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Update on the upper 6 GHz band

Our current position in preparation for WRC-23

Welsh overview available

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1. Overview

1.1 Wireless broadband traffic has grown significantly over the last decade, and we expect this to continue. The development of new, innovative consumer and business applications will likely drive increasing traffic demand over public and private networks using mobile and licence exempt (such as Wi-Fi) technologies. Access to spectrum is one of the elements, alongside technology improvements and densification, that will support this traffic growth, as we outline in our conclusions paper, Ofcom's future approach to mobile markets and spectrum.

1.2 There is intense and competing industry interest in the use of the upper 6 GHz band (6425 to 7125 MHz), for higher power licenced mobile use and for lower power Wi-Fi and other licence exempt uses.[1] One of Ofcom's strategic objectives for spectrum is to ensure innovation and growth for existing and new users and to do so, we have made available a significant amount of spectrum for each of these uses.[2] [3] The upper 6 GHz band is currently used by a variety of services in the UK, including Fixed Links, Fixed Satellite Services, certain Short-Range Devices, Earth Exploration Satellite Services and Radio Astronomy. We will need to consider the impact on these users of any future decision on the band.

1.3 Against this backdrop, the upper 6 GHz band will be considered at the next World Radiocommunications Conference (WRC) in 2023, for identification for International Mobile Telecommunications (IMT)[4] (6425-7025 MHz is being considered for "IMT identification" in ITU-R Region 1 only, whilst 7025-7125 MHz is being considered globally). Such an identification would send a strong signal that the band is being prioritised for higher power licenced mobile use.[5] Parallel to this, the European Conference of Postal and Telecommunications (CEPT) is studying the possible technical conditions under which lower power licence exempt uses such as Wi-Fi could operate and coexist with existing services in the band. We are actively engaging in all this work.

1.4 We see potential for consumer benefit from either higher power licenced mobile or from lower power Wi-Fi and other licence exempt uses of the upper 6 GHz band and the case between the two is currently finely balanced. However, a "no change" position would give us the flexibility to respond to market and industry developments whilst continuing to engage with the relevant stakeholders in the run-up to and after WRC-23.

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[1] Most of the industry interest on licence exemption is for Wi-Fi use, and the evidence we use on traffic growth under licence exemption relates to Wi-Fi. Therefore, we often talk about Wi-Fi specifically, as opposed to licence exempt uses in general. However, a licence exemption that enables Wi-Fi would also enable several other types of technology, and there is also interest in those. We will highlight these other technologies where appropriate.

[2] Most recently we have made available the lower 6 GHz band (5925 to 6425 MHz) for licence exempt use, and the 700 MHz and 3.6 to 3.8 GHz bands for licenced mobile.

[3] In Ofcom's strategic objectives for spectrum, July 2021.

[4] IMT is the name used internationally (especially in the ITU) for commercial mobile broadband applications using mobile (e.g., 3G, 4G and 5G) technologies.

[5] An identification does not give priority over the other services and applications in the ITU Radio Regulations, but it sends a very strong message that the band is intended to be used in this way.

Our position

Ofcom is directed by Government to develop positions and represent the UK on international spectrum issues, including at WRCs.

At this stage, for the upper 6 GHz band, we favour a "no change" outcome at WRC-23, based on the balance of risks and opportunities.

This document sets out our rationale and supporting evidence for this position, which is informed by our wider work on mobile spectrum as described in our conclusions paper, Ofcom's future approach to mobile markets and spectrum. We will consult on proposals for the future use of the band in the UK at a later date.

1.5 While an "IMT identification" would not compel the UK to make the band available for licenced mobile use, there is a strong risk that an identification could significantly weaken the full development and availability of the licence exempt device ecosystem in the UK. The bands widely used by Wi-Fi today (2.4 GHz and 5 GHz) are global bands and consumers benefit from the global economies of scale in these bands; not only for Wi-Fi but for many other licence exempt products that use the same components in the same bands. There is now a substantial international effort to develop the entire 6 GHz band (5925 to 7125 MHz) as the primary band for expansion and innovation in Wi-Fi. We are not aware of alternative bands that would be likely to attract industry support at the same scale for the foreseeable future. [6] [7]

1.6 On the other hand, a "no change" outcome at WRC-23 (i.e., the lack of an "IMT identification") would not preclude us from authorising higher power mobile use if that turns out to be the optimal use for the band. Without an "IMT identification", there is a risk that the development of a mobile device ecosystem may be delayed in the short term. However, we think that this risk is small, and we would still expect the ecosystem to have developed by the time the spectrum could be made available for higher power mobile use (i.e., towards the end of this decade). In contrast to Wi-Fi, innovation efforts related to higher power mobile technologies are not primarily reliant on the availability of the upper 6 GHz band, they occur across many bands.

1.7 We will advocate for a "no change" outcome, both in Europe and internationally, as this will drive discussion on how best to use the band and will keep options open on its ultimate use. We plan to carry out further analysis on the band in the run up to WRC-23. We will consider international developments and engage with relevant stakeholders as needed prior to consulting on the proposals for the future use of the upper 6 GHz band in the UK.

[6] The entire 6 GHz band encompasses both the lower 6 GHz band between 5925-6452 MHz and the upper 6 GHz band between 6425-7125 MHz.

[7] For example, Meta's response to our WRC-23 CFI states that the 6GHz band is the only band for very high capacity, low power use in Wi-Fi. The next generation of Wi-Fi standards, Wi-Fi 7, is being planned for wide bandwidths in the 5 GHz and 6 GHz bands. There is extensive public evidence of the global effort in the FCC website – for example, this filing from Apple, Broadcom, Cisco, Google, Hewlett Packard, Intel, Meta and Microsoft refers to the investment in developing, designing, testing and marketing 6 GHz low power devices.

1.8 We also plan to investigate potential options for a “hybrid” approach, where both types of use would share access to the band. For instance, low power, licence exempt use indoors with medium power, licenced mobile use outdoors, facilitated by a sharing mechanism or set of rules to protect indoor use. We recognise there might be challenges in developing such an arrangement and we encourage relevant industry stakeholders to work on solutions.

2. Potential of the band to enable wireless broadband growth and innovation

Introduction

2.1 The upper 6 GHz band is currently used by a variety of services in the UK, including Short-Range Devices (such as ultra-wide band equipment and radar level gauges), Fixed Links (used by several sectors including MNOs and the financial sector), Fixed Satellite Services, Earth Exploration Satellite Services, Radio Astronomy and Permanent and Transportable Satellite Earth Stations.

2.2 The band will be considered at the next World Radiocommunications Conference (WRC) in 2023, under agenda item 1.2, for identification for International Mobile Telecommunications (IMT).[8] Such an identification would signal that the band is being prioritised for licenced mobile. There is also a CEPT work item studying the possible technical conditions under which licence exempt uses such as Wi-Fi could operate and coexist with existing services in the band. We are actively engaging in all this work.

2.3 In our call for input: UK preparations for the World Radiocommunication Conference 2023 (WRC-23) we set out the provisional views on items being considered at the conference including on the upper 6 GHz band. [9] [10] Responses to that call for input were divided on the upper 6 GHz band. One group of stakeholders is interested in using the band for high power mobile services (for example, 5G) and is in favour of an "IMT identification". Another group of stakeholders is interested in using the band for Wi-Fi (and other lower power technologies that could be enabled via licence exemption) and in general opposes an "IMT identification".[11]

2.4 Over the last few years wireless broadband traffic has grown significantly, and stakeholders have flagged the potential use of upper 6 GHz to address future demand and to support innovation. This section provides a comparative overview of the potential for upper 6 GHz to address future demand and support innovation via licensed use by higher power mobile networks, or via lower power licence exempt technologies such as Wi-Fi, and the potential consequences for the existing users of the band. This informs our risk analysis (in Section 3), where we present our reasons for currently favouring a "no change" outcome rather than "IMT identification" at WRC-23.

There is a wide range of incumbents in the upper 6 GHz band

2.5 In the UK, the upper 6 GHz band is currently used for a variety of services, including:

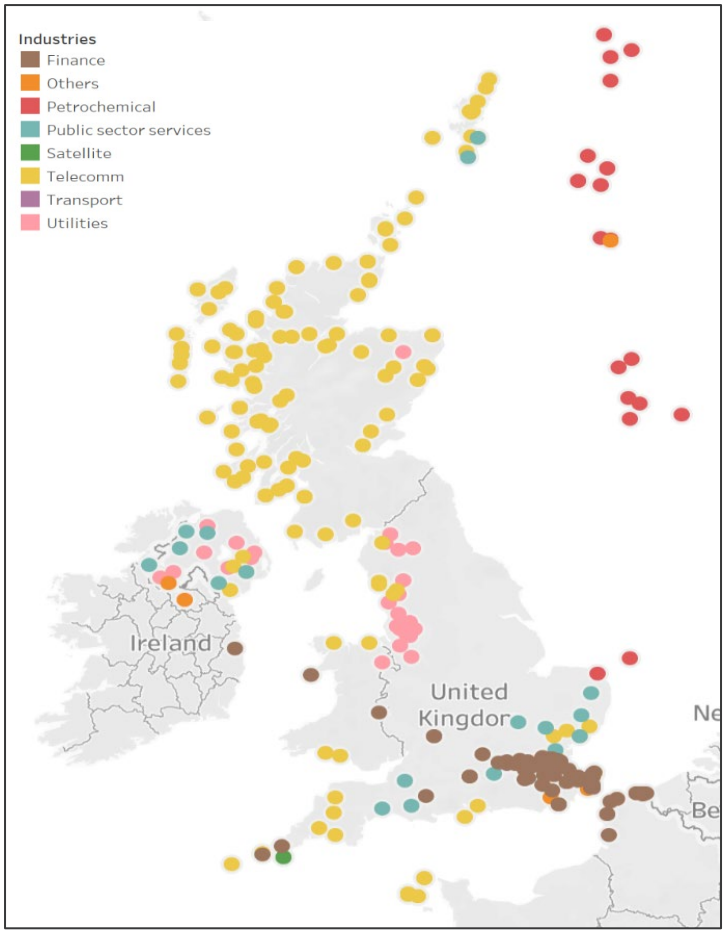
[8] 6495-7025 MHz is considered for Region 1. The 7025-7125 MHz band is being considered globally.
[9] Call for input: UK Preparations for the World Radiocommunication Conference, Ofcom, June 2022
[10] In the call for input we indicated that, "Presently Ofcom has an open mind as to whether to support, or oppose, an "IMT identification […]"
[11] Stakeholder responses to the Call for Input: UK Preparations for the World Radiocommunications Conference 2023

- **Fixed links**, of which there are approximately 500 links operating in the band located across the UK, supporting several industries.[12] Figure 2.1 shows the distribution of the links in the band. Fixed Links in the band are distributed across the UK. For instance, financial services high-frequency trading links are mainly concentrated around London, and those used by the petrochemical sector mostly offshore, whereas links for mobile backhaul can be seen across wide areas of the country, particularly in Scotland.
- **Short Range Devices** such as radio determination devices, radar level gauges and ultra-wideband equipment for various applications.
- **Permanent and Transportable Earth Stations** (5925 to 6700 MHz and 6700 to 7075 MHz bands) to communicate with satellites, as well as licence exempt receive-only earth stations on a non-protected basis; and
- **Earth Exploration Satellite Services and Radio Astronomy** for environmental and weather forecasting, and for the study of star formation and the structure of our galaxy and monitoring sea surface temperatures.[13]

2.6 Most of the incumbents operate outdoors and are distributed across the country. Any new users of the band would need to coexist with these, unless the band is cleared or sharing mechanisms between incumbents and new users of the band are imposed. We describe the likely coexistence challenges with incumbents in Section 3.

[12] Most Fixed Links in this band are used for mobile backhaul, programme making and special events (PMSE), satellite services, public bodies, utilities, and financial services (such as high frequency trading links).
[13] Whilst the Radio Astronomy services does not have Recognised Spectrum Access in the upper 6 GHz band, a footnote to the Radio Regulations (5.149) advises that administrations should take all practicable steps to protect this service from harmful interference.

Figure 2.1: Locations of fixed links sites in the upper 6 GHz band per industry



Different stakeholders have expressed interest in the upper 6 GHz band[14]

2.7 We have received views on the upper 6 GHz band from a wide range of stakeholders including Mobile Network Operators (MNOs), vendors and equipment manufacturers (including Google, Meta, Nokia, and Ericsson) and some current users of the band.[15]

2.8 MNOs said, in response to Ofcom's Mobile Spectrum Demand discussion paper and Ofcom's Spectrum Roadmap, that making available additional spectrum for mobile would enable them to meet future demand in a more cost-effective manner than densification of macro cells and small cells using mmWave. The MNOs also flagged practical barriers to densification which might prevent it from being an effective solution. MNOs said that mid-band spectrum, such as the upper 6 GHz band, would be particularly useful given its capacity and coverage characteristics.

[14] This section describes the feedback we have received from stakeholders in relation to the upper 6 GHz band and it does not represent Ofcom's views or assessments.
[15] We have received responses from several stakeholders to Ofcom's Meeting future demand for mobile data discussion paper (February, 2022), Ofcom's Spectrum Roadmap (March, 2022) and Ofcom's WRC-23 Call for Input (June, 2022). Stakeholder responses to each document can be found on the relevant pages in those websites.

2.9 Stakeholders that support licence exempt use claimed that there are more benefits from licence exempt use of the band, compared to mobile use. They highlighted that, mobile networks benefit from Wi-Fi capacity to offload traffic, and access to the upper 6 GHz band would ensure users experience high-capacity connectivity as the rollout of fibre to the premise continues, by preventing Wi-Fi from becoming a bottleneck in the delivery of fixed broadband services. Stakeholders stressed that most data is currently generated, or consumed, indoors and future applications, including Augmented Reality (AR) and Virtual Reality (VR), will be predominantly indoors where Wi-Fi is the technology of choice, noting that several countries, including the USA and South Korea, have already authorised access to the whole 6 GHz band.

2.10 In responses to Ofcom's Call for Input: UK preparations for the World Radiocommunication Conference 2023 (WRC-23 Call for Input) stakeholders highlighted several applications and services that would benefit from using the upper 6 GHz band.

2.11 Many mobile industry stakeholders noted that, as the metaverse takes off and "all day" AR becomes a reality towards the end of the decade, these applications would use 5G to meet the throughput and latency requirements.[16] However, several AR/VR suppliers have claimed that the upper 6 GHz band is more useful to VR under a licence exempt regime. They stated that access to several, non-overlapping 320 MHz channels in the entire 6 GHz band is integral to the delivery of these technologies, as this can enable very low latency communication links supporting the rendering of high-resolution graphics.

2.12 Some equipment suppliers for both mobile and licence exempt markets, have also noted their preference for licence exempt in the band highlighting the benefits of wider channel bandwidths.

2.13 Several incumbent users of the band have implied that lower power licence exempt use of the band presents fewer coexistence challenges for existing services. Some incumbent users stated that any potential use of the band by high-power mobile needs to ensure significant protection to incumbent uses, without imposing any further regulatory or technical constraints.

The roles of Wi-Fi and mobile in enabling wireless broadband

2.14 As set out in the Ofcom documents mentioned in the previous section, there is strong interest in the band for two uses:

- **Wi-Fi and other licence exempt lower power use**: More of the respondents expressed interest in use for Wi-Fi to support new applications, capacity expansion and congestion avoidance. There is also interest in using the band to connect devices directly without an intermediate network – for example connecting AR/VR headsets to a nearby computer. Licence exemption could also allow use by mobile networks via 5G

[16] Ofcom's Call for input for WRC 23, June 2022

NR-U subject to the same licence exemption rules, typically requiring lower power limits and access sharing mechanisms.[17]

- **Higher power, licensed mobile use**: Used by Mobile Network Operators (MNOs) to deliver mobile internet access, primarily using outdoor macro base stations, outdoors and indoors small cells. A licensed approach would enable higher power levels than licence exemption, enabling MNOs to provide wide area coverage (including some level of indoor coverage), internet access and mobility to many users.

2.15 Table 1.1 gives a high-level comparison between Wi-Fi and mobile networks use and their ability to provide internet access and support other applications. We focus on factors that affect the consumer as opposed to the inner workings of the technologies - including ability to provide indoor or outdoor coverage, availability of devices to consumers and ease of access. There are many similarities between the two types of use, but we focus here on the aspects where they differ. Technologies are in constant evolution, and the differences laid out in the table could become more, or less prominent in the future.

[17] 5G NR U is the licence exempt version of the 5G 3GPP technology. In brief, uses the 5G protocol stack in licence exempt spectrum, under the same access sharing mechanisms (for example, Listen before Talk).

Table 1.1: High level comparison of characteristics of Wi-Fi (licence exempt) and licensed networks

	Wi-Fi (and other licence exempt use)	Higher power licensed mobile
Indoor use	Wi-Fi access points are generally placed indoors, and currently carry the majority of wireless broadband traffic, including the majority of indoor traffic from mobile devices. The coverage of an individual access point is limited (due to power constraints) and several access points may be needed to provide coverage throughout an entire premise.	Mobile base stations are generally placed outdoors. They can provide indoor coverage (even in "deep indoor" locations such as basements), but building entry losses, especially at higher frequencies, attenuate mobile signals which in some situations significantly limit the coverage and capacity that can be delivered indoors.
Outdoor and mobility	Wi-Fi deployments provide very limited connectivity outdoors or to moving objects. However, Wi-Fi is often used to provide broadband services within moving vehicles e.g., in trains, buses and airplanes, typically backhauled by mobile networks. Newer versions of Wi-Fi technology may also enable improved mobility or other new outdoor use cases.	Mobile networks provide good outdoor, on the go connectivity and coverage in open areas (e.g., roads or streets, parks, shopping areas, etc.), and can be used to provide other services such as Fixed Wireless Access and backhaul for Wi-Fi coverage in trains, or other means of transport.
Variety of devices	Wi-Fi provides connectivity to a wide range of devices (wearables, most laptops, TVs, smart home appliances, industrial applications), as well as to mobile handsets. To date, most providers of Augmented Reality and Virtual Reality (AR and VR) devices have indicated that they will typically only provide Wi-Fi connectivity options in their initial offerings. Generally, licence exempt chipsets are less expensive than those of licenced technologies, which helps drive a wider ecosystem of devices.	Mobile networks support mostly connectivity for handsets and CPEs, but also various types of IoT (for example, narrowband IoT or 5G Redcap) and devices (for example, cellular tablets), but use of some of the latter is limited so far. As eSIM use becomes more widespread, this could encourage wider use of mobile technologies in different devices.
Device ecosystem	Wi-Fi chipsets that can use the upper 6 GHz band are already available and we would expect the number of new devices placed on the market that could make use of the whole 6 GHz band to grow at a significant level following any decision to make it available for licence exempt use.	It may be several years before operators could start to use the band for high power mobile, due to clearance and award timescales and device availability. As far as we are aware, there are no mobile chipsets currently available that can make use of the band.[18]
Deployment decisions	If broadband connectivity is available, customers can install additional access points to enable the services that Wi-Fi can support without relying on additional network rollout, for example by including APs wired to the existing installation or using mesh systems to increase coverage.	Typically, MNOs roll out sites in geographical areas where they can monetise investment in additional capacity or new services (e.g., 5G SA), which may be influenced by factors such as traffic demand, congestion and barriers to deployment.

[18] GamBoD database, checked for chipsets and devices supporting n102 or n104 bands. Accessed on 28/11/2022.

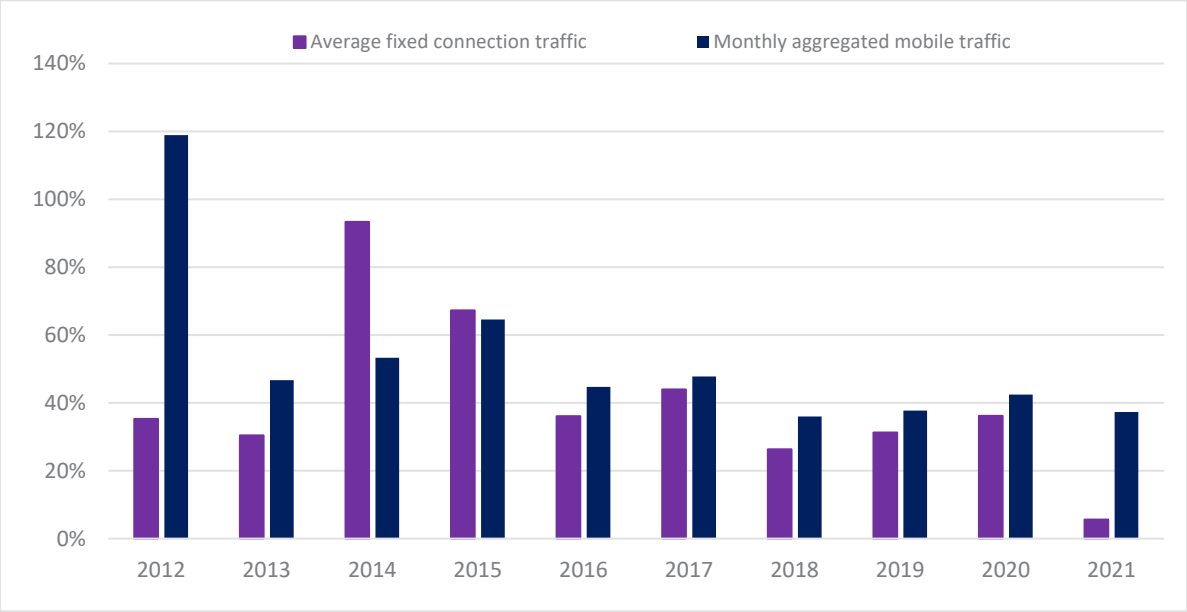
Wireless broadband traffic will continue to grow, but there is uncertainty about its evolution

2.16 In this sub-section we analyse the growth in traffic licenced mobile and Wi-Fi have experienced in the last decade, and how it might evolve in the future. We look at the drivers behind this growth, and where this traffic is consumed (e.g., indoors, or on the go).[19]

Mobile and fixed traffic have grown significantly over recent years, with a predominance of indoor traffic

2.17 Both **fixed and mobile traffic have grown, on average, at similar rates in recent years.** Figure 2. 2 shows that, while there have been significant differences in the growth rates experienced between the two in any particular year, on average growth has been similar (approximately 40%).[20] **There is a significant overlap of the drivers behind mobile and fixed traffic** including: video sharing and social platforms, streaming, growth of cloud-based services as well as enhancements in consumer devices' processing power and screen resolution.

Figure 2.2: Year-on-year growth (YoY) in fixed and mobile networks, 2012 to 2021[21]



2.18 **Most traffic is consumed in fixed networks, indoors.** Ofcom's research shows that fixed residential traffic averaged 453 GB a month in 2021 compared to 5.3 GB for the average

[19] We use fixed traffic growth as a proxy for Wi-Fi traffic growth. By "Fixed traffic" we refer to residential broadband traffic from Ofcom's Connected Nations data, from 2012 to 2021; We proxy Wi-Fi traffic with fixed traffic, as there has been a significant and stable proportion of fixed traffic being carried over Wi-Fi. See ASSIA, State of Wi-Fi Reporting, 2021.
[20] To note, this looks at a longer period than that used in our Future demand for mobile data discussion paper (10 years rather than 5) however, the year-on-year growth is consistent with our "medium growth" scenario.
[21] Ofcom Connected Nations, Annual Reports, Connected Nations, from 2012 to 2021.

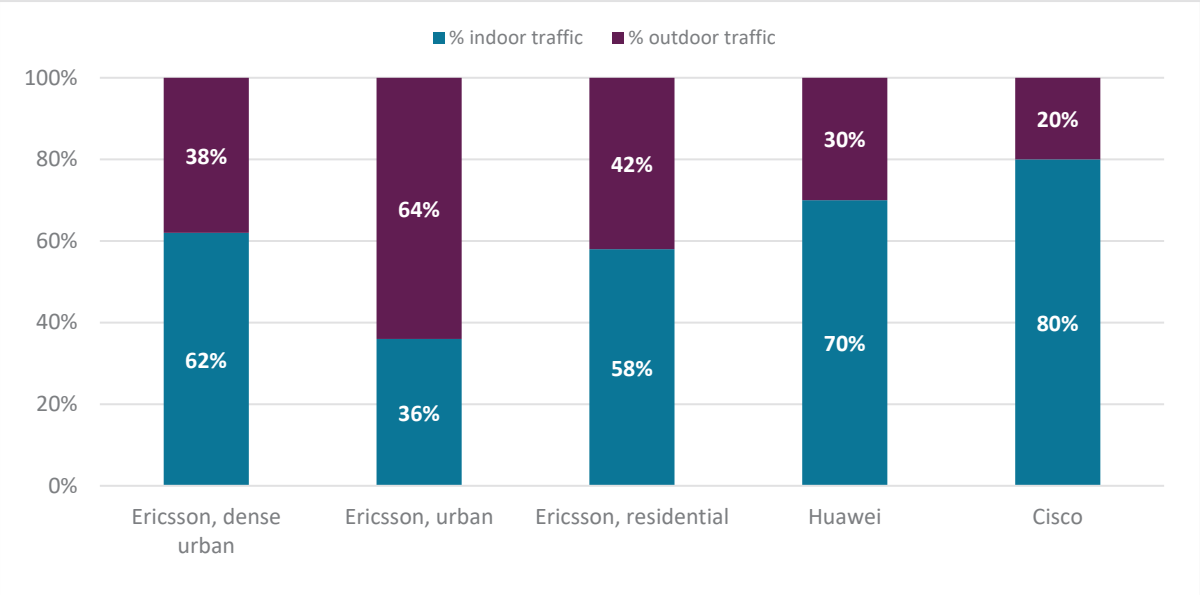
mobile subscription.[22] [23] Cisco predicts that, by 2023, 69% of all networked devices in Western Europe will be wired or connected over Wi-Fi, compared to 31% over mobile. Further, a high proportion of traffic in mobile networks is generated indoors: studies from Ericsson, Huawei and Cisco describe that there is a higher proportion of mobile traffic carried in indoor locations, with most sources pointing to more than 60% indoors (see Figure 2. 3). [24]

2.19 **On average, more than 70% of connections from mobile devices are through Wi-Fi**.[25] In addition, mobile operators are also increasingly giving consumers the choice to use Wi-Fi for voice calls and SMS. [26] [27]

2.20 The expansion of **fibre availability will continue to support growth in indoor traffic**. Gigabit internet is now available to 68% of UK homes (full fibre is now available to 11 million homes).[28] Government targets aim for gigabit-broadband to be available to 85% of premises by 2025 and nationwide by 2030.[29]

[22] Communications Market Report, Ofcom, July 2021.
[23] Meeting Future Demand for Mobile, Ofcom, February 2022.
[24] Ericsson, Planning indoor 5G coverage; Cisco, 5G Thriving indoors; Huawei, Better Indoor coverage, Better 5G networks
[25] Crowdsourced data collected from around 280,000 Android devices between 1 January and 31 March 2021 showed that 73% of active connections were made on Wi-Fi and 27% were made on mobile networks. These figures are rounded to the nearest whole percentage and refer to the proportion of connection tests run every 15 minutes, not data traffic. We proxy the time spent in a network by the number of connections made in that network. Mobile Matters: Using crowdsourced data to assess people's experience of using mobile networks, Ofcom, September 2021.
[26] Wi-Fi calling traffic sit between 2% and 16% per MNO in 2021, see p 40, of Ofcom's Connected Nations Report, 2021
[27] See EE's How do I use Wi-Fi calling; VMo2's Wi-Fi and 4G calling; Three's Wi-Fi calling, and Vodafone's Wi-Fi calling: Everything you need to know
[28] Connected Nations: Autumn Update, Ofcom, October 2022.
[29] "Nationwide" coverage means at least 99% of premises.

Figure 2.3: Proportion of indoor and outdoor mobile traffic, several sources



We consider several growth scenarios to reflect the uncertainty about future traffic

2.21 Whilst traffic has grown rapidly in recent years, there is a lot of uncertainty about how it will evolve in the future. Future rates of growth will depend on many unknowns - for example the future rate of growth in existing applications and the development and uptake of new applications, potentially using new devices. We have therefore reflected these uncertainties in a set of scenarios that encompasses a very wide range of possible outcomes, aligned with those used in our Future Approach to Mobile Markets and Spectrum conclusions paper:

- **Low growth:** 25% increase per year to 2030, 20% increase per year from 2030-2035.
- **Medium growth:** 40% sustained increase per year to 2035.
- **High growth:** 55% increase per year to 2030, 60% increase per year from 2030-2035.

2.22 We have used the same growth scenarios for mobile and fixed traffic as we think it likely that they will grow similarly given the overlap in the applications driving data demand. However, we note that certain applications may be more suited to mobile and others to fixed/Wi-Fi, so the drivers won't necessarily be identical.

2.23 In response to the discussion paper, a number of stakeholders agreed with our general approach, and some said that the medium growth scenario aligned with their own forecasts and analysis, though others disagreed.[30]

[30] Please see Ofcom's conclusions paper, Ofcom's future approach to mobile markets and spectrum for a more detailed discussion on these scenarios in relation to mobile.

The role of upper 6 GHz in meeting future wireless broadband demand and enabling innovation

2.24 We discuss in this sub-section how the upper 6 GHz band could enable growth and how it could facilitate innovation, under a licence exempt or licensed approach.

The potential use of upper 6 GHz for Wi-Fi and licence exempt technologies

Wi-Fi benefits from economies of scale in global bands, the 6 GHz band has international momentum for further growth and innovation

2.25 Wi-Fi is currently widely used in the 2.4 GHz and 5 GHz bands across the world. This global use has created valuable consumer benefits, driving up economies of scales and creating a diverse device ecosystem and cheap components. This has spurred innovation not only in Wi-Fi but also in many other consumer applications such as wireless headphones, wireless PC mice, wireless game controllers, and wirelessly controlled light bulbs are built on the cheap components from this global ecosystem.

2.26 There is now a substantial international effort across various technology sectors in developing innovative wide bandwidth applications for low power, licence exempt use (especially Wi-Fi), focusing on the entire 6 GHz band.[31] This is because the band can support higher contiguous bandwidths than existing Wi-Fi bands (2.4 GHz and 5 GHz). We are not aware of realistic alternative bands where this innovation effort could happen at a similar scale for the foreseeable future.

2.27 We are aware of innovative applications that can be enabled by Wi-Fi and other licence exempt technologies (such as AR/VR, healthcare services, remote education, and device to device communications). It is likely that further innovative applications will be developed that will take full advantage of the advances in technology that Wi-Fi 6/6E and Wi-Fi 7 will bring, as well as further improvements likely to be available in future.

2.28 Some of these applications will need the very low latencies that access to the wide bandwidth channels that 6 GHz can provide (for example, 160 MHz in Wi-Fi 6E or 160 MHz and 320 MHz in Wi-Fi 7). The high density of Wi-Fi access points is also an enabler for innovations that require high capacity. One of the key providers of AR/VR equipment and services, Meta, emphasised the need for additional licence exempt 6 GHz spectrum to enable better graphics in VR.[32]

2.29 Today, there is only a single 320 MHz channel available in the lower 6 GHz band. Making the upper 6 GHz band also available for licence exempt use would enable a total of three non-overlapping 320 MHz channels, enabling better performance and reducing the

[31] For example, Meta's response to our WRC-23 CFI states that the 6GHz band is the only band for very high capacity, low power use in Wi-Fi. The next generation of Wi-Fi standards, Wi-Fi 7, is being planned for wide bandwidths in the 6 GHz band. There is extensive public evidence of the global effort in the FCC website – for example, this filing from Apple, Broadcomm, Cisco, Google, Hewlett Packard, Intel, Meta and Microsoft that makes reference to the investment in developing, designing, testing and marketing 6 GHz low power devices.

[32] By moving the headset's graphical processing to a more powerful processor in a computer close by.

likelihood of network congestion and interference from neighbouring access points using the same channel.

Access to the upper 6 GHz band could significantly increase capacity before 2030

2.30 Wi-Fi currently has access to three different spectrum bands: 2.4 GHz, 5 GHz and the lower 6 GHz band, with a total of 1169 MHz.[33] However, the 5 GHz band is fragmented and has other constraints on its use such as DFS.[34] The upper 6 GHz band would increase the amount of spectrum available by 700 MHz (an increase of 60%). However, the increase in overall capacity would likely be greater than 60%, due to use by newer, more spectrally efficient, technologies (e.g., Wi-Fi 6E and Wi-Fi 7).

2.31 Additional spectrum and technology improvements can significantly increase the available Wi-Fi capacity. However, they are unlikely to be sufficient to address all future growth, particularly beyond 2030, if traffic increases similarly to our medium or high growth scenarios; in which case other mitigations would be needed, such as densification and/or further additional spectrum. In any case, the upper 6 GHz band would delay the likely time when Wi-Fi networks face congestion.[35]

Upper 6 GHz can ease the likelihood of a "wireless bottleneck" in the UK's fibre roll-out

2.32 To support the increasing need for reliable and fast internet, encouraging the deployment of fibre networks is a priority for Ofcom.

2.33 For fibre networks to be successful in delivering reliable gigabit-speeds to consumers, it is important that Wi-Fi does not become a bottleneck as demand grows. By increasing Wi-Fi capacity as described above, licence exempt use of upper 6 GHz, particularly in areas of high usage (such as high-density housing) would help avoid or mitigate this bottleneck risk.

The potential use of licensed mobile of the upper 6 GHz band

2.34 In our Future Approach to Mobile Markets and Spectrum conclusions paper, we explained that MNOs have a number of options to address future demand for data, including through more extensive deployment of existing spectrum, making use of planned spectrum releases (including mmWave); investment in technology upgrades to increase the amount of data that can be carried over a given amount of spectrum; and increasing the number of sites in areas where additional capacity is needed (network densification).[36] [37]

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[33] We note there is not a significant amount of traffic being carried over the lower 6 GHz band (5925 to 6425 MHz) so far, as it has only recently been made available. See Ofcom's Improving spectrum access for Wi-Fi Spectrum use in the 5 GHz and 6 GHz bands, Ofcom, July 2020.

[34] We have removed the Dynamic Frequency Selection (DFS) requirements from channels used by Wi-Fi in the 5.8 GHz band (5725-5850 MHz), see Ofcom's Improving spectrum access for Wi-Fi.

[35] Widespread adoption of Wi-Fi 6E is expected around 2028, based on forecasts for the shipment of chipsets (Wi-Fi Alliance, 2021) and assuming a four year average refresh cycle for consumer devices (YouGov Survey Results, 2020); we anticipate widespread adoption of Wi-Fi 7 devices around 2032. We note these dates can be delayed in absence of a rapid take up of newer technologies or refresh rates slow down.

[36] See Ofcom's future approach to mobile markets and spectrum.

[37] We are making additional spectrum available in the 26 GHz and 40 GHz bands from 2024. We see a growing ecosystem of devices for these bands (led, in particular, by the US), See Enabling mmWave spectrum for new uses, Ofcom, May 2022.

Upper 6 GHz is one of several bands that provide opportunities for innovation and additional capacity for mobile networks

2.35 Additional mid-band spectrum in the form of the upper 6 GHz band could increase the capacity of mobile networks, and therefore delay or reduce the need for densification. However, it may not reduce the need for densification significantly if traffic grows similar to or faster than our medium growth scenario. We recognise there are practical barriers that may pose challenges to densification, particularly in siting and use of small-cells, and whilst these are unlikely to fully disappear, we expect many of them to reduce over time. Further discussion on densification and barriers can be found in our conclusions paper.

2.36 In principle, availability of the upper 6 GHz band for commercial mobile presents similar innovation opportunities to those of licence exempt. However, we are not aware of any significant innovation that specifically require access to upper 6 GHz that is not planned for other IMT bands.

2.37 In the event that coexistence issues could be resolved, the upper 6 GHz band can provide access to wider bandwidth channels for licensed mobile use that could enable faster speeds, higher capacity and lower latency, thus better support the promise of 5G.

2.38 MNOs in the UK will soon have access to mmWave spectrum, where wide bandwidth channels are available to drive innovation and expand capacity, whilst there is little or no other alternative for licence exempt spectrum. [38] [39] For example, the engagement carried out as part of the mmWave work showed new, early cases included Fixed Wireless Access (FWA) providing speeds of over 1 Gbps, integrated access and backhaul (IAB) and mobile private networks. [40] These wide bandwidth channels could also be potentially found in other spectrum bands, aside mmWave, for example, if future work to make available other mid-band spectrum above 7 GHz and/or sub-THz spectrum for mobile use is successful.

It is unlikely that the upper 6 GHz band could be made available for high power mobile use before at least five years from now

2.39 Whilst the upper 6 GHz band could be used to provide additional mobile capacity, it takes time for new spectrum to be made available. If coexistence were not possible, and we conclude that high power mobile would be the optimal use of the spectrum, then clearance of the existing uses would be needed. It could take 5 years or more before MNOs could start deploying. We currently consider it unlikely that the band could be made available for mobile use much before the end of the decade.

[38] Enabling mmWave spectrum for new uses, Ofcom, May 2022
[39] There is licence exempt spectrum available in the 60 GHz band, but it lacks good propagation characteristics and might only be suitable for short-range, line of sight communications.
[40] Page 16, Enabling mmWave spectrum for new uses, Ofcom, May 2022.

The possibility for "hybrid" sharing

2.40 We are investigating the potential options for a "hybrid" approach, as we believe there might be an opportunity for licence exempt and licenced mobile to share access to the band.

2.41 Historical experience and initial analysis suggest this approach might be difficult to realise where, for example, licenced mobile using a high-power macro deployment shares the spectrum with low-power licence exempt use indoor. This is largely because the energy detect mechanism used by licence exempt technologies such as Wi-Fi would mean they "detect" nearby licenced mobile use (from base stations and the user devices connected to them) and "back-off" their own use. Separation distances of the order of several kilometres are likely to be required to avoid this, absent additional mitigation mechanisms.

2.42 However, we think there is scope to explore other potential options for use, including, for example, low-power licence exempt use indoors sharing the spectrum with medium-power licenced use outdoors, facilitated by a sharing mechanism or set of rules to protect indoor use.[41] We will consider whether it is feasible to allow indoor licence exempt use in the near future (to take advantage of the earlier availability of the device ecosystems) whilst giving time for industry stakeholders to develop sharing solutions that could allow the introduction of licence mobile at a later date.

2.43 We will continue to explore potential hybrid access to the band and engage with relevant stakeholders and international counterparts in the run-up to WRC-23 and before making proposals on the use of the band in the UK.

[41] If coexistence studies show a favourable environment for medium-power mobile, the band could potentially be available at an earlier date than for high-power mobile.

3. Our risk analysis

Our position at WRC-23 is separate from a potential UK decision

3.1 This section presents the risk assessment that led us to the conclusion that we currently prefer a "no change" outcome rather than an "IMT identification" at WRC-23. We chose to conduct a risk assessment because it allows us to engage with the uncertainties surrounding the issue in the context of the negotiation process in the run up to WRC-23. When we bring proposals on use of the band on a consultation, we will conduct a full impact assessment as usual.

Our risk analysis includes direct and indirect risks of an "IMT identification" versus "no change"

3.2 As part of our analysis, we have looked at two types of risk:

- **Direct risks:** These are risks that are caused directly by a decision for the "IMT identification" of this band at WRC-23, or by "no change".
- **Indirect risks:** These risks arise if, for example, "IMT identification" or "no change" at WRC-23 indirectly influences our later impact assessment and policy decision on UK use (e.g., via impacts on device ecosystem), tipping the balance towards mobile use or licence exemption. Because there are several steps between the cause ("no change" / "IMT identification") and the risk (for example, congestion in mobile networks), we called these indirect risks. However, these indirect risks are no less important and are a clear cause of concern to stakeholders on both sides of the debate.

We are more concerned about the direct risks from an "IMT identification" than with "no change"

3.3 An "IMT identification" or a "no change" outcome will, in practice, impact the equipment ecosystem supporting the band in Europe. Stakeholders on both sides of the debate agree on this. For instance, GSMA has noted that the main trigger for the commencement of product development will be operator demand, driven by WRC-23 through an "IMT identification" and national regulatory decisions.[42] Some stakeholders noted in responses to our WRC-23 Call for Input that an "IMT identification" would essentially make the band inaccessible to other technologies in Europe as there would be little, or no, equipment support. [43]

3.4 These impacts on ecosystem would be negative (and therefore a risk) if they do not align with the optimal use of this spectrum for the UK, which we will assess at a later stage via a consultation process. For example, if the optimal use for the UK is Wi-Fi and licence

[42] The 6 GHz IMT Ecosystem: Demand Drives Scale, GSMA (2022)
[43] Ofcom's Call for Input, and the stakeholder responses to this publication.

exempt use, but there is an "IMT identification", this would be a negative impact for UK consumers.

3.5 While there are risks on both sides, we believe that "IMT identification" is more likely to close down the option for Wi-Fi and licence exempt use than "no change" is to close down the option for mobile use. This is because:

- An "IMT identification" is typically interpreted as a clear signal that the band is being prioritised for and therefore likely to be used by high power mobile. This, in turn, may discourage industry and countries from considering licence exemption. "No change" would not send such a clear signal – as it does not automatically mean the band is being prioritised for, for example, Wi-Fi use.
- As we discussed in section 2, the upper 6 GHz band is unlikely to be available for nationwide higher power mobile use until the end of the decade giving time for a mobile ecosystem to develop (if it turns out that the UK and European countries consider mobile the optimal use).

3.6 In addition, an "IMT identification" could attract additional constraints in the Radio Regulations that could be detrimental to mobile use and would require coexistence with satellite services to be addressed in a globally consistent fashion.[44] However, we note that stakeholders who would like to use upper 6 GHz for higher power mobile prefer an "IMT identification" of the 6 GHz band over "no change", despite this potential disadvantage.

The indirect risks of "IMT identification" are also viewed as slightly higher than those of "no change"

3.7 We have also examined the indirect risks of "IMT identification" that are related to eventual mobile use of the band and compared those to risks related to eventual licence exemption of the band. The indirect risks draw on the analysis in section 2 and include the following types of risks:

- Risks related to growth in demand
- Risk of missing opportunities to enable innovation and
- Risks of negative impacts on incumbents (coexistence risks)

Risk of missing opportunities to enable innovation

3.8 As explained in Section 2, the Wi-Fi ecosystem has delivered significant consumer benefits and innovation, using the large economies of scale in global bands (2.4 GHz and 5 GHz). The Wi-Fi industry is focusing its efforts, internationally, on the entire 6 GHz band, to continue developing innovation and growth. For example, there are innovation

[44] For example, in part of the 1.4 GHz band, WRC-15, as part of the "IMT identification" process, decided to place constraints on IMT relating to the protection of aeronautical telemetry. These constraints were considered excessive for some CEPT countries that eventually decided to exclude themselves from the footnote identifying the band for IMT (even though many CEPT countries have made the band available for mobile).

opportunities that may be facilitated by increasing the number of available 160 MHz and 320 MHz channels in the entire 6 GHz band.

3.9 Without access to the entire 6 GHz band, there is a risk that the UK will not fully benefit from some of the future evolution in Wi-Fi technology and other technologies that share the same global ecosystem (e.g., technologies for device-to-device connection in licence exempt bands). Innovative licence exempt uses that are developing in other regions (North and South America, Asia) may not be available in the UK or would only be available at a lower quality, thus disadvantaging UK consumers.

3.10 There may also be potential innovation opportunities facilitated by licenced mobile access to the upper 6 GHz band. But in contrast to the above example, we have not identified any particular applications that would specifically require the upper 6 GHz band. If applications requiring very wide bandwidth were to arise in the near future, MNOs could access up to 400 MHz wide channels in the mmWave bands (26 GHz and 40 GHz). [45]

Risks related to growth in demand

3.11 If we eventually make the upper 6 GHz band available for licence exempt uses such as Wi-Fi, there is a risk that mobile networks might not have the capacity to meet potential future demand from consumers, unless they adopt additional mitigations which may be costly. A similar risk also exists for Wi-Fi and other licence exempt uses, should we make the band available for licenced mobile use.

3.12 Newer generations of mobile and Wi-Fi technologies generally increase the capacity they can offer, as well as enabling new use cases. For example, Wi-Fi 6E and Wi-Fi 7 provide access to wider bandwidth channels, enhanced spatial multiplexing and support a higher number of antennas in devices, leading to better performance and throughput. Similarly, MNOs can increase the amount of data that can be carried over a given amount of spectrum by migrating to newer mobile technology generations (such as 5G), or by moving to more advanced antenna systems such as massive Multiple Input Multiple Output (MIMO), with a larger number of transmit/receive elements and beamforming. [46] All of these can address some level of increased demand, but might not be sufficient on their own if demand continues to grow at a rate at or above our medium growth scenario. There are, however, other mitigations available for both. Table 3.1 shows the mitigations available to address excess demand, based on our analysis in Section 2:

[45] This could increase to more than 1 GHz wide channels with carrier aggregation.
[46] See Section 5 of Ofcom's Meeting demand for future mobile data discussion document, February 2022.

Table 3.1: Mitigation measures, absent upper 6 GHz spectrum

	Risk that, without upper 6 GHz, mobile capacity cannot keep up with demand	Risk that, without upper 6 GHz, Wi-Fi capacity cannot keep up with demand
Mitigation 1: Densification (with or without mmWave)	MNOs can address network congestion via densification, particularly with small cells and mmWave: spectrum will be available in mmWave bands, with a nascent device ecosystem, which could potentially address traffic demand. We note that, if traffic grows at a rate similar to our medium or high scenario, a significant scale of densification may be required towards the end of the decade. MNOs expressed concerns that densification may not be cost-effective and flagged practical barriers to it. We expect some barriers, particularly those related to small cells, to reduce with time. We will continue to investigate these.	There is scope to densify Wi-Fi networks, either by adding new access points wired to the existing installation or by reusing spectrum to provide backhaul (i.e., mesh systems), and (were it in ISPs interest) to deploy and improve the quality of service offered to customers. However, depending on the bands used, there might be a limitation of the points that can be deployed in an area from spatial reuse of the frequencies. In summary, while there is scope for densification, there might barriers to it in some cases. The 60 GHz band could be used to address demand. However, due to its propagation characteristics, this band is mostly suitable to provide line of sight connectivity. Whilst technology in the band can improve in the future, we are not aware of industry plans to use the band on a mass consumer scale.
Mitigation 2: Offload	As most mobile traffic is generated or consumed indoors, congestion could be eased by offloading additional traffic to Wi-Fi (if available), however there are fewer opportunities to offload traffic outdoors.	Wi-Fi is unlikely to offload to mobile networks at scale due to the difference in network area capacity: with around hundreds of access points for each mobile base station, offload could overwhelm base stations, except in exceptional circumstances (e.g., if there are many small cells in a given area). This would also depend on other factors such as user choice or presence of network agreements. There could also be a negative impact on mobile networks: if Wi-Fi networks get congested, there will be reduced ability for MNOs to offload traffic.

3.13 There is a risk that, depending on future demand growth, and absent other mitigations, both licensed mobile and Wi-Fi networks might become congested, particularly beyond 2030. In this case, making upper 6 GHz available for lower power, licence exempt use might be better overall: for example, Wi-Fi networks can carry a much greater volume of traffic per MHz in an average (indoor) area, even if some traffic demand might be unserved. Additionally, 5G NR-U could also be used under licence exemption to support MNOs with indoor, and some outdoor, traffic.

3.14 There is also a risk that Wi-Fi and licenced mobile networks face congestion at different times. Mobile networks could face congestion before Wi-Fi networks, or vice versa. However, given the level of growth in wireless traffic on both mobile and licence exempt

networks, it is likely a question of time before both types of services need to prevent or mitigate potential congestion.

3.15 We have identified risks around the potential of future growth in demand being unevenly concentrated on specific applications using licence exempt, or licenced mobile networks, resulting in different rates of traffic growth. This presents certain risks for each:

- Applications that require mobility (e.g., driverless cars, augmented reality in handsets) could dominate future demand. These types of applications would potentially be better served by mobile networks, driving increased costs for MNOs. This particular type of traffic would also be harder to offload to Wi-Fi networks due to the mobility requirement of the applications.
- Alternatively, growth in indoor applications could dominate future demand. For example, more extensive use of localised AR/VR in different settings, including classrooms and hospitals. This traffic would potentially be better served by Wi-Fi as it would be difficult to address from outdoor base stations due to the propagation characteristics of the band, and lower density of mobile base stations.

3.16 So far, we haven't seen evidence suggesting any significant change in the current balance between indoor and outdoor, or between low mobility and high mobility traffic levels. For instance, there are Government policies that support fibre network deployment, increasing adoption of VR applications which are predominantly used indoors, ultra-high definition 4K/8K TVs, and most laptops and tablets are currently only enabled via Wi-Fi. However, we acknowledge that there are innovation opportunities that could shift this balance towards outdoor and/or high mobility traffic, for example, smart cities, sports broadcasting, or cellular-connected drones.

Risks of negative impacts on incumbents (coexistence risks)

3.17 Coexistence studies for the band are still ongoing in international fora. Most work so far is in relation to coexistence between higher power mobile and fixed links or Fixed Satellite Services. The studies show that separation distances in the order of several tens of kilometres are likely to be required between mobile base stations and fixed links.[47] There is no clear consensus on the sharing studies between licenced mobile and Fixed Satellite Services (FSS) for this band. Some studies indicate sharing is feasible, whilst others conclude the opposite. Whilst our preliminary view is that sharing with outdoor higher power mobile might be difficult in many circumstances, our analysis is ongoing.

3.18 Wi-Fi and other lower power, predominantly indoor, licence exempt uses are less likely to cause interference to incumbent (predominantly outdoor) users of the band when compared to outdoor, higher power mobile use.[48] As we previously noted, any future use

[47] On-going studies in ITU-R Working Party 5D suggest separation distances of around 10km to more than 100km might be needed, depending on the assumptions used in the studies.

[48] New studies will be needed for a definitive conclusion on coexistence of licence exempt uses and incumbents in the upper 6 GHz band, but we have studies for similar situations that allow us to make an informed judgement on the overall risk of coexistence issue at this stage. For example, international studies for the lower 6 GHz band (such as ECC Reports

of this band for licenced mobile would likely require some level of clearance and/or the imposition of technical constraints on users to allow the band to be shared.

3.19 It is unlikely that we would need to limit use or clear incumbents if usage was indoor lower power only; similarly, sharing with fixed satellite services is likely to be possible. In our upper 6 GHz shared access consultation we indicated that indoor usage of the band did not point to major coexistence issues. [49] Medium power outdoor licence exempt use could require coordination with fixed links or sharing mechanisms such as Automated Frequency Control (AFC). [50]

302 and 316) and, on the upper 6 GHz band, for a licenced variation of Wi-Fi-like services on our upper 6 GHz shared access consultation.

[49] Enabling sharing spectrum in the upper 6 GHz band, Ofcom, February 2022.

[50] We note the work carried out by the USA Federal Communications Commission to enable medium-power outdoor usage with an Automated Frequency Control mechanism to pursue coexistence with the band incumbents.

4. Conclusions and next steps

Conclusions

4.1 We have considered a number of risks related to an "IMT identification" in the upper 6 GHz band at WRC-23, and, on balance, we are more concerned with an "IMT identification" than a "no change" outcome. An "IMT identification" could impact the development of a licence exempt device ecosystem and significantly weaken the licence exempt Wi-Fi option. On the other hand, the lack of "IMT identification" will not preclude us from making the band available for licenced mobile use or stop the development of a mobile device ecosystem if that turns out to be the most efficient use.

4.2 We have also considered the indirect risks of an "IMT identification", and of "no change". These risks arise if, for example, "IMT identification" or "no change" at WRC-23 indirectly influences our later impact assessment and policy decision on UK use (for example via impacts on device ecosystem), tipping the balance towards mobile use or licence exemption. Indirect risks include:

- The risks of missing out on innovation opportunities would be higher, on balance, if WRC-23 were to agree an "IMT identification". Wi-Fi has developed using global bands and the Wi-Fi industry's international focus for innovation and expansion is now on 6 GHz and the large bandwidth available in the band. There is no other band with similar prospects for Wi-Fi. Mobile innovation in contrast is progressing across many bands.
- Mobile networks may face increased challenges to meet demand, without access to more mid-band spectrum. This is counterbalanced by a similar risk on the Wi-Fi side: if Wi-Fi did not have access to upper 6 GHz, there is risk Wi-Fi networks could not keep up with demand.
- The use of higher power outdoor mobile in the band carries a greater risk of co-existence issues than lower power Wi-Fi and licence exempt applications.

4.3 However, our analysis points to a fine balance between the benefits of licence exemption and licenced mobile, being sensitive to elements such as continuing evolution of the device ecosystem. We will be in a better position to make proposals for the UK after we have seen more progress in the current discussions taking place in the run up to WRC-23.

Next steps in preparation for WRC-23

4.4 As outlined above, we currently favour a "no change" outcome at WRC-23. Therefore, we intend to promote the adoption of a "no change" European Common Proposal (ECP) in the relevant CEPT preparatory meetings (e.g., ECC PT1 and CPG).

4.5 Ofcom is directed by Government to represent the UK delegation at the WRC and in the relevant preparatory work, including the various regional preparatory meetings. As part of our ongoing preparatory work in the UK, we will continue to seek stakeholder views and consider additional evidence.

4.6 Whilst we are not expecting formal responses to this position paper, we are keen to continue engaging with relevant stakeholders over the next year, and welcome further discussions on the future use of the upper 6 GHz band.

Making spectrum available in the UK

4.7 We will continue monitoring the evidence for and against the competing future uses of the band and international developments. We plan to consult on specific proposals for the future use of the upper 6 GHz band at an appropriate future date.

4.8 We will further investigate the potential options for a hybrid approach (for example, enabling license-exempt use in indoor environments, and some level of outdoor mobile use). We note that these solutions may be complex to implement and require a close cooperation between the different industry stakeholders.