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August 24, 2016

VIA ELECTRONIC FILING

R. S. Sharma
Chairman
Telecom Regulatory Authority of India
Mahanagar Door Sanchar Bhawan
Jawahar Lal Nehru Marg
New Delhi 110002
India

Re: *Consultation Paper on Proliferation of Broadband Through Public Wi-Fi Networks*, Consultation Paper No. 14/2016

Dear Chairman Sharma:

Wi-Fi Alliance®[1/] is a global, non-profit industry association of approximately 700 leading companies from dozens of countries devoted to seamless interoperability. With technology development, market building, and regulatory programs, Wi-Fi Alliance has enabled widespread adoption of Wi-Fi® worldwide, certifying thousands of Wi-Fi products each year. The Consultation Paper the Authority issued examines how to encourage the proliferation of Wi-Fi networks – one of the same missions of Wi-Fi Alliance.[2/] Accordingly, Wi-Fi Alliance is pleased to have the opportunity to provide this response to the Wi-Fi Consultation.[3/]

1/ Wi-Fi®, the Wi-Fi logo, the Wi-Fi CERTIFIED logo, Wi-Fi Protected Access® (WPA), WiGig®, the Wi-Fi ZONE logo, the Wi-Fi Protected Setup logo, Wi-Fi Direct®, Wi-Fi Alliance®, WMM®, and Miracast® are registered trademarks of Wi-Fi Alliance. Wi-Fi CERTIFIED™, Wi-Fi Protected Setup™, Wi-Fi Multimedia™, WPA2™, Wi-Fi CERTIFIED Passpoint™, Passpoint™, Wi-Fi CERTIFIED Miracast™, Wi-Fi ZONE™, WiGig CERTIFIED™, Wi-Fi Aware™, Wi-Fi HaLow™, the Wi-Fi Alliance logo and the WiGig CERTIFIED logo are trademarks of Wi-Fi Alliance.

2/ *See Consultation Paper on Proliferation of Broadband Through Wi-Fi Networks*, Consultation Paper No. 14/2016, at 1 (2016), *available at* http://www.trai.gov.in/Content/ConDis/20782_11.aspx ("Wi-Fi Consultation"). While the Authority is focused on public Wi-Fi networks, many of the same issues raised in the Wi-Fi Consultation – particularly access to additional spectrum under favorable conditions -- also affect the proliferation of Wi-Fi generally. In fact, as noted below, taking the actions that Wi-Fi Alliance recommends here will create a virtuous cycle of promoting overall Wi-Fi use, which in turn will create the demand for additional public Wi-Fi.

3/ As an initial matter, Wi-Fi Alliance notes that the Authority appears to conflate the Wireless Broadband Alliance and Wi-Fi Alliance. The Wireless Broadband Alliance was founded in 2003 and

I. THE IMPORTANCE OF WI-FI

Wi-Fi has become increasingly central in enabling access to the Internet and, as the Authority recognizes, can be deployed at relatively low costs.[4/] In particular, the cost per megabyte of deploying Wi-Fi access infrastructure — and, ultimately, the cost for the end user — is substantially lower than for 3G or 4G mobile broadband networks.[5/] So it is no surprise that hundreds of millions of people rely on Wi-Fi every day, and Wi-Fi usage continues to grow. Wi-Fi now has an installed base of more than 6.8 billion devices.[6/] By the end of 2019, there is expected to be more than 10 billion devices in households worldwide.[7/] Global Internet traffic is anticipated to increase by about three times over the next five years, and Wi-Fi, through these billions of devices, will play an important role in driving that growth; it is estimated that Wi-Fi and mobile devices will account for two-thirds of all Internet traffic by 2020.[8/]

As the Authority notes, many new and emerging applications and industry verticals rely on Wi-Fi.[9/] Numerous cities already offer city-wide, public Wi-Fi coverage. LinkNYC, for instance, uses old payphone locations to provide Wi-Fi hotspots and charging stations for USB devices across the United States' most populous city.[10/] Residential use of Wi-Fi, to access TV and video streaming, especially ultra high-definition streaming, and Internet of Things or smart home applications, places increasing demands on the spectrum available for Wi-Fi. The rapid acceleration of data demands over Wi-Fi will require an increase in available spectrum for Wi-Fi.

Wi-Fi Alliance therefore applauds the Authority's efforts to encourage the deployment of public Wi-Fi networks. While all the questions that the Authority asks are important, Wi-Fi Alliance is in the best position to address Questions 1, 3 and 5, regarding certain actions

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works with Wi-Fi Alliance. *See Who We Are*, Wireless Broadband Alliance, http://www.wballiance.com/who-we-are/ (last visited Aug. 1, 2016). However, it is Wi-Fi Alliance that certifies Wi-Fi devices and owns and controls the "Wi-Fi CERTIFIED" logo. *See Who We Are*, Wi-Fi Alliance, http://www.wi-fi.org/who-we-are (last visited Aug. 1, 2016).

4/ *See* Wi-Fi Consultation at 3.

5/ *See id.*

6/ *See Wi-Fi Device Shipments to Surpass 15 Billion by End of 2016*, WI-FI ALLIANCE NEWSROOM (Jan. 5, 2016), http://www.wi-fi.org/news-events/newsroom/wi-fi-device-shipments-to-surpass-15-billion-by-end-of-2016.

7/ *Id.*

8/ *The Zettabyte Era—Trends and Analysis*, CISCO (June 2016), *available at* http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html.

9/ *See* Wi-Fi Consultation at 16.

10/ *See* LinkNYC, https://www.link.nyc (last visited Aug. 1, 2016).

that can be taken to facilitate Wi-Fi growth. Specifically, removing restrictions on the use of unlicensed 5 GHz spectrum and opening up additional bands – including in the 5 GHz range -- for unlicensed use will not only promote public Wi-Fi growth, but will increase Wi-Fi use generally, which will ultimately help drive the results the Authority seeks to achieve — to facilitate the spread of Internet access in rural and urban areas alike.[11/] Finally, as noted below, Wi-Fi Alliance has already taken measures to ensure interoperability of Wi-Fi networks throughout the world.

II. Q1. Are there any regulatory issues, licensing restrictions or other factors that are hampering the growth of public Wi-Fi services in the country?

Different unlicensed bands promote different unlicensed uses of spectrum based on, among other things, propagation characteristics and available bandwidth. Additional spectrum enables greater capacity, while wider channels promotes higher transmission speed – both facilitating new use cases. Moreover, as noted above, the use of Wi-Fi is rapidly increasing in the bands that are currently allocated for unlicensed operations. As the Authority itself notes, the 2.4 GHz band, long the home for Wi-Fi, is becoming increasingly congested.[12/]

The 5 GHz band can provide access to greater bandwidth, enabling gigabit Wi-Fi – the type of use that can support emerging applications and technology. Today, India makes only certain segments of the 5 GHz band available for Wi-Fi and only, in certain cases, under conditions that constrains its use. In particular, the 5150-5350 MHz band can be used on an unlicensed basis for indoors, with a maximum EIRP of 200 mW (with no unlicensed outdoor use permitted); the 5725-5875 MHz band is similarly restricted for unlicensed operations for indoor use (with limited outdoor use permitted at 5725-5825 MHz); and 5825-5875 MHz band is designated for lower power use both indoors and outdoors.[13/] India should make additional 5 GHz spectrum available for unlicensed operations and modify its rules governing those segments of the 5 GHz band already available to allow greater proliferation of Wi-Fi and wireless Internet access.

However, there are additional segments of the 5 GHz band that India should consider making available for unlicensed operation. In particular, the International Table of Allocations contains, in all regions, a Mobile allocation in the 5470-5725 MHz and 5850-5925 MHz bands. At a minimum, India should permit unlicensed operations in those bands. Making more 5 GHz spectrum available for unlicensed use would be consistent with international efforts to increase deployment of 5 GHz spectrum for unlicensed use. The United Kingdom's Ofcom recently sought comment on whether to further open the 5 GHz band for unlicensed uses, "to enhance spectrum access for Wi-Fi and enable growth and

11/ *See* Wi-Fi Consultation at 3-4.

12/ *See id.* at 8.

13/ *See id.* at 20.

innovation in new wireless services for consumers."[14/] The U.S. is also considering unlocking additional spectrum above 5825 MHz for unlicensed uses like Wi-Fi.[15/]

India should also open the 5150-5350 MHz and 5725-5825 MHz bands – where unlicensed operations are currently restricted -- for outdoor, unlicensed use. The power limits for both bands should also be increased from 200 mW to 1 watt for access points. These bands are also designated for unlicensed use in many countries. As the Authority recognizes, the 5150-5350 MHz and 5470-5825 MHz bands are designated for unlicensed use in both the United States and in Europe.[16/] Permitting greater use of these bands in India is the next logical step for expanding access to spectrum that can be used for Wi-Fi.

Permitting indoor-only unlicensed operations, with correspondingly restrictive power limits, impedes Wi-Fi proliferation. Wi-Fi is intended to be an "anytime, anywhere" technology, and users expect to be able to use their Wi-Fi devices whether they are indoors or outdoors. Allowing higher-power unlicensed use of the 5 GHz bands to accommodate both indoor and outdoor use will enable a greater range of Wi-Fi applications and promote Wi-Fi signal reliability without compromising other uses of the band. This is particularly important as Wi-Fi devices and Wi-Fi-based applications expand. The U.S. has recognized this by permitting the use of the 5150-5250 MHz band with increased power coupled with relaxed antenna requirements[17/] — and, to date, this has not produced any harmful interference to Globalstar's satellite operations in that band. In the U.S., unlicensed access point devices in the 5 GHz band may have a maximum conducted power of 1 watt, except for operations in the 5250-5350 MHz band.[18/] If public Wi-Fi networks are to serve as an effective complement to existing mobile broadband networks, maximizing public use of the spectrum requires authorizing both indoor and outdoor unlicensed use of the 5 GHz band and creating power limits that can support both sets of applications. Greater harmonization of spectrum available for unlicensed uses promotes the manufacturing of Wi-Fi equipment that can be marketed, sold, and used across international borders and enables expanded access to Wi-Fi much more quickly and efficiently.

14/ *Improving Spectrum Access for Consumers in the 5 GHz Band*, Ofcom Consultation, at ii (rel. May 13, 2016), *available at* http://stakeholders.ofcom.org.uk/binaries/consultations/5-GHz-Wi-Fi/summary/improving-spectrum-access-consumers-5GHz.pdf. ("Ofcom Consultation").

15/ *See The Commission Seeks to Update and Refresh the Record in the "Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band" Proceeding*, Public Notice, 31 FCC Rcd. 6130 (2016).

16/ *See* Wi-Fi Consultation at 23.

17/ *See* 47 C.F.R. § 15.407(a)(1).

18/ *See id.*.

III. Q3. What measures are required to encourage interoperability between the Wi-Fi networks of different service providers, both within the country and internationally?

No measures are required to encourage interoperability between the Wi-Fi networks of different service providers. Wi-Fi Alliance has taken the lead to address this precise issue. In the past, it was complex for Wi-Fi users to access (by selecting the correct service set identifier, or "SSID" code) and then gain authentication to a Wi-Fi Network. Security concerns added to that complexity. Wi-Fi Alliance addressed those issues in 2012 by launching the the Wi-Fi CERTIFIED Passpoint program -- an industry-wide solution to streamline network access and eliminate the need for users to find and authenticate a network each time they connect. Passpoint automates that entire process, enabling a seamless connection between hotspot networks and mobile devices, all while delivering the highest WPA2™ security. Passpoint provides a streamlined method to use existing user accounts and establish new user accounts, facilitating connectivity for both Wi-Fi/cellular devices and Wi-Fi-only devices such as tablets and notebooks, enabling a more cellular-like experience when connecting to Wi-Fi networks.

The Passpoint program has been recently enhanced to offer new features that expand the program's strategic value to mobile and fixed operators, and to open opportunities for other sectors as they invest in Wi-Fi to meet business challenges. These new features include online sign-up and immediate account provisioning, secure registration, and distribution of operator policies. These enhancements promote usage by streamlining connectivity and enabling in-pocket connection across a service provider's network of hotspots, all with secure exchange of credentials and new account establishment. For service providers the ability to distribute subscriber policies -- such as the identity of networks to join and the order of preference -- enables them to deliver the best user experience on Wi-Fi, while still easily maintaining the business requirements of Wi-Fi roaming agreements.

In addition to providing a reliable, secure, connection experience in, Passpoint is delivering value to service providers by:

- Supporting data offload with instant network detection, selection, and authentication
- Enabling new value streams through inter-carrier Wi-Fi roaming, reaching new devices and new venues for the existing subscriber base
- Increasing customer satisfaction and reducing churn
- Offering best-in-class security for SIM and non-SIM devices alike

Passpoint is a foundational ingredient to Wi-Fi roaming standards currently taking shape across the world. Multi-operator trials on Passpoint-certified equipment are taking place now. Wi-Fi Alliance is collaborating with various industry groups to ensure the building blocks are in place to create a truly global Wi-Fi roaming experience.

IV. Q5. Apart from frequency bands already recommended by TRAI to DoT, are there additional bands which need to be de-licensed in order to expedite the penetration of broadband using Wi-Fi technology? Please provide international examples, if any, in support of your answer.

Wi-Fi Alliance suggests that the Authority consider other bands in addition to the 5 GHz sub-bands noted above.

First, permitting unlicensed use of the 57-64 GHz ("60 GHz") and adjacent bands will enable a variety of new uses, including high-capacity and future WiGig® communications. As the next frontier in unlicensed technologies, WiGig makes use of unlicensed spectrum in the millimeter wave bands to support very high data rates of up to 7 gigabits per second — enabling such applications as instant wireless synchronization, docking between personal devices, ultra-high definition streaming, and cordless computing.[19/] As the Authority recognizes, the band is already allocated for use in multiple countries for unlicensed operations and there a good device ecosystem in the band.[20/] And, the FCC recently extended the unlicensed 57-64 GHz band up to 71 GHz, and is further considering opening up the complementary 71-76 GHz and 81-86 GHz bands for unlicensed use.[21/] The Authority should consider recommending similar action. As the Authority notes, it already recommended that the 60 GHz band be explored for telecommunications service providers. This band should be made available for unlicensed operations, consistent with the approach taken in other countries. In making the band available, a channel bandwidth of 2.16 gigahertz should be adopted, not the 50 megahertz bandwidth recommended by the Authority. 2.16 gigahertz is the standard channel size for 802.11ad WiGig transmissions and is permitted internationally. Greater international harmonization of spectrum will help promote Wi-Fi deployment in India. The Authority should also consider making the 64-71 GHz band available for unlicensed operations, as the United States has. Finally, the Authority should consider recommending that the 71-76 GHz and 81-86 GHz be made available on an unlicensed basis.

19/ *See Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Notice of Proposed Rulemaking, 30 FCC Rcd. 11878, ¶ 58 (2015); Wi-Fi Alliance, WiGig ® and the Future of Seamless Connectivity, at 2-4, 8 (2013), *available at* http://www.wi-fi.org/file/wigig-and-the-future-of-seamless-connectivity-2013; Wi-Fi Alliance, Discover Wi-Fi, WiGig CERTIFIED, http://www.wi-fi.org/discover-wi-fi/wigig-certified (last visited Aug. 1, 2016).

20/ *See* Wi-Fi Consultation at 23; *see also, e.g.,* Robert C. Daniels, *et al*., "60 GHz Wireless: Up Close and Personal," IEEE Microwave Magazine at S44 (Dec. 2010 Supplement), *available at* http://faculty.poly.edu/~tsr/General/60ghz/systems07.pdf (noting that unlicensed spectrum at the 57-64 GHz frequencies is available in North America and Korea, and unlicensed spectrum at the 59-66 GHz frequencies is available in Europe and Japan).

21/ *See Use of Spectrum Bands Above 24 GHz for Mobile Radio Services, et al.*, Report and Order and Further Notice of Proposed Rulemaking, GN Docket No. 14-177, FCC 16-89, ¶¶ 424-441 (July 14, 2016).

Second, India should make the 902-928 MHz ("900 MHz") band more accessible for unlicensed use. As noted above, frequency bands have different characteristics and can best support a variety of applications. While the 5 GHz band is critical to permitting greater wireless Internet access and 60 GHz can support very high data rates over shorter distances, lower band spectrum, which typically features narrower bandwidths is particularly useful for Internet of Things sensors and devices that may require long range connectivity that 900 MHz propagation can support. The 900 MHz band is already available for unlicensed use in the United States, and Wi-Fi Alliance has introduced Wi-Fi HaLow™ as the designation for products incorporating IEEE 802.11ah technology, which makes use of this band. Opening up the 900 MHz band to unlicensed use in India would provide spectrum with the ideal propagation characteristics for deployment of these new Wi-Fi based applications.

Third, the Authority notes that other countries have explored the use of TV White Spaces for unlicensed operations.[22/] Advancements in television technology have permitted more intense use of TV band spectrum and the employment of a real-time database to monitor access to the spectrum make deployment of TV White Space access possible. India should explore adopting a similar regime. Doing some may particularly permit citizens to leverage unlicensed technologies in rural areas, permitting connections to BharatNet.[23/]

Finally, to the Authority should study whether the entire 6 GHz band, or at least the 5925 MHz – 6425 MHz segment, could be made available for unlicensed use. The combination of wider bandwidths and good propagation characteristics make the band ideal for serving many people over a wide geographic area; the additional unlicensed spectrum allocation would provide a sufficient number of larger bandwidth channels to provide faster broadband access in even the most dense deployment scenarios within India. Wi-Fi radios could be readily tuned so that this band could effectively operate as an extension of the 5 GHz band. This additional spectrum could provide three additional 160 megahertz channels and six additional 80 megahertz channels. This band has been considered for

22/ *See* Wi-Fi Consultation at 24; *see also Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, et al.*, ET Docket No. 14-165 (2014).

23/ *See id.* at 15.

unlicensed mobile radio allocation in the past,[24/] and the Wi-Fi Alliance has recently encouraged Ofcom to consider this band for unlicensed allocation in this band .[25/]

* * *

Wi-Fi Alliance supports the Authority's efforts to encourage public Wi-Fi networks to promote expanded broadband Internet access in India. Accordingly, the Authority should ensure that both indoor and outdoor unlicensed operations are permitted in the 5 GHz band, with 1 watt power limits. The Authority should also consider recommending the 60 GHz, TV White Spaces and 900 MHz bands for de-licensing to pave the path for future unlicensed applications and developments. Wi-Fi Alliance also recommends the Authority to study whether the 6 GHz band could be allocated for unlicensed operations. Should you have any questions, please contact the undersigned. Finally, Wi-Fi Alliance notes that its Passpoint program is already addressing the interoperability requirements identified by the Authority.

Respectfully submitted,

WI-FI ALLIANCE

Edgar Figueroa
President and CEO

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24/ The International Telecommunications Union (ITU) has conducted sharing studies between IMT and FSS and FS. *See* Presentation to IEEE, "OFCOM Future Spectrum Requirements," IEEE 802.18-16/0016r0, at 31 (Mar. 16, 2016), *available at* https://www.google.com/url?url=https://mentor.ieee.org/802.18/dcn/16/18-16-0016-00-0000-ofcom-future-spectrum-requirements.pptx&rct=j&frm=1&q=&esrc=s&sa=U&ved=0ahUKEwjJ4ZHSzqPOAhWDLmMKHe-TB1oQFghIMAg&usg=AFQjCNGCeQL-unA0AW65GpKz-RiP6LGMtw. In 2013 Russia proposed to the World Radio Conference (WRC) that the 5925-6425 MHz band be considered as a candidate for mobile broadband. *See* Comments of the Russian Federation on the bands considered under WRC-15 AI 1.1 and proposals for draft CEPT Brief on AI 1.1, European Conference of Postal and Telecommunications Administrations (Mar. 9, 2013), *available at* http://cept.org/Documents/cpg-pt-d/12621/CPG-PTD(13)084_Comments-of-the-Russian-Federation-on-the-bands-considered-under-WRC-15-AI-11-and-proposals-for-draft-CEPT-Brief-on-AI-11.

25/ *See* Response of Wi-Fi Alliance to Ofcom Consultation (filed July 16, 2016), appended hereto as Attachment 1.

ATTACHMENT 1
WI-FI ALLIANCE RESPONSE TO OFCOM CONSULTATION
(as filed July 16, 2016)

Question 1: Do you agree with our proposal to prioritise consideration of the 5725-5850 MHz frequencies for Wi-Fi, subject to appropriate protections to other users, in particular satellite services?:
With hundreds of millions of people depending on Wi-Fi every day of their lives, we understand the need for maintaining sufficient spectrum to protect against network congestion and connection failures as the use of high data rate services continues to increase. Addition of 5725-5850 in UK greatly facilitates the possibility for worldwide allocation with relaxed limits (high power) similar to a number of other countries. As such, any decision that expedites the process of keeping up with the needs would be welcome. We believe that Ofcom clearly understands and articulates the reasons for moving first on the 5725-5850 MHz band, and agree with this choice. The entry into the spectrum dominated by Wi-Fi for 20 years, of other technologies, even if they share fairly, reduces the already congested space, making the need for additional spectrum real and urgent. This is a good start.

Question 2: Do you agree with our proposal to re-examine the requirement for DFS across the 5 GHz band, subject to appropriate protections to other users?:
Yes, however we believe that this should be a path to improved user experience and avoiding unnecessary restriction for Wi-Fi and not establishing new restrictions. Current DFS rules were developed over ten years ago, and Wi-Fi technologies have advanced significantly during that time. Basing modified DFS rules on today's Wi-Fi and radars actually in use, could benefit all of the users in the DFS bands. Wi-Fi devices operating under current rules have never been shown to cause interference into the radars that the DFS technology was designed to protect. Securing the regulatory operational parameters will maintain sufficient controls to provide full protection. IEEE 802.11 REVmc D6.0 (expected to be approved in 2016) provides the means for more rapidly clearing a radar channel, making the existing DFS protections even more effective.

Question 3: Do you think we should pursue the other options we have identified: opening up 5850-5925 MHz, outdoor Wi-Fi use at 5150-5350 MHz, and opening up the 'centre gap' at 5350-5470?:
Our answer to Question 1. makes our opinion clear on the need for additional spectrum. The three items listed in this question would enable not only improvement in the quality of connections, but also provide more wider channels, needed to support the demand for the higher throughput applications and improved user experience in the next five to ten years. The addition of a technology that could potentially create significant additional congestion in these bands, makes this essential to maintain the viability of the Wi-Fi ecosystem. We also believe 5150-5350 MHz and 5850-5925 MHz bands would be good choices. The US FCC has enabled outdoor use and increased transmit power in 5150-5250 MHz using simple antenna restrictions, we encourage Ofcom to consider a similar approach. To date, Globalstar has not experienced disruptions to their operations in the 5150-5250 MHz band

as a result of the US FCC regulatory action. The US is currently testing ITS interference mitigation techniques in order to enable sharing in the 5850-5925 MHz band. We recognise the importance of protecting ITS applications from RLAN interference.

Question 4: What are your views on the future growth in demand for Wi-Fi? In which use scenarios do you expect to see the greatest pressure for delivery of high quality Wi-Fi access? What evidence do you have to support your views?:
Below are listed use scenarios with pressure for delivery of high quality Wi-Fi Access:
- Residential - UHD TV/video streaming, IoT / smart home (including video, e.g. security cameras), artificial/augmented reality (gaming, educational, etc), interactive multimedia
- Hotspots - City-Wide coverage (Metro Wi-Fi, LinkNYC) primarily for mobile devices with cellular-like use cases and growth in demand, increasingly rich SaaS services used by nomadic professionals (Wi-Fi only laptops drive high traffic for rich applications, file downloads, etc);
- Education
Existing allocated license-exempt spectrum is increasingly unable to sustain current demand in critical environments such as airports, convention centers, stadia, and multi-tenant high-rise buildings, as well as enterprise environments. New technologies vying for the spectrum that Wi-Fi virtually has exclusive use of today, will exacerbate this problem for Wi-Fi, requiring additional spectrum just to maintain current service levels.

To provide a better estimation of required spectrum in dense networking environments, one of our members, Qualcomm Inc., conducted a simulation study for which a report can be downloaded at https://www.qualcomm.com/documents/quantification-5-ghz-unlicensed-band-spectrum-needs . The study is based on the latest Wi-Fi technology (802.11ax) and identifies the spectrum requirements to deliver a 1Gb/s data rate consistently over an area with different configurations, taking interference into account. 1Gb/s is widely considered as an appropriate measure of the performance expected from access systems around the 2020 horizon.
The conclusions of the study are that 455 MHz of spectrum are not enough in most scenarios to deliver a 1Gb/s consistently even with the latest technologies. Additional 160 MHz wide channels are very beneficial to meet required QoS. For example, in a dense enterprise configuration, using 2 antenna STAs, 1280 MHz of spectrum is required to deliver 1 Gb/s, whereas for 4 antenna STA's 640 MHz of spectrum is required.
The study indicates that ideally 1280 MHz of spectrum should be made available to unlicensed technologies in the 5 GHz band, in order to support most scenarios.

Question 5: Do you think technology improvements and densification of access points will be sufficient to meet demand or will there also be a need for more spectrum beyond that which we propose to make available? What evidence do you have to link between demand for data and demand for additional spectrum?:
Wi-Fi has become the dominant Internet access technology (approximately 15:1 over LTE), a trend we believe will continue beyond what technology improvements alone will address. The rapid acceleration of demand of data over Wi-Fi will therefore require a commensurate increase in available spectrum for Wi-Fi. Technology improvements will help but are reaching theoretical limitations (Shannon's Law, etc). Technology improvements will also

facilitate more effective spatial reuse when Access Points are densely deployed (e.g. 11ax). However, densification is costly and sometimes impossible (physical siting and permission from owner, power supply, deployment scenario, etc). Backhaul is also a major limiting factor in siting - improvements in wireless backhaul (e.g. low-cost 60 GHz P2P) will mitigate to some extent but only in some scenarios. Considering an estimated 20-25% CAGR [CISCO VNI], one cannot solely rely on densification and other spectral and other system efficiency improvements to meet demand; additional spectrum is also vital.
To quantify the impacts of densification and resulting spectrum requirements, one of our members, Qualcomm Inc., analysed performance requirements in dense residential and enterprise settings.
The study is using the technology characteristics of the latest Wi-Fi technology (802.11ax). It identifies the spectrum requirements to deliver a 1 Gbps data rate consistently over an area with different configurations, taking interference into account. 1Gbps is widely considered as an appropriate measure of the performance expected from access systems around the 2020 horizon.
The study shows that in an apartment block environment with 30 (10m x 10m) dwellings over 3 stories, a 1 Gbps coverage target cannot be met with a single Access Point per apartment combined with the use of 2 antenna clients. The 1 Gbps target can be met assuming 4-antenna clients. This requires 1280 MHz of spectrum.
Assuming an all 5 GHz Wi-Fi scenario with 4 Access Points per apartment (one for each room), and 5 GHz Wi-Fi backhaul links between the Access Points using a separate 5 GHz channel, 960 MHz of spectrum will be required assuming 2-antenna clients and 800 MHz for 4-antenna clients to reach the 1 Gbps throughput target.
Overall, the conclusions of the study are that 455 MHz of spectrum are not enough in most scenarios to deliver a 1 Gb/s consistently.
The study indicates that ideally 1280 MHz of spectrum should be made available to unlicensed technologies in the 5 GHz band in order to support most scenarios.

Question 6: What real life speed and quality of experience can consumers expect in practice from devices using the 5GHz spectrum as authorised in the UK now? What changes can we expect as the number of devices increases and technology improves? What difference in speeds and quality of experience would additional spectrum make?:

In residential scenarios, assuming modern Wi-Fi equipment (e.g. 80 MHz 11ac 3x3, 11ac AP and 2x2 11ac client), consumers can typically achieve up to 500 Mb/s throughput at close range if there is a single active client device and no interference from neighbouring networks. However throughput may fall to a few Mbps at edge of coverage (certain areas of the house, depending on construction). In hotspot scenarios, throughput is much more variable and can fall to very low throughput (e.g. 1 Mb/s or less) in scenarios with a large number of users trying to access the network, especially when some of those users are located at edge of coverage with weaker signal strengths. Upcoming Wi-Fi technology improvements (e.g. MBO/OCE/11ax) will improve throughputs in dense scenarios (e.g. due to improved PHY link efficiency and MAC efficiency by multiplexing users in frequency domain, and reducing management frame overhead), and include enhanced mechanisms to enable Wi-Fi networks to load balance over available spectrum. These will improve typical user experience when there are many users, although not necessarily increase the best-

case throughput for a single user. Technology improvements are most efficient for enhancing spectrum sharing *within* a network, and less so for sharing between independent networks. Additional spectrum makes it more likely that networks can operate without having to contend with a large number of other independent networks. User expectations will also continue to increase. Additional spectrum is the only way to deliver very high bandwidth services to multiple users at the same time.
A simulation study conducted by one of our members (which can be downloaded at https://www.qualcomm.com/documents/quantification-5-ghz-unlicensed-band-spectrum-needs) identified the following throughput performance metrics for various dense deployment scenarios:
For a Single Access Point per apartment in a dense residential scenario, a sustained 500 Mbps can be delivered in 640 Mbps to 4 antenna stations
A sustained 100 Mbps coverage can be delivered to 2 antenna client devices using 240 MHz of spectrum, in the single AP per apartment, residential scenario
For a dense enterprise deployment scenario, 640MHz would enable a throughput of 500 Mbps to 2 antenna clients, and 1 Gb/s to 4 antenna clients.
In more dense deployment scenarios 560 MHz would deliver 500 Mbps throughput to 2 antenna stations in apartments with 4 Access Points (one for each room), while using a separate 5 GHz channel for backhaul.
For a residential scenario where the last hop between Access Points (on in each room) an the client is using 60 GHz WiGig technology and the backhaul between the 4 Access Point is using 5 GHz spectrum, 320MHz of 5 GHz spectrum enables 500 Mbps of coverage to 60 GHz clients and 480 MHz of 5 GHz spectrum enables 1 Gb/s throughput coverage (assuming 5 GHz Backhaul connections using 4 antennas).
Currently authorised spectrum is not sufficient in dense deployment scenarios. Even with upcoming technological advances (e.g., 1Gb/s fibre to the home and advances in IEEE 802.11 technologies), user experience will be challenged by the addition of other forms of sharing. The quality of service Wi-Fi users have become accustomed to, including call voice quality and video streaming may be adversely impacted. With some percentage of IoT in these bands, especially smart home IoT, additional impacts will be experienced. Together, advances in video and audio technologies will be challenged by the wireless quality impairments these other technologies will create.

Question 7: How important is contiguous spectrum? How wide should channels be to support future demand?:
Wi-Fi is designed to operate using non-contiguous blocks of spectrum and we successfully do this today in many regulatory domains. However, the sub-band size for high data rate applications is 80 MHz, which can be used either to create additional 160 MHz Channels, to deliver gigabit service in a single 80 MHz, or be sub-channeled into four twenties for high density applications. Certainly, in the next five to ten years, wider channels to support the new applications, some of which we may not even anticipate today, will be necessary.
Industry needs more contiguous 80 MHz and 160 MHz channels for 11ac and 11ax deployments. Applications that take advantage of 160 MHz channels are being delayed due to the limited number of available channels. Making them available will result in the release of many more of these applications.
A study conducted by one of our members (which can be downloaded at

https://www.qualcomm.com/documents/quantification-5-ghz-unlicensed-band-spectrum-needs) indicated that the use of 160 MHz channels will be key in delivering sustained throughputs in the 1 Gb/s range in dense enterprise and residential settings. Some example data points:
To deliver 1 Gb/s of sustained throughput to 2 antenna clients in a dense enterprise setting, four non-overlapping 160 MHz channels will be required
To deliver 1 Gb/s of sustained throughput to 2 Antenna clients in a scenario with 4 Access Points per apartment (1 per room), that are backhauled using 5GHz Wi-Fi, six non-overlapping 160 MHz channels would be required
In case 60 GHz WiGig connectivity is used for the last hop between the Access Points (situated in each of the 4 rooms in the dense apartment set up) and 5 GHz Wi-Fi connectivity is used for backhaul between the rooms, three non-overlapping 160-MHz channels will be required to deliver 1 Gb/s throughput to the 60 GHz clients.
Even in the case where wired Ethernet is used for backhaul between the 4 Access Points inside a dwelling in a dense residential apartment set up, 3 non-overlapping 160 MHz channels are required to deliver 1 Gb/s of sustained coverage to 2 antenna clients.

Question 8: Do you believe we have correctly identified the incumbent services in 5150-5925 MHz which need to be taken into account in considering opening up more 5 GHz spectrum for Wi-Fi? Are there any other services which will need to be taken into account in future studies?:
We do not know of any other incumbent services that need to be protected.

Question 9: What coexistence studies, measurement campaigns and mitigation techniques do you believe would be most effective for demonstrating coexistence between Wi Fi and incumbent users?:
Studies to improve clutter and building penetration models, and time of day usage variations will be helpful for future maximisation of spectrum efficiency. Ofcom's aerial survey of the 2.4 GHz band was a good start at understanding the true nature of the interference with satellites models. Similar surveys in the 5 GHz bands, at various times of day, would add significantly to our understanding and ability to mitigate interference effectively. As these bands are shared spectrum, understanding the true nature of the interference potential is necessary to provide protection while maintaining maximum spectrum utilisation. Current sharing methods are based on simulations with very conservative conclusions. Measurements of ground clutter, building attenuation and busy hours, and actual measurement at altitude, to verify/contradict the simulations will go a long way to improving spectrum utilisation.
With regard to Ofcom's proposals for short-term change, we agree that it is important to assess the potential impact on other services including FSS and that this assessment should be reported on in the second consultation proposed by Ofcom. It has been difficult to make progress with the CEPT SE24 sharing studies, in particular with the FSS-RLAN sharing problem. This work is incomplete and we believe that an assessment of the potential impact on FSS in the short-term and any future study work (CEPT, ITU) should take account of these difficulties and of the outstanding modelling questions. On this basis we attach some notes covering some specific areas of the study work. We believe that this information will assist Ofcom in developing a critical appraisal of the studies completed to-

date within SE24 and with any further studies in the period ahead. In general, we believe that incomplete study work should be appraised and, where necessary, progressive modelling developed, before any constraints on RLAN operations such as are power-caps or indoor-only are considered. A complete sharing study, independent of CEPT and ITU, with a progressive and non-conservative approach to modelling, could be a valuable resource in the period ahead. Ofcom's measurement work can contribute to an evaluation of the sharing studies. We believe that further work will be beneficial and detailed analyses of measurements can help to highlight conservative inputs to the models.

Question 10: Do you intend to participate and provide technical material into the ITU and CEPT work? In what way?:

Yes. We are planning better coordination of the RLAN community, commensurate with the size of the industry and the greater Wi-Fi ecosystem.