Your response

Question	Your response
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?	*Is this response confidential? – N* Broadcom is a global leader in wired and wireless communications semiconductors. We estimate that 99.9% of the worldwide internet traffic goes through at least one Broadcom chip. We look at the end-to-end connectivity capabilities of the communications pipeline - from the data centre, all the way to the end-user devices. Based on our analysis, the area of greatest near-term wireless demand is for indoor wireless broadband connectivity. The vast majority of internet traffic is consumed over indoor fixed networks, and the majority of fixed broadband traffic is distributed to devices over Wi-Fi. The 6 GHz band is the only expansion band that has been identified for Wi-Fi 6 (e.g., Wi-Fi 6E, Wi-Fi 7, and in the near future, Wi-Fi 8 (802.11bn)). No other bands have been identified for these Wi-Fi technology generations. 6 GHz Wi-Fi is designed to provide wireless throughput equivalent to the throughput of the associated fixed network, and to do so at very low latency and higher reliability than previous generations of Wi-Fi. Access to the entire 6 GHz band is critical for Wi-Fi 7 and Wi-Fi 8, which will use 320 MHz channel bandwidths. We believe that it takes a minimum of 3-4 non-overlapping channels for a market. The only way this can be done for 320 MHz channels in the UK is if the upper 6 GHz band is also made available for Wi-Fi. In addition, large public venues, such as stadiums, require a large number of narrower channels. Most deployments require at least 14 channels to meet performance goals with very dense device usage, and some public venues can require up to 26 different channels to avoid co-channel interference from nearby networks. Broadcom has reviewed technical

	studies provided by enterprise access vendors and has found that a typical stadium user's experience could be five times better if the full 6 GHz band is available compared to only the lower 500 MHz. It is therefore critical that Ofcom make the entire 6 GHz band available for RLAN use. We do not see 6 GHz as a core 5G band. Too many other major economies are unable to make it available for licensed mobile, and as such economies of scale would be very difficult to achieve to drive initial adoption. However, if necessary, it could be used on a case-by-case basis for excess outdoor capacity should Ofcom believe that mobile networks require such capacity via the 6 GHz band. The constraints to coexist with other licensed services in the band, however, are likely to greatly impact the viability of a 5G commercial service in the 6 GHz band. Ofcom would need to impose constraints regarding mobile signal strength, directionality, etc., in order for mobile service in the 6 GHz band to coexist with licensed Fixed Service (FS), Fixed Satellite Service (FSS), and Radio Astronomy Service (RAS). In addition, there is no path to global harmonisation for IMT in the 6 GHz band. The US, Canada, South Korea, and other countries have already made the full 6 GHz band available for licence-exempt use for many reasons, including the large number of fixed service operations that make the band challenging for IMT. So, at best, countries considering IMT would only achieve a fragmented global market. Consumers in any market allowing 6 GHz IMT would have to bear the entire costs for the development of such technologies, raising costs for all consumers in the UK, and likely putting commercialization out of reach for many markets. As noted above, should Ofcom believe that excess mobile capacity is required in certain areas using frequencies in the 6 GHz band, Broadcom believes that it is possible for Ofcom to enable limited sharing on a case-by-case basis under certain constraints.

	Responses to questions below delve into further detail.
Question 2(a): 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. 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?	*Is this response confidential? – N* Ofcom should prioritise Wi-Fi use of the upper 6 GHz band rather than 5G mobile use. If the mobile 5G service in the 6 GHz band were to be limited to client devices outdoors, the base station power was reduced, a physical separation distance between Wi-Fi and 5G was provisioned, and—in some special circumstances—additional mitigation procedures were applied, then Broadcom believes that Ofcom could permit hybrid sharing between Wi-Fi and mobile use while still allowing economies of scale for indoor wireless broadband. Wi-Fi connectivity is common in a wide range of consumer electronics equipment, at a reasonable price point. By contrast, cellular connectivity is currently limited to mobile phones, cars, a small percentage of cameras, watches, laptops, tablets, and some special purpose enterprise devices. The price points, network-specific certification requirements, engineering constraints, and limited ability to connect indoors put this technology out of reach for most consumer electronics equipment. The 6 GHz band is also not ideal for mobile calls, whether indoors or outdoors. When indoors, it is much more cost effective to provide mobile voice coverage using lower band spectrum or via Wi-Fi calling. In addition, it is much more cost effective to use Wi-Fi for indoor wireless broadband than to attempt to provide indoors service from outdoor macrocell base stations. For outdoor use, while it is true that some venues are constrained in their cellular and Wi-Fi capacity, many of the constraints for cellular can be met through densification of their existing networks and more fully using the bands that were deployed. In outdoor venues that have capacity constraints, the venues themselves should have

	the choice to deploy the technology that will meet their goals. In special circumstances where outdoor cellular capacity cannot be achieved with existing bands, Broadcom believes that it would be possible for 5G base stations to be deployed in the upper 6 GHz band as a temporary stopgap as 6G bands are being defined, and as millimeter wave[1] infrastructure becomes more pervasively deployed. Note that millimeter wave capability is already included in many mobile devices, unlike ability to use the 6 GHz band for IMT.
Question 2(b): Similarly, what are the priorities from the point of view of Wi-Fi deployments?	*Is this response confidential? – N* Wi-Fi is a key connectivity enabler for wireless broadband indoors and at large venues. There is no alternate wireless technology for most electronic devices. Wi-Fi is ubiquitous and cost effective. There are many devices that do not have fixed broadband or cellular connectivity, but can only be connected via Wi-Fi. Based on growing demand for wireless connectivity and data rates, along with the increasing availability of gigabit-capable fixed broadband, Broadcom believes that it is absolutely critical that Ofcom provide access to the upper 6 GHz band for immediate Wi-Fi use. Our Wi-Fi 7 access points are capable of 320 MHz wide channel operations. A minimum of three 320 MHz channels are needed for a resilient network. Many residences and small businesses rely on mesh systems for coverage, but many buildings do not have Ethernet or broadband connections in all the locations where coverage is needed. With a 320 MHz mesh backhaul, it is possible to achieve wireless gigabit internet throughout a home or a small business. This will ensure that users will obtain the full value of their Internet connection. As noted above, however, the full 6 GHz band is

[1] mmWave frequencies 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz, and 66-71 GHz were defined for IMT at WRC19. These add an additional 17.25 GHz of bandwidth, are all available for IMT, and were identified as capacity bands for IMT.

	needed to support this number of 320 MHz channels. In enterprises and public venues (indoors and outdoors), access to the entire 6 GHz band for Wi-Fi is even more critical. It typically takes a minimum of 7 non-overlapping channels for enterprises, and 14-26 channels for public venues such as stadiums, to deliver sufficient performance at typical user density. A full 6 GHz band allocation achieves wider channels for higher data rates in each of these deployment scenarios. As discussed above, based on measurements and technical studies conducted by Broadcom's customers, Wi-Fi performance in typical stadiums is five times better with access to the full 6 GHz band than with only the lower 500 MHz. Stadiums, venues, artists, and sporting leagues are eager to provide next generation fan experiences and would be able to do so if the entire 6 GHz band is available. Experiences such as instant replay on a device and the ability to look at a football goal from a different perspective are capabilities here today when there is sufficient connectivity available. Venues want to be able to build on this to provide even more immersive experiences. In short, Wi-Fi is needed mostly indoors, except in certain venue scenarios where Wi-Fi is more effective in provisioning the quality of service and communications needs as defined by the venue. In both settings, however, access to the full 6 GHz band is key.
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?	*Is this response confidential? – N* Automated Frequency Coordination (AFC) was designed to protect Fixed Service and Radio Astronomy Service from standard power RLANs. It is a very economical way to deploy outdoor access points and for large installations, and it could be readily available for use in the UK in a relatively short timeframe. In fact, Broadcom and others are currently working on the development of an

	Open AFC instance for use in the UK.[2] AFCs are being approved for RLAN operations in Canada and the United States, including for outdoor use. Mobile interests are actively working with AFC operators through bodies such as the WInnForum.[3] In short, AFC technology is well understood and has been validated for RLAN deployment. However, Broadcom would note that using an AFC for most residential RLAN deployments could be cost prohibitive. AFC capable access points require geolocation capabilities, and support from an AFC system is expected to require additional fees for use. This increases costs for consumers and may not meet the market requirement for some device classes, limiting the value of the upper 6 GHz for RLANs. In addition, using an AFC for hybrid sharing would be a novel approach and would require significant code changes for an AFC. Ofcom would need to consider rules and propagation models first for 5G base station deployments, protection of incumbent services, and a necessary separation distance between mobile and Wi-Fi networks. Based on these considerations, Broadcom recommends that AFC requirements be used sparingly, such as for major RLAN deployments for enterprises and public venues. Enterprises and public venues are the most likely to be located in places where IMT networks could possibly need more capacity in dense urban areas. By coordinating only these types of deployments, Ofcom could manage the most significant risk of interference and also ensure that enterprises and venues are able to realize the benefits of the investments that they made in their wireless infrastructure. Such RLAN equipment would need to be listed in the AFC, and Ofcom should require IMT to protect such RLANs. Likewise, Ofcom could require that any IMT base station, and coverage area, that is listed in the AFC be protected from RLAN

[2] Open AFC is a software project under the Telecom Infra Project. Broadcom is a founding member and cochair of Open AFC. For more please see: https://telecominfraproject.com/open-afc/

[3] https://www.wirelessinnovation.org/

	deployments listed in the AFC. Such a mechanism would significantly reduce the risk from hybrid sharing. Residential RLANs and VLP devices would require different mechanisms (e.g., listen before talk, the use of their channel selection algorithms, channel puncturing) for hybrid sharing.
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?	*Is this response confidential? – N* Broadcom recommends that Ofcom handle individual RLAN to IMT interference and IMT to RLAN interference primarily via power requirements, network planning, and current protocols inherent in IMT and RLAN technologies. Several protocols and sensing mechanisms already exist to further enable hybrid sharing where appropriate. We note that Wi-Fi has a listen before talk (LBT) mechanism that limits transmissions upon detecting the energy of another system. We recommend that Ofcom require LBT in the upper 6 GHz at the same energy detection (ED) Threshold as the lower 6 GHz defined under the ETSI requirements,[4] where the ED threshold defined in clause 4.3.6.3.3 equates to -72 dBm/20 MHz for devices operating at a maximum transmit power (Pmax) of 24 dBm or higher. This should be sufficient to help protect IMT networks. In the event IMT is transmitting at energy levels that lead to poor medium access for RLANs, RLAN equipment can enable channel selection algorithms that would change their channel to one that is not being used by the IMT base station. In addition, Wi-Fi 7 has additional protocols that allow the puncturing of a sub channel, so that RLANs could avoid transmitting on a 100 MHz IMT channel, and still make use of a 320 MHz channel. Finally, Wi-Fi 7 has a feature called multi-link operations (MLO) which allows it to operate simultaneously on the 2.4 GHz, 5 GHz, and 6 GHz frequencies. If there happens to be an IMT

[4] ETSI published standard EN 303 687 v1.1.1. https://www.etsi.org/deliver/etsi_en/303600_303699/303687/01.01.01_60/en_303687v010101p.pdf

	base station transmitting and its energy reaches an indoor RLAN network, the RLAN could avoid transmitting on the 6 GHz channel occupied by IMT. We note that if Ofcom does not impose network design requirements such as power limitations or antenna pointing, that IMT signals are likely to make it inside buildings and greatly impact RLAN networks. While Wi-Fi technology can defer using sensing mechanisms, IMT devices are not designed with the same mechanisms to facilitate sharing. Accordingly, mobile deployment will need to be deployed with carefully defined boundaries and power levels to avoid significant disruption to Wi-Fi use. In situations where network planning is insufficient to protect indoor RLAN networks, we suggest that Ofcom consider requiring the IMT technology to incorporate a contention-based protocol such as that adopted by 5G NR-U. (refer to response to Question 8(b) for further details.)
Question 5: What mechanisms could potentially enable device-to-device connectivity?	*Is this response confidential? – N* Broadcom is a strong proponent of device-to-device connectivity, as it dramatically reduces time needed to transfer data between two pier devices.[5] For Wi-Fi, device-to-device connectivity can be easily accomplished by requiring low power indoor (LPI) devices seeking such connectivity to be able to decode the enabling signal of 6 GHz enabled Wi-Fi access point. Such a requirement would ensure that client devices communicating with other client devices are constrained to indoor locations.
Question 6: If hybrid sharing is eventually adopted, and requires licensed mobile to	*Is this response confidential? – N*

[5] C2C Updated proposal including TPC.m ETSI BRAN Contribution: BRAN(22)113009r3 https://docbox.etsi.org/BRAN/BRAN/05-CONTRIBUTIONS/2022//BRAN(22)113009r3_C2C_Updated_proposal_including_TPC.docx

operate at medium power, in what way would mobile networks use the upper 6 GHz band?	Ofcom should only allow medium power 5G for outdoor areas on an "as needed basis." Broadcom believes that operators and the public are best served via densification of networks on currently available frequencies. Densification can not only provide better coverage, but will also help to meet latency, a key performance indicator for 5G. Macrocell networks already have some challenges meeting lower latency requirements. The greater the distance travelled, the higher likelihood the signal will be attenuated or interrupted from clutter, building attenuation, and/or multipath. Densification allows operators to provide a higher quality of service. In instances where Ofcom believes that 6 GHz IMT is needed for capacity, Broadcom believes that this should be used on a limited basis, in areas where it is difficult to densify using existing frequencies. Broadcom believes that this should be used primarily for outdoor coverage. Indoor wireless broadband needs can be met via RLAN technologies such as Wi-Fi or 5G NR-U. 3GPP has standardized its core network such that both technologies can be seamlessly integrated. Furthermore, Wi-Fi offers a technology called Passpoint, which allows seamless roaming from a mobile network to a Wi-Fi network. There are many operators around the world that have deployed Passpoint to enable more efficient indoor mobile operations.
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?	*Is this response confidential? – N* Hybrid sharing could be enabled through a combination of indoor RLAN use (except for venues, which should have the choice), and outdoor 5G on an as needed basis. The typical outdoor to indoor building attenuation today assuming 30% energy efficient and 70% traditional mix is estimated to lead to approximately 100 times weaker signal today (~20 dBm in loss). As buildings become more energy efficient, is highly probable that in the future the energy efficient / traditional mix could change to 40/60 or even 50/50, which would lead to a typical signal being attenuated by 200 or even 400 times when it travels from

	an outdoor environment to indoors. Building entry loss would be a primary mitigation against interference. Further mitigation could be achieved through requirements for lower power 5G, antenna pointing restrictions, and using databases such as AFC for ensuring adequate separation distances. In some cases, Ofcom should require a contention-based protocol such as that implemented by 5G NR-U.
Question 8(a): Assuming the future of the band includes indoor use for Wi-Fi and outdoors use for mobile: How could this be achieved without creating or suffering interference?	*Is this response confidential? – N* Broadcom has been studying the potential for hybrid use. Our early findings lead us to believe that limited sharing is possible with the right combination of rules, spatial separation and possible mitigation requirements, as discussed above. We have submitted a study to the CEPT PT1 work group, where our initial findings are that hybrid sharing could be enabled for lower power 5G base stations operating only outdoors, and with appropriate separation distances between Wi-Fi and 5G.[6] Our initial findings indicate that separation distances between IMT and Wi-Fi could be in the hundreds of meters, leaving many users located within an IMT footprint without the ability to access the 100 MHz IMT channel located in the 6 GHz spectrum. However, as we evaluate current 5G sites in dense urban corridors where additional IMT capacity could be required, it appears that in many instances, it is primarily enterprises that are collocated next to IMT base stations. This means that additional steps may be needed to accommodate sharing between outdoor IMT base stations and enterprise Wi-Fi networks. Such a step could be a simple registration requirement for enterprise access points and 5G base stations. Ofcom could require both types of deployments to be registered in order to be protected and to avoid interfering with the other radio network. We believe that sharing should be achievable in residential deployments without registration,

[6] See https://cept.org/Documents/ecc-pt1/79530/ecc-pt1-23-200_broadcom-mfcn-rlan-cochannel-operation-in-upper-6ghz

	subject to the proviso that the non-registered Wi-Fi network would not be protected from interference. Should a non-registered Wi-Fi network be co-located with an IMT base station, the power disparity between a mobile base station and the Wi-Fi access point would mean that the Wi-Fi would be likely to defer using the listen before talk protocol, or would move to a different channel if the channel selection algorithm included in Wi-Fi devices found that the noise floor increased sufficiently in the channel where it was operating. Interference from indoor Wi-Fi to even nearby IMT is unlikely because the Wi-Fi transmissions will be very weak by the time they exit the building. The following studies confirm this: 1. ECC Report 302 (2019) concludes that Low Power Indoor (LPI) and Very Low Power (VLP) devices do not present a significant risk of interference to Fixed Service Satellite (FSS) links. - While these studies were conducted for the lower portion of 6 GHz, they are applicable to the upper portion of the band as well. 2. The US FCC decision (2020) to permit license-exempt use of the full 6 GHz band finds no significant risk of harmful interference at paragraphs 89-92 (coexistence with Standard Power devices) and paragraphs 169-172 (coexistence with Low Power Indoor devices). Note that coexistence between Wi-Fi and Fixed Microwave and Fixed Satellite Service is still feasible in the 6 GHz band. We believe that coexistence between outdoor IMT and such services, particularly fixed microwave services, will be technically challenging. As a result, Wi-Fi is better suited for coexistence with such services in the UK.
Question 8(b): Could there be a combination of technical adjustments such as power limits and other mechanisms (including databases or sensing mechanisms)?	*Is this response confidential? – N* We believe that the combination of energy detection by Wi-Fi will facilitate significant sharing when combined with physical separation of Wi-Fi and mobile base stations.

	The following will need to be adhered to for Wi-Fi and mobile connectivity to exist side by side:
	
	- Mobile limited to outdoors
	- Mobile limited to 100 MHz bandwidth per base station
	- Mobile transmit power limited to reduce the probability of indoor UE operations by end users
	- Mobile use of directional antennas to focus beam energy precisely
	- Mobile use outdoors only, or if indoors, based on the public venue requirements
	- Wi-Fi use listen before talk mechanism with energy sensing at -72 dBm/20 MHz
	- Building attenuation can vary between 1 and 100 dB (20 dB median). Thus, in addition to building attenuation, sufficient separation distances and network configuration, such as antenna pointing, would need to be provisioned between enterprise Wi-Fi and mobile deployments:
	  - If Wi-Fi is deployed first, and is registered for protection, then mobile will have the responsibility of protecting such operations
	  - If mobile is deployed first, then enterprise Wi-Fi networks will have the responsibility of ensuring protection of such networks.
	  - A coordination mechanism, such as one based on an AFC, could be used to govern this registration process.

Question 9(a): 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. 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?	*Is this response confidential? – N* 3. As noted in response to question 8a, transmissions from indoor Wi-Fi access points and user devices will be very weak by the time they exits the building. The studies cited in response to question 8a are also relevant here.
Question 9(b): What are your views on the initial analysis we have conducted around hybrid sharing and coexistence with incumbents?	*Is this response confidential? – N* As noted in response to question 8(a), Wi-Fi can readily coexist with incumbent uses. By contrast, as noted in response to question 1, incumbent operations such as Fixed Service,

	Fixed Satellite Service, Mobile Service, and Radio Astronomy Service are unlikely to coexist with mobile networks unless the mobile networks are deployed sparingly and at limited power levels. If the mobile deployments could avoid incumbent areas via well controlled signal strength and boundaries, perhaps that could lend itself to coexistence with incumbent uses. We note that such limitations may also impact the viability of a mobile network deployment. As a result, Broadcom does not recommend 5G mobile networks in the 6 GHz band.
Question 9(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?	*Is this response confidential? – N* Broadcom is not aware of viable alternatives for sharing between mobile use and incumbent uses in the 6 GHz band beyond those addressed in response to question 9(b).

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