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July 21st, 2017

Ms. Aileen Chia
Director General (Telecoms and Post)
Info-communications Media Development Authority of Singapore

Dear Ms. Chia,

Re: Consultation on 5G Mobile Services and Networks

Qualcomm Inc. welcomes the opportunity to provide input to the Info-Communications Media Development Authority (IMDA) on its *Consultation on 5G Mobile Services and Networks* ("Consultation Paper").

Qualcomm is a world leader in 3G, 4G, and next-generation wireless technologies. For more than 30 years, Qualcomm's ideas and inventions have driven the evolution of digital communications, linking people everywhere more closely to information, entertainment, and each other. Qualcomm is the world's largest fabless semiconductor producer and the largest provider of wireless chipset and software technology, which powers many wireless devices commercially available today. We are a recognized world leader in advanced wireless technologies and continue to bring technology enhancements to market. Since our founding, Qualcomm's philosophy has been to enable many other companies in the value chain to succeed. Today, we license nearly our entire patent portfolio to more than 275 manufacturers worldwide – from new market entrants to large multinational companies. Qualcomm's business model has created a pro-competitive, pro-innovation value chain of global scale of which the ultimate beneficiaries are consumers.

Qualcomm's vision for 5G is a unifying connectivity fabric that will expand the value of mobile networks to connect new industries and devices, empower new services, enable new deployments, utilize new spectrum bands and types of access, open up new business models, and bring new levels of cost savings and energy efficiency. 5G will be a new kind of network supporting a vast diversity of devices with unprecedented scale, speed and complexity. That network will change the way we work and the way we live. The world around us – our homes, cars, cities, manufacturing, and healthcare – will become more intelligent, automated and interconnected. Entire industries will change and emerge as data speeds go up and data costs come down. Every part of our lives will benefit from the steady flow of critical information gathered by billions of intelligent, connected sensors. 5G will be introduced into a multi-connectivity world which will help to enable a seamless and phased 5G introduction that fully leverages the 4G, 3G and Wi-Fi investments with 5G, 4G, 3G, Wi-Fi multimode devices. QC has been investing in 5G technology innovations for many years, accelerating the path to 5G by leading the research and standardization, as well as creating best-in-class prototypes and testbeds that allow us to work closely with ecosystems partners on impactful 5G trials.

5G will make mobile even more essential than it is today. In 2035 when 5G's full economic benefit should be realized across the globe, a broad range of industries – from retail to education, transportation to entertainment, and everything in between – could produce up to $12 trillion worth of goods and services enabled by 5G.[1] The 5G value chain alone is estimated to generate up to $3.5 trillion in revenue in 2035, and support up to 22 million jobs.

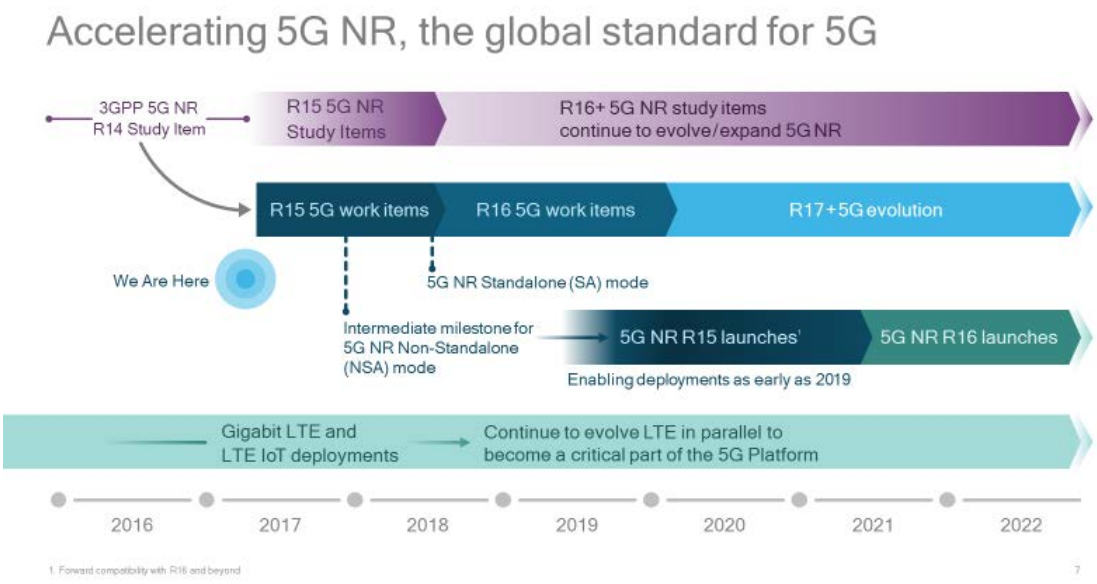
[1] IHS Economics and IHS Technology, *The 5G economy: How 5G technology will contribute to the global economy* (January 2017), available at https://www.qualcomm.com/documents/ihs-5g-economic-impact-study

Importantly, 5G is a platform for future innovation. When defining 4G LTE in 2004, technology innovators such as Qualcomm could not at the time predict the full potential of the technology until smartphones, then a new class of devices, were released to the mass market. 5G will be similar. It is hard to predict all the new types of services 5G will enable, as it is designed to be a robust, future-proof platform that will unlock new values. We have yet to imagine all the ways that we can use the data, connectivity and computing capability that will become available, put that to work proactively and, as our devices get smarter and smarter, even let the devices act on our behalf.

Qualcomm's responses to IMDA questions:

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?**

Qualcomm encourages IMDA to accelerate its timeline for the deployment of 5G. We have been very active in standardization efforts at the 3rd Generation Partnership Project (3GPP) and the International Telecommunication Union (ITU). Notably, a recent 3GPP RAN Plenary meeting (March 6, 2017 in Dubrovnik Croatia) accelerated the timeline for the 5G New Radio (NR) global standard. This acceleration received broad support at the meeting. By introducing an intermediate milestone for a configuration of 5G NR "Non-Standalone mode", commercial deployments of the 5G NR global standard will be enabled as early as 2019. Non-Standalone mode utilizes the existing LTE network as an anchor for mobility management and coverage while adding a new 5G radio access carrier. Forward compatibility is a key design principle for the standardization of 5G NR and will enable in-band introduction of new capabilities and features in subsequent releases critical to enabling yet to be identified industries and use cases. Qualcomm is therefore working actively to enable large scale trials and commercial deployments starting in 2019.



The ITU, taking into account 3GPP's work, is in the process of defining the IMT-2020 specifications. Guided by Resolution ITU-R 65 on the "Principles for the process of future development of IMT for 2020 and beyond" which outlines the essential criteria and principles which will be used in the process of developing the Recommendations and Reports for IMT-2020, including Recommendation(s) for the radio interface specification, the ITU-R has commenced the process of developing ITU-R Reports and Recommendations for the terrestrial components of the IMT-2020 radio interface(s). The ITU-R, in Circular letter 5/LCCE/59 and its addenda, has announced the availability of:

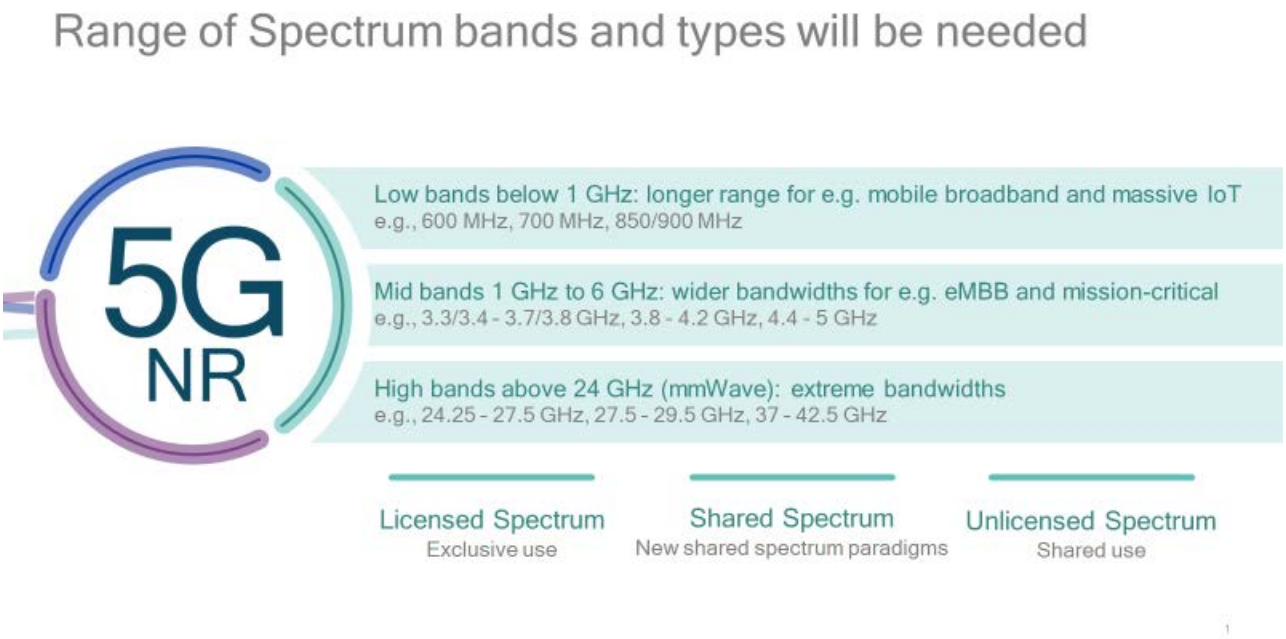
- draft new Report ITU-R M.[IMT-2020.TECH PREF REQ] – *Minimum requirements related to technical performance for IMT-2020 radio interface(s)*
- draft new Report ITU-R M.[IMT-2020.SUBMISSION] – *Requirements, evaluation criteria and submission templates for the development of IMT-2020* and
- draft new Report ITU-R M.[IMT-2020.EVAL] – *Guidelines for evaluation of radio interface technologies for IMT-2020*.

These three draft new Reports have been submitted for consideration and approval at the Study Group 5 meeting in November 2017. After approval by Study Group 5, these Reports will be used for the submission and evaluation process of candidate terrestrial radio interface technologies of IMT-2020.

With respect to regulatory measures, the primary need is for the IMDA to set a clear policy prioritizing the availability of sufficient and suitable radiofrequency spectrum to create an enabling environment for 5G. Notwithstanding the groundbreaking technological advancements that Qualcomm and other R&D companies have achieved, additional spectrum is needed to support the increasing numbers of connected devices, mobile broadband (MBB) growth, and the advent of 5G services.

All spectrum bands — low-band spectrum below 1 GHz, mid-band spectrum from 1 to 6 GHz, and high-band spectrum above 24 GHz also known as mmWave — are needed for the successful deployment of 5G, IoT, enhanced mobile broadband, and mission-critical applications and services, like connected autonomous vehicles, critical infrastructure management, remote medical procedures, as well as command and control communications for drones and robotics. 5G will make the best use of a wide array of spectrum available across regulatory paradigms and spectrum bands. Previous generation networks primarily operated in licensed spectrum bands below 3 GHz. 5G will also bring the next level of convergence with support for licensed, shared, and unlicensed spectrum.

5G will be driven by heterogeneous services with vastly different requirements – from very low energy sensors, wearables and new form factors, to new mission critical applications with high reliability and low latency (e.g., smart city and critical infrastructure, medical and emergency response, sensing and remote control), to very high data rate backhaul and access transmissions across wide bandwidths for ultra-high capacity broadband. The goal is for 5G to be a new platform with the scalability and adaptability to cost efficiently support new wireless applications, services, and deployment models for 2019-2030 and beyond. Spectrum resources across all spectrum bands and regulatory paradigms are needed to support such 5G applications, services, and deployment models.



Qualcomm is pioneering spectrum sharing technologies today with various efforts including LTE Unlicensed (LTE-U), Licensed-Assisted Access (LAA), LTE Wi-Fi Link Aggregation (LWA), MulteFire, Authorized Shared Access (or Licensed Shared Access), among others. 5G will be built to natively support and advance these technologies as spectrum sharing becomes increasingly important to meeting tomorrow's connectivity needs for faster data rates and increased network capacity. Further Qualcomm views on LTE-U, LAA, LWA and MulteFire are contained in responses to Questions 15 onwards.

Authorized Shared Access (ASA) is a new and innovative spectrum use regime for the cases where exclusive licensed use is not feasible in a timely manner or in all geographic locations, or where dedicated 5G-appropriate spectrum is not available. ASA provides a regulatory approach that allows operators to collaborate with incumbent non-mobile spectrum licensees to obtain exclusive access to part of the latter's spectrum (in those bands identified for mobile broadband use). ASA permits the incumbent licensed user – for example, defense, aeronautical, public safety, satellite, or other non-mobile licensees – to sub-license and share spectrum with mobile licensees. The sharing can be in terms of geography, frequency, or time, on an exclusive basis without interfering with the incumbent's operations. ASA aims to provide a level of interference protection for both incumbents and ASA licensees, thereby allowing for a predictable quality of mobile service.

In Europe, the European Conference of Postal and Telecommunications Administrations (CEPT) has issued a report on the benefits of Licensed Shared Access (LSA, also known as ASA) and is undertaking additional work to support the introduction of LSA.[2] Within the ITU, in response to Question ITU-R 208-1/1 on "Alternative methods of national spectrum management," ITU-R Study Group 1 has approved Report ITU-R SM.2404-0 on Regulatory tools to support enhanced shared use of the spectrum. This Report addresses possible regulatory

[2] See, for example, CEPT ECC Report 205 on Licensed Shared Access (LSA) (February 2014), available at http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP205.PDF.

solutions which may be implemented on a national basis in order to facilitate the shared and efficient use of the spectrum, and contains a detailed treatment of Licensed Shared Access (LSA). APT Report 68 on "Authorized/Licensed Shared Access as a National Solution to Access Spectrum for IMT" also contains relevant information on LSA.

Qualcomm encourages the IMDA to advance its 5G spectrum policy taking into account the developments listed above on the global acceleration of 5G NR timelines as well as other technology leading nations' plans to roll out 5G commercial networks. Initial 5G network deployments will be earlier than originally envisioned and it is necessary for the IMDA to prepare its spectrum policy and plans now to support network rollouts over the next few years.

IMDA should avoid policies that would constrain the ability for available spectrum to be employed in its highest-value use. For example, offering larger, contiguous blocks of spectrum will be an important enabler of 5G technologies, especially in the bands above 1 GHz. Providing the maximum amount of flexibility in spectrum use is a key enabler of evolution and innovation in wireless services, including 5G, leading to new business models and use cases. Flexible arrangements also increase service providers' ability to nimbly respond to changes in technology, services or usage patterns.

Beyond ensuring the availability of sufficient and suitable radiofrequency spectrum for 5G, key enabling approaches that maximize regulatory certainty and allow for flexibility and innovation include:

- pursuit of harmonized spectrum allocations, both regionally and globally when possible;
- continued objective and transparent treatment of mobile operators and potential market entrants, increasing regulatory certainty;
- seeking to set spectrum fees as low as possible while covering administrative costs, in order to promote investment in networks and services, given the increasing need for spectrum resources;
- ensuring that regulatory actions maximize operator and user flexibility to employ the technology or mix of technologies that best suit needs.

More broadly, beyond regulations targeted at the ICT sector, policy frameworks that encourage and safeguard private sector risk taking, investment, and innovation, are critical. For example, the Government of Singapore should critically review regulations related to intellectual property protection, public safety, cybersecurity, privacy, public infrastructure, healthcare, and education, training, and development. In these areas, the challenge will be to develop innovative policies dealing with – and even encouraging – the ubiquity of 5G in everyday life without stunting continued innovation.

2. **To facilitate and understand potential spectrum requirements for IoT deployments in Singapore, IMDA would like to seek views on the following:**

    i) **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?**

    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?

Qualcomm supports the efforts of the IMDA to harmonize and ensure interoperability of IoT equipment in Singapore via its TSAC Working Group 6 IoT Task Force, and notes that sub-1 GHz bands currently assigned and suitable for LTE IoT technologies in Singapore are band 8 and band 28 (noting that Band 28 is not yet available for use).

In any case, a range of spectrum bands in the low, mid and high bands will be needed and should be considered for 5G Internet of Things (IoT) applications. Some IoT applications will demand ultra-high-bandwidth support and thus may work best in the millimeter wave (mmWave) bands, while other IoT applications will need low-power, low-duty-cycle, long-range performance and thus be best supported by the sub-6 GHz or sub-1 GHz bands. IMDA should explore all spectrum bands for potential use for 5G applications, but should avoid designating or limiting specific frequency bands for IoT use only. Policies and regulations that limit spectrum use to particular technologies or services may serve short-term goals, but run the risk of creating long-term constraints.

3GPP has already introduced a suite of two complementary narrowband LTE IoT technologies in Release 13: eMTC (enhanced machine-type communication) and NB-IoT (narrowband Internet of Things). Both are optimized for lower complexity/power, deeper coverage, and higher device density, while seamlessly coexisting with other LTE services such as mobile broadband. Together, they expand the LTE technology portfolio to support an even wider range of low-power IoT use cases.

eMTC can deliver up to 1 Mbps of throughput utilizing just 1.4 MHz of bandwidth, and supports essential capabilities such as VoLTE and full mobility for a broad range of IoT use cases, including asset trackers and wearables. NB-IoT, on the other hand, scales down to extreme simplicity for low-throughput, delay-tolerant applications, such as meters and sensors. It enables data rates of just 10's of kbps with 200 kHz of bandwidth, and can provide even deeper coverage. NB-IoT can be deployed within an existing LTE band, in guard-band between two regular LTE carriers, or in standalone mode, which provides an easy migration path for the re-farmed GSM (2G/GPRS) spectrum.

Beyond 3GPP Release 13, there is a rich roadmap of LTE IoT technology inventions that will deliver many further enhancements to meet tomorrow's massive IoT connectivity needs. Eventually, there will be a 5G NR-based massive IoT solution. Some future advanced design elements will include NOMA (non-orthogonal multiple access), enabling grant-free transmissions leveraging RSMA (resources speared multiple access) — in which the device sends data whenever needed without asking for permission — and mesh networking that expands on LTE's device-to-device capabilities.

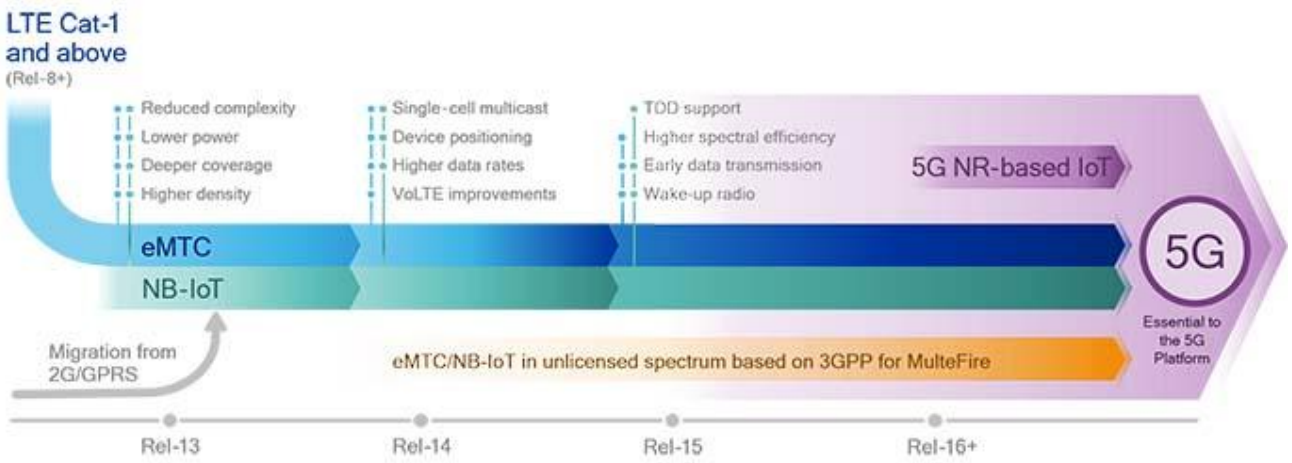


Figure 2: LTE IoT evolution in 3GPP Release 13 and beyond.

Today, Qualcomm is delivering commercial multimode solutions that support eMTC's device category Cat-M1, NB-IoT's device category Cat-NB1, and E-GPRS.[3] The Qualcomm MDM9206 is a flexible, single-SKU solution that enables global deployments with a single hardware, software, and RF design. Mobile operators around the globe are also starting to launch commercial LTE IoT networks supporting both Cat-M1 and Cat-NB1 devices. More than 20 mobile operators having publicly announced their commitment to deploy LTE IoT, with even more trialing eMTC and/or NB-IoT technologies in preparation for commercialization.

3. **IMDA would like to seek views and comments from industry on what they consider will be the key technologies for 5G and whether current regulatory frameworks sufficiently facilitate the deployment of such technologies.**

As identified in the Consultation Paper, new technologies and functionalities in areas such as aggregation of different spectrum types and bands, antenna technology, modulation, and coding will be critical to meeting the increasing connectivity requirements for emerging consumer mobile broadband experiences such as virtual reality, augmented reality and fiber-like cloud connectivity, as well as to enabling new high-reliability, low-latency services for use cases such as autonomous vehicles, drones and industrial equipment. These new technologies are incorporated into the 5G NR design, including orthogonal frequency-division multiplexing (OFDM), multiple input/multiple output (MIMO), scalable OFDM numerologies, and targeted use of Resource Spread Multiple Access (RSMA). In addition, 5G NR's flexible framework will efficiently multiplex 5G services and features, including scalable transmission time interval (TTI) for diverse latency and quality of service, and a new self-contained TDD subframe design that brings additional benefits. Further, massive MIMO leverages many antennas at the base station to exploit 3D beamforming for improved coverage/capacity; allows macro deployments at mid spectrum bands, such as 3 and 4 GHz, and mobile mmWave uses adaptive beamforming and beam-tracking techniques that enable robust and sustained mobile broadband communications at high spectrum bands above 24 GHz.

[3] www.qualcomm.com/LTE-IoT.

4. **IMDA would like to seek views and comments on whether going forward, there is a need for further spectrum below 1 GHz to be identified and released for mobile services?**

Yes, sub-1 GHz spectrum is particularly valuable for coverage and in-building penetration, as well as support to IoT. One of the sub-1 GHz bands which presents opportunities for enhancing mobile service capacity and coverage is the 600 MHz band and there have been some recent developments in the United States worth highlighting. In April 2017, the U.S. Federal Communications Commission (FCC) announced the closing of the broadcast incentive auction, making available broadcast spectrum in the 600 MHz band for nationwide wireless mobile use.[4] A total of 50 winning bidders won 70 MHz of licensed spectrum nationwide. T-Mobile USA has already announced plans to deploy a combination of LTE and 5G in the 600 MHz spectrum it acquired in the auction. An additional 14 MHz of spectrum was made available for unlicensed use and wireless microphones. The FCC is currently commencing a 39-month transition period to move affected broadcast stations to their new channel assignments. This repacking involves reorganizing and assigning channels to the remaining broadcast television stations in order to create contiguous blocks of cleared spectrum suitable for flexible use. The 600 MHz band in the United States is expected to be available in 2020, in line with 5G deployment timelines. In the Asia Pacific region, work is ongoing within the Asia Pacific Telecommunity Wireless Group (AWG) to develop harmonized frequency arrangements for the 600 MHz band, for those administrations that wish to use this band for mobile.

5. **IMDA would like to seek views and comments on the following:**

    i) **The frequency arrangement that is better suited for adoption in Singapore for the L band (i.e. SDL, TDD or FDD) and the supporting reasons; and**

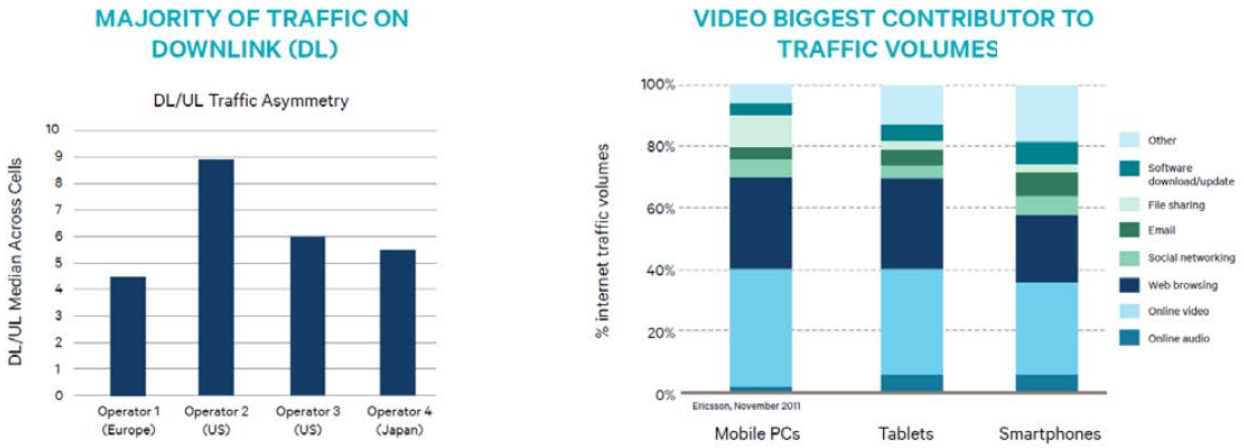
Qualcomm supports re-farming of the 1.5 GHz band for MBB services in Singapore, potentially using a Supplemental Downlink (SDL) frequency arrangement. The convergence of multimedia services on mobile devices is leading to a growing asymmetry in overall mobile data traffic, with much more traffic on the downlink (DL) than on the uplink (UL). Smartphones and tablets are driving the usage of video, which is the biggest contributor to downlink traffic volumes. This shift in consumer habits due to the new devices is particularly relevant when considering that smartphones and tablets are quickly overtaking desktop/laptop computers as users' favorite way to access data services. SDL can be employed as the primary use of the L-band for mobile, or it may be combined with FDD deployments.

In order to assess how this traffic asymmetry may evolve, Plum Consulting made estimates of the proportion of downlink traffic by application and then weighted these proportions by the application mix of mobile data traffic.[5] They suggest that the current ratio of downlink to uplink traffic was around 6:1 in 2010 and that this could rise to 10:1, as the proportion of video traffic in the total mobile traffic grows. Qualcomm's measurements in mobile networks confirm the asymmetrical nature of the data traffic with consumers

[4] CITEL PCC.II Document 4262/17, "Updates on the United States' broadcast incentive auction," (June 7, 2017).
[5] Plum Consulting, "Economic study of the benefits from use of 1452-1492 MHz for a supplemental mobile downlink," (June 4, 2011), available at http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf.

downloading considerably more data and multimedia content than they are uploading, as shown in in the figure below.

Figure: Mobile Downlink traffic as multiple of uplink traffic



From a technology perspective, SDL can address traffic asymmetry on MBB networks by providing additional downlink capacity. This is due to the fact that SDL uses wider channels for the downlink than for the uplink by aggregating the usual downlink channel of the paired FDD band with a supplemental downlink channel in an unpaired band.

In Europe and the Americas/CITEL, the 1427-1518 MHz (or portions thereof) has already been harmonized for SDL usage. In the ITU-R, Working Party 5D is developing a working document towards a preliminary draft revision of Recommendation ITU-R M.1036-5 - *Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the radio Regulations (RR)* that includes five options (G1 – G5) for the L-band (1427 – 1518 MHz) as per the table below. Future work in WP5D is may reduce the options by combining option G4 with G1 and option G5 with G2.

EXTRACT FROM WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT REVISION OF RECOMMENDATION ITU-R M.1036-5

Frequency arrangements	**Paired arrangements (FDD)**				**Un-paired arrangements (TDD) (MHz)**
	Mobile station transmitter (MHz)	**Centre gap (MHz)**	**Base station transmitter (MHz)**	**Duplex separation (MHz)**	
G1	External	–	1 427-1 517	––	None
G2	1 427-1 470	5	1 475-1 518	48	None
G3					1 427-1 517
G4	External	-	1 430-1 515	-	None

G5	1 430-1 470	5	1 475-1 515	45	None

ii) The timeline for access to the L band and the availability of the equipment (specifically whether it will be available earlier or later than 2020).

Currently, most parts of the L band are not heavily used in many countries, and could be released for mobile services in the near term. There is strong support for this band worldwide, including Asia Pacific, Europe and the Americas. Therefore, initial assignments and deployments in Europe (presently, in the United Kingdom Hutchison 3 have deployed a commercial network, and in Italy TIM are in the process of deployment). In this regard, a report developed for the GSM Association (GSMA) on the L band shows that the initial 40 MHz (i.e., 1452 – 1492 MHz) could be in commercial use in Europe and Latin America in 2018 and in Africa and Asia-Pacific in 2020.[6] The surrounding 50 MHz could be commercially available in many countries by 2025. 3GPP Band Class 32 has already been standardized by 3GPP, so availability of devices supporting this band would only depend on network deployments. With ongoing efforts in international and regional bodies, it is timely for national regulators to proceed with the identification of the 1.5 GHz band for IMT and the assignment of spectrum.

6. Considering the spectrum bands within the range of 1-6 GHz to support the deployment of enhanced mobile broadband services, IMDA would like to seek views on whether all of the 91 MHz of spectrum in the L-band should be allocated for IMT to address Singapore's data demand and growth.

As MBB demand continues to grow, administrations are seeking additional spectrum bands that can be used to increase capacity and enhance the user experience. Qualcomm believes that the complete 91 MHz of the L-band (1427-1518 MHz), will be an important resource to meet future MBB demand and should be allocated to MBB in its entirety. There are ongoing discussions on the possible band plans, and one possibility, which would be compatible with Band 32, is the use of 90 MHz for SDL in the 1427-1518 MHz range, divided into 18 blocks of 5 MHz. The use of SDL in this range would bring several benefits, such as: having at least four blocks of 20 MHz, in comparison with an average of three blocks of 10+10 MHz when using FDD; maximizing spectrum use; and making partial re-farming possible.

7. If it is only the extended C-band that is considered for IMT, would the migration of existing satellite users to the other parts of the C-band (i.e. 3.7- 4.2 GHz) impact their service provisioning?

No comment.

8. Considering the challenges of co-channel deployment of FSS and IMT services in the extended C-band, IMDA would like to seek views and comments on the coexistence measures for adjacent bands and cross border operations.

[6] Plum Consulting, "Global momentum and economic impact of the 1.4/1.5 GHz band (L-band) for IMT," (2015), available at http://www.gsma.com/spectrum/wp-content/uploads/2015/10/1-4-1-5GHz-L-band-for-IMT-OCTOBER-2015.pdf.

Qualcomm strongly supports the use of extended C-band, either 3.4 - 3.6 GHz or 3.4 - 3.7 GHz, for LTE/5G in Singapore. As IMDA notes in the Consultation paper, there is increasing interest and support for accessing the C-band for mobile, either for LTE or 5G. Harmonization of the 3.4 – 3.8 GHz band, or portions thereof, for mobile LTE/5G is increasing across the globe. Europe has taken decisions to pioneer the use of the 3.4 – 3.8 GHz band for 5G; China and a number of other countries in Asia have designated 3.4 – 3.6 GHz; Korea, Australia, Hong Kong and some of the Americas are targeting 3.4 – 3.7 GHz for 5G; and the United States has authorized use of the 3.55 – 3.7 GHz band, among others. Based on above, we believe the extended C-band will be widely used for LTE/5G and many of the initial 5G deployments will be in this band.

Harmonized frequency arrangements minimize coexistence issues at border regions and negate the need to address potential interference on a case-by-case basis. Thus, efforts should be made to further harmonize this band across the region. Beyond frequency separation and geographic separation, there are a wide range of established mitigation techniques available to regulators and operators to facilitate coexistence for adjacent band and cross border operations, as the IMDA notes in its Consultation Paper.

9. IMDA would like to seek views and comments on whether there are other frequency bands in the 1-6 GHz frequency band that IMDA should consider for IMT / 5G.

Other bands in this range to consider include the 4.4 – 4.99 GHz band, or portions thereof, also under discussion for LTE/5G in the Asia Pacific region.

Qualcomm is planning product support for a wide range of frequency bands in the 3.3 - 5 GHz range.

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;

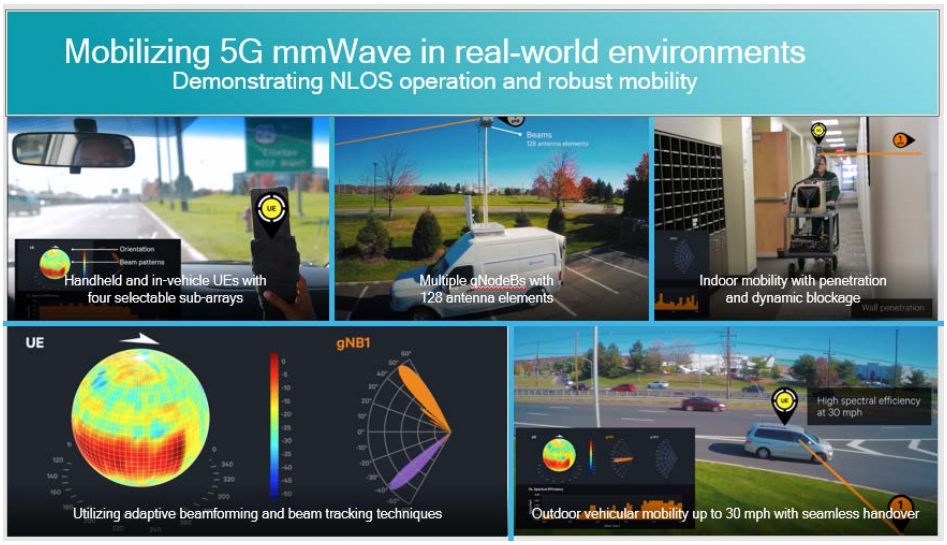
Qualcomm is inventing technologies to deliver robust mobile broadband communications at mmWave spectrum bands. The large bandwidths afforded by mmWave spectrum above 24 GHz allow for delivery of ***mobile*** services at very high data speeds and capacity that cannot currently be achieved with lower band spectrum. We recently announced our first 5G modem, the Qualcomm Snapdragon X50, to support both sub-6 GHz and multi-band mmWave Spectrum.[7]

These new modems are designed to provide a unified 5G design for all major spectrum types and bands while addressing a wide range of use cases and deployment scenarios. The Snapdragon X50 5G modem family is engineered to provide wider bandwidths and extreme speeds for enhanced mobile broadband. Additionally, the modem solutions are designed to support both Non-Standalone and Standalone (where all control signaling and user data are sent over 5G NR) modes of operation, and are designed to enable the next generation of premium-tier mobile cellular devices, while also aiding operators to execute early 5G trials and deployments. Commercial products integrating 5G NR modems from the Snapdragon X50 family

[7] https://www.qualcomm.com/news/releases/2017/02/25/qualcomm-expands-industrys-first-announced-5g-modem-family-support-5g-nrmodem.

are expected to be available to support the first large-scale 5G NR trials and commercial network launches starting in 2019.

Importantly, the X50 modem is built from the ground up for mobility. Years of research and development have allowed Qualcomm to invent technologies to overcome mmWave's limitations, such as 802.11ad which has been commercialized at 60 GHz. Instead of using only a handful of antennas (as with 4G), the Snapdragon X50 5G modem relies on multi-element antenna arrays. The antennas are designed to work together intelligently, using beamforming and beam tracking technologies, extending mmWave's mobility and reach to non-line-of-sight scenarios. For instance, the Snapdragon X50 5G modem can direct the energy of the mmWave beam, bouncing off obstacles to reach the mmWave 5G small cell with which it is communicating.



ii) The amount of spectrum required in the mmWave spectrum bands to meet 5G applications that will require higher bandwidths; and

As one measure of mmWave spectrum requirements, ITU-R WP 5D sent a liaison statement to Task Group 5/1 in February 2017 regarding spectrum needs for terrestrial IMT between 24.25 GHz and 86 GHz.[8] Using two different approaches to estimating spectrum needs, WP 5D's statement includes the following figures:

Estimated spectrum needs based on the application-based approach

Example	Teledensities	24.25-33.4 GHz	37-52.6 GHz	66-86 GHz	Total
Example 1	Overcrowded, Dense urban and Urban areas	3.3 GHz	6.1 GHz	9.3 GHz	18.7 GHz

[8] ITU-R Working Party 5D, Document 5D/TEMP/249(Rev.1), "Spectrum needs for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz," (February 28, 2017).

	Dense urban and Urban areas	2.0 GHz	3.7 GHz	5.7 GHz	11.4 GHz
Example 2	Highly crowded area	666 MHz	1.2 GHz	1.9 GHz	3.7 GHz
	Crowded area	333 MHz	608 MHz	933 MHz	1.8 GHz

Spectrum needs estimate result of IMT-2020 for different frequency ranges between 24.25 GHz and 86 GHz

Deployment scenario	**Micro**	**Indoor hotspot**
Total spectrum needs for 24.25-86 GHz	14.8-19.7 GHz*	
Spectrum needs for 24.25-43.5 GHz	5.8-7.7 GHz	9-12 GHz
Spectrum needs for 45.5-86 GHz	–**	

* Considering the coexistence between multiple network operators (e.g. the guard band(s) may be required in the case of multiple network operators scenarios), the total spectrum needs are expected to be increased.
** The division in this table regarding frequency ranges and deployment scenarios is just an indicative example on how spectrum needs could be distributed for different spectrum sub-ranges within 24.25-86 GHz and different deployment scenarios. This table should not be understood nor used to exclude any possible IMT-2020 deployment options in the range 45.5-86 GHz.

Further, WP 5D's statement incorporates survey responses from seven countries, summarizing those administrations' views on spectrum needs as follows:

Spectrum needs based on the information from some countries

Frequency ranges	**24.25-43.5 GHz**	**43.5-86 GHz**
Spectrum needs	2-6 GHz	5-10 GHz

The various approaches and inputs provide an indication of the potential amounts of mmWave spectrum that may be ideal for provision of 5G services.

iii) The specific mmWave bands that you consider should be a priority in Singapore for IMT services and why?

24.25 - 29.5 GHz and 37 - 43.5 GHz are being considered for early commercialization and global and regional harmonization may be expected of these bands. The IMDA has highlighted the 28 GHz band in the Consultation Paper and Qualcomm agrees this should be the highest priority in the near term. Important developments relative to the mmWave bands include:

a) 28 GHz: The development of 5G mmWave over 28 GHz band is driven by the U.S., Republic of Korea and Japan. The FCC in the U.S. decided to allow mobile services on 27.5 - 28.35 GHz.

The government of the Republic of Korea is assigning the 26.5 - 29.5 GHz band in multiple phases for 5G trials in the 2018 Winter Olympic Games and is timing 5G commercialization for this band before 2020.

The government of Japan has assigned 27.5 - 29.5 GHz for 5G trials and Japan's mobile network

operators are expected to initiate 5G commercialization for this band in 2020.

b) 26 GHz: The European Union has identified 24.25 - 27.5 GHz band as a "5G Pioneer band" and is targeting commercialization in major cities from 2020.

   China MIIT has opened a public consultation on use of 24.75 - 27.5 GHz and plans to use the band for 5G trials.

c) 3GPP is working on two 5G NR bands for this range: 24.25 - 27.5 GHz and 26.5 - 29.5 GHz, and the eco-system are being developed to support the deployment from year 2018. The 28 GHz band would be the first mmWave band seeing 5G commercial deployment, while the 5G ecosystem over 26 GHz may follow soon after by leveraging the existing 28 GHz eco-system

d) 37 - 43.5 GHz after being identified as a candidate band for 5G at WRC-15 is receiving support for global harmonization. Importantly, the 37-43.5 GHz frequencies are not extensively encumbered. In the U.S. the FCC has decided the band 37-40 GHz be used for 5G and mobile network operators have indicated that they plan to start 5G commercial service on this band before 2020.

   China's MIIT opened a public consultation on 37 - 42.5 GHz for 5G, and plans to use the band for 5G trials.

   The Radio Spectrum Policy Group of the European Union has identified the 40.5 - 43.5 GHz band as a long term 5G band.

e) 3GPP is currently working to standardize 5G NR in the 37 - 40 GHz band, and the 40 - 43.5 GHz band may be added if requested by mobile operators. This standardization effort will assist the development of associated eco-systems to support the deployments from year 2018.

11. Considering that there are 11 candidate bands under consideration at WRC-19, how would making available the 28 GHz band help in the deployment of 5G services in Singapore? Would this band play a significant role in achieving the targets set out for 5G (i.e. higher throughput, ultra-low latency)?

The 28 GHz band is a key band for early 5G deployments, providing very large bandwidths for delivering multi-Gbps data rates, as well as extremely dense spatial reuse for increased capacity. Qualcomm's research demonstrates that the release of the 28 GHz band would enable the implementation of technologies that will enable and improve broadband communications. As such, 28 GHz will be one the earliest bands for which 5G devices are designed and released.

A culmination of many years R&D, Qualcomm carried out live demonstrations of our 5G mmWave prototype operating at 28 GHz at the February 2017 Mobile World Congress in Barcelona, Spain and in June 2017 in Shanghai, China. The demonstrations showed successful beamforming and beam-tracking techniques that enable robust and sustained broadband communications under line-of-sight (LOS) and non-line-of-sight (NLOS) RF channel conditions and device mobility. As investment and innovation by Qualcomm and other mobile sector players continues in developing products in the 28 GHz band, economies of scale

will be important to realize gains. Qualcomm strongly supports IMDA making the 28 GHz band available for 5G deployment in Singapore. This would ensure Singapore remains at the forefront of 5G as it attracts companies in deploying, advancing, and benefiting from 5G.

12. If the 28 GHz band is opened for IMT services in Singapore, would there be any future competing services that may be deployed in this band which may cause interference issues?

Qualcomm supports the opening of the 28 GHz band with priority to IMT as a highest-value use for the band, and agrees with IMDA's assessment of the band as currently underutilized in Singapore. Further, licensing rules can be leveraged to minimize or eliminate the potential for interference. For example, the FCC in the United States adopted a variety of rules for the bands, including geographic area licensing, unlicensed use, and a licensing mechanism that can accommodate private enterprise uses and traditional mobile broadband deployments. These rules promote coexistence among different use cases and could serve as a model for IMDA as it considers how best to utilize this band.

The 28 GHz band is under study for Earth Stations in Motion (ESIM) under WRC-19 Agenda Item 1.5 and technical conditions for such use will be developed by the ITU to ensure protection of, and not impose undue constraints on, services allocated in this frequency band, i.e., the fixed and the mobile services. In this regard, Resolution 156 (WRC-15), states that ESIM, with respect to any terrestrial systems operating in the bands, shall not claim protection or impose constraints on the development of these services. Furthermore, as stated in the consultation document, ESIM usage is restricted to only 28.6 – 29.1 GHz in Singapore and restricted to air platforms or vessels. Implementation of specific conditions as developed for WRC-19 will be important to ensure the protection of the use of the 28 GHz band for 5G terrestrial systems.

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

The estimates presented in the Consultation Paper reflect those presented by TG 5/1 and referenced in our response to Question 10. These estimates are in line with the best information available at present.

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?

Yes access to the mmWave spectrum should be provided earlier than 2022. Please also refer to Qualcomm's response to Question 1 and 10.

Most of the initial 5G deployments will be from networks deployed in mmWave bands and many other administrations and regions have already taken decisions to release mmWave spectrum for 5G. If Singapore wishes to maintain its lead in mobile technology and policy development, including 5G, it should finalize its 5G spectrum policy and planning, and ensure spectrum is released well in advance to allow commercial deployments as early as 2019.

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:

Overview of LTE-U, LAA, LWA, MulteFire:

LTE-U and LAA combine LTE in unlicensed spectrum (in the 5 GHz band) with LTE in the licensed band through carrier aggregation, initially in the downlink only and then in the uplink and the downlink for so-called enhanced LAA, is standardized in 3GPP Release 14.[9] This aggregation of spectrum provides for a fatter pipe with a more responsive user experience. By also maintaining a persistent anchor in the licensed spectrum to carry all of the control and signaling information, the user experience is both seamless and reliable. A key benefit of LTE-U and LAA is better performance than carrier Wi-Fi through extended coverage and higher capacity, especially for dense deployments. LTE-U/LAA performs twice as well as Wi-Fi—meaning that a LAA or LTE-U deployment can deliver twice as much capacity as Wi-Fi using the same number of access points/small cells, or LAA or LTE-U can achieve the same capacity as Wi-Fi using half the number of access points/small cells. LTE-U is based on 3GPP Rel. 12 and was introduced to address time-to-market needs in specific regions such as the U.S., Korea and India. LAA is defined in 3GPP Rel. 13 and has the additional benefit of meeting global regulations. LAA will enjoy 3GPP's cadence of regular enhancements and, as noted above, the subsequent 3GPP release 14 introduced enhanced LAA (eLAA). Both (e)LAA and LTE-U ensure fair co-existence with Wi-Fi.

LTE - Wi-Fi link aggregation (LWA) leverages existing and new carrier Wi-Fi deployments and utilizes both 2.4 and 5 GHz bands. LWA aggregation allows operators to fully manage Wi-Fi resources through the LTE anchor. This ensures better load balancing between the LTE and Wi-Fi links. Since aggregation is performed at the LTE RAN-level, it can adapt to the fast changing signal and loading conditions on both LTE and WiFi links. LWA is part of 3GPP Rel 13.

MulteFire™ is a new LTE-based technology that provides LTE-like performance with WiFi-like deployment simplicity. Unlike LAA or eLAA with an "anchor" in licensed spectrum, MulteFire enables LTE operation solely in unlicensed or shared spectrum.[10] Earlier this year, the MulteFire Alliance announced completion of Release 1.0 of the MulteFire specification and made it available for public download[11]. We believe this will bring innovation with new kinds of deployments that will offer new services and increase productivity to a wider ecosystem. Examples where we anticipate MulteFire would enable new kinds of deployments include Industrial IoT and enterprise services. Companies using MulteFire can deploy their own private high-performance LTE-based network that is fully under their control and tailored for their applications (e.g., factory floor, warehouse, container port, remote site, hospital, smart building) - refer to additional details in "The Private LTE Opportunity for Industrial and Commercial IoT" whitepaper.[12] Another deployment scenario where MulteFire brings new benefits is 'neutral host network,' where it can serve subscribers from any service provider to provide additional LTE capacity and extended LTE coverage in challenging places such as sport stadiums, airports, etc. MulteFire uses Listen-Before-Talk (LBT) for over-the-air contention to share the spectrum fairly, both with other MulteFire users as well as with Wi-Fi and LAA users. In 2016,

[9] https://www.qualcomm.com/invention/technologies/lte/laa
[10] www.qualcomm.com/MulteFire
[11] http://www.MulteFire.org/specification/specification-release-1-0-1download/
[12] www.MulteFire.org/white-papers/

Qualcomm demonstrated the first MulteFire over-the-air system, showing that the technology can increase network throughput beyond what Wi-Fi alone could deliver as well as fair coexistence with Wi-Fi.[13]

i) The adoption of LBT to facilitate sharing of licence-exempt spectrum and whether there would be any implication arising from such a requirement;

Listen-before-talk (LBT) is a standardized over-the-air contention mechanism that ensures fair sharing of unlicensed spectrum and applies to LAA, eLAA, MulteFire, and Wi-Fi. This is accomplished by dynamically selecting clear channels to avoid other users. If no clear channels are available, then channel is shared fairly with other users.

However, adoption of LBT is not required, as evidenced in other jurisdictions. LTE-U uses an over-the-air contention mechanism called CSAT—(carrier sensing adaptive transmission) to ensure that LTE-U shares spectrum fairly with Wi-Fi. In the United States, the Federal Communications Commission (FCC) issued its first authorization for LTE-U devices in the 5 GHz band in February 2017.[14] As the chief of the FCC's Office of Engineering and Technology noted "this action follows a collaborative industry process to ensure co-existence of LTE-U with Wi-Fi and other unlicensed devices operating in the 5 GHz band." The FCC noted the extensive work undertaken by LTE-U and Wi-Fi stakeholders in the Wi-Fi Alliance to develop coexistence guidelines and an evaluation test plan. The LTE-U devices were evaluated successfully under the co-existence test plan, however, this is not an FCC requirement and similar to conformity testing for private sector standards the co-existence test results are not included in the FCC's equipment certification records.

Negative implications include increased administrative costs and a risk of increasing equipment costs in Singapore due to the need to conduct additional testing.

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

As stated above, LBT is a well-recognized standardized over-the-air contention mechanism that ensures fair sharing of unlicensed spectrum and applies to LAA, eLAA, MulteFire, and Wi-Fi. Beyond standard, basic technical requirements for unlicensed operations (e.g., power limits, out-of-band emissions limits), no further technical requirements and regulatory measures should be imposed. We also note that, in September 2016, the FCC clarified that it would proceed to grant equipment certification for LAA devices.[15]

Qualcomm recommends IMDA minimize additional regulatory mandates and requirements in order to achieve the full potential of these innovative new technologies and utilize spectrum most efficiently and effectively. IMDA should leverage voluntary, industry-driven test plans for LAA and LTE-U devices in order to

[13] https://www.qualcomm.com/news/releases/2016/10/17/qualcomm-makes-worlds-first-MulteFire-over-air

[14] See "OET Authorizes First LTE-U devices," (February 22, 2017) available at https://www.fcc.gov/news-events/blog/2017/02/22/oet-authorizes-first-lte-u-devices.

[15] See "Industry Makes Progress on Unlicensed LTE Coexistence," (September 23, 2016), available at https://www.fcc.gov/news-events/blog/2016/09/23/industry-makes-progress-unlicensed-lte-coexistence.

harmonize with emerging best practices. This includes the test plan developed by the Wi-Fi Alliance for LTE-U[16] and the test plan developed by 3GPP for LAA.[17]

iii) The need for companies with commercial LTE-U networks to upgrade to LAA once the software/hardware products are commercially available.

LTE-U and LAA are part of the same evolution, and the LTE-U specification enables a migration to LAA via a software upgrade. Therefore, migration from LTE-U to LAA will be a natural evolution and there is no need for any regulatory requirements. Commercial LAA products are expected to be available by the end of 2017.

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:

Qualcomm welcomes IMDA's plans to facilitate industry trials for LAA/LTE-U technologies. LTE-U/LAA deployments have begun in the US, and trials have been conducted or are currently ongoing in a number of other countries including the United States, Hong Kong, Germany, and Turkey. These industry trials are a significant milestone towards further commercialization.

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

No comment.

ii) To minimise impact to Wi-Fi users, should IMDA limit LAA/LTE-U trials to parts of the 5 GHz licence-exempt spectrum?

LAA/LTE-U industry development has been focused on the 5 GHz unlicensed spectrum. Therefore, it may be reasonable for now to limit trials to the 5 GHz frequency band range. There is no further need to limit which parts of the 5 GHz band are available for a trial.

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

While the 5 GHz license-exempt spectrum has been the primary focus for LAA/LTE-U to date, LAA and MulteFire are not limited to the global 5 GHz band. They can also be deployed in other shared spectrum, such as the Citizens Broadband Radio Service (CBRS) in the United States' 3.5 GHz band or other bands including those where private LTE networks are contemplated.

ii) The regulatory and coexistence measures that should be adopted for MulteFire.

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[16] http://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-delivers-lte-u-coexistence-test-plan.

[17] 3GPP TR 36.789, "Multi-node tests for Licence-Assisted Access (LAA) (Release 13)", V13.0.0 (2017-06)

MulteFire technology is based on 3GPP LAA and eLAA standards and has similar performance and the same coexistence as LAA and eLAA in unlicensed. MulteFire uses LBT for over-the-air contention to share the spectrum fairly, both with other MulteFire users as well as Wi-Fi and LAA. MulteFire caters to all regulations in unlicensed spectrum, including power levels, channel sensing for coexistence and LBT requirements using Clear Channel Assessment Procedures and channel occupancy limits. While MulteFire has some additional short duration transmissions which are subject to a short LBT or no LBT, these are compliant with ETSI specification; in particular - like WiFi - MulteFire does not require channel sensing for some short (gap <16 us) UL-DL and DL-UL transmissions, as well as allowing fixed-duration sensing for high-priority signaling. Therefore, similar to LAA/eLAA in the 5 GHz unlicensed bands, beyond standard technical requirements for unlicensed operations, no further technical requirements and regulatory measures should be imposed.

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?**

Qualcomm supports the use of multiple methods to ensure the best possible coverage and service, depending on the particular environment. Approaches such as LAA, MulteFire and LWA all have appropriate use cases. It is important to note that LWA alone will not address the need for additional spectrum for mobile services. We encourage IMDA to consider all spectrum usage approaches that are feasible in Singapore – including use of both licensed and unlicensed bands – in order to enable the best possible 5G and mobile broadband service delivery.

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.**

With mobile operators grappling with increasing spectrum and capacity demand, the advent of LAA/LTE-U, MulteFire, and LWA present innovative new solutions for enhancing capacity through the use of carrier aggregation. LAA/LTE-U enables carriers to combine unlicensed spectrum with their own licensed spectrum to create larger bandwidths to ferry more data for users. LAA/LTE-U allows the carriers to combine spectrum for the downlink, and the more recent eLAA (Enhanced Licensed Assisted Access) technology allows a similar approach to the uplink. Whereas these modes allow offloading to unlicensed spectrum and ease carrier burdens, they rely on licensed spectrum as the "anchor" to which carriers then add capacity from unlicensed spectrum. MulteFire opens the door for a wide ecosystem and deployments to offer 4G LTE-like service using unlicensed or shared spectrum bands only, with the added benefit of extending LTE capabilities to such unlicensed spectrum bands with high spectrum efficiency, cellular-system security, wide-area coverage, seamless mobility, etc.

<u>Conclusion</u>

Qualcomm welcomes the opportunity to convey our views to IMDA on the *Consultation on the Proposed Approaches to Introduce the Next Generation of Mobile Services*. Qualcomm supports efforts by IMDA to ensure Singapore provides a conducive environment for the development and deployment of 5G technology. We applaud the IMDA for its thoughtful consideration of the ways to move 5G forward, as well as for continuing to engage stakeholders to provide inputs as such activities proceed.

Should you have any questions or comments on this submission, please do not hesitate to contact me at +852

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Sincerely,

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