# Hybrid sharing: enabling both licensed mobile and Wi-Fi users to access the upper 6 GHz band

Consultation

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**CONSULTATION:**

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# Contents

## Section



## Annex

# 1. Overview

1.1 Wireless broadband, delivered via mobile and Wi-Fi, has become an essential service for people and businesses enabling a wide range of everyday activities, and traffic on these networks has grown significantly in recent years.

1.2 The development of new technologies and applications mean we expect overall demand for these services will continue to rise. This in turn will put pressure on radio spectrum, the valuable and finite resource on which all radiocommunications depend.

1.3 The upper 6 GHz band (6425-7125 MHz) is currently a focus for industry interest, including in the debate leading up the World Radiocommunications Conference (WRC-23). Much of this interest has focused on approaches that would support the exclusive introduction[1] of either:

- higher power licensed mobile; or
- lower power licence exempt uses such as Wi-Fi.

1.4 However, we believe an alternative approach is possible. We are exploring options that would enable the introduction of both Wi-Fi and licensed mobile use of the band in relatively close proximity – we are calling this "**hybrid sharing**".

1.5 Hybrid sharing could result in significant additional benefit for consumers and businesses, providing more capacity, supporting faster internet and enabling innovative services. We believe it is likely to maximise consumer benefits and result in optimal use of the upper 6 GHz band, in line with our statutory duties.

1.6 At present, the band is used for other valuable services, including Fixed Links, Fixed Satellite Services, Programme Making and Special Events (PMSE), space science uses such as Earth Exploration Satellite Services (EESS) and Radio Astronomy, and Short-Range Devices. We want to understand the coexistence challenges that the introduction of hybrid sharing may have for existing users and how they may be solved.

[1] Alongside existing services that already use the band where these can coexist.

**What we are proposing - in brief**

We are exploring options that would enable both licensed mobile and Wi-Fi users to access the upper 6 GHz band (6425-7125 MHz). To achieve this objective, we propose to:

- Identify appropriate hybrid sharing mechanisms to facilitate coexistence between licensed mobile, Wi-Fi and, where appropriate, existing users of the band;
- Encourage the development of technology-based coexistence solutions such as managed databases and enhanced dynamic sensing;
- Continue pressing for international harmonisation of hybrid sharing of the band to enable economies of scale for equipment.

We seek comments from interested stakeholders on both the principle of hybrid sharing and on the practicalities of its implementation.

1.7 This consultation is not seeking views on the upper 6 GHz band in relation to WRC-23 agenda item 1.2[2]. Our current position on that agenda item is set out in our December 2022 Update on the upper 6 GHz band.

## Potential benefits of hybrid sharing

1.8 With growing demand for spectrum from a range of new and existing services and applications it is likely to become harder to justify awarding bands for the *de facto* exclusive use by a single application, such as licensed mobile.

1.9 As noted in our Spectrum Strategy Statement, it is more important than ever that spectrum is used efficiently to maximise the benefits for consumers and business, and to support further innovation.

1.10 One important way to secure increased efficiency is to promote greater sharing of spectrum between different users, wherever possible. New technologies are enabling more efficient ways of supporting coexistence between different services; the innovative hybrid sharing mechanisms we are exploring for the upper 6 GHz band will likely be relevant to many other frequency bands (for example, bands under discussion for 6G mobile in the 7-24 GHz and THz ranges).

1.11 Hybrid sharing in the upper 6 GHz band has the potential to increase utilisation of the spectrum by leveraging the particular characteristics of the frequencies and the different patterns of use of licensed mobile and Wi-Fi, for example:

- **Indoor outdoor split.** Wi-Fi access points tend to be deployed indoors – carrying localised indoor traffic tethered to a fixed broadband service, whereas mobile base stations are predominantly located outdoors – providing wider area coverage (including indoor connectivity). Therefore, we want to explore the possibility of enabling the indoor use of Wi-Fi (or other low power licence

[2] WRC 23 Agenda Item 1.2: to consider identification of the frequency bands 3.300-3.400 MHz, 3.600-3.800 MHz, 6.425 – 7.025 MHz, 7.025-7.125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 245 (WRC-19).

exempt technologies such as 5G NR-U) whilst also enabling licensed mobile use outdoors.

- **Geographical sharing.** The bulk of data traffic in mobile networks tends to be concentrated in a relatively small proportion of sites. It might be possible to enable licensed mobile use in specific high-traffic locations whilst allowing Wi-Fi use elsewhere. It might also be possible to prioritise Wi-Fi use in specific areas of high demand whilst allowing mobile use in other areas.

1.12 These two examples are not necessarily mutually exclusive, and a practical implementation of hybrid sharing may include both (and may also include other elements we have not yet considered in detail).

## Hybrid sharing mechanisms

1.13 Hybrid sharing will require the use of mechanisms to manage coexistence between the different Wi-Fi and licensed mobile technologies. We set out several such mechanisms and how they could be used along with some of their advantages and disadvantages. These include:

- **Use of managed databases**: Enabling a prioritised use by Wi-Fi or licensed mobile in a particular area in the presence of the other service, controlled through a centralised database.
- **Modifications to sensing and channel access**: For example, Wi-Fi currently chooses when to transmit based on whether or not it detects other nearby users in the channel. However, Wi-Fi does not detect mobile signals in the same way as it detects other Wi-Fi signals: an enhancement of the current protocols may facilitate coexistence between Wi-Fi and licensed mobile.

1.14 The optimal solution may need a combination of mechanisms. It may also require some additional technical constraints on one or both sides – for example tighter power limits on licensed mobile.

## Incumbent use of the band

1.15 The analysis we have conducted so far indicates that coexistence between fixed links and licensed mobile base stations deployed outdoors is likely to be a challenge. In addition, unconstrained, licensed mobile use may have some level of impact on fixed satellite services and other incumbent uses depending, for example, on power levels. Use of low power Wi-Fi indoors is much less likely to pose a risk of harmful interference to incumbent services.

1.16 Hybrid sharing mechanisms could help facilitate coexistence with some incumbents, for example with databases. However, there is a risk that at least a partial clearance of fixed links from the band may be needed were we to allow licensed mobile use in particular areas.

1.17 We will need to ensure that any future course of action that we contemplate will consider the impact on incumbents and is proportionate and objectively justified in line with our statutory duties. We will therefore conduct a more comprehensive analysis once we are ready to consult on specific implementation proposals.

## International harmonisation

1.18 Any hybrid sharing mechanisms required will likely need certain features and capabilities implemented in devices and/or network equipment for which international harmonisation is important to create economies of scale. This will provide an incentive for equipment manufacturers to integrate hybrid sharing mechanisms in a way that would be unlikely for UK-specific requirements.

1.19 If harmonised across Europe, hybrid sharing could also allow flexibility for different countries to decide how they prioritise licensed mobile and/or Wi-Fi depending on their individual needs. We have initiated work with other European administrations in the European Conference of Postal and Telecommunications Administrations (CEPT) on a harmonised approach to hybrid sharing.[3]

1.20 This CEPT work is scheduled to complete in early 2025, though we are hopeful that the main elements should be stable towards the end of 2024 when the report on the work goes out for public consultation. Responses to this consultation will help us drive that international work.

1.21 Our work with other European administrations to develop harmonised hybrid sharing mechanisms will continue after WRC-23, regardless of the outcome of WRC-23 on agenda item 1.2.

[3] ECC Work Item PT1_50: Feasibility and sharing studies on the potential shared use of the 6425-7125 MHz frequency band between MFCN and Wireless Access Systems including Radio Local Area Networks (WAS/RLAN).

# 2. Introduction

## Background

2.1 In our December 2022 Update on the upper 6 GHz band, we said we could see potential consumer benefit from making the frequencies available for either higher power licensed mobile[4] or from lower power Wi-Fi[5] and other licence exempt uses. We explained that the competing cases were finely balanced.

2.2 We said we planned to investigate the potential options for a "hybrid" approach, where both Wi-Fi and licensed mobile would share access to the band.

2.3 We also published a conclusions paper on Ofcom's future approach to mobile markets and spectrum in December 2022 where we said that the mobile network operators (MNOs) are likely to use a range of approaches to deliver more capacity to meet demand. This includes technology upgrades; making more extensive use of their (existing) spectrum holdings; and increasing the number of sites where additional capacity is needed (densification).

2.4 We said we expected MNOs to continue using alternative solutions to manage traffic, such as making use of Wi-Fi where it is available, particularly for indoor data traffic. We indicated that we remain open minded on options for additional spectrum for mobile use, if needed, including looking at the upper 6 GHz band.

2.5 In this consultation, we explore the options for a hybrid sharing approach that would enable the introduction of both Wi-Fi and licensed mobile in the upper 6 GHz band.

## Traffic carried by licensed mobile and Wi-Fi networks is growing

2.6 We have seen a significant growth in traffic on both mobile broadband and Wi-Fi networks over the last decade, a trend we expect to continue.

2.7 Between 2013 and 2022, licensed mobile traffic grew on average by approximately 40% year on year, a similar growth rate to the average fixed broadband growth in the same period.[6] Although our latest annual Connected Nations report shows this rate of increase slowing, it still stood at 27% between 2021 and 2022. The report also shows that the average *fixed* traffic growth rate was 6% for the same period, see Figure 1.

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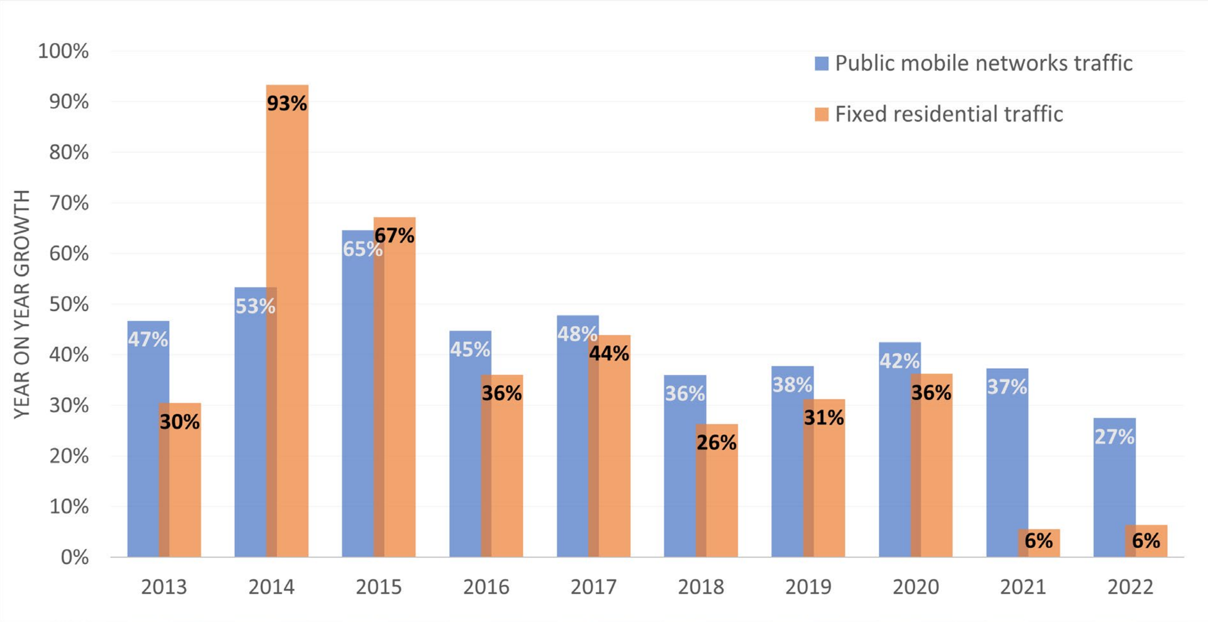
[4] By "licensed mobile" we mean provision of wide area mobile services by the commercial mobile network operators (MNOs) (using technologies such as 4G and 5G), mostly from outdoor base stations. Spectrum used by these types of networks is usually authorised under a Wireless Telegraphy Act licence. For simplicity, we sometimes refer to this as "mobile".

[5] For simplicity, we use "Wi-Fi" as shorthand for a family of radio local area network (RLAN) and similar licence exempt technologies, of which Wi-Fi is the most well-known example. Licence exempt uses also includes low power technologies that might be deployed as part of an MNO network such as 5G NR-U, and device to device communications which could be deployed when we refer to Wi-Fi.

[6] We use fixed broadband traffic (residential broadband traffic from Ofcom's Connected Nations data, from 2012 to 2021) as a proxy for Wi-Fi traffic growth. We do so there is a significant and stable proportion of fixed traffic being carried over Wi-Fi. See ASSIA, State of Wi-Fi Reporting, 2021.

**Figure 1 Year-on-year evolution of growth in traffic of mobile and fixed networks, 2013-2022. (Fixed residential broadband traffic growth is used as a proxy for Wi-Fi).**[7]




2.8 We expect that demand will continue growing but the rate of that growth is highly uncertain. Long-term growth trends are hard to predict because they are dependent on various factors, including new use cases and applications as well as improvements in coverage and data speeds.

2.9 There is a level of overlap between the drivers of mobile and Wi-Fi traffic growth, including video sharing and social platforms, streaming, and the growth of cloud-based services. Many of these can be delivered over mobile or Wi-Fi, often giving consumers the flexibility to choose between the two.

2.10 Depending on the circumstances and the specific nature of the application being used, either Wi-Fi or licensed mobile networks may be better suited – for example, in many indoor static situations using Wi-Fi may be more appropriate, whereas outdoors or where wide area mobility is needed licensed mobile may be the best choice.

2.11 Mobile offloading to Wi-Fi has become increasingly prevalent in recent years. As mobile data usage continues to rise, Wi-Fi networks provide an attractive option for offloading some of this traffic in certain indoor locations. This is because they might offer better quality of experience, provide coverage in hard-to-reach locations where mobile can't get to, or be more cost effective.

2.12 UK MNOs already support Wi-Fi calling, meaning that users can make calls and send messages over Wi-Fi networks when they are connected.[8] As a result, ensuring a seamless handover between Wi-Fi and mobile networks is becoming more important. In response to

[7] We note there have been changes in the methodology applied in different reports in the period 2013 to 2022, but we do not consider these have a significant impact on the overall year-on-year growth rates.

[8] VM-o2, BT/EE, Vodafone UK and Three UK all offer Wi-Fi calling.

this, 3GPP has been working on standardised protocols for handovers between the two technologies.[9]

## There is competing industry interest in the upper 6 GHz band for addressing this traffic growth

2.13 There is a great deal of uncertainty around how demand for wireless data will grow over the next decade – and what the role of the upper 6 GHz band might be in supporting this. We understand that it could be used, for example:

a) **To increase mobile capacity in macro-sites:** Some stakeholders, including MNOs, have expressed the view that the upper 6 GHz band is crucial to provide operators with a more cost-effective solution to address congestion in mobile macro-cell networks. Some parts of the mobile industry have indicated that advances in antenna technology mean the upper 6 GHz band could be deployed on macro-sites and obtain a similar level of outdoor and indoor coverage as the 3.5 GHz band.

b) **To meet mobile demand in key areas:** Some MNOs believe that demand for this band will be determined by the rate of 5G rollout and the consequent increase in new mobile (5G) use cases later in the decade, driving demand in specific hotspots. Some of these areas present latent demand already (evidenced by a sudden rise in traffic when sites are upgraded), where parts of the industry predict additional spectrum will be needed in the next few years.

c) **For deployment on a small cell layer to increase capacity:** Some MNOs, such as BT/EE, have previously signalled that the upper 6 GHz band would be a valuable option for use on small cells, noting that it would enable their efficient deployment.[10] Whilst we recognise that use on macro-sites may be the MNOs' current preference, there could be an opportunity for them to deploy the upper 6 GHz band on small cells at lower powers to offload traffic from congested lower frequency bands.

d) **To improve end-user experience in Wi-Fi networks:** This is especially important given the country's fibre roll-out efforts. Some stakeholders have said they are already experiencing congestion[11] and would require the entire 6 GHz band to address forecast demand and maintain quality of experience.

e) **To improve Wi-Fi performance in enterprises:** Congestion might be particularly noticeable in locations with a high concentration of businesses and enterprises, where additional Wi-Fi spectrum could support the use of up to seven 160 MHz channels across the whole 6 GHz band. [12]

f) **To drive innovation through access to wide Wi-Fi channels:** We are aware of multiple examples of innovation that could be boosted by access to wide bandwidth channels

[9] For example, N3IWF (Non-3GPP/N3 Interference Interworking Function) in 3GPP.
[10] BT response to Ofcom discussion paper: Meeting future demand for data, February 2022
[11] Congestion on 2.4 GHz and 5 GHz Wi-Fi bands.
[12] When trying to provide contiguous coverage over an enterprise, Wi-Fi works better when it can access several different non-overlapping channels where each channel can be used in different locations within the building – with stakeholders noting 7 channels is often the optimal solution.

across the whole 6 GHz band, including AR and VR, and device-to-device communications. These innovative uses differ in nature, but they share a common set of requirements in order to provide a consistent quality of experience e.g. fast data speeds, very low delay, the ability to connect a large number of devices.

## The upper 6 GHz band is not the only route to enabling future growth and innovation

2.14 We recognise the potential to increase consumer benefit from these industries accessing this spectrum. However, there are alternatives available. In particular:

a) As outlined in our December 2022 conclusions paper, we understand the band can increase capacity on mobile networks, but we also acknowledge there are several ways in which operators could provide additional capacity over the next ten years including through the deployment of mmWave spectrum. There are also ongoing initiatives in industry to explore additional bands that could be identified for 6G mobile in the future, particularly parts of the 7-24 GHz range.

b) There are also alternatives that ISPs and industries relying on licence exempt wireless technologies can explore, such as upgrading devices to the latest standards or offering Wi-Fi boosters and mesh network solutions to improve Wi-Fi coverage.[13] There is also scope for existing Wi-Fi bands (e.g. the 5 GHz bands (5150–5350 MHz and 5470–5850 MHz) and the lower 6 GHz band (5925–6425 MHz) to be further utilised to support increasing traffic and new applications on Wi-Fi networks.

## There are stakeholders already using the upper 6 GHz band for existing services

2.15 In the UK, the upper 6 GHz band is already being used for a variety of existing services. Some are licensed, including Fixed Links and Fixed Satellite Services and Programme Making and Special Events (PMSE). Other services are unlicensed, including space science uses like Earth Exploration Satellite Services (EESS) and Radio Astronomy, and short-range devices, such as radio determination devices and radar level gauges.

2.16 Most of the incumbent uses of the band operate outdoors and are distributed across the country. Any new uses would need to coexist with these, unless the band is fully or partially cleared, or we introduce coexistence mechanisms between incumbents and new users of the band.

2.17 Section 5 of this document gives an initial view of the coexistence impact that (higher power) outdoor licensed mobile and indoor Wi-Fi may have on incumbents. Any future consultation on the implementation of hybrid sharing in the band will include a further, more detailed assessment of the impact on incumbents.

[13] For example: BT Whole Home Wi-Fi, Virgin Media 'Intelligent Wi-Fi' [accessed 15 05 2023].

## Legal background

2.18 Our principal duties under the 2003 Communications Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (amongst other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

2.19 Ofcom is responsible for authorising use of radio spectrum. We permit the use of the radio spectrum either by granting wireless telegraphy licences under the Wireless Telegraphy Act 2006 (the "WT Act"), or by making regulations exempting the use of particular equipment from the requirement to hold such a licence.

2.20 It is unlawful and an offence to install or use wireless telegraphy apparatus without holding a licence granted by Ofcom unless the use of such equipment is exempted. In Annex A5 we set out in more detail the relevant legal framework, which we have taken into account in making the proposals set out in this document. This annex should be treated as part of this document.

## Impact Assessment

2.21 We are mindful of the impact of our hybrid sharing proposals, which explore options that would enable both licensed mobile and Wi-Fi users to access the upper 6 GHz band (6425-7125 MHz).

2.22 We discuss the potential benefits that a hybrid sharing approach could bring to consumers and businesses in Section 3 of this document. However, we have not yet undertaken a full impact assessment of the options because we have not yet fully developed specific proposals for the optimal future use of the band.

2.23 We have undertaken some preliminary analysis as part of this consultation which may form part of a future full impact assessment. This includes:

- We have carried out an initial assessment of the potential coexistence impact that (higher power) outdoor licensed mobile and indoor Wi-Fi may have on incumbents. Once we have developed more specific proposals on the introduction of hybrid sharing in the upper 6 GHz band, we will conduct a full impact assessment of those proposals.
- In preparing this document, we have considered the citizen and consumer interests relating to technologies supporting wireless broadband growth and innovation. As part of our ongoing work on enabling hybrid sharing in this band, we are also considering the impact on existing users of the upper 6 GHz band, and on service providers, manufacturers and users of devices and applications.

2.24 Ofcom is an evidence-based organisation, and we welcome responses to this consultation. Any comments about our assessment of the impact of our proposals should be sent to us by the closing date for this consultation. We will consider all comments before deciding how to proceed. For further information about our approach to impact assessments, see the guidelines 'Better policy making: Ofcom's approach to impact assessments' on our website.[14]

### Equality Impact Assessment

2.25 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects, and practices on the following equality groups: age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion or belief, sex, and sexual orientation.

2.26 Equality impact assessments also assist us in making sure we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity. We consider that our proposals would not be detrimental to any of the defined equality groups: our proposals aim to improve the benefits for all consumers.

2.27 We have not carried out separate equality impact assessments in relation to the additional equality groups in Northern Ireland: religious belief, political opinion, and dependents. This is because we anticipate that our proposals would not have a differential impact in Northern Ireland compared to consumers in general. We welcome any stakeholder views on this assessment.

## Structure of this document

2.28 The structure of the rest of this document is as follows:

- **Section 3:** Explains why we think that hybrid sharing in the upper 6 GHz band has the potential to maximise benefits for consumers and businesses in the UK.
- **Section 4:** Presents our views about the need for new spectrum management mechanisms to facilitate sharing and manage coexistence challenges. It outlines the mechanisms available and how these could enable hybrid sharing.
- **Section 5:** Presents our initial high-level analysis of the ability of outdoor mobile and indoor Wi-Fi to share with incumbents.
- **Section 6:** Sets out our next steps in relation to the upper 6 GHz band and the ongoing international work on hybrid sharing.
- **Annex A7:** Presents our initial measurements and analysis of the potential for mobile to share with Wi-Fi in the upper 6 GHz band.
- **Annex A8:** Provides information on our in-building coverage measurements.

[14] Ofcom have recently proposed changes to the Impact Assessment guidance to align with our current approach to assessing impacts. A final version of this assessment is expected in summer 2023.

# 3. Hybrid sharing of upper 6 GHz has the potential to maximise consumer benefits

## Introduction

3.1 Our overall objective when considering the future use of the upper 6 GHz band is to maximise the benefits to people and businesses. We believe the best way to achieve this is via hybrid sharing that enables the introduction of both mobile and Wi-Fi, whilst mitigating the impact on existing users.

3.2 The alternative to this would likely mean making a choice between using the band for either licensed mobile or Wi-Fi. Making a choice now would mean losing the entire benefits of the alternative. Whilst hybrid sharing may limit some of the benefits of each use individually, we believe the combined benefits could be greater overall.

3.3 For example, if we were to decide that indoor Wi-Fi use was likely to generate the greatest benefits for people and businesses, there would be clear additional benefit from also allowing some licensed mobile use outdoors - even if we needed to place some constraints to ensure coexistence.

3.4 In this section, we identify some options we could explore for hybrid sharing in the upper 6 GHz band and discuss how these could lead to benefits from greater spectrum utilisation.

3.5 In the following section (Section 4) we consider how the different mechanisms that could facilitate hybrid sharing might work in practice.

## Hybrid sharing to facilitate Wi-Fi indoors and mobile outdoors

3.6 Wi-Fi and licensed mobile networks are typically deployed in different ways although they are often used to provide the same or similar services, such as wireless broadband access to phones, laptops, TVs and many other devices.

3.7 Wi-Fi access points tend to be deployed indoors, carrying localised indoor traffic tethered to a fixed broadband service. In contrast, mobile base stations are mainly located outdoors, providing wider area coverage (both outdoors and indoors). Combining Wi-Fi use indoors with licensed mobile use outdoors could have greater total benefits than choosing one or the other.

3.8 The majority of licensed mobile and Wi-Fi traffic is to or from devices located indoors.[15] However, Wi-Fi carries significantly more traffic than licensed mobile, serving a wide set of devices in addition to mobile handsets (e.g. games consoles, TVs, and other smart devices in the home).

3.9 Mobile data provision is subject to capacity constraints, and mobile providers typically charge a premium for higher data usage; consumers may respond to this premium by using

[15] 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. [accessed 09/06/2023]

Wi-Fi where possible. The average mobile user consumes 8 GB of data a month; the average fixed connection sees around 482 GB of traffic, per month.[16]

3.10 Today, more than 90% of premises have indoor coverage for 4G[16], but actual indoor performance can vary by premises depending on a variety of factors including the thickness of the walls, the building materials used in construction, and where in a building people are using their devices.

3.11 The frequency band used to deliver indoor coverage also has a significant impact, with lower frequencies typically being able to reach deeper into buildings due to their more advantageous propagation characteristics and lower building entry losses.

3.12 Mobile operators have indicated that they would like to use the upper 6 GHz band on existing macro-sites where the 3.4–3.8 GHz frequency bands have been deployed to provide additional capacity as needed (including to users indoors). Mobile operators and vendors point to improvements in antenna technology, such as higher order massive MIMO antennas, allowing upper 6 GHz spectrum to achieve a similar level of indoor coverage to the 3.4–3.8 GHz band. Some mobile operators have also said they might use the band on small cells in areas of particularly high demand.

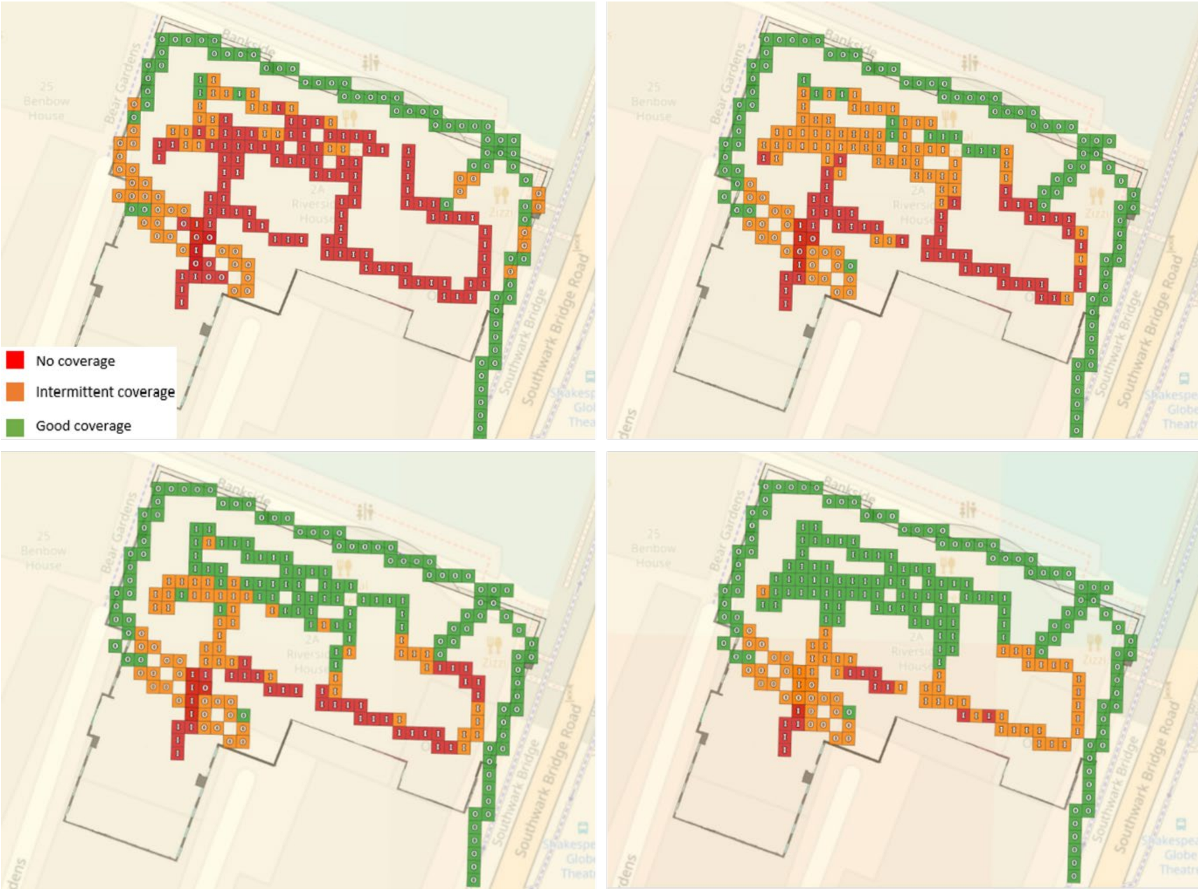
3.13 Whilst it is clearly important for mobile networks to provide good indoor coverage from their outdoor base stations, the upper 6 GHz band may not be the best band for this purpose because the level of indoor coverage achieved may be relatively modest, particularly in thermally efficient buildings.

3.14 As an example, Figure 2 shows the result of measurements we made in the 3.4-3.8 GHz band of signal levels delivered by the four MNOs in and around the lower levels of Ofcom's central London headquarters – which our measurements show has building entry losses that are similar to those of a thermally efficient building[17] (see Annex A8 for more details).

3.15 Whilst we cannot say if these measurements are representative of all thermally efficient buildings, they illustrate that due to the additional building entry loss, the signal level indoors (shown as "I" in the figure) can be significantly lower than the level measured outdoors (shown as "O") at street level. [18,19]

[16] Ofcom, Connected Nations Report 2022 and Communications Market Report 2022.
[17] In comparison to the theoretical curve for thermally efficient buildings from Recommendation ITU-R P.2109
[18] We have classified the likely performance of the 3.4 GHz network as "good" (signal level between 0 and -100 dBm), "intermittent" (level between -100 and -115 dBm) and "no coverage" (level lower than -115 dBm). Intermittent means that signal strength fluctuates depending on traffic loading, time of day, etc.
[19] Some outdoor measurement points appear to be inside the building due to a combination of GPS accuracy, pixel size (2m x 2m) and the fact that parts of the building overhang the street.

**Figure 2 Mobile signal strength measurements in the 3.4 GHz band inside and outside Ofcom Riverside House office for the four MNOs**




3.16 MNOs could deploy the band on outdoor base stations to provide additional capacity (predominantly outdoors) whilst we also enable use of Wi-Fi indoors. We note this may require the deployment of coexistence mechanisms to avoid interference at the overlap.

3.17 Indoor mobile services could also benefit indirectly, as the additional outdoor capacity provided by upper 6 GHz spectrum could reduce the load on MNOs' other, lower frequency bands that are better suited to providing indoor coverage. MNOs could also make use of licence exempt technologies indoors in the upper 6 GHz band by using Wi-Fi offload or 5G NR-U.

3.18 We discuss how building entry losses can be exploited to enable hybrid sharing in more detail in Section 4.

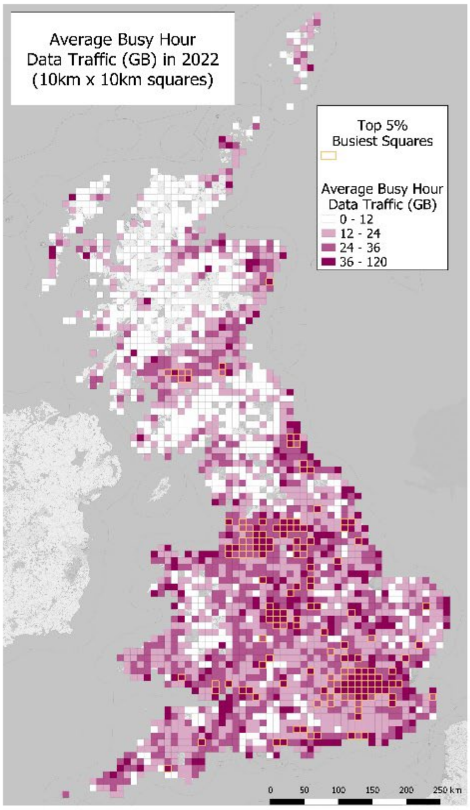
**Question 1:** Hybrid sharing could mean that the upper 6 GHz band will be used for mobile outdoors, and Wi-Fi indoors. What are your views on the priorities for each of these two services, assuming that suitable coexistence mechanisms are developed?

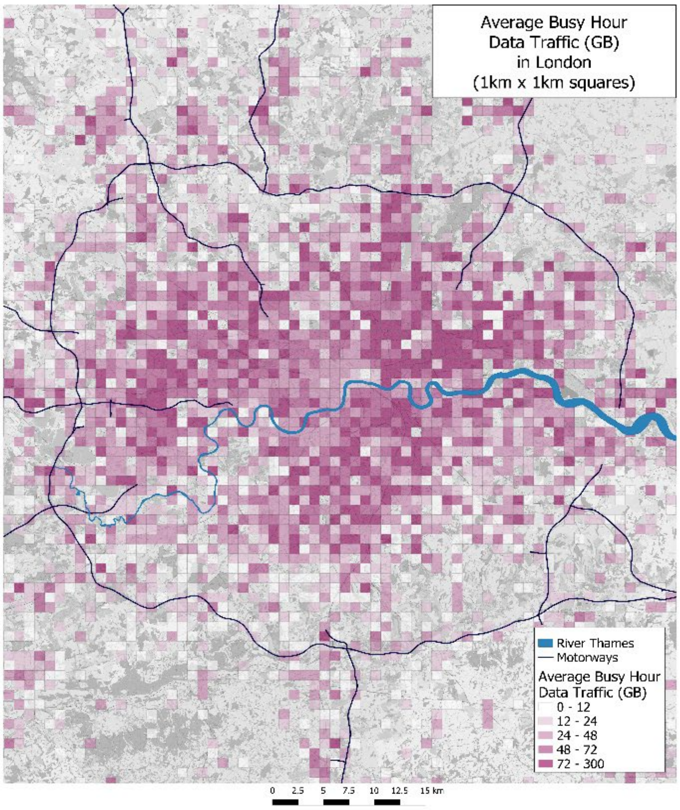
## Hybrid sharing through the definition of areas of priority and opportunistic use

3.19 As noted in our December 2022 Future approach to mobile markets document there is a high level of concentration of licensed mobile traffic in areas of high footfall, mostly around dense urban environments. MNOs respond to this by deploying extra spectrum bands (e.g. 3.4-3.8 GHz) to provide additional capacity. These capacity deployments are typically focused on a subset of locations, creating the scope for the spectrum in other locations to be used for other purposes, such as Wi-Fi.

3.20 Figure 3 shows this uneven distribution, where most of the mobile traffic is concentrated in a small number of areas in the country.[20]

**Figure 3 Average busy hour data traffic in GB - May 2022 (UK wide and Greater London)[21]**




3.21 Data from May 2022 showed that around 60% of mobile traffic was contained in approximately 5% of the geographic area of Great Britain (see the left-hand side of Figure

[20] We note that the maps included in Figure 2 and Figure 3, and the histogram shown in Figure 4 provide only a snapshot of data recorded over a specific time (May 2022 for Figure 2, the right-hand map of Figure 3 and Figure 4, and May 2018 for the left-hand map of Figure 3), more recent traffic data may be different.

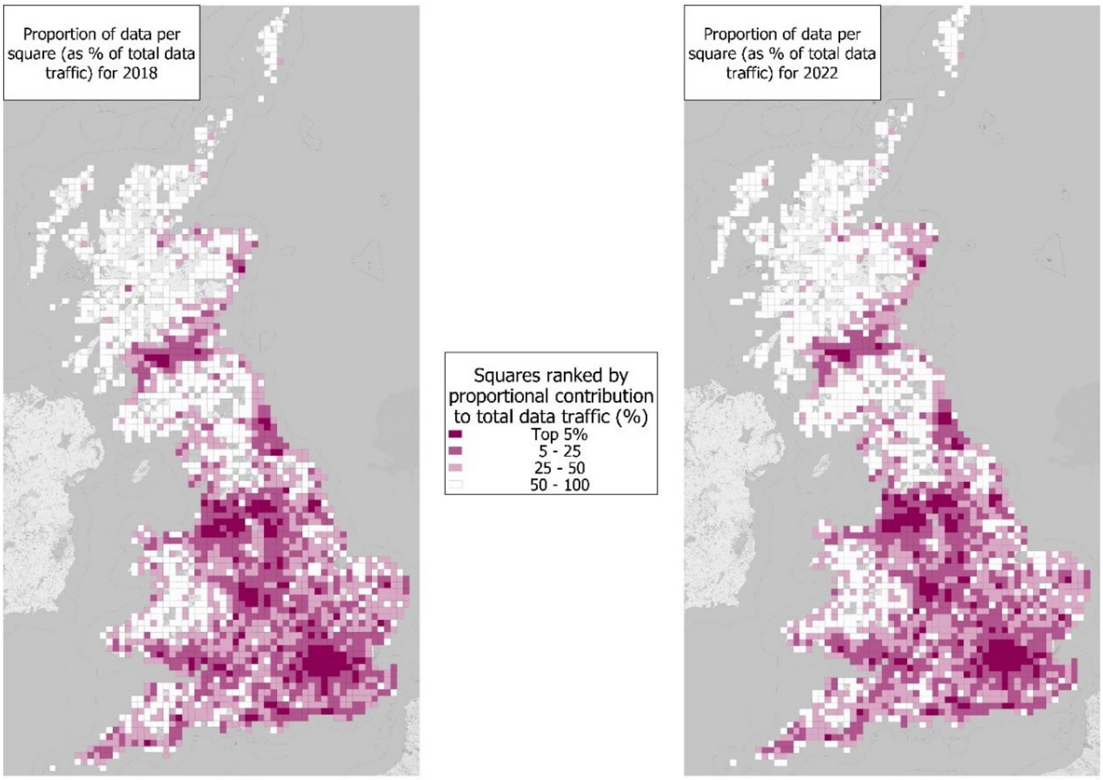
[21] Legend and scale are different in the left- and right-hand sides of the graphs, this is due to significant different average traffic levels when averaging out in sites located in 10km x 10km and 1 km x 1km squares.

3).[22] Even within busy areas, there is still a large variability in the distribution of traffic when looking at a more granular level (see the area inside the M25 – right-hand side of Figure 3).[23]

3.22 We also see that, nationwide, most of the traffic is generated from a small proportion of sites (around 20% sites carry more than half of the total data traffic). These sites are generally located in busier areas, although even within the busiest areas there is also a proportion of less busy sites.

3.23 We also note that, whilst the volume of mobile traffic has significantly increased over time, the areas where traffic is concentrated have remained largely unchanged. See Figure 4 for a comparison between 2018 and 2022.

**Figure 4 Proportion of data per 10kmx10km square (as % of the total traffic), 2018 and 2022**




3.24 The MNOs take this uneven spread into account in their network deployments. In general, the busiest sites tend to have four or more bands deployed. In contrast, the least busy areas typically make use of only two or three bands.

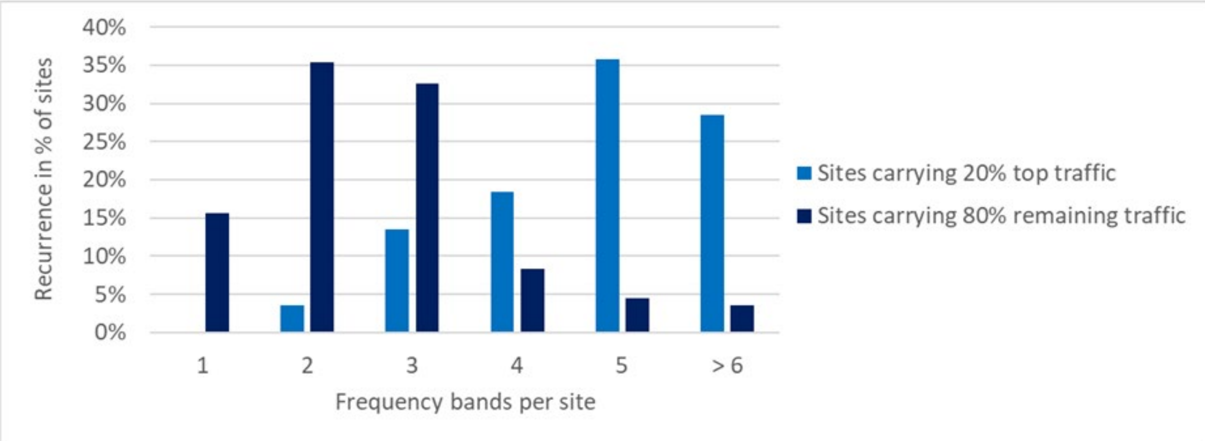
3.25 Figure 5 shows how frequency bands are distributed among different sites. There are, however, different factors that influence how mobile operators decide to configure their sites and choose which frequency bands to deploy. These factors include interference with

[22] 10km x 10km squares covering Great Britain.

[23] 1km x 1km squares, still larger than the average inter-side distance (ISD) in Greater London.

nearby sites, the weight and wind load of the equipment, planning permissions, and considerations around ICNIRP compliance.[24]

**Figure 5 Distribution of frequency bands deployed per sites carrying 20% and 80% of total mobile licensed traffic**




3.26 Nonetheless, operators have the scope to increase the capacity of most of their sites by adding other bands which are already licensed to them. The addition of upper 6 GHz spectrum would be useful in providing additional capacity in a subset of sites that are in the busiest areas, but it is unlikely to be needed everywhere.

3.27 As a result, we believe that hybrid sharing could allow MNOs to increase capacity using the upper 6 GHz band in specific busy areas, whilst also allowing Wi-Fi to use the spectrum elsewhere, or in places where upper 6 GHz spectrum deployed on MNOs outdoor sites does not reach (for example, in indoor and deep indoor locations, especially within premises built with thermally efficient materials with higher building entry losses).

**Question 2:** Hybrid sharing could mean that the upper 6 GHz band will be used for mobile in some locations, and Wi-Fi in others. We would like feedback on the priorities for each of these two services, assuming that suitable coexistence mechanisms are developed.

a) From the point of view of mobile, is the upper 6 GHz band most useful to provide outdoor coverage, or indoor coverage? Is it most useful in urban areas, or in those base stations that are currently carrying more traffic, or some other split?

b) Similarly, what are the priorities from the point of view of Wi-Fi deployments?

## Hybrid sharing might be more robust in the face of uncertainties around the future nature of demand

3.28 Consumer technology develops quickly, with new applications and use cases that will contribute to driving future traffic growth. It is difficult, however, to predict with certainty how this growth will evolve. It is possible to imagine future scenarios where the greatest need for additional spectrum comes from mobile networks, or from Wi-Fi and other licence

[24] The International Commission on Non-Ionizing Radiation Protection (ICNIRP) sets exposure limits for electromagnetic fields generated by radio communications devices.

exempt uses. For example, it is possible that in the future, self-driving cars could require large amounts of data delivered outdoors, in a way that seems best suited to delivery by mobile networks.

3.29 On the other hand, new applications might increase the indoor dominant distribution of traffic. These new applications could include future device-to-device communications (for example, an increasing use of AR/VR headsets indoors). Arguably, this could drive additional traffic on licence exempt spectrum.

3.30 Hybrid sharing could mitigate some of the risk of making a choice in favour of one use or another that could prove to be inefficient later. It would also provide additional capacity for both uses, as long as coexistence can be appropriately managed.

# 4. Enabling the benefits of hybrid sharing

4.1 In Section 3 we set out our reasons for believing that hybrid sharing in the upper 6 GHz band could deliver optimal use of the spectrum for the benefit of UK consumers and businesses, in line with our statutory duties.

4.2 However, we recognise there are some obstacles to overcome in order to make hybrid sharing possible. In this section we discuss the issues involved and suggest some ways of approaching them.

4.3 We begin by describing our views on the need for mechanisms to facilitate hybrid sharing between licensed mobile and licence exempt systems such as Wi-Fi. These mechanisms should, ideally, be harmonised internationally. We go on to outline some existing mechanisms and how these – or a combination of these – may be used and developed to enable different forms of hybrid sharing. We also talk briefly about how hybrid sharing may be enabled by new techniques.

4.4 We recognise that we are in the early stages of the development of an innovative approach – there are no current examples of mobile and Wi-Fi sharing a band in a similar manner. As such, we are open to a range of possible variations on hybrid sharing.

4.5 There are examples in which mobile networks use licence exempt spectrum (for example, LTE-LAA and 5G NR-U), under the same rules that apply to Wi-Fi, including the low power limit. We discuss in this section ways that could enable higher power or prioritised services in particular locations without the need for mobile to necessarily follow all the licence exemption rules.

4.6 In this section we use examples to illustrate how these mechanisms could work. Our goal is to indicate possible avenues for further study and prompt feedback – these examples are not policy proposals and are not yet fully developed technically.

## Additional hybrid sharing mechanisms will be needed to enable coexistence

4.7 We have carried out some initial analysis of the coexistence between mobile networks using outdoor macro-cells and indoor Wi-Fi systems. We have also undertaken some testing to understand how off-the-shelf Wi-Fi access points[25] perform if we set mobile signals to operate on the same frequency.

4.8 Our view is that, unmanaged, co-frequency sharing would result in an unpredictable interference environment for both networks. Even reducing the transmit power of the outdoor macro-sites may not fully resolve this, although it may reduce the number of areas and the extent of interference.

4.9 Hybrid sharing mechanisms to control spectrum access are therefore likely to be required to allow coexistence between the different networks. We discuss these later in this section.

[25] These are access points that conform to the recent Wi-Fi 6E standard.

4.10 The details of the analysis we have conducted, and the results of our testing are described in Annex A7.

## 5G mobile degrades Wi-Fi performance

4.11 Wi-Fi is an adaptive technology that adjusts its throughput in response to the quality of the spectrum channel. It also uses a protocol called Listen before Talk (LbT) to enable multiple users to share access to the spectrum. The Wi-Fi users "take turns" as one would do in a conversation – they wait for other users to stop transmitting before starting their own transmissions.

4.12 Additionally, some Wi-Fi access points use a sensing mechanism called Automatic Channel Selection (ACS) to detect and select the channel that provides the best conditions to ensure good performance.

4.13 These protocols allow multiple Wi-Fi networks (and some other licence exempt uses such as 5G NR-U) to access spectrum in an equitable way. However, our analysis shows that they might be less useful in the presence of mobile signals (which do not use either LbT or ACS) as they occupy the band more frequently, leading to poor performance or even loss of connectivity for Wi-Fi users.

## Wi-Fi also has the potential to degrade licensed mobile performance

4.14 Our modelling shows there is also a risk that emissions from a distant outdoor licensed mobile base station may not be detected by an indoor Wi-Fi system as the emissions could be received at levels below the Wi-Fi detection thresholds (as it will be attenuated by propagation and building entry losses). In this situation, Wi-Fi would continue to transmit, potentially causing interference to nearby mobile user equipment.

4.15 The extent of the degradation caused to the licensed mobile network is uncertain, as mobile networks use adaptive technology and other interference management mechanisms to adjust their performance in noisy environments. The mobile network may decide that the interference is severe enough that it moves connection with that user equipment to another channel or band.

4.16 Given that current licensed mobile networks will have several other frequency bands available to them in many locations, such a move for an individual user may not be problematic where these other bands are not congested.

## Our preliminary view on the need for coexistence mechanisms

4.17 Our analysis shows several scenarios where interference is likely to be caused to licensed mobile or Wi-Fi networks unless additional measures are put in place. We also recognise that there will be a range of scenarios where interference is less likely, even without such additional measures, for example when the loading on both networks is low.

4.18 We consider that, without additional measures, the interference to both licensed mobile and Wi-Fi operating on the same channel is likely to be unacceptable, at least in some locations and at some times, but these locations and times will be hard to predict. In our view, coexistence mechanisms and mitigation techniques are therefore necessary if we are to enable use of both licensed mobile and Wi-Fi in the band.

## A hybrid mechanism should be harmonised internationally

4.19 International harmonisation is an important factor in enabling hybrid sharing of the band. This would facilitate economies of scale, incentivising equipment manufacturers to integrate sharing mechanisms in a way that would be unlikely for UK-only requirements.

4.20 In our view, if there is no international harmonisation (e.g. across Europe), it would be less likely that consumer devices would have the upper 6 GHz band enabled for hybrid sharing in the UK, especially if there is a need to develop new hardware to make it possible.

4.21 Even if hybrid sharing does not need hardware development, harmonisation will still be important. We understand that certification of consumer devices can be costly and complex for industry. Lack of harmonisation could result in the need for multiple certification processes which reduces attractiveness if implementing a hybrid sharing approach specific to one jurisdiction.

4.22 As we explained earlier in this document, we have already started the work with other European administrations within CEPT on a harmonised approach to hybrid sharing, and we will use responses to this consultation, where appropriate, to help us progress harmonisation at a European level.

## Enabling hybrid sharing

4.23 In Section 3 we presented two potential options for hybrid sharing – an indoor/outdoor split and a geographical split with defined areas of priority. We now go on to explain the types of hybrid mechanisms that could help enable these.

4.24 In particular, we explore the following existing mechanisms, and how they may be developed further to enable hybrid sharing. We also provide some hybrid sharing examples and discuss how these would be facilitated. These mechanisms are:

- managed databases;
- spectrum sensing; and
- a combination of both.

4.25 In all cases, we expect that there will be some trade-off between the complexity of mechanisms and the extent to which different systems can use the same spectrum in relatively close proximity. These technologies could underpin (dynamic) spectrum sharing, aiming to provide gains in the efficiency of spectrum use, by allowing users to share the same spectrum by managing the times and places at which they transmit.[26]

4.26 We also discuss at high level some alternative approaches (from paragraph 4.53), noting that where existing techniques cannot be used as a starting point, development may be

[26] As we describe in our Discussion Document: Opportunities for dynamic or adaptative approaches to managing spectrum in the UK

more complex. In other cases, a simpler restriction on power or antenna beam pointing may be more appropriate (though at some loss of technical efficiency).

## Managed databases

4.27 When we talk about databases in this document, we are referring to databases that:

- know the location and characteristics of a network or devices that need to be protected from interference (the 'protected user')[27];
- receive queries from some other devices ('database user') that could potentially cause interference. These devices provide information about themselves (e.g. locations);
- use the knowledge about the protected user and the database user to determine and communicate appropriate transmit parameters (such as channel or power) that the database user is allowed to use.

4.28 Potential options for database managed access are:

- prioritising mobile in an area by control of Wi-Fi access points; or
- prioritising Wi-Fi in an area by control of licensed mobile base stations; or
- prioritising either licensed mobile or Wi-Fi at a given location by control of both services. This would also allow greater protection of incumbent services.

4.29 We note that mobile user equipment and Wi-Fi client devices are associated with a base station or access point respectively and so they may not need a database connection themselves (reducing potential implementation costs).

### Existing implementations of databases

4.30 There are already some forms of database in use or under consideration to manage Wi-Fi and licensed mobile use in other parts of the world.[28]

4.31 For example, an Automated Frequency Coordination (AFC) regime is being introduced in the US to manage coexistence between Wi-Fi users and existing fixed links in the 6 GHz band. This will enable Wi-Fi to operate outdoors at higher powers[29] where this will not have an interference impact. Similarly, the US adopted a tiered and dynamic approach in the 3550-3700 MHz band (the Citizens Broadband Radio Service, or CBRS) to enable mobile broadband and other uses alongside incumbent military systems and civilian satellite earth stations using spectrum access systems (SAS) to manage coexistence.

[27] A protected user could also be another database user that was issued transmit parameters on a first come first served basis. Whilst we focus the protection of mobile and Wi-Fi in this section, we recognise that databases could also be useful in protecting incumbent services in the band. We talk more about incumbent services in Section 5.
[28] Our March 2023 Discussion Document: Opportunities for dynamic or adaptative approaches to managing spectrum in the UK, provides a more thorough list of existing database implementations.
[29] The FCC rules will allow Wi-Fi in the 6 GHz band at 'Standard Power' (for access points this allows for a maximum E.I.R.P of 36 dBm and maximum power spectral density of 23 dBm/MHz).

4.32 In the UK, Ofcom implemented a database managed framework, known as "White Space Devices".[30] This was not designed to enable Wi-Fi or licensed mobile but used a similar design to the examples above.

4.33 We understand that AFC capability would likely be included in future Wi-Fi 6E and Wi-Fi 7 chipsets covering the whole 6 GHz band, regardless of whether that functionality is actually enabled in the device. AFC and SAS databases have many similarities in both their messaging and the type of information passed between database and transmitters. Whilst they currently have different re-query timescales, this could potentially be configured based on the requirements of hybrid sharing.

## Operation of databases in USA

| Automated Frequency Coordination (AFC) | Spectrum Access System (SAS) |
| --- | --- |
| This system would perform regular checks against a database of assignments from existing users (in the US the existing users are point-to-point links) to ensure higher powers would not cause interference. | This is a priority-based (hierarchical) approach, with multiple databases controlling access, informed by a network of sensors. |
| Should a link be detected, the quality of the Wi-Fi access points would reduce incrementally, as operations would have to remain at low power. | Using this network of sensors and database controllers the SAS facilitate the coexistence of mobile and other wireless systems alongside incumbent naval radar systems and civilian satellite earth stations. |
| Wi-Fi access points are required to have geolocation capabilities and to regularly access an AFC database for available frequency channels and maximum power. | Pre-existing users have the highest level of protection, followed by PAL holders with limited interruptions, and GAA users who can connect quickly but have lower priority and fewer safeguards. |

### How could we use databases?

4.34 As databases set transmission parameters based on the location of the user and the proximity to other database users or incumbents, they work well for sharing between different outdoor systems in different geographical areas. However, geolocating indoor systems can be difficult as GPS signals are not always available, particularly deep indoors.[31]

4.35 Databases also don't know about the localised radio environment, for example building entry losses, and so may need to rely on generic assumptions (which may need to be cautious) in setting separation distances between different users. This means that, without a detailed understanding of the building construction and precise indoor locations, they are unlikely to be useful, on their own, in enabling indoor Wi-Fi and outdoor licensed mobile in a particular geographical area.

[30] For an overview of how this framework operated, see our 2015 Statement, Implementing TV White Spaces.

[31] And other geolocation approaches (such as by reference to the known location of other radio sources) may also be impaired or not practical.

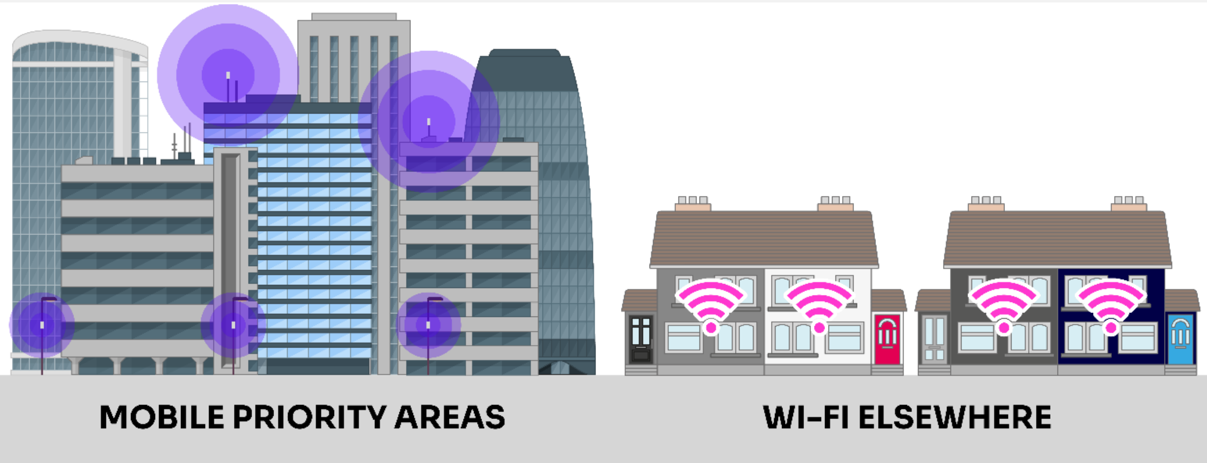
4.36 Databases have the advantage that the protected users, protected areas[32] or separation distances can be varied over time, providing some flexibility. But we recognise that this flexibility needs to be balanced with the desirability of creating a stable environment to promote investment, particularly where a user may become constrained or excluded as a result of a new user which now has higher priority. Setting clear expectations around when it is appropriate to flexibly vary key parameters will be important.

4.37 We describe below two examples where hybrid sharing could be enabled by databases.

[32] An area could be the size of a town, city, or small rectangular geographical area (a database resolution pixel).

**Example 1 – Priority areas for mobile, Wi-Fi everywhere else**

Use of AFC type databases would allow the upper 6 GHz band to be prioritised for licensed mobile in busy areas. As an illustrative example, the centre of London as defined by "Zone 1" in the London Underground map could be prioritised for mobile. This area would be defined in the database and Wi-Fi permitted in other areas. Wi-Fi access points, including those indoors, would be required to implement AFC in order to access the band and an approach to ensure that indoor access points were appropriately geolocated would be necessary.




**Example 2 – Prioritising either mobile or Wi-Fi by location or time**

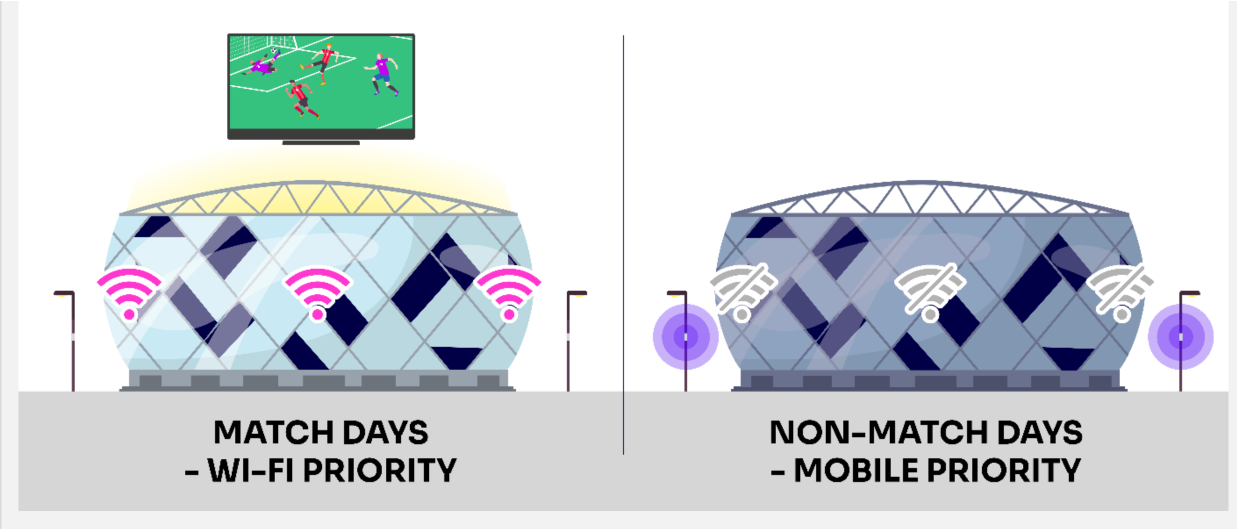
Modern football stadiums, such as Tottenham Hotspur in London, leverage both Wi-Fi and mobile technology to provide visitors and fans with high quality experiences. The 1,600 Wi-Fi access points that have been installed across Tottenham's ground allow more than 40,000 people[33] within the stadium to simultaneously stream live video during match days, as well as supporting operational systems such as digital signage, lighting, turnstile access systems, CCTV, e-ticketing, and other services during events.

If both Wi-Fi and licensed mobile use were controlled by databases, the upper 6 GHz band could be prioritised for Wi-Fi during match times (when Wi-Fi demand is high). Before and after the match and on other days, licensed mobile could be given priority instead.

This would require Wi-Fi access points (including those indoors) to implement AFC in order to access spectrum at match times; and mobile base stations to implement an SAS database interface, in order to be able to gain access, at other times. The same challenges around geolocating indoor access points exist as in Example 1.

A variant of this example would be where Wi-Fi was prioritised permanently in the stadium, in which case Wi-Fi would not need to implement any database, but licensed mobile may still need to be controlled by a database.

[33] 'HPE partners with Tottenham Hotspur to create unrivaled fan experience at new stadium' [accessed 08/06/2023]




### What additional work might be needed to help use databases for hybrid sharing?

**4.38** The existing versions of managed databases could provide a starting point for hybrid sharing, thereby saving some development time. Table 1 provides an indication of what additional work would be needed to make this possible.

**Table 1 Summary of existing spectrum databases and possible use in hybrid sharing**

| Existing implementation | What it could be used for | Potential additional work needed |
|---|---|---|
| AFC | It could be used to implement a geographic split, similar to Example 1.<br><br>The database would protect licensed mobile. | The AFC system can be adapted to protect different types of system – but some additional work would be needed to set appropriate parameters to protect licensed mobile deployments.<br><br>AFC capabilities may need to be included in all Wi-Fi routers that use the upper 6 GHz band (in the US, it is only required for routers that are placed outdoors or that use a higher power limit, known as "standard power"). Ofcom or a third party would need to develop and administer the database. Mobile operators would need to send information to databases as they deploy (alternatively the information could come from the particular local/regional areas in which each MNO is licensed to operate, but this would have less granularity than being based on individual deployments) |
| SAS | SAS could allow Wi-Fi deployments to be prioritised in a particular area. | Mobile operators would need to add the capability to query databases to base stations using the upper 6 GHz band. Some additional development would be needed to determine the parameters to be used in the database in order to protect Wi-Fi deployments.<br><br>As with AFC, a database administrator would be needed.<br><br>Wi-Fi deployments that wanted protection would need to be notified to the database, which would be a requirement on an otherwise licence exempt use. |

| Existing implementation | What it could be used for | Potential additional work needed |
|---|---|---|
| SAS combined with AFC | Combining SAS with AFC could allow a more flexible mechanism at a given location with priority between Wi-Fi and mobile changing over time, as in Example 2 above | One way to implement this example might be via modifications to existing AFC or SAS designs. A combined solution could consist of a single database with two interfaces, one for Wi-Fi access points, and one for mobile base stations. A single database could therefore be configured to prioritise either mobile or Wi-Fi within a given area. It would also be possible to adjust that prioritisation by location, time of day or for it to evolve as demand drivers change.<br>The work described above for AFC and SAS would also be required. |

**Question 3:** What are your views on a modified AFC or SAS-type approach to enable hybrid sharing? What additional work do you think would be required?

## Spectrum sensing

4.39 When we talk about spectrum sensing in this document, we are referring to techniques that allow equipment to sense when spectrum is being used by others and assess if it is quiet. This can be done based on time, frequency or both.

### Existing implementations of sensing protocols

4.40 Time-based sensing is based around the Listen before Talk (LbT) protocol and is a requirement of some licence exempt devices, such as Wi-Fi. Licence exempt versions of mobile, such as 5G NR-U, also have to screen the channel prior to transmission when accessing licence exempt spectrum.

4.41 Other sensing mechanisms are currently implemented in Wi-Fi for some bands or will be included in future revisions of the Wi-Fi standard, such as in Wi-Fi 7. Some, such as Dynamic Frequency Selection (DFS) and Automatic Channel Selection (ACS) enable Wi-Fi access points to change frequency when other users are detected. Others, such as basic service set colouring or pre-amble puncturing allow other users in all or part of the channel to be avoided. We summarise these in Table 2.

**Table 2 Summary of potential sensing mechanisms**

| Protocol | Description |
|---|---|
| Listen Before Talk | A protocol implemented in Wi-Fi, where all Wi-Fi devices listen for transmissions and only transmit if the relevant channel is quiet. If the channel is occupied, then the device trying to gain access must wait (back-off) for a random period before trying again.<br>The protocol is also used by 5G NR-U to allow mobile networks to access licence exempt spectrum. |

| Protocol | Description |
|---|---|
| Automatic Channel Selection (ACS) | Where implemented, a Wi-Fi access point will scan all available channels for other access points or sources of interference; ranks the channels in terms of how busy they are, and then selects a less congested one. |
| Dynamic Frequency Selection (DFS) | DFS is an automated system which facilitates spectrum sharing between radar and other wireless technologies, based on measurements undertaken by the equipment seeking to transmit in the band. In the 5.8 GHz band, DFS-enabled Wi-Fi devices scan the band for radar-free channels on which to operate, switching channels when they detect radar activity to avoid harmful interference. |
| Basic Service Set colouring (BSS colouring) | A feature added in Wi-Fi 6 allowing access points to determine whether there can be simultaneous use of the same channel, even in the presence of other signals. Uses a 'colour code' allowing devices to quickly identify local traffic and effectively 'tune out' noise from other nearby networks. |
| Preamble puncturing[34] | A new feature mandated in Wi-Fi 7 that allows an access point to still transmit using parts of a wider bandwidth channel which do not use certain frequencies within the channel (frequencies are punctured) to avoid narrower interfering signals. |

### How could we use sensing protocols?

4.42 Enhanced sensing might play an important role in enabling Wi-Fi to operate indoors in the same areas as mobile is operating outdoors. The signal loss between indoors and outdoors (building entry loss) will vary widely depending on building construction and the location of the access point indoors.

4.43 A hybrid mechanism based on sensing can exploit the situations with higher building entry loss and take advantage of those hyper-local conditions such as thick walls and metalised windows. An equivalent level of granularity is unlikely to be practical via a database approach, as it would require data collection about these types of characteristics on a premises-by-premises level.

4.44 We describe below an example where hybrid sharing could be enabled by sensing.

### Example 3 – enabling indoor Wi-Fi even in mobile priority areas

In this example, we would authorise licensed mobile to operate at higher power in some priority areas and would rely on enhanced sensing protocols on the Wi-Fi side to ensure that it would be able to detect local use of mobile and react immediately, to avoid causing or suffering interference.

Where there are higher building entry losses, or mobile base stations are some distance away, then the mobile signal strength inside the building may be weak and indoor Wi-Fi could operate without suffering significant interference. In this case, there is likely to be a high probability that any indoor

[34] Immediately before transmitting data, Wi-Fi devices transmit a known sequence of symbols, or "preamble". The function of the preamble is to allow synchronisation and other necessary tasks for data transmission. "Preamble puncturing" uses the preamble to detect a narrower interfering signal which can then be avoided. It is an optional capability in the Wi-Fi 6 standard but has not been widely adopted in Wi-Fi 6 devices.

devices using licensed mobile spectrum will be on lower frequency bands than the upper 6 GHz band and so are unlikely to suffer interference from Wi-Fi.

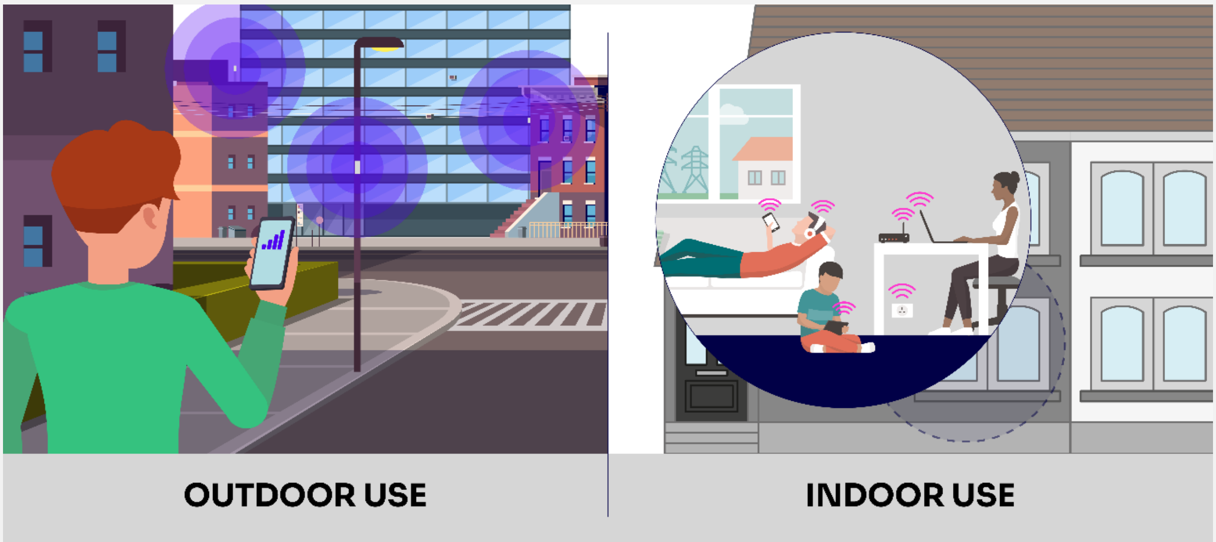
However, when the upper 6 GHz mobile signal is stronger indoors then it is important that Wi-Fi avoids using the mobile frequencies when mobile is transmitting. We think that improvements in Wi-Fi's ability to sense mobile signals will be needed to achieve this.

There are a range of approaches that could be taken, including requiring mobile base stations to transmit a preamble that Wi-Fi networks can detect.

In addition to detecting the mobile signal, Wi-Fi devices should be better at responding than they are today. This may be to use gaps in the mobile transmission or to avoid the frequencies used by mobile or to switch channel completely. For example, puncturing certain overlapping frequencies or using enhanced versions of DFS/ACS.

Extending this further, to give Wi-Fi priority indoors, may also require mobile handsets using the upper 6 GHz band to sense when they are indoors close to a co-channel Wi-Fi network, and report that to the mobile network so that they use an alternative channel or band. Whilst mobile handsets may not normally track whether they are indoors, there may be acceptable proxies, for example indicators of low channel quality.

In this example, Wi-Fi access points near to the window might end up using lower 6 GHz spectrum whereas those deeper indoors could make use of upper 6 GHz channels, enabling a greater number of wider channels to be used throughout the building; in areas where one or more MNOs have not deployed the band, Wi-Fi would be free to use any available upper 6 GHz spectrum.




### What additional work might be needed to help use sensing protocols for hybrid sharing?

4.45 As with databases, the existing versions of sensing protocols can provide a starting point for the development of hybrid sharing, see Table 3 for a summary.

**Table 3 Sensing protocols that could support hybrid sharing**

| Existing implementation | What it could be used for | Additional work needed |
|---|---|---|
| Listen Before Talk | In the 5 GHz band, both Wi-Fi and 5G NR-U use the same detection threshold based on the principle that 5G NR-U should not cause any more impact to an existing Wi-Fi access point than would be the case if another access point was introduced.<br><br>5G NR-U could be used with no need for modifications to implement a "level playing field" between Wi-Fi and mobile. In this case, mobile could operate on a licence exempt basis but would be constrained to the same levels of power as Wi-Fi. | The ability of Wi-Fi to detect mobile base station signals, at levels similar to those it is able to currently detect from other Wi-Fi systems, could be an important improvement. In 5G NR-U, the mobile system must transmit a preamble signal in order to improve detection by Wi-Fi.<br><br>Requiring licensed mobile to also transmit a preamble may be one way to help Wi-Fi detect licensed mobile signals at similar levels to Wi-Fi.<br><br>Additionally, it is worth investigating whether higher power licensed mobile could detect Wi-Fi at modified detection thresholds to compensate for the power imbalance between the two services. |
| Use of DFS or ACS mechanisms | Dynamic frequency selection could be used to force an access point to change channels (or even frequency band) when a mobile signal is detected.<br><br>This could also be achieved with a more dynamic version of ACS.<br><br>This new version would aim to allow use of a less congested channel as soon as significant licensed mobile use is detected. | The upper 6 GHz band presents an opportunity to develop an enhanced version of sensing, addressing issues (such as false triggers and non-occupancy periods[35]) seen in existing mechanisms.<br><br>When using sensing for hybrid sharing, it would be important for the sensing mechanism to react promptly to signal detection. In our testing, we found that most current implementations of ACS only trigger when an access point is powered up or re-booted (although one access point did switch channels when the throughput reduced to almost zero).[36] Investigation of suitable trigger thresholds and approaches may be needed to understand the impact on throughput and latency of these approaches. Mobile transmission of a preamble in the upper 6 GHz band that can be detected by Wi-Fi may help address the current issues. Multi-Link Operation in Wi-Fi 7 allows Wi-Fi to re-route traffic to a less congested band in a matter of milliseconds. We believe there is potential for this existing technology to be adapted into a more responsive sensing mechanism. |

[35] False triggers occur when a channel is mistakenly assessed to be busy, triggering a channel change. The non-occupancy period is the time before a channel can be used again once it has been assessed to be busy.
[36] We found this in our lab testing of Wi-Fi 6E routers. In a managed network, such as an enterprise network in an office or university campus, ACS is performed typically once every twenty-four hours, usually overnight when network traffic is low.

**Question 4:** How could existing access protocols and sensing mechanisms be leveraged (i.e., those in Wi-Fi or 5G NR-U) to enable hybrid sharing?

## Combination of managed databases and spectrum sensing

4.46 Combining databases with sensing may give additional benefits. For example, by:

- Allowing a less conservative set of coexistence assumptions to be implemented in databases (database solutions typically err on the side of caution and use a relatively conservative set of assumptions). This could result in smaller separation distances between systems. Sensing would play its part in ensuring that mobile remains protected. This could mean that Wi-Fi indoors (especially deep indoors) is possible even in areas where licensed mobile is prioritised, which may not be possible with a database only approach.
- Adding database control of mobile in addition to improved sensing, which would allow greater access for Wi-Fi, with prioritisation in some areas and sensing based use deep indoors or in areas without mobile.

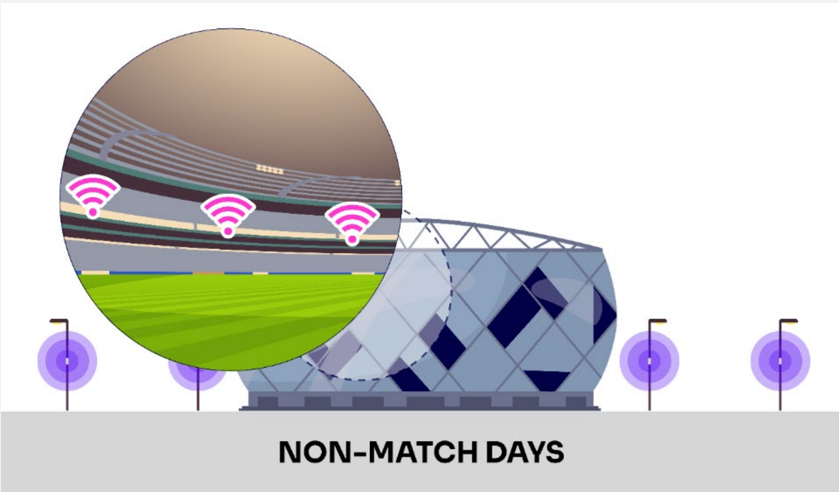
4.47 We do however recognise that combining both these techniques may add greater complexity to device design and implementation.

4.48 We describe below how Example 2 and Example 3 could be extended with a combination of databases and sensing.

**Example 4 – enabling more Wi-Fi use, even in mobile priority areas**

We could add enhanced sensing requirements in Example 3 to the set-up of Example 2. The enhanced sensing would allow Wi-Fi to make use of spectrum on days when mobile has the priority in the local area - days other than match days. This could allow some access points deeper indoors to still use upper 6 GHz channels.

This addition of sensing, when also using databases, would allow the databases to be less cautious in their determination of separation distances as the Wi-Fi networks would be able to use sensing to ensure that mobile deployments are avoided.



## Application of mechanisms to device-to-device use

4.49 As explained earlier, there is interest from the industry in device-to-device licence exempt use, for example to connect AR/VR headsets to PCs, phones, or game consoles.

4.50 In some hybrid sharing scenarios, we might require Wi-Fi use to be used indoors only, to avoid interference with mobile use outdoors (see Example 3). Such a restriction is easier to ensure when using Wi-Fi access points - mostly indoors in any case - than in device-to-device use such as connecting wireless headphones to a mobile handset.

4.51 In such a Wi-Fi indoor only scenario, we would need a mechanism to ensure device-to-device use is also constrained to indoor operation. We are aware of a proposed solution using an 'enabling signal' transmitted from an indoor Wi-Fi access point, and devices would need to hear this signal before operation in device-to-device mode. The idea is that, by and large, devices outdoors would not be able to detect the enabling signal.

4.52 Alternatively, device-to-device systems may need to sense the spectrum environment to select channels that have low levels from other Wi-Fi or mobile users. In some cases, this may mean that they would have to operate in bands other than the upper 6 GHz, e.g. 5 GHz.

**Question 5:** What mechanisms could potentially enable device-to-device connectivity?

## Alternative approaches considered

4.53 Some stakeholders have suggested that the easiest way to accommodate licensed mobile and Wi-Fi use in the upper 6 GHz band would be by having two clear, **separate assignments**. This would mean, for example, that the first 160 MHz or 320 MHz channels in the upper 6 GHz band (from 6425 MHz upwards) would be assigned for licence exempt use, extending the available spectrum from the lower 6 GHz band for Wi-Fi. The remaining bandwidth would be assigned for licensed mobile use.

4.54 In theory, this solution offers a simple way to support some level of additional capacity and new use cases for both Wi-Fi and licensed mobile. However, this option ignores the potential benefits of a hybrid approach as described in this document, as different parts of the band would be uniquely assigned to different uses.

4.55 Once we have more developed proposals for hybrid sharing, we will be able to assess them against alternatives where Wi-Fi and mobile do not coexist in the same frequencies, including partitioning the band, or single use for either.

4.56 The approaches that we describe in this consultation are intended to get as close as possible to **fair sharing** of the spectrum resources between licensed mobile and Wi-Fi at a given location as the approaches can achieve. For example, fair sharing[37] is the outcome today when multiple Wi-Fi networks access the same channel or in the case of Multi-

[37] Fair sharing does not necessarily mean an even split of resources between the two networks but an assurance than one is not squeezed out by the other.

Operator Core Network configurations where two mobile core networks utilise the same frequency channel with an agreed prioritisation or minimum guarantee of capacity.[38]

4.57 We expect that getting closer to this approach would require more advanced techniques, including complex sensing using mobile handsets and reporting between networks[39] as part of the process. One area for study is whether sensing on mobile handsets might also be beneficial to ensure they switch to other bands when indoors and in the presence of a co-channel Wi-Fi system.

4.58 **Increasing the isolation** between different systems by using massive MIMO[40] antennas for beamforming and/or interference cancellation techniques could help reduce interference between the two systems.

4.59 On the other hand, it is also possible that **less complex mechanisms** may be necessary where, for example, licensed mobile transmit powers are reduced in comparison to the maximum permitted in other bands (or other limitations are put in place to ensure coexistence between mobile and Wi-Fi).

4.60 We also recognise that there could be **other approaches** that interested stakeholders may want to propose in response to this consultation.

**Question 6:** If hybrid sharing is eventually adopted, and requires licensed mobile to operate at medium power, in what way would mobile networks use the upper 6 GHz band?

**Question 7:** How would you suggest that the mechanisms presented here can be used, enhanced, or combined to enable hybrid sharing or are there any other mechanisms that would be suitable that we have not addressed?

**Question 8:** Assuming the future of the band includes indoor use for Wi-Fi and outdoors use for mobile:

a) how could this be achieved without creating or suffering interference?

b) could there be a combination of technical adjustments such as power limits and other mechanisms (including databases or sensing mechanisms)?

[38] In this case there is a minimum guaranteed level of access that each network gets when the demand is high from both, but when one service is lightly used, the other network can take a greater share of resources and vice versa.
[39] For example, if mobile handsets closer to Wi-Fi devices formed part of the sensing network this may enable better sharing of spectrum resources between mobile and Wi-Fi if this was reported back to the mobile network.
[40] Multiple-input and multiple-output, or MIMO is a method for multiplying the capacity of a radio link by using multiple transmission and receiving antennas.

# 5. Sharing with incumbent users of the band

5.1 In the UK, the upper 6 GHz band is currently used for a variety of services including fixed links, the fixed satellite service (both space and Earth stations), radio astronomy, short-range devices, and space science. Programme Making and Special Events (PMSE) also use the 7075-7125 MHz portion of the band.

5.2 We have undertaken some initial high-level analysis looking at outdoor licensed mobile or indoor Wi-Fi sharing with existing users of the band. Our analysis shows that low power indoor Wi-Fi can share with incumbent services with negligible risk of interference.

5.3 However, if we allow outdoor high power licensed mobile into the band, our analysis suggests there is the potential for interference to fixed links. There is also potential for interference to fixed satellite service receivers unless international measures are agreed to protect these receivers.[41]

5.4 One option we might consider would be to clear fixed links from some locations where high mobile demand is likely (i.e. the areas where MNOs are most likely to deploy in the upper 6 GHz band). Another possibility we might consider is the use of databases (e.g. SAS and AFC) to facilitate sharing with existing users. This might be especially attractive if we implement such databases as part of our hybrid sharing approach.

## High power outdoor licensed mobile sharing with incumbent users

### Fixed links

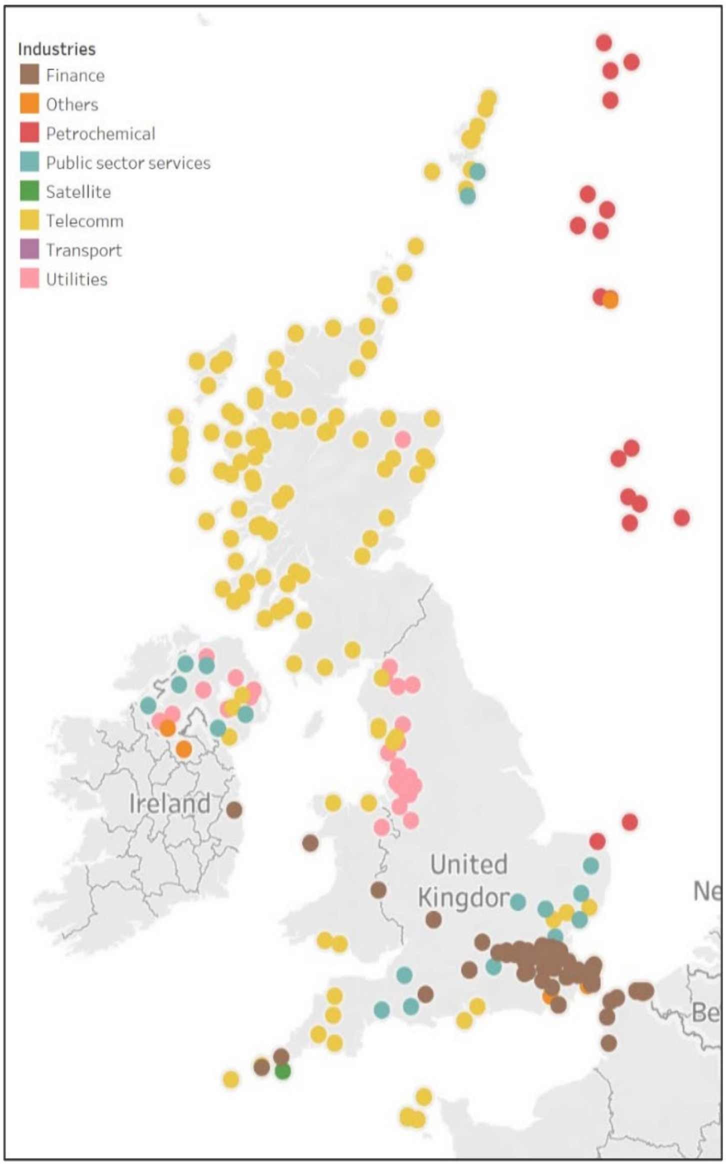
5.5 Various international studies[42] show that coexistence between higher power mobile and fixed links in the upper 6 GHz band is possible with site-by-site coordination.

5.6 The required separation distances between the two systems vary depending on the site parameters and input assumptions, but a typical example presented in the ITU studies is a keyhole shape, with a circular zone of 4 km and an additional 58 km radial zone in the direction of the main lobe of the fixed link.

5.7 There are approximately 500 fixed links in the UK in the upper 6 GHz band supporting several different industry sectors including telecoms, transport, utilities, and finance (see Figure 6).

[41] Protection of fixed satellite service receivers from high power mobile in the upper 6 GHz band is currently under discussion internationally in relation to WRC-23 agenda item 1.2.
[42] For example, the studies in ITU-R Working Party 5D

**Figure 6 Fixed links in the upper 6 GHz band**[43]



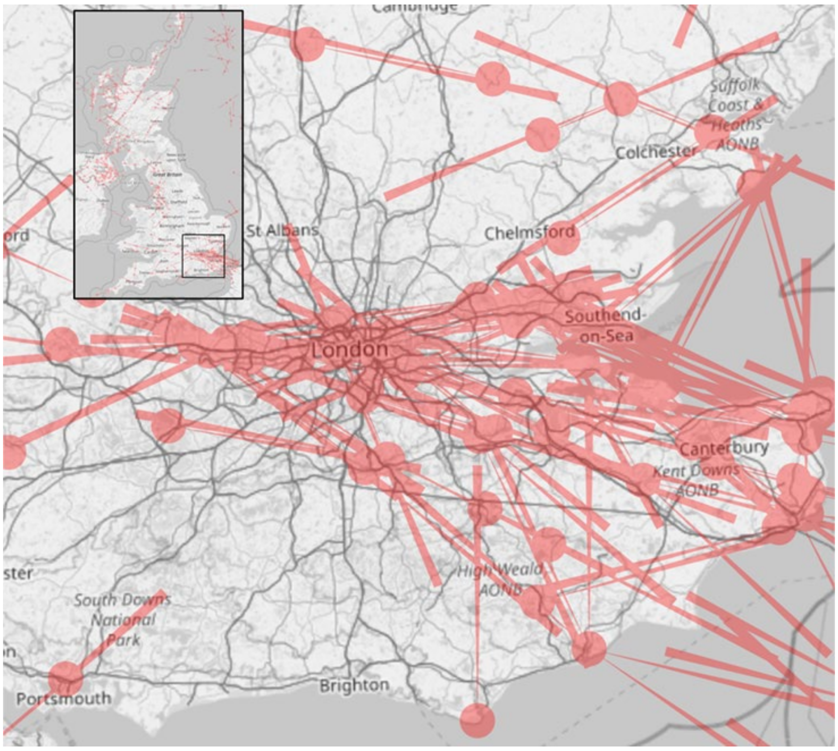

5.8 We mapped the fixed links currently authorised in London and the south-east along with the potential separation distances that the ITU studies say are needed to protect them. The results in Figure 7 show the distances from higher power mobile base stations (4 km to 58 km). If licensed mobile was restricted to medium power, this would lead to significantly lower separation distances.

5.9 We also compared the location of the fixed links with the locations where the mobile network operators have deployed most available frequency bands on existing macro-sites, as a proxy for base station sites where the MNOs might deploy the upper 6 GHz band for capacity purposes. The analysis suggests that, if the upper 6 GHz band were to be deployed

[43] The figure is based on data as of July 2022, whilst some changes may have occurred since then, this figure is representative of the type of deployments and industries that are currently using the upper 6 GHz band.

on these sites at higher power, about half of the fixed links in the UK could potentially suffer some interference.

**Figure 7 Fixed links in London and the Southeast showing potential separation distances based on the results of ITU studies**




## Fixed satellite

5.10 We undertook a study to consider sharing between higher power licensed mobile and fixed satellite services in the upper 6 GHz band, to protect geostationary satellite receivers, in which we studied the impact from two different densities of mobile network deployments[44]:

- D1, a lower density network, similar to UK MNO deployments in the 2600 and 3500 MHz bands as they were in 2021, where these bands were not deployed on all sites in the country. In the UK such networks consisted of approximately 3,500 sites, and the satellite would receive interference from around 100,000 sites in total (including sites outside the UK).
- D2, a higher density network, similar to UK MNO deployments in the 2100 MHz band as they were in 2021, where network deployments were considered to have reached a level of maturity. In the UK such networks consisted of approximately 16,000 sites, and the satellite would receive interference from around 600,000 sites in total (including sites outside the UK).

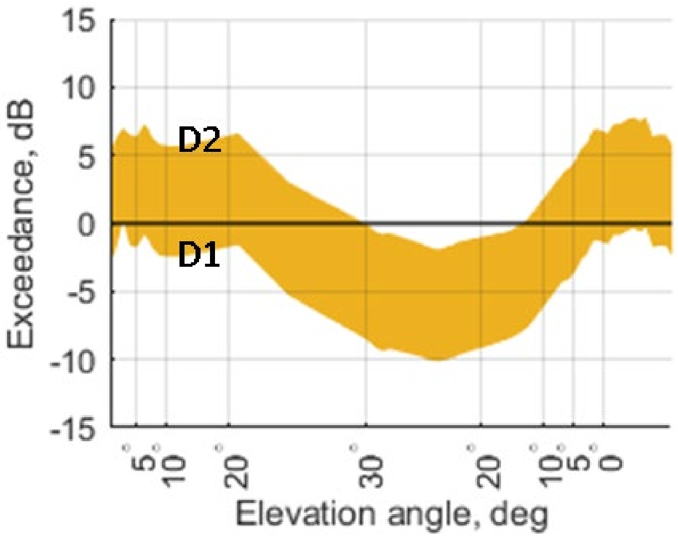
5.11 Our analysis indicates that sharing would be possible with the global beams of fixed satellite systems if mobile network densities remain relatively low. Figure 11 shows that

[44] Our study is summarised in the following paragraphs but further details can be found in our submission to ECC PT1.

interference from a network with a density D1 is below the 0 dB threshold – meaning that satellite services are not impacted. A network with a density similar to or greater than D2 may interfere with satellite services in some orbit locations as the level of interference is higher for low elevation angles.[45]

5.12 We note there is activity underway internationally to agree on base station antenna emission limits at elevations above the horizon, as a mitigation mechanism to ensure coexistence in case higher densities of base stations are deployed. If agreed internationally, it is likely that we will implement these or similar restrictions in the UK, if we were to enable high power licensed mobile in the upper 6 GHz band.

**Figure 8 Level of interference exceedance (for global beams) depending on the elevation angle from the UK to the satellite**




## Low power indoor Wi-Fi sharing with incumbent users

5.13 When we made the lower 6 GHz band (5925-6425 MHz) available for Wi-Fi use, see our July 2020 statement, we considered sharing with a range of incumbent services including fixed links, fixed satellites, space science and short-range devices. We reviewed and refreshed this analysis for our February 2022 consultation on shared licences in the upper 6 GHz band.

5.14 Our analysis was based on the sharing model and studies proposed by CEPT and published in ECC Report 302. We considered the conclusions presented in this report and how they could be applied to the upper 6 GHz band. For example, for fixed links, we reviewed the technical parameters held in our licence database and did not find any significant difference between the upper and lower 6 GHz bands.

5.15 Our own analysis was in line with the conclusions in ECC Report 302, that the risk of interference from Wi-Fi into incumbent services would be negligible. We see no reason to

[45] Regional or spot beams would be impacted to a greater extent than global beams.

change our earlier conclusions that, due to the similarity in use between the lower and upper 6 GHz bands, low power indoor Wi-Fi can share with incumbent services.[46]

5.16 In the UK there is also an allocation for PMSE in the 7075-7145 MHz band. This tends to be used to support temporary outside broadcasts such as music festivals or sporting events. We will conduct a more comprehensive analysis of sharing with incumbents, including PMSE, once we are ready to consult on specific implementation proposals.

5.17 We note that ECC SE45 is considering sharing between RLANs and incumbent services in the 6425-7125 MHz band. We are closely following this work and are expecting the studies to be published as an ECC Report in May or June 2024.[47]

**Question 9:** We are interested in input about the importance of the upper 6 GHz band for its incumbent users, and on the potential impact of hybrid sharing of the band.

a) What evidence do you have on whether incumbents are likely to coexist with hybrid sharing of the band with mobile and Wi-Fi? Are there unique advantages of the upper 6 GHz band for these uses?

b) What are your views on the initial analysis we have conducted around hybrid sharing and coexistence with incumbents?

c) For any incumbent uses that you view as unlikely to be able to coexist, what alternatives are there? What are the barriers that might prevent those alternatives?

[46] Very low power outdoor use of Wi-Fi would also not affect incumbent users, although we have not assessed how this may coexist with licensed mobile networks as part of hybrid sharing.
[47] ECC Work Item PT1_50

# 6. Overarching questions and next steps

## Overarching questions

**Question 10:** Do you have any other thoughts that you would like to share about hybrid sharing in the upper 6 GHz band, or about hybrid sharing more generally and its potential for applications in other bands?

**Question 11:** Do you have any other comments to make on these proposals or on the future use of the upper 6 GHz band?

## Next steps

6.1 Our consultation will close on 15 September 2023. Annex A1 includes the relevant information about how to respond to this consultation. We will publish a summary of responses in the autumn of 2023.

6.2 We will continue to engage internationally, contributing to the studies on hybrid sharing in ECC PT1 and in relation to Wi-Fi sharing with incumbents in ECC SE45.

6.3 We intend to follow up with a further consultation (which we aim to publish in 2024) on specific proposals for the implementation of hybrid sharing in the upper 6 GHz band. This will take into consideration the responses to this consultation, the ongoing harmonisation work in CEPT, and other relevant international developments.

# A1. Responding to this consultation

## How to respond

A1.1 Ofcom would like to receive views and comments on the issues raised in this document, by 15 September 2023.

A1.2 You can download a response form from https://www.ofcom.org.uk/cymru/consultations-and-statements/category-1/hybrid-sharing-to-access-the-upper-6-ghz-band. You can return this by email or post to the address provided in the response form.

A1.3 If your response is a large file, or has supporting charts, tables or other data, please email it to hybridupper6ghz@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet.

A1.4 Responses may alternatively be posted to the address below, marked with the title of the consultation:

Spectrum Policy and Analysis
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 We welcome responses in formats other than print, for example an audio recording or a British Sign Language video. To respond in BSL:

- Send us a recording of you signing your response. This should be no longer than 5 minutes. Suitable file formats are DVDs, wmv or QuickTime files; or
- Upload a video of you signing your response directly to YouTube (or another hosting site) and send us the link.

A1.6 We will publish a transcript of any audio or video responses we receive (unless your response is confidential)

A1.7 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.

A1.8 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.

A1.9 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed in Annex A4. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

A1.10 If you want to discuss the issues and questions raised in this consultation, please contact Rebekah Haskayne at 02079813698 or by email to hybridupper6ghz@ofcom.org.uk.

## Confidentiality

A1.11 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish all responses on the Ofcom website as soon as we receive them.

A1.12 If you think your response should be kept confidential, please specify which part(s) this applies to and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.

A1.13 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.14 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further in our Terms of Use.

## Next steps

A1.15 Following this consultation period, Ofcom plans to publish a statement later in 2020.

A1.16 If you wish, you can register to receive mail updates alerting you to new Ofcom publications.

## Ofcom's consultation processes

A1.17 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in Annex 2.

A1.18 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

A1.19 If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact the corporation secretary:

Corporation Secretary
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA
Email: corporationsecretary@ofcom.org.uk

# A2. Ofcom's consultation principles

## Ofcom has seven principles that it follows for every public written consultation:

### Before the consultation

A2.1 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. If we do not have enough time to do this, we will hold an open meeting to explain our proposals, shortly after announcing the consultation.

### During the consultation

A2.2 We will be clear about whom we are consulting, why, on what questions and for how long.

A2.3 We will make the consultation document as short and simple as possible, with a summary of no more than two pages. We will try to make it as easy as possible for people to give us a written response. If the consultation is complicated, we may provide a short Plain English / Cymraeg Clir guide, to help smaller organisations or individuals who would not otherwise be able to spare the time to share their views.

A2.4 We will consult for up to ten weeks, depending on the potential impact of our proposals. We allow additional time on this occasion to account for the summer period.

A2.5 A person within Ofcom will be in charge of making sure we follow our own guidelines and aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.

A2.6 If we are not able to follow any of these seven principles, we will explain why.

### After the consultation

A2.7 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish all the responses on our website as soon as we receive them. After the consultation we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

# A3. Consultation coversheet

## BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

## CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

| | |
|---|---|
| Nothing | o |
| Name/contact details/job title | o |
| Whole response | o |
| Organisation | o |
| Part of the response | o |
| If there is no separate annex, which parts? | ____________________________________________ |

________________________________________________________________________________

If you want part of your response, your name, or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

## DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here.

Name                                        Signed (if hard copy)

# A4. Consultation questions

A4.1 This annex lists the questions that we are consulting on.

**Question 1:** Hybrid sharing could mean that the upper 6 GHz band will be used for mobile outdoors, and Wi-Fi indoors. What are your views on the priorities for each of these two services, assuming that suitable coexistence mechanisms will be developed?

**Question 2:** Hybrid sharing could mean that the upper 6 GHz band will be used for mobile in some locations, and Wi-Fi in others. We would like feedback on the priorities for each of these two services, assuming that suitable coexistence mechanisms will be developed.

a) From the point of view of mobile, is the upper 6 GHz band most useful to provide outdoor coverage, or indoor coverage? Is it most useful in urban areas, or in those base stations that are currently carrying more traffic or some other split?

b) Similarly, what are the priorities from the point of view of Wi-Fi deployments?

**Question 3:** What are your views on reusing a modified AFC or SAS-type approach to enable hybrid sharing? What additional work do you think would be required?

**Question 4:** How could existing access protocols and sensing mechanisms be leveraged (i.e. those in Wi-Fi or 5G NR-U) to enable hybrid sharing?

**Question 5:** What mechanisms could potentially enable device-to-device connections?

**Question 6:** If hybrid sharing is eventually adopted, and requires mobile to operate at medium power, in what way would mobile networks use the upper 6 GHz band?

**Question 7:** How would you suggest that the mechanisms presented here can be used, enhanced, or combined to enable hybrid sharing or are there any other mechanisms that would be suitable that we have not addressed?

**Question 8:** Assuming the future of the band includes indoor use for Wi-Fi and outdoors use for mobile:

a) how could this be achieved without creating or suffering interference?

b) Could there be a combination of technical adjustments such as power limits and other mechanisms (including databases or sensing mechanisms)?

**Question 9:** We are interested in input about the importance of the upper 6 GHz band for its incumbent users, and on the potential impact of hybrid sharing of the band.

a) What evidence do you have on whether incumbents are likely to coexist with hybrid sharing of the band with mobile and Wi-Fi? Are there unique advantages of the upper 6 GHz band for these uses?

b) What are your views on the initial analysis we have conducted around hybrid sharing and coexistence with incumbents?

c) For any incumbent uses that you view as unlikely to be able to coexist, what alternatives are there? What are the barriers that might prevent those alternatives?

**Question 10:** Do you have any other thoughts that you would like to share about hybrid sharing in the upper 6 GHz band, or about hybrid sharing more generally and its potential for applications in other bands?

**Question 11:** Do you have any other comments to make on these proposals or on the future use of the upper 6 GHz band?

# A5. Legal framework

## Duties under the Communication Act 2003 and the Wireless Telegraphy Act 2006

A5.1 Ofcom's statutory powers and duties in relation to spectrum management are set out primarily in the Communications Act 2003 (the "2003 Act") and the Wireless Telegraphy Act 2006 (the "WT Act"). Among our functions are the making available of frequencies for use for particular purposes and the granting of rights of use of spectrum through wireless telegraphy licenses and license exemptions.

A5.2 Our principal duties under section 3 of the 2003 Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are required to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

A5.3 We must also have regard to: (i) the desirability of promoting competition in relevant markets; (ii) the desirability of encouraging investment and innovation in relevant markets; (iii) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it; and (iv) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas.

## Duties under the Wireless Telegraphy Act 2006

A5.4 Additionally, in carrying out our spectrum functions we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use, or further use, for wireless telegraphy; (ii) the demand for use of that spectrum for wireless telegraphy; and (iii) the demand that is likely to arise in future for such use.

A5.5 We also have a duty to have regard to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy; (ii) the economic and other benefits that may arise from the use of wireless telegraphy; (iii) the development of innovative services; and (iv) competition in the provision of electronic communications services.

A5.6 Under section 8(1) of the WT Act, it is unlawful to establish or use a wireless telegraphy station or install or use wireless telegraphy apparatus except under and in accordance with a wireless telegraphy licence granted under the WT Act.

A5.7 Under sections 8(3) - 8(3B) of the WT Act, Ofcom may make regulations exempting from the licensing requirements under section 8(1) the establishment, installation or use of wireless telegraphy stations or wireless telegraphy apparatus of such classes or description as may be specified in the regulations, either absolutely or subject to such terms, provisions and limitations as may be specified.

A5.8 Under sections 8(4) and 8(5) of the WT Act, we must make regulations to exempt stations and apparatus from the requirement to be licensed if their establishment, installation, or use is not likely to:

a) involve undue interference with wireless telegraphy;

b) have an adverse effect on technical quality of service;

c) lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy;

d) endanger safety of life;

e) prejudice the promotion of social, regional or territorial cohesion; or

f) prejudice the promotion of cultural and linguistic diversity and media pluralism.

A5.9 In accordance with the requirements of section 8(3B) of the WT Act, the terms, provisions and limitations specified in the regulations must be:

a) objectively justifiable in relation to the wireless telegraphy stations or wireless telegraphy apparatus to which they relate;

b) not such as to discriminate unduly against particular persons or against a particular description of persons;

c) proportionate to what they are intended to achieve; and

d) transparent in relation to what they are intended to achieve.

A5.10 Before making any exemption regulations, we are required by section 122(4) of the WT Act to give statutory notice of our proposal to do so. Under section 122(5), such notice must state that we propose to make the regulations in question, set out their general effect, specify an address from which a copy of the proposed regulations or order may be obtained, and specify a time period of at least one month during which any representations with respect to the proposal must be made to us.

# A6. Glossary

| Term | Definition |
|---|---|
| **2003 Act** | The Communications Act 2003 (c.21) |
| **3GPP** | The 3rd Generation Partnership Project. An umbrella term for a number of standards organisations which develop protocols for mobile telecommunications. |
| **4G and 5G** | The fourth and fifth generation of mobile phone standards and technology. |
| **ACS** | Automatic Channel Selection. The Wi-Fi Access Point scans all wireless channels and selects an operating channel the 'most optimal' channel, minimizing interference from other Aps and from non-Wi-Fi sources. |
| **AFC** | Automated Frequency Coordination. A spectrum use coordination system, specifically designed for 6 GHz operation in the US, that consists of a registered database of the frequencies in use by various types of radio frequency services in a given area. |
| **AP** | Access point. A hardware device that allows other Wi-Fi compatible devices to connect to a wired network. For example, an AP can be part of, our connected to, a router within the premises. |
| **AR** | Augmented Reality. An interactive video technology that overlays computer-generated information (e.g. images, text, sound) over real-world images or video. A type of VR. |
| **Beamforming** | A technology that controls and focuses a wireless signal towards a specific receiver, creating a faster and more reliable connection. |
| **BSS Colouring** | Basic service set colouring, which decreases the time to establish a connection during the initial Listen Before Talk protocol and enables the connection to less congested Wi-Fi channels. |
| **CBRS** | Citizens Broadband Radio Service. A 150 MHz wide broadcast bands of the 3.5 GHZ band in the United States. |
| **CEPT** | European Conference of Postal and Telecommunications Administrations. A coordinating body for European state telecommunications and postal organisations. |
| **dBi** | Decibel isotropic. A measure of antenna gain. |
| **dBm** | The power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW). |
| **device-to-device (d2d)** | A broad term to describe any technology that enables networked devices to exchange information and perform actions without manual assistance. |
| **DFS** | Dynamic Frequency selection. A system that makes Wi-Fi routers change frequency when a radar using the same frequency is near. |
| **Earth Station** | A station located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for radio communication with one or more satellites or space stations. |

| Term | Definition |
|---|---|
| **ECC** | Electronics Communications Committee – one of the three business committees of the European Conference of Postal and Telecommunications. |
| **EIRP** | Equivalent Isotropically Radiated Power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain). |
| **ETSI** | European Telecommunications Standard Institute. A standardisation organisation in the field of information and communications. |
| **FCC** | Federal Communications Committee (FCC). An agency of the United States federal government that regulates communications by radio, television, wire, satellite and cable. |
| **Fixed Link** | A terrestrial-based wireless system operating between two or more fixed points. |
| **GHz** | Gigahertz. A unit of frequency of one billion cycles per second. |
| **ICNIRP** | International Commission on Non-Ionising Radiation Protetion. The organisation determines exposure limits for electromagnetic fields used by devices such as mobile phones. |
| **IEEE** | Institute of Electrical and Electronics Engineers. The IEE sets Wi-Fi specifications, typically beginning at '802.11'. The most recent generation of standards, 802.11be is known as Wi-Fi 7. |
| **I/N** | Interference over noise ratio. Measures signal quality: the strength of the wanted signal compared to the unwanted interference and noise. |
| **IMT** | International Mobile Telecommunications. A generic term used by the ITU community to designate broadband mobile systems. |
| **ISP** | Internet Service Provider. A company that provides end-users with access to the internet. |
| **ITU** | International Telecommunications Union. Part of the United Nations with a membership 193 countries and over 700 private-sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland. |
| **Latency** | A measure of delay in transmission over a transmission path. |
| **LbT** | Listen before Talk protocol. When spectrum users in unlicensed bands share the same channels LBT causes their devices to detect ('listen for') other users transmitting information and waiting for this to finish before they transmit ('talk'). This avoids interference but can worsen device performance in congested bands. |
| **LTE-LAA** | LTE Licensed Assisted Access. A version of LTE designed to leverage unlicensed radio frequency bands |
| **Macro-cell** | A cellular base station that sends and receives signals through large towers and antennas, providing radio coverage to a large area. |
| **Mesh systems or networks** | A wireless network comprising many connected devices (or nodes) that can deliver better wireless coverage than a single Access Point. |
| **MHz** | Megahertz. A unit of frequency of one million cycles per second. |

| Term | Definition |
|---|---|
| **Mid-band spectrum** | Frequencies between 1 GHz and 24 GHz |
| **mmWave** | Millimetre Wave. The range of spectrum above 24 GHz (but below 100 GHz). |
| **MIMO** | (Multiple-input, multiple-output), a method that multiplies the capacity of a radio link by exploiting multipath propagation in several radio links |
| **MNO** | Mobile Network Operators. A mobile network provider that owns its own national public mobile network. |
| **NR-U** | New Radio Unlicensed. A 3GPP Release 16 mode of operation that provides the necessary technology for cellular operations to integrate unlicensed spectrum into 5G networks. |
| **PT1** | ECC Project Team 1. Responsible for mobile (IMT) issues, including compatibility studies, development of band plans. |
| **Radio Regulations** | A basic document of the International Telecommunications Union (ITU) that regulates on law of nations scale radiocommunication services and the utilisation of radio frequencies. |
| **RLAN (or WLAN)** | Radio (Wireless) Local Area Network. A radio access system used to provide wireless access between computer devices. RLANs are intended to cover smaller geographic areas like homes, offices and, to a certain extent, buildings adjacent to each other. |
| **SAS** | Spectrum Access System. The core service in the network responsible for dynamic frequency allocation in the shared spectrum range of the CBRS band in the US. |
| **SRD** | Short-range devices. These are usually mass-produced devices that are used in numerous applications like alarm systems, medical implants, radio frequency identification, intelligent transport systems or local communication equipment such as Wi-Fi routers. |
| **Throughput** | The rate of digital radio data delivery. |
| **VR** | Virtual Reality. An interactive and immersive video technology that simulates realistic images and other information in a virtual setting. It can be used in both individual user and industry applications (such as gaming and medical training). See also, AR. |
| **Wi-Fi** | Commonly used to refer to radio local area network (RLAN) technology, specifically that conforming to the IEEE 802.11 family of standards. Such systems typically use one or more access points connected to wired Ethernet network, which communicate with wireless network adapters in end devices such as PCs. It was originally developed to allow wireless extension of private LANs but is now also used as a general public access technology via access points known as “hotspots”. |
| **WRC** | World Radiocommunications Conference. An international conference organised by the ITU to review and revise radio regulations held every four years. The most recent WRC (WRC19) was held in Egypt, October – November 2019. |
| **WT Act** | Wireless Telegraphy Act 2006 (c. 36) |

# A7. Coexistence between Wi-Fi and mobile in the upper 6 GHz band

A7.1 Section 3 of this consultation sets out our reasons for believing that a hybrid approach to authorising use of the upper 6 GHz band could deliver efficient use of the spectrum for the benefit of UK people and businesses, in line with our statutory duties.

A7.2 In this annex we outline our initial analysis on the coexistence of mobile networks using outdoor macro-cells sharing with indoor Wi-Fi networks.

A7.3 Our analysis has shown that, without additional measures, interference to both services is likely, at least in some locations and at some times. Additional interference management mechanisms and mitigation techniques are therefore likely to be necessary to manage the sharing of resources between the two services to enable use of both mobile and Wi-Fi in the band. We describe some of these mechanisms in Section 4.

## Coexistence between outdoor mobile and indoor Wi-Fi

### 5G mobile degrades Wi-Fi performance

A7.4 To investigate the impact of co-channel mobile signals on Wi-Fi performance we undertook some lab-based measurements on Wi-Fi 6E equipment operating in the lower part of the 6 GHz frequency band (up to 6425 MHz)[48].

A7.5 Our findings suggest that mobile signals are likely to cause a significant reduction in Wi-Fi throughputs, leading to reduced coverage, or increased delay (latency) when the two systems are operating co-frequency in the same location. In some cases, where the mobile signal exceeds the Wi-Fi energy detect (ED) threshold[49], Wi-Fi throughput may stop altogether.

A7.6 We also looked at how some current Wi-Fi features, such as automatic channel selection, might help to mitigate interference. Our testing showed that, whilst one access point did switch to an alternative frequency (but only after its throughput was severely degraded), the other access points we tested needed to be manually re-booted before they would move to an alternative channel in the band with less interference.

A7.7 The next generation of Wi-Fi technology (Wi-Fi 7) will bring new features such as preamble puncturing that could also help with hybrid sharing, but at the time of our testing we did not have access to any Wi-Fi 7 equipment.

#### Results from our measurements

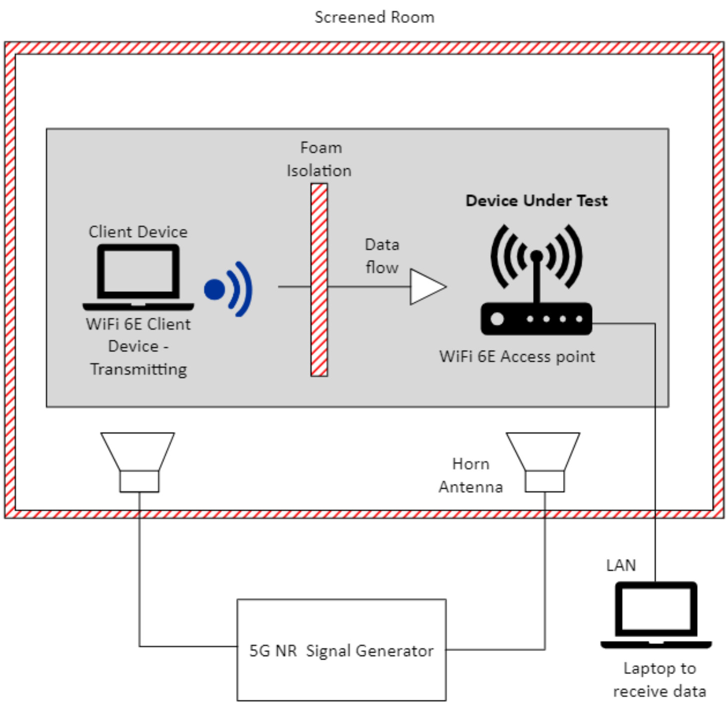
A7.8 Figure 12 illustrates our test configuration where we set up a wireless link between a Wi-Fi 6E client device and access point inside an RF screened room. Data was sent in the uplink

[48] Upper 6 GHz band equipment was not available, but we configured the interfering signals to operate in this band too.
[49] Wi-Fi assesses if the channel is clear to transmit. If the measured power is above the energy detect (ED) threshold, then it considers the channel occupied by non-Wi-Fi transmissions.

direction from the client to a laptop connected to an Ethernet port on the access point, which was also used to monitor data throughput. Due to the size limitation of the screened room, RF absorbing foam was placed between the client and access point to reduce the signal levels, which has a similar effect to increasing the physical separation distance.

A7.9 A signal generator output was split between two antennas[50] to transmit a co-channel 5G mobile signal to both the access point and the client device so that we could observe the impact on throughput as we varied the interference power.

**Figure 9 Test configuration inside an anechoic screened room**



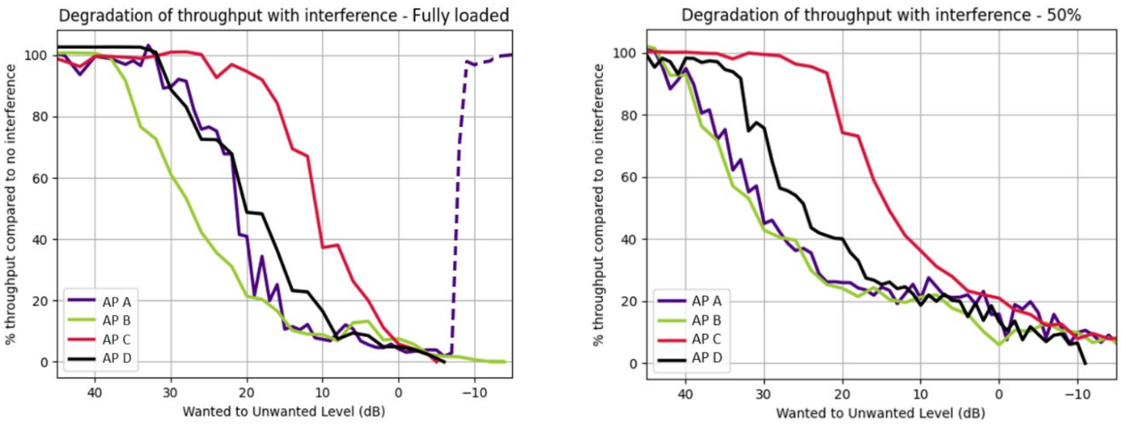

A7.10 For 5G signals, both the base station and mobile share the same frequency so downlink and uplink transmissions are separated in time (known as time division duplexing (TDD)). For both our test signals we used a 70:30 downlink-to-uplink ratio, so the available downlink time was 70% of the total available transmission time (i.e. 7 out of every 10 msec used for downlink transmissions with the other 3 msec for uplink). We used the 3GPP Test Model (TM) 1.1 waveform to represent a fully loaded traffic scenario whereby the signal from the base station was transmitting for 100% of the available downlink time.[51] The tests were also repeated using a lighter traffic loading scenario whereby the signal from the base station was transmitting for 50% of the available downlink time.[52]

A7.11 Figure 13 illustrates how Wi-Fi throughput is impacted as the unwanted mobile signal level is increased when using the fully loaded waveform and the 50% loaded 5G waveform. As interference is increased, the throughput degrades.[53] At low wanted to unwanted signal

[50] This allows us to simulate the scenario where both the access point and the client device are subject to interference
[51] This used a 100 MHz channel with 256 QAM modulation and 60 kHz sub carrier spacing.
[52] We simulated this by transmitting a full load for 50 msec and then zero load for the next 50 msec and so on.
[53] The maximum data throughput varied by access point, with access point A, for example, having 20% higher starting throughput than access point B. We have normalised the throughput to 100% in the figures for presentation purposes.

levels[54], performance is degraded to the point where little to no throughput is achievable. This will mean that applications which require high data rates and low latencies[55] are likely to be unusable and large files will take significantly longer to download.

**Figure 10 Example performance degradation of Wi-Fi throughput in the presence of a co-channel 5G mobile signal with 100% downlink traffic loading (left) and 50% loading (right)**




A7.12 The results in Figure 13 are examples of the trends and impacts of coexistence with Wi-Fi undertaken with the Wi-Fi devices in close proximity and so relatively high wanted signal levels. Actual performance could be worse where Wi-Fi devices are further apart with lower wanted signal levels and may also vary with multiple users sharing the spectrum.

A7.13 Wi-Fi has several mechanisms that could help to mitigate interference from other services such as automatic channel selection (ACS), designed to select an operating channel that minimises interference from other access points and from non-Wi-Fi sources.

A7.14 To test the ACS functionality, we initially restricted the access points to the 6 GHz band by disabling the 2.4 and 5 GHz radios (to simulate heavy load on other bands). Only one access point switched to a different 6 GHz channel (see Figure 13, where the throughput of AP-A returns to 100% once the channel switches).

A7.15 When the access points were manually re-booted, the ACS function on the other access points successfully chose an alternative channel that did not have a mobile signal present. Once the interference was removed, we found that the devices did not automatically switch back to the original channel.

A7.16 When we enabled the 2.4 and 5 GHz radios, most of the access points we tested were able to switch to a different frequency band automatically after some delay (ranging from 5 to 30 seconds). We observed a loss in data throughput and in some cases the connection to the client device dropped during the switching process. However, we did not need to manually re-boot the device for it to change frequency band.

[54] Wanted to unwanted level indicates the difference in level between the fixed wanted Wi-Fi signal and the unwanted 5G signal level measured at the access point. 0dB means they are at the same level.
[55] While we have not measured latency in these tests, it is highly likely that the latency will also suffer significantly, and the lag will become noticeable.

## Wi-Fi has the potential to degrade 5G download performance

A7.17 We performed some link budget calculations to estimate the typical separation distance that might be needed to minimise the degradation of mobile downlink performance from nearby Wi-Fi devices, i.e. when an access point is in close proximity to a receiving mobile handset.

A7.18 Our initial findings show that indoor Wi-Fi access points (or client devices) may not be able to detect low level signals from outdoor mobile base stations. In this case, the listen-before-talk protocol may incorrectly assume the channel is clear and the access point may start transmitting, potentially causing interference to any nearby mobile handsets receiving data from the base station.

### Results from our calculations

A7.19 Figure 14 shows an example geometry where the mobile base station signal at an indoor access point (AP1) is below the energy detect threshold. AP1 therefore continues to transmit, causing interference to the nearby mobile user equipment.

A7.20 We analysed two scenarios where Wi-Fi is installed in different types of buildings. Firstly, a thermally efficient building with 33 dB of building entry loss; and secondly a building of traditional materials with a 17 dB building entry loss[56]. The mobile user equipment (UE) was outdoors in both cases.

A7.21 Additionally, we considered a UE situated indoors, a number of floors away but inside the same building where the Wi-Fi access point is installed.

A7.22 We assumed an onset of degradation to the UE when the interference power exceeded -101 dBm/MHz[57].

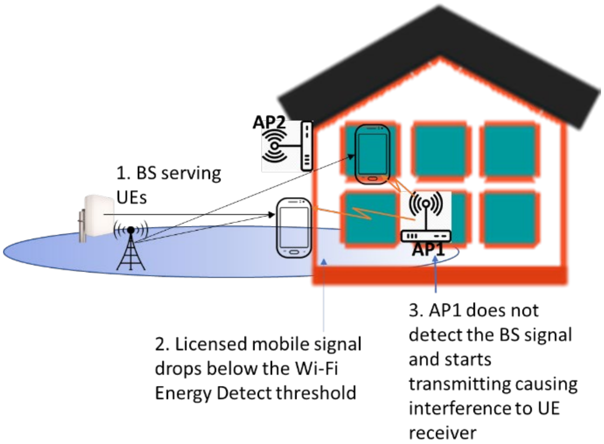
A7.23 If AP1 were inside a traditional building, outdoor UEs within 18 metres would suffer some throughput degradation. If AP1 was instead located deep inside a thermally efficient building, it might not cause any degradation to outdoor UEs. Indoor UEs would need to be at least 3 floors away from AP1 to avoid any degradation[58].

A7.24 Although outdoor macro-cells are further away from Wi-Fi access points, it is still possible in some circumstances for the access point to cause interference to a base station, in which case the upload performance of all users in the cell would be affected. Assuming a macro-cell with an interference threshold of -128 dBm/MHz[59], we calculated that a Wi-Fi access point in a traditional building within 170 metres[60] from the macro-cell could cause some interference. A Wi-Fi access point inside a thermally efficient building might not cause any

[56] These building entry losses are the median values for traditional and thermally efficient buildings taken from ITU-R P.2109-1.
[57] This threshold takes account of 11 dB noise figure and constrains the interference to 6dB below the noise floor. It also accounts for 4 dB body loss and -4 dBi UE antenna gain.
[58] We used the 3GPP 38.900 UMi optional path loss model for outdoor UEs, and IEEE TGax Simulation Scenarios for the indoor UE.
[59] This includes: -6 dB I/N, 6 dB noise figure and 14 dBi macro cell antenna gain (average over the sector azimuth with value at -3° elevation angle with respect to horizon).
[60] We used the 3GPP 38.900 UMa optional path loss model, and 17 dB building entry loss for traditional buildings from Rec. ITU-R P.2109-1 assuming 3° elevation angle.

interference to macro-cells[61]. Regardless of the building type, the degradation could be more significant and more likely when the macro-cell beam steers toward the access point or the access point is located on higher floors[62].

**Figure 11 Example where Wi-Fi causes interference to licensed mobile because it fails to detect it**




A7.25 The extent of interference to the mobile network is a little uncertain as 5G and other mobile technologies include beam steering and interference management mechanisms. For example, reports of the channel quality are used by the base station scheduler to avoid using parts of the channel that have poor quality, and channel sounding is used to steer the antenna beams to directions that minimise interference.

A7.26 These mechanisms may allow 5G service on parts of the channel that do not overlap with Wi-Fi. However, ultimately the network may decide that the interference is so severe as to move UEs to another channel or band altogether.

[61] The interference threshold is -125 dBm/MHz, with 11 dBi macro-cell gain as an average value at -10° elevation angle with respect to horizon. We used 34 dB building entry loss from Rec. ITU-R P.2109-1 assuming 10° elevation angle.
[62] We used an average height of 9 metres above ground level for the access point (taken from ECC Report 316).

# A8. Further analysis of in-building coverage measurements

A8.1 We undertook some walk test measurements in our office building in central London to understand how far into the building signals in the 3.4 GHz band get. We measured the signal received from all four MNOs at ground level around the outside of the building and at various locations inside the building in and around the lower levels.

A8.2 The results in Figure 2 show how the signal strength[63] varies for the different MNOs. Anything above -100 dBm we classify as good coverage[64], between -100 to -115 dBm we classify as intermittent coverage (meaning that coverage can vary depending on factors such as traffic loading or propagation conditions) and anything below -115 dBm we classify as no coverage.[65]

A8.3 We also used the measurement data to derive the probability of the building entry loss on the lower floors of our office and compared this to the prediction of building entry loss from Recommendation ITU-R P.2109-1 (assuming a frequency of 3.6 GHz and elevation angle of 0°).

A8.4 Our result of 27.5 dB median building entry loss (for 50% probability) compares reasonably well to the 31 dB loss predicted for a thermally efficient building in ITU-R P.2109-1, as does the majority of the CDF curve – see Figure 15.

[63] Signal strength is the highest value of Reference Signal Received Power (RSRP) per MNO measured for all available 5G channels in the 3.4 to 3.8 GHz band.
[64] By good coverage we mean there is a 95% probability of 5G coverage being present at the location.
[65] See our Connected Nations 2022 Methodology for further information on how we classify mobile signal strength thresholds.

**Figure 12 Probability of building entry loss derived from ground floor measurements in our London office**