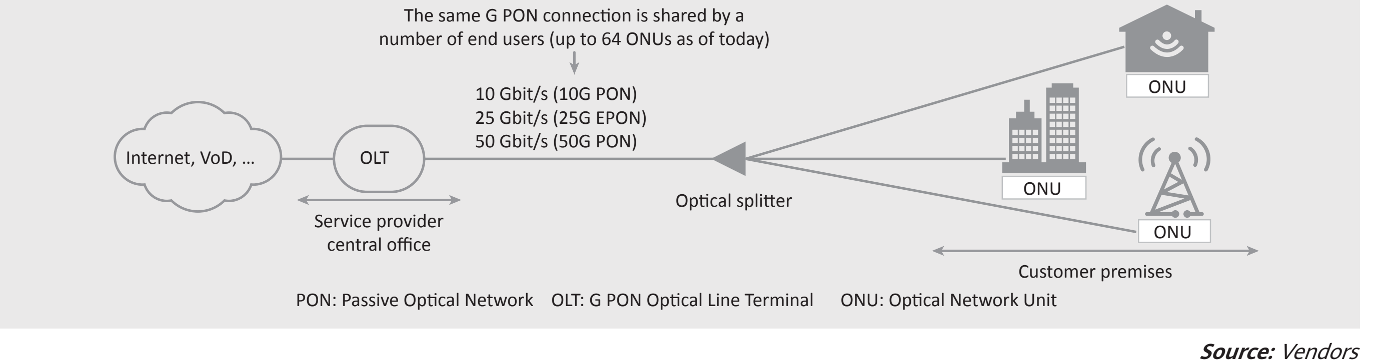
> FTTH connections to homes at around 1 Gbit/s are expected to become broadly available in advanced economies from 2026, with this reaching about 6 Gbit/s from 2029. Furthermore, 10 Gbit/s speeds are expected to be introduced in the next decade, subject to market demand. Wi-Fi spectrum availability should account for such constraints on home connection speeds.

We highlight that while 5G NR mobile networks are end-to-end communication solutions, Wi-Fi RLANs only offer "last few metres" connectivity, with their most popular use being within residential premises. As such, the performance of Wi-Fi is ultimately constrained by the speed of the fixed broadband (FBB) connectivity supplied to the Wi-Fi access points. For this reason, in deciding the amount of additional spectrum assigned for Wi-Fi, policy makers should account for FBB penetration and speeds.

The penetration of fibre to the home (FTTH) or advanced cable modem services varies greatly across countries. In high to medium income countries – which already have an advanced fixed telecoms infrastructure – penetration is likely to approach 100% of urban households within the 2025-2030 timeframe. On the contrary, in lower income countries Internet access is synonymous with wireless access, and FBB accounts for less than 10% of all connections and this proportion is declining.

Fibre optic technologies behind FTTH and advanced modem solutions have seen rapid developments: 10G PON became available from 2017 and is expected to reach large-scale take-up by 2026, delivering up to around 1.3 Gbit/s on average to end users. 10 G PON is being followed by 25G EPON and ITU-T 50G PON, which became available in 2020 and 2021, respectively, with the latter expected to deliver around 6.6 Gbit/s on average to end users.

Exhibit 6: Shared connectivity in FTTH networks



Source: *Vendors*

The first products for 50G PON are expected to be commercially available by 2023, and the technology is expected to have a large-scale market by 2029. Notably, should market demand materialise in the future, the next generation technology capable of delivering up to 10 Gbit/s to end users is unlikely to arrive until the next decade. Accordingly, the demand for spectrum to allow Wi-Fi access points to deliver speeds greater than 10 Gbit/s within this timeframe is questionable.

What can be achieved with existing RLAN spectrum?

Wi-Fi technology advances will allow home connectivity demands to be met with the currently available mid-bands spectrum in the 2.4 / 5 GHz (or lower 6 GHz bands if available), even in dense urban apartment settings.

The maximum theoretical downlink data rate that can be delivered by Wi-Fi with a 160 MHz wide channel at 5 or 6 GHz is about 9.6 Gbit/s. We note that commercially available Wi-Fi access points can already use the combination of a 40 MHz channel in 2.4 GHz band and a 160 MHz channel in the 5 GHz band to achieve a data rate of 10.75 Gbit/s. As such, and in light of FBB speeds expected to be available to households over the next decade, the assignment of additional mid-bands spectrum for use by Wi-Fi does not appear to be necessary.

Simulations [8] of a three-storey building with ten apartments per floor, four rooms per apartment, have shown that, when using a 160 MHz channel in the 5 GHz or 6 GHz bands, each Wi-Fi 6/6E access point can deliver a downlink throughput in the order of 500 to 1000 Mbit/s depending on the number of available spatial streams and on the number of antennas available at the access points and stations. Wi-Fi performance today is quite limited by legacy capabilities: performance enhancing features provided by Wi-Fi 7 will significantly improve the capability of Wi-Fi within their existing mid-bands spectrum. We expect that more advanced access points will become available in the future supporting throughputs that will be in the order of 2 Gbit/s in a 160 MHz channel in such dense urban environments.

Exhibit 7: Apartment in a densely populated environment

Source: *Vendors*

Utilisation of high-band spectrum for Wi-Fi will reduce the need for license-exempt mid-bands. Not leveraging high-bands for Wi-Fi would represent an inefficient use of spectrum.

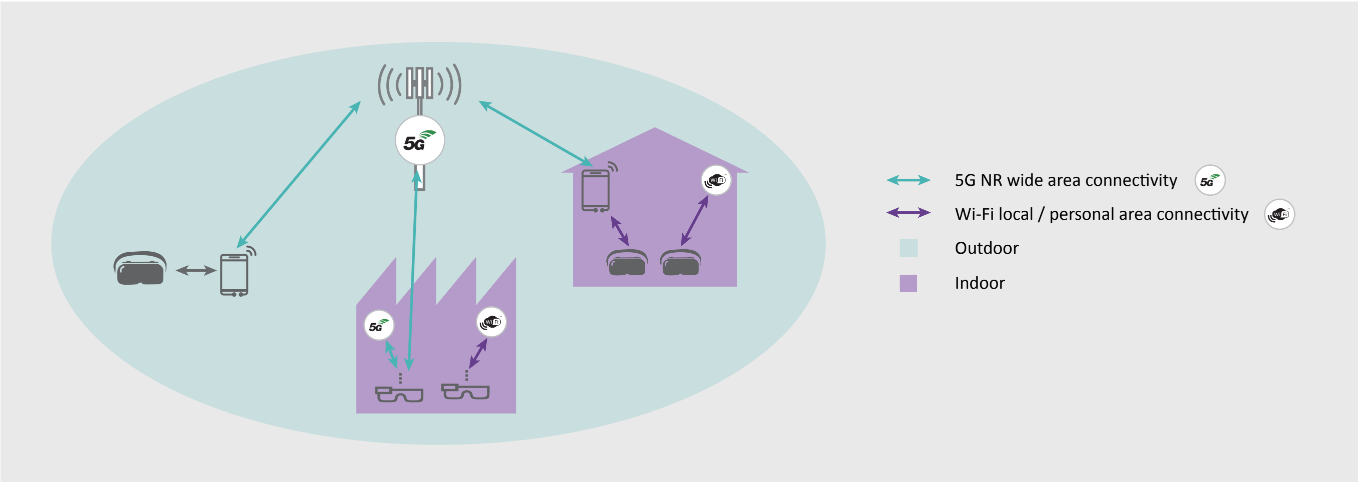
Furthermore, high-bands spectrum is also available (or is being considered) on a licence-exempt basis in many countries, particularly within the 60 GHz band (57-71 GHz). Going forward and considering the growing demand for high-capacity short-range RLAN communications, Wi-Fi is expected to increasingly exploit a combination of its existing mid-bands spectrum as well as high-bands , thereby relieving the pressure to access additional mid-bands frequencies which are more optimal for high-capacity wider-area mobile communications. Mobile operators are already deploying at high-bands today (e.g. 26/28 GHz) to address very high capacity needs in dense areas. These deployments allow capacity demand to be “offloaded” from mid-bands.

UBIQUITOUS CONSUMER AND ENTERPRISE METAVERSE NEEDS 5G

Licensed 6 GHz for macro-cellular wide-area 5G NR deployments will be needed to support the Metaverse AR/VR/XR in both indoor and outdoor scenarios.

The Metaverse will involve AR/VR/XR in both indoor and outdoor scenarios for consumers and enterprises. For this reason we consider that high data-rate (Gbit/s) wide-area outdoor seamless mobility will be an important element of the Metaverse, enabled by macro-cellular networks and relying on additional licensed mid-bands spectrum such as the 6 GHz band. Outdoors smartphones will need to be connected to 5G macro-cellular mobile networks with sufficient bandwidth in order to provide on-the-move connectivity to XR headsets. The short-range personal area connections between smartphones and headsets will rely on the licence-exempt 5 GHz band (and the lower 6 GHz in some countries) as well as the high-bands (e.g. the 60 GHz band). Alternatively, XR headsets might themselves directly connect to 5G mobile networks, avoiding the need for short-range communications.

Exhibit 8: Ubiquitous consumer and enterprise Metaverse needs licensed 6 GHz



Source: *Operators and vendors presentation at "The 17th European Spectrum Management Conference" – June 2022*

5G-NR FOR INDUSTRIES AND ENTERPRISES

5G NR offers excellent managed quality of service for industrial and enterprise use cases which have more challenging latency and reliability requirements, while Wi-Fi can play a complementary role in addressing use cases with less stringent requirements on a best effort basis. Simulations [9] of a factory environment have shown that 5G NR can deliver three times greater spectral efficiency than Wi-Fi 6 in meeting the more challenging latency requirements of industrial applications, even when assuming an optimised Wi-Fi6 scheduler, all in a controlled environment and without external sources of interference.

Importantly, the deployment of wireless networks in mission-critical industrial and enterprise applications – for example, to control production processes – requires substantial investments, and such investments can be more readily justified where there is certainty of access to the spectrum resource. This can only be guaranteed in wireless networks which operate in licensed spectrum.

THE SOCIO-ECONOMIC BENEFITS OF THE 6 GHZ BAND

GSMA Intelligence has conducted a cost-benefit analysis of different authorisation models for the 6 GHz band to assist policymakers in decisions on the future use of the band.

GSMA Intelligence has conducted a cost-benefit analysis [10] aiming at assisting policy makers in their decisions on different authorisation models for the 6 GHz band. The analysis has shown that the key factors which impact the benefits of 6 GHz spectrum assignment policies are: the existing spectrum availability for licensed and licence-exempt authorisation in mid-bands, the use of the high-bands by 5G and Wi-Fi, and the availability of high-speed broadband connections to feed the Wi-Fi access points.

The report draws the following conclusions in house dwelling or apartment settings:

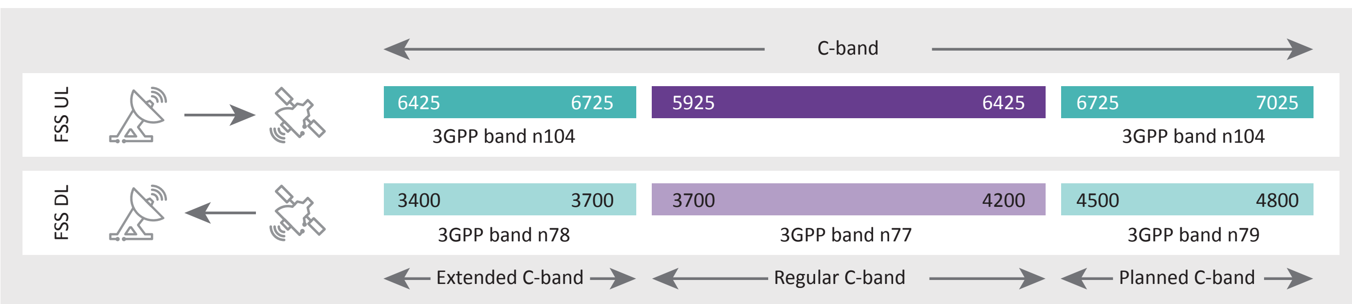
- In general, allocating the full 6 GHz band for licensed mobile use will drive the greatest economic benefit;
- Allocating the lower 6 GHz band for licence-exempt use and the upper 6 GHz band for licensed mobile use could drive the greatest economic benefit only under certain conditions in some countries (e.g. where there is high fibre/cable broadband adoption and very high FBB speeds of 10 Gbit/s to all fibre/cable users);
- Allocating the full 6 GHz band for licence-exempt use will not be the most beneficial option in any of the considered analyses.

COEXISTENCE BETWEEN 5G NR MACRO-CELLULAR NETWORKS AND INCUMBENT SERVICES

A large number of contributions to ITU-R concludes that IMT macro-cellular deployments can coexist with the incumbent systems with primary allocation in the band.

The 6 GHz band has an allocation to the Mobile Service on a primary basis in the ITU Radio Regulations (RR), along with other primary services. Accordingly, studies of sharing and coexistence between International Mobile Telecommunication (IMT) networks and other primary services in the 6425-7125 MHz band are being undertaken by ITU-R in preparation for the upcoming World Radiocommunication Conference of 2023 (WRC-23). Although discussions are still on-going, a large number of contributions submitted to ITU-R by administrations and industry have concluded that macro-cellular IMT (5G NR) deployments can coexist with the Fixed Satellite Services (FSS) uplink. Studies have further indicated that co-existence with FSS downlink and the Fixed Service (FS) is also feasible through coordination and/or geographic separation on a case-by-case basis.

Exhibit 9: C-band frequency plan for FSS



Source: *Vendors*

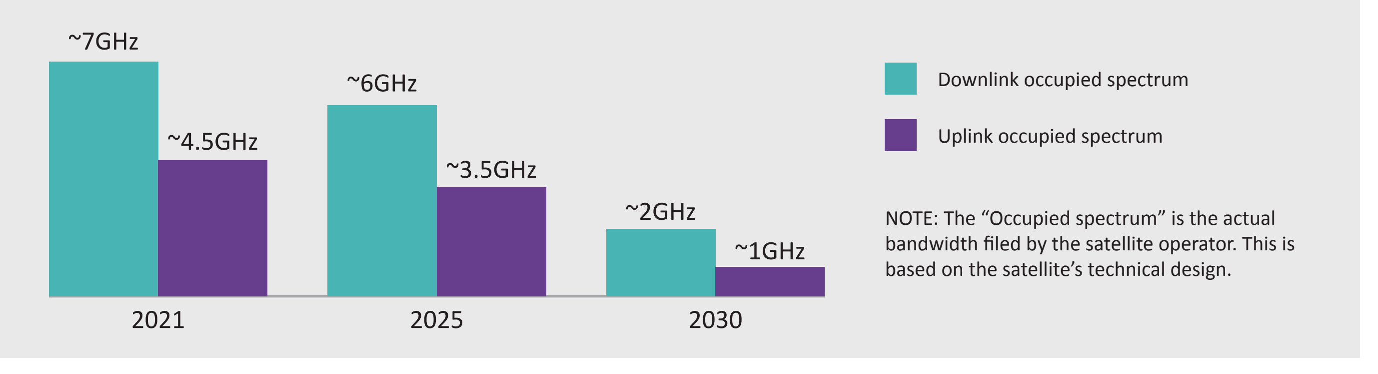
In considering the impact on FSS in the 6 GHz band, it is also important to address the expected extent of the use of the band by FSS in the future. Due to the primary role that the 3400-3800 MHz has played in the initial introduction of 5G NR, several administrations have decided not to issue new FSS licenses in the “Extended C-band” (3400-3700 MHz). This is illustrated in Exhibit 9. In fact, Some European administrations when providing their feedback to the ECC Questionnaire [11] have stated that FSS uplink usage in the upper 6 GHz band is going to be affected by changes in the European regulation in the downlink band (3400–3800 MHz).

In considering the impact on FSS in the 6 GHz band, it is also important to address the expected extent of the use of the band by FSS in the future. Around ~70% of the 54 satellites currently deployed in the Extended and Planned C-bands on the downlink and visible from ITU Region 1 are expected to no longer be in operation by 2030.

A recent study by Euroconsult [12] on the usage of the Extended C-band, “Planned C-band” and 7025-7075 MHz in Region 1 concluded that:

- A total of 51 satellites exist with payloads in the Extended C-band downlink, among which only 21 satellites use uplink in the Extended C-band;
- Only three satellites include Planned C-band capacity in uplink and downlink;
- Use of Extended and Planned C-band capacity would currently represent around 2% of the total commercial satellite capacity leased;
- Demand for Extended C-band capacity at 3400-3700 MHz (and for the associated Extended C-band uplinks) is on a declining trend which seems likely to continue;
- The relatively low use rate of a majority of those satellites, combined with the limited prospects for capacity usage, results in a limited rationale for their replacement;
- The likelihood of investment in a new Planned C-band satellite appears low.

Exhibit 10: Capacity supply attrition from existing satellites and prospects for new systems in the Extended C-band, Planned C-band and 7025-7075 MHz band



Source: *Euroconsult*

Solutions can also be found for other services which do not have primary status in the ITU-R Radio Regulations but which may be important for some administrations.

In parallel with WRC-23 preparations, ITU-R is also considering the potential impact of IMT on the Radio Astronomy Service (RAS), whereby protection zones can be specified at a national level. Additionally, passive microwave satellite sensors for the measurement of sea surface temperature – including the European Copernicus project – have been considered for deployment in the 6925-7325 band under the Earth Exploration Satellite Service (EESS), albeit without a primary allocation. Administrations are now considering alternative frequency bands for this purpose, with the aim of a protected status in the ITU Radio Regulations [13].

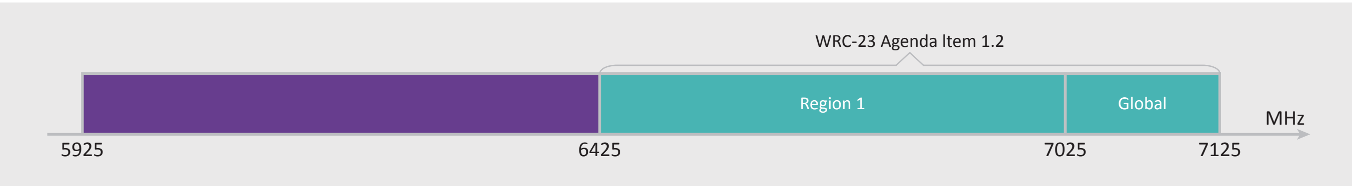
THE WRC-23 OPPORTUNITY

WRC-23 offers the unique opportunity to identify a harmonised, contiguous 700 MHz portion of mid-bands spectrum to support the evolution of 5G.

The upcoming World Radiocommunication Conference (WRC-23) offers the unique opportunity to identify a harmonised, contiguous 700 MHz portion of mid-bands spectrum to support the evolution of 5G. This is through Agenda Item 1.2 which considers the range 6425-7025 MHz in ITU Region 1 (Europe, Middle East and Africa), and 7025-7125 MHz globally, for IMT identification, noting that these frequencies are already allocated to the Mobile Service on a primary basis.

The WRC decision in December 2023 will be based on the strategic decisions of administrations who should carefully consider the information provided in this paper and provide the most appropriate balance between licensed and licensed-exempt spectrum at mid-bands through identification of the upper 6 GHz band (6425-7125 MHz) for IMT.

Exhibit 10: The WRC-23 opportunity for the 6 GHz band



Source: *ITU-R*

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