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VIA ELECTRONIC FILING

Ms Aileen Chia
Director General (Telecoms and Post)
Infocomm Media Development Authority of Singapore
10 Pasir Panjang Road
#10-01 Mapletree Business City
Singapore 117438

Re: **5G MOBILE SERVICES AND NETWORKS CONSULTATION PAPER**

Dear Ms. Chia,

Wi-Fi Alliance®[1/] is a global, non-profit industry association of over 750 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.

Wi-Fi Alliance commends the IMDA on its ongoing work in spectrum management. The 5G Mobile Services and Networks consultation paper[2/] is an important part of IMDA's work ensuring that new mobile networks are developed and deployed in concert with existing and future unlicensed technologies, allowing Singaporean consumers and businesses to get the most of scarce spectrum resources.

I. INTRODUCTION AND BACKGROUND

Wi-Fi has become increasingly important in connecting people and devices. Hundreds of millions of people rely on Wi-Fi every day and studies show this is increasing rapidly.[3/] It is now the primary means by which traffic connects to the Internet and can be deployed at relatively low

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2/ Infocomm Media Development Authority of Singapore, *5G Mobile Services and Networks,* Consultation Paper (May 23, 2017) ("Consultation").

3/ *See* Wi-Fi Alliance, *Additional unlicensed spectrum needed to deliver future Wi-Fi® connectivity*, Feb. 27, 2017, available at https://www.wi-fi.org/news-events/newsroom/additional-unlicensed-spectrum-needed-to-deliver-future-wi-fi-connectivity.

cost.[4/] Many new and emerging applications and industry verticals rely on Wi-Fi. For example, residential use of Wi-Fi permits access to television and video streaming, especially ultra high-definition streaming. Similarly, Internet of Things ("IoT") and smart home applications are expanding rapidly, and much of the traffic created by those applications will be carried by Wi-Fi.

Wi-Fi will be an even more essential component of 5G networks, supporting these applications and many others and working alongside new and existing mobile wireless infrastructure and future IMT-2020 technology. As IMDA noted in the consultation, 5G networks will be "heterogeneous," using both licensed and licence-exempt spectrum bands,[5/] consisting of "several different platforms or networks" at the same or at different times.[6/] This means that different connection methods will play different roles, but optimally, they will be integrated and interoperable, providing seamless coverage, with one available when the other is not. Any plan for the deployment of 5G networks must therefore take into consideration the support of, and sufficient licence-exempt spectrum for, Wi-Fi networks.

While all the questions that IMDA asks are important, Wi-Fi Alliance is well positioned to address a selection of them, and does so below.

II. RESPONSES TO SPECIFIC CONSULTATION QUESTIONS

Question 1: IMDA would like to seek views and comments on the estimated timeline for the deployment of 5G. Besides ensuring that spectrum is made available in a timely manner, what other regulatory measures could assist in facilitating the deployment of 5G technology and applications? What other use cases should IMDA take note of when developing the regulatory framework?

Users, and the devices on which they depend, should be able to access the Internet from anywhere, at any time. No one connection method can achieve this on its own, and a combination of access technologies will be necessary. For example, IMDA estimates that 50% of Singapore's mobile data traffic is offloaded onto Wi-Fi,[7/] while Cisco estimates that 60% of total worldwide mobile data traffic was offloaded onto Wi-Fi in 2016.[8/] This trend will continue, meaning that the networks and facilities that comprise this integrated 5G ecosystem will rely on both licensed and licence-exempt spectrum.

4/ CISCO, *VNI Complete Forecast Highlights Tool*, North America, United States, Wired Wi-Fi and Mobile Growth (2016), http://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html (select "United States" from the "North America" drop-down menu, select "2020 Forecast Highlights" and expand "Wired Wi-Fi and Mobile Growth.").

5/ *Consultation* at 3.

6/ *Id. at 4.*

7/ *Id.* at 23.

8/ CISCO, Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2012 White Paper, Executive Summary, Mar. 28, 2017, available at http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html.

Indeed, Wi-Fi will be even more important as part of the 5G systems than it is of current networks because it will be able to offer reliable access and gigabit throughputs by using 80 megahertz channels and Multiple Input, Multiple Output ("MIMO") technologies,[9/] mirroring the capabilities of other wireless 5G technologies. This, along with other advantages like low deployment costs and operational flexibility, will make Wi-Fi a critical component of new 5G wireless networks and can also offer these benefits as an extension of wireline networks.

Wi-Fi Alliance also notes that, as discussed in greater detail below in the response to Question 14, the sequential development phase-in for 5G spectrum bands described by the Consultation[10/] may not be realistic and may unnecessarily delay the deployment of technologies that rely on unlicensed millimeter wave spectrum. Technologies that use millimeter wave spectrum are already being developed.[11/] For example, there are unlicensed technologies in use in the 60 GHz range that take advantage of unlicensed spectrum.[12/] It is therefore very likely that some components of 5G technology utilizing millimeter wave spectrum – including spectrum available on a licence exempt basis – will be ready sooner than IDMA projects. Singapore should therefore not delay access to this spectrum until "after 2020" by incorrectly assuming that all 5G deployments will be in lower frequency bands first.

> Question 2: To facilitate and understand potential spectrum requirements for IoT deployments in Singapore, IMDA would like to seek views on the following: ii) Based on the current spectrum allocated for mobile services in the sub-1 GHz frequency bands, are there further suitable spectrum resources that could be released to support both IoT and LTE services? And ii) How will future generations of mobile networks (e.g. high capacity, low latency) support the growth of IoT and what would be the spectrum requirements?

Any review of 5G – and the need for spectrum to support it – should also consider its possible use for IoT network solutions especially at lower frequencies. Those applications may not require the same high-throughput as mobile broadband, but they will still require spectrum assets to provide connectivity as more and more connected devices are deployed around the country. Even in the pre-5G environment, Wi-Fi solutions for IoT in the bands below 1 GHz are already being developed – Wi-Fi HaLow uses the 802.11ah standard in under 1 GHz spectrum, and will soon be available.[13/] It allows Wi-Fi products to operate at low power while maintaining connections at long range, twice as far as a typical Wi-Fi connection operating in the 2.4 GHz or 5 GHz bands.

9/ Cisco, *802.11ac: The Fifth Generation of Wi-Fi*, Technical White Paper (May 15, 2017) available at http://www.cisco.com/c/en/us/products/collateral/wireless/aironet-3600-series/white_paper_c11-713103.html.

10/ *Consultation* Figure 3 at 6.

11/ See, e.g., 9 to 5 Mac, Apple testing 'millimeter wave' 5G wireless technology, experimental license shows (May 23, 2017) available at https://9to5mac.com/2017/05/23/apple-testing-5g/.

12/ *See infra*, Question 10.

13/ *See*, Wi-Fi Alliance, *Discover Wi-Fi HaLow*, available at http://www.wi-fi.org/discover-wi-fi/wi-fi-halow.

In addition to licence-exempt spectrum on which Wi-Fi HaLow will operate to support IoT devices, spectrum below 1 GHz can and will be used to facilitate devices that use the so-called "TV White Spaces." As the IDMA is aware, TV White Spaces are the unused frequencies in the TV broadcast band, frequencies which have great potential for wireless data connections. Singapore was one of the first countries to adopt rules allowing the use of TV White Spaces for wireless networks,[14/] innovation that Wi-Fi Alliance applauds. As these networks grow and develop, they will also play an important role in supporting existing and future IoT devices and can use Wi-Fi HaLow protocols.

> Question 10: IMDA would like to seek your views and comments on the following: i) The role mmWave bands will play in delivering the vision of 5G, in particular, what services could not be delivered by alternative frequency bands and / or technologies; ii) The amount of spectrum required in the mmWave spectrum bands to meet 5G applications that will require higher bandwidths; and iii) The specific mmWave bands that you consider should be a priority in Singapore for IMT services and why?

The IMDA asks about the specific millimeter wave bands that should be a priority for Singapore for IMT services. As noted above, licence-exempt spectrum, including in the millimeter wave bands, will be a critical component of the 5G landscape. The IDMA should consider multiple millimeter wave bands for licence-exempt designation. Last year, at the urging of Wi-Fi Alliance, the U.S. Federal Communications Commission ("FCC") opened the entire 64-71 GHz band for unlicensed operations.[15/] This will allow unlicensed operations, using Wi-Fi for example, to occur between 57 GHz and 71 GHz in the United States. Wi-Fi Alliance certifies products in that band under the name WiGig that are now available in the U.S.[16/] In the same proceeding, the FCC is considering allowing unlicensed operations to extend into the 71-76 GHz and 81-86 GHz bands.[17/]

IMDA should consider taking similar action and allow licence-exempt operation in all of these bands. Exciting new technologies like augmented reality and virtual reality operations are well-suited to these bands because of their low-latency, high-throughput characteristics.[18/] These

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14/ *See*, IDMA, *Decision Paper Issued by the Info-Communications Development Authority of Singapore, Regulatory Framework for TV White Space Operations in the VHF/UHF Bands* (Jun. 16, 2014).

15/ *In the Matter of Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, Report and Order and Further Notice of Proposed Rulemaking, FCC 16-89 at ¶ 125 (rel. Jul. 14, 2016) ("Spectrum Frontiers Order").

16/ *See*, Wi-Fi Alliance, *Discover Wi-Fi Certified WiGig*, available at http://www.wi-fi.org/discover-wi-fi/wi-fi-certified-wigig.

17/ *Spectrum Frontiers Order* at ¶ 424-441.

18/ CTIA, *High Band Spectrum: The Key To Unlocking the Next Generation of Wireless*, Jun. 13, 2016, available at https://www.ctia.org/docs/default-source/default-document-library/5g-high-band-white-paper.pdf (noting that "high-band spectrum's wider channel bandwidth and ultra-low latency hold the promise of enabling and supporting" VR and AR operations.)

bands are also well suited to new "hotspot" uses, whereby a licence-exempt device provides 5G access to a large number of users operating in a small area without producing the same stress on the mobile networks.

> Question 13: IMDA seeks views and comments on the estimated spectrum demand of 3360 MHz by 2025 and whether this estimate is realistic?

Wi-Fi Alliance notes the information provided by IMDA from its spectrum needs analysis, and offers as additional data its own spectrum needs study, published in February 2017.[19/] While Wi-Fi Alliance's study focuses primarily on spectrum below 6 GHz, and IMDA's analysis focuses on spectrum above 6 GHz, both analyze the same needs – the amount of additional spectrum necessary to accommodate future wireless growth.

Wi-Fi Alliance found even greater disparities between projected spectrum needs and spectrum supply by 2025 than did IMDA. In particular, it found that the shortfall will be between 500 megahertz and 1 gigahertz, with a worst-case-scenario figure showing a possible 1.8 gigahertz shortfall.[20/] IMDA's and Wi-Fi Alliance's spectrum needs analyses both show that IMDA's efforts to identify and allocate additional spectrum for license-exempt designations, is vital to the continued growth and development of spectrum-dependent products and services. Because these needs will be in spectrum above and below 6 GHz, Wi-Fi Alliance urges IMDA to address the shortfall throughout the spectrum.

Wi-Fi Alliance believes aggressive measures will be necessary to make sufficient spectrum available for use by licence-exempt devices. In particular, IMDA should make more licence-exempt spectrum available in several bands, including in millimeter wave bands such as 66-71 GHz, 71-76 GHz, and 81-86 GHz.[21/]

Wi-Fi Alliance also suggests the inclusion of the 6 GHz band (5.925-7.125 GHz) for licence-exempt operation. The 6 GHz band is internationally harmonized and is particularly well-suited for sharing because incumbent users are mostly fixed or mobile in defined areas, and their existing coordination methods can be adapted to allow for lower-power, licence-exempt operation without interference to primary users.

The propagation characteristics of the 6 GHz band make it particularly useful for Wi-Fi as congestion in existing licence-exempt bands continues to grow. The introduction of licence-exempt operation at higher and lower frequencies, while important for future Wi-Fi development, is not a substitute for additional spectrum near the existing primary Wi-Fi frequencies of 2.4 GHz and 5 GHz.

Wi-Fi Alliance recommends that IMDA issue a Consultation about opening the 6 GHz band for licence-exempt operation, allowing incumbent users and other interested parties to recommend appropriate rules for its use. This spectrum, along with existing licence-exempt spectrum and the proposed changes to the millimeter wave bands, will provide manufacturers

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19/ Wi-Fi Alliance, Wi-Fi Spectrum Needs Study, Feb. 2017, available at https://www.wi-fi.org/download.php?file=/sites/default/files/private/Wi-Fi%20Spectrum%20Needs%20Study_0.pdf.

20/ *Id.* at 25.

21/ *See supra*, Question 10.

with maximum flexibility to design and market licence-exempt devices for a variety of use-cases, some of which may not even have yet been conceived of.

> Question 14: Noting that several regulators have made available mmWave bands for IMT services, IMDA would like your views and comments on whether access to the mmWave spectrum should be provided earlier than 2022 for commercial network deployment?

As noted above, the timeline provided in the Consultation may not prove to be accurate with respect to when millimeter wave spectrum should be available.[22/] Because technologies using millimeter spectrum are already available and under further development now, they may be ready for deployment alongside technologies for lower-frequency networks, rather than becoming available only after those lower-frequency networks have been deployed. IMDA should therefore not wait until "after 2020" to make the spectrum needed by millimeter wave networks available. Instead, it engage in those efforts now so that the spectrum can be put to use as soon as the technology is available.

Freeing this spectrum as soon as possible will also allow the deployment of equipment utilizing the 802.11ad standard, which operates in the millimeter wave bands.[23/] Several 802.11ad devices are already available for this spectrum,[24/] and would be able to take advantage of additional frequencies as soon as they are made available. The 802.11ay standard, which is an evolution of the 802.11ad standard that is expected to be finalized in 2019, will allow for the bonding of up to four 2.16 gigahertz-wide channels, allowing a transmission rate of over 20 Gbits/s. This type of bandwidth has the potential to revolutionize many Wi-Fi applications. IMDA should work to make the spectrum for which these licence-exempt millimeter wave devices are optimized available now, to ensure that Singaporeans can benefit from this technology as soon as it is available.

> Question 15: Considering the current regulations/policies for licence-exempt use and the possibility of LTE-U interfering with Wi-Fi users, IMDA would like to seek views and comments on the following: i) The adoption of LBT to facilitate sharing of licence-exempt spectrum and whether there would be any implication arising from such a requirement; ii) The need for further technical requirements and regulatory measures to facilitate the sharing of licence-exempt spectrum in an efficient and fair manner; and iii) The need for companies with commercial LTE-U networks to upgrade to LAA once the software/hardware products are commercially available.

22/ *See supra*, Question 1.

23/ *See*, IEEE P802.11 Task Group ay, *Status of Project IEE 802.11ay*, available at http://www.ieee802.org/11/Reports/tgay_update.htm. *See also*, NetworkWorld, *FAQ: What is 802.11ay wireless technology?*, Mar. 28, 2017, available at http://www.networkworld.com/article/3184827/wi-fi/faq-what-is-80211ay-wireless-technology.html.

24/ *See, e.g.*, NetworkWorld, *FAQ: What is 802.11ad wireless technology*? Sept. 27, 2016, available at http://www.networkworld.com/article/3124911/mobile-wireless/faq-what-is-802-11ad-wireless-technology.html.

Wi-Fi Alliance commends IMDA for its efforts to ensure that LTE-U deployments do not interfere with existing Wi-Fi users in the 5 GHz band. IMDA should focus on the goal of ensuring licence-exempt spectrum is shared fairly with Wi-Fi, rather than supporting one particular way to achieve that goal. Appropriate coexistence testing ensures fair spectrum sharing with Wi-Fi and will serve as a valuable tool for vendors and service providers seeking to improve how their deployments coexist with Wi-Fi networks. Wi-Fi Alliance and LTE manufacturers have already done much of the work needed to ensure this coexistence.[25/] In order to ensure compatibility between technologies, IMDA may wish to require that devices satisfy the coexistence test that Wi-Fi Alliance has developed to promote fair coexistence.[26/]

Supporting LBT will not, on its own, achieve efficient and fair licence-exempt spectrum sharing. Therefore, Wi-Fi Alliance recommends using the Wi-Fi Alliance Coexistence Test Plan for LAA/eLAA that was developed jointly by Wi-Fi Alliance and LTE device manufacturers. Wi-Fi Alliance is open to assisting in determining those testing procedures as needed.

> Question 16: During the interim period before regulations are finalised, IMDA plans to facilitate industry trials for LAA/LTE-U technologies. As such IMDA would like to seek views and comments on the following: i) Besides the information listed in Para 80, should MNOs/MVNOs interested in conducting LTE-U trials submit any further information for IMDA's assessment; and ii) To minimise impact to Wi-Fi users, should IMDA limit LAA/LTE-U trials to parts of the 5 GHz licence-exempt spectrum?

IMDA could require carriers wishing to deploy LTE-U/LAA systems to certify that they have successfully completed the Wi-Fi Alliance Coexistence Test requirements, as discussed in Question 15. This would be in addition to any site survey and proposed operations information which IMDA chooses to require from carriers. Should IMDA wish, once more is known about the interplay of LTE-U/LAA and Wi-Fi, to require additional action, then that can be determined at a later date.

> Question 17: IMDA would like to seek views and comments on the following: i) The possibility of deploying LAA and / or MuLTEfire in other frequency bands besides the licence-exempt 5 GHz band; and ii) The regulatory and coexistence measures that should be adopted for MuLTEfire.

Wi-Fi Alliance has particular concerns about MulteFire's ability to share spectrum fairly. Unlike Wi-Fi and LAA/eLAA, MulteFire introduces several new short control signals, transmitted with high access priority using channel sensing for fixed duration, and does not require channel sensing, even in license-exempt spectrum (e.g. paging, ePUCCH, PRACH).[27/]

25/ Wi-Fi Alliance, Wi-Fi Alliance® Delivers LTE-U Coexistence Test Plan, Sept. 21, 2016, available at http://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-delivers-lte-u-coexistence-test-plan.

26/ *See*, Wi-Fi Alliance, Coexistence Test Plan Package v.1.1, available at https://www.wi-fi.org/downloads-registered-download/Coexistence_Test_Plan_Package_v1.1.zip/downloads-registered/172056/1.

27/ MulteFire Alliance, *MulteFire Release 1.0 Technical Paper* at 16, available at https://www.multefire.org/wp-content/uploads/MulteFire_Release-1.0_WhitePaper_FINAL_4.24.17.pdf.

Wi-Fi Alliance is not aware of any coexistence studies ascertaining the impact on Wi-Fi of signals transmitted with fixed duration channel sensing or without channel sensing. Since Wi-Fi does not use such signaling, this behavior in MulteFire is likely to cause coexistence concerns with existing and future Wi-Fi systems. Further work must be done to establish that such operations can share spectrum fairly with Wi-Fi. IMDA should take these concerns into consideration when deciding whether to promote, or even allow, MulteFire operations in Singapore.

> Question 18: Considering that the LWA approach would not create coexistence issue with Wi-Fi users, would this approach be better suited for countries with extensive Wi-Fi usage?

LWA is a part of 3GPP LTE Release-13, which reduces congestion on mobile networks by enabling the offloading of mobile traffic onto Wi-Fi through the aggregation of LTE and Wi-Fi spectrum.[28/] Wi-Fi Alliance notes that 3GPP has defined two ways of aggregating Wi-Fi networks and mobile networks - LWA (PDCP layer combination) and LWIP (IP layer combination with IPSec tunnel).[29/] Both are available in Release 13, with enhancements known as eLWA and eLWIP in Release 14.[30/] The combination performed at the core network may be accomplished at various levels either at a PDN level or IP Flow Level.[31/]

Because all these technologies use Wi-Fi standards in a licence-exempt band, there are no special coexistence concerns. Wi-Fi Alliance therefore believes that both LWA and LWIP are compatible with existing Wi-Fi networks; they provide a transparent, industry-standard coexistence mechanism that ensures fair, good neighborly operation of LTE and Wi-Fi. Both are potential solutions to IMDA review of how to allow carrier aggregation of licensed and licence-exempt operations without any co-existence concerns.

> Question 19: IMDA would like to seek views on how the above approaches (i.e. LAA, MuLTEfire and LWA) would enhance the capacity of the mobile network in ways that Wi-Fi offloading is not able to achieve.

While IMDA is justified in its consideration of potential options for offloading for mobile networks, Wi-Fi Alliance believes that the better answer is allocation of additional spectrum for licence-exempt operation. Wi-Fi's existing and future protocols are more than capable of handling all off-loading necessary to ensure and enhance the capacity of mobile networks, and will in fact be superior to other alternative methods. It only needs the necessary spectrum to do so.

28/ *See* Intel, *LTE-WLAN Aggregation (LWA): Benefits and Deployment Considerations*, White Paper, available at https://www.intel.com/content/dam/www/public/us/en/documents/white-papers/lte-wlan-aggregation-deployment-paper.pdf.

29/ *Id.* at 5.

30/ *Id.* at 21.

31/ *Id.* at 4.

III. CONCLUSION

The future of wireless connectivity is sure to bring more traffic, more devices, and more uses.[32/] License-exempt devices will be at the center of this growth, whether in users' hands or out of sight, seamlessly integrated into their lives. Wi-Fi will use this licence-exempt spectrum as an essential part of the 5G networks of the future, operating alongside existing and future mobile infrastructure and wireline networks to provide high-speed Internet access anytime and anywhere for a variety of different uses.

Therefore, the IMDA should ensure that Singaporeans can make the most of that future by both protecting existing Wi-Fi operations in licence-exempt bands, particularly through cooperatively developed coexistence testing, and identifying additional spectrum for licence-exempt designation in the future in, among others, the millimeter wave and 6 GHz bands.

Wi-Fi Alliance applauds the IMDA's efforts to carefully craft the rules governing 5G networks to ensure it can reach its full potential without undermining, and in fact furthering, other valuable operations in the same bands.

Respectfully submitted,

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32/ *Id.* at 3.