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9 July 2019

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Re: Second Consultation on 5G Mobile Services and Networks

1.1 Introduction

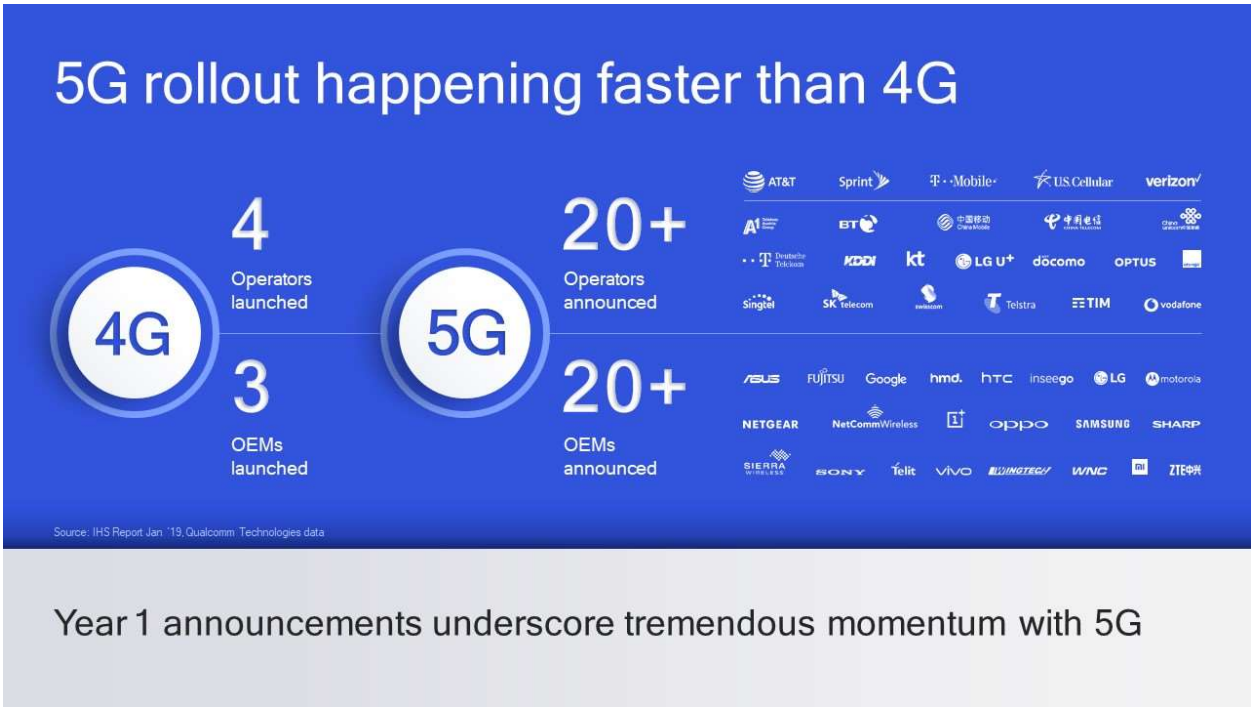
Qualcomm Inc. (Qualcomm) welcomes the opportunity to provide input to the Info-Communications Media Development Authority (IMDA) on the *Second Consultation on 5G Mobile Networks and Services* (the Consultation Paper).

Qualcomm is a world leader in 3G, 4G, 5G, Wi-Fi, and next-generation wireless. 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 Technologies, Inc., a wholly owned subsidiary of Qualcomm Incorporated, is the world's largest fabless semiconductor producer and the largest provider of wireless chipset and software technology powering many of the wireless devices commercially available today. Our technologies are driving the convergence of mobile communications and consumer electronics making wireless devices and services more personal, affordable and accessible to people everywhere. We are redefining the experience of wireless mobility by applying our unmatched legacy of wireless innovation to enable new generations of increasingly powerful cell phones, smartphones, computers and consumer electronics, and Internet of Things (IoT) devices. Today, we license nearly our entire patent portfolio to more than 300 manufacturers worldwide – from new market entrants to large multinational companies – and this model has created a pro-competitive, pro-innovation value chain of global scale whose ultimate beneficiaries are consumers.

To transition to 5G, spectrum will be needed in low, mid, and high bands and the 5G technologies and standards have been designed with this in mind. Qualcomm's vision is for 5G to enable new services and devices, connect new industries, and empower new user experiences. Together with other mobile industry partners, we are developing a unified 5G system addressing both licensed and unlicensed spectrum in low, mid and high bands, including the 3.5 GHz, 26 GHz, and 28 GHz bands proposed by IMDA for release in the first tranche. 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 requiring 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. 5G will 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.

The IMDA's second consultation on 5G policy and spectrum is timely. The first wave of 5G launches has already begun, and a number of 5G commercial network deployments and devices have already been announced across the globe. Qualcomm believes 5G uptake will occur at a much faster rate than 4G LTE considering, among others, the large number of network operators and equipment manufacturers who have already released 5G announcements.



Qualcomm applauds IMDA for its continued careful consideration of the appropriate approaches to enabling the successful deployment and adoption of 5G services across Singapore's economy. The remainder of this submission presents information on Qualcomm's views on the issues raised in the Consultation Paper.

1.2 Introductory comments

Qualcomm strongly supports IMDA's proposal to allocate the 3.5 GHz, 26 GHz, and 28 GHz bands for the deployment of 5G networks. As noted in the Consultation Paper, these bands represent the global "front-runner" bands for 5G deployments and have the most advanced device and infrastructure ecosystem. The first 5G deployments worldwide leverage spectrum in some or all of these bands, including Telstra in Australia, all three mobile carriers in the Republic of Korea, Swisscom and Sunrise in Switzerland, EE in the United Kingdom, Verizon in the United States and Vodafone in Spain.

5G services are available today to users with devices from manufacturers including HTC, LG, OnePlus, OPPO, Samsung, Motorola, Xiaomi and ZTE. In fact, Qualcomm's own data indicates that there are more than 75 devices launched or in the design process using the company's products, indicating continued ecosystem growth in just the intervening period.

Figure 1: 5G devices

These devices span the range of key 5G bands, including support for sub-6 GHz frequencies, such as the 3.5 GHz band, as well as mmWave bands including 26 GHz and 28 GHz. Further, this first wave of devices includes multiple form factors, such as hotspots, indoor and outdoor customer premises equipment, modules and snap-on dongles/adapters. Upcoming devices include the world's first 5G PC, the result of a collaboration between Qualcomm and Lenovo that incorporates Qualcomm's Snapdragon 8cx 5G compute platform, incorporating the Snapdragon X55 5G modem.[1]

The importance of 5G technology to Singapore's policy objectives cannot be overstated, particularly with respect to Smart Nation Initiatives and Industry 4.0 goals. Singapore's Smart Nation plans span the entire economy, including urban living, transportation, health and medical services, digital government services, and strategic national projects. Many aspects of Singapore's Smart Nation vision will be enabled or enhanced by 5G connectivity and applications, including expanded access to healthcare through remote presence and virtual reality, distance learning in the education sector, smart transportation networks and autonomous vehicles, and sensor networks enabling smart energy generation and usage. Similarly, Industry 4.0 is typified by a connected manufacturing ecosystem, incorporating computing, networking, and physical processes, connected via processing power residing across devices and the cloud. This enables activities including movement of automated vehicles or other transports, robotic assembly, optimization of production processes, and remote monitoring and control. All aspects of Industry 4.0 are touched by 5G's capabilities, including fiber-like broadband speeds and ultra-reliable, low latency communications.

Keeping in mind the numerous applications of 5G connectivity and services and their potential impact on Singapore's society and economy, Qualcomm strongly encourages IMDA to move forward with the allocation of the 3.5 GHz, 26 GHz, and 28 GHz bands for use by 5G services as expeditiously as possible.

[1] Qualcomm, "Qualcomm and Lenovo Unveil World's First 5G PC Powered By The Qualcomm Snapdragon 8cx 5G Compute Platform," (May 27, 2019), https://www.qualcomm.com/news/releases/2019/05/27/qualcomm-and-lenovo-unveil-worlds-first-5g-pc-powered-qualcomm-snapdragon.

1.3 Industry Updates on C-V2X, Private networks and the Industrial IoT

1.3.1 C-V2X

As 5G technology is deployed and leveraged by companies and users across Singapore, it will have an impact on multiple facets of society and the economy. One visible example is expected to be the incorporation of 5G technology into automobiles and transportation, notably through the use of cellular vehicle-to-everything (C-V2X) technology, which includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) communications, as well as network communications (V2N). C-V2X technology is incorporated into current and planned future 3GPP releases, adding new capabilities with each release, including support for autonomous driving enabled by features such as non-line-of-sight sensing, conveying intent for direction changes, and situational awareness. C-V2X also complements other vehicle sensors, improving upon capabilities that currently provide collision warning assistance to drivers.

C-V2X is a stepping stone to 5G starting with LTE-V2X and it has two modes of operation, including 'direct' over 5.9 GHz spectrum and 'network' over licensed spectrum. Sufficient bandwidth in 5.9 GHz is required to support basic safety services (LTE-V2X Rel 14) and advanced use cases for autonomous driving (NR V2X Rel16 and on). 5.9 GHz spectrum is globally harmonized for Intelligent Transportation Systems (ITS) including in Europe, United States, China, S. Korea, and Australia with other countries in progress.[2]

In January 2019, after working together with Qualcomm on technology development and field trials,[3] Ford announced its commitment to deploy C-V2X technology in all their new vehicle models in the United States beginning in 2022.[4] C-V2X trials and deployments leveraging Qualcomm solutions are in development with partners across the globe. In the U.S., Ford and Panasonic have partnered with the Colorado Department of Transportation in a C-V2X deployment, and there have been a host of demonstrations in Washington D.C. as well as Las Vegas. The Las Vegas demonstrations at the 2019 Consumer Electronics Show (CES) conducted by Audi, Ducati, Ford, the City of Las Vegas and the Regional Transportation Commission of Southern Nevada[5] transcended the basic safety applications shown in other demonstrations by showing complex maneuvers in potentially complicated intersection environments, something that C-V2X does well. In Europe, trials are ongoing in various corridors compiling automakers including PSA,[6] BMW,[7] Audi,[8] and many other partners within the vast 5GAA ecosystem, as well as the live demonstration event recently held in Berlin.[9] In Barcelona earlier this year, the first technology

[2] http://5gaa.org/wp-content/uploads/2019/01/5GAA_White-Paper-CV2X-Roadmap.pdf

[3] Qualcomm, "Qualcomm and Ford Collaborate on C-V2X Global Initiative to Improve Vehicle Safety, Traffic Efficiency and Support for Autonomous Driving," (January 9, 2018), https://www.qualcomm.com/news/releases/2018/01/09/qualcomm-and-ford-collaborate-c-v2x-global-initiative-improve-vehicle.

[4] "Ford Breaks With Auto Rivals By Committing To C-V2X Vehicle Communications Tech," https://www.forbes.com/sites/samabuelsamid/2019/01/07/ford-becomes-first-automaker-to-commit-production-c-v2x-communications/#741a4485788f. See also "Panasonic, Qualcomm and Ford Join Forces on First U.S. Deployment for C-V2X Vehicle Communications in Colorado," (June 1, 2018), https://www.qualcomm.com/news/releases/2018/06/01/panasonic-qualcomm-and-ford-join-forces-first-us-deployment-c-v2x-vehicle.

[5] https://www.digitaltrends.com/cars/cv2x-system-ces-2019/

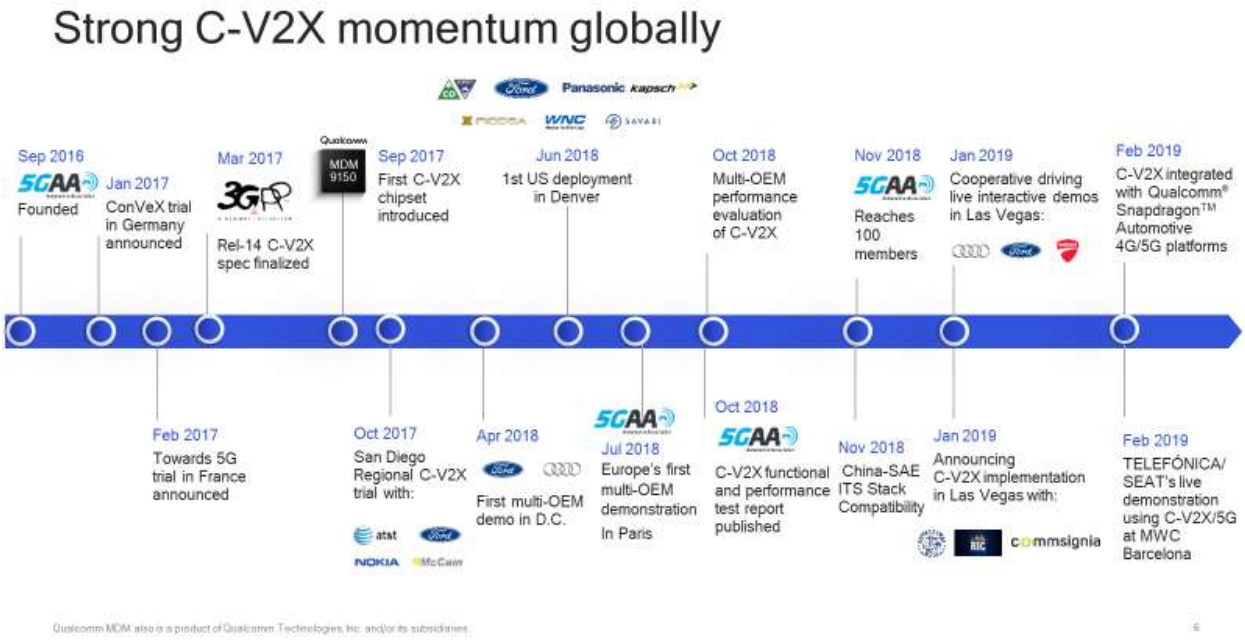
[6] https://www.groupe-psa.com/en/newsroom/corporate-en/le-groupe-psa-accelere-dans-le-deploiement-des-vehicules-connectes/

[7] https://media.ford.com/content/fordmedia/feu/en/news/2018/07/11/-5gaa--bmw-group--ford-and-groupe-psa--exhibit-first-european-c-.html

[8] https://www.ducati.com/ww/en/news/ducati-is-working-with-industry-leaders-in-developing-direct-communication-interoperability-between-motorcycles-vehicles-and-infrastructure

[9] http://5gaa.org/news/c-v2x-contributes-to-safer-roads-for-everyone-5gaa-live-demo-event-in-berlin/

demonstration combining 5G NR and C-V2X was conducted.[10] In China, there is strong government and ecosystem support for C-V2X technology including automakers Audi China, BAIC, ChangAn, Geely and Great Wall, among others. The industry recently convened at GSMA Shanghai (June 2019) to explain the advancing state of C-V2X deployment throughout China, including the progress of C- V2X applications and services in terms of readiness of the ecosystem and commercialization.[11]



Qualcomm is also founding member of the 5G Automotive Association (5GAA), an industry organization supporting the C-V2X ecosystem which in less than three years has grown to more than 125 members including leading carmakers, tier-1 automotive suppliers, infrastructure providers, mobile operators and technology suppliers. The ongoing development of C-V2X technology by Qualcomm and others promises to leverage 5G connectivity to reshape transportation in Singapore and beyond.

1.3.2 Private networks and the Industrial IoT

Qualcomm supports IMDA consideration of mechanisms to enable localized private wireless broadband deployments within the framework of its 5G spectrum and deployment planning. This may include, for example, leveraging innovative licensing approaches to allow for non-public use of bands in areas where spectrum is not fully utilized.

Private 5G networks are suited to enable or optimize critical business processes especially in locations not covered by public networks, where dedicated capacity and radio configuration is required, or where there are challenging RF conditions. Private, purpose-built networks enable businesses and other organizations to optimize and tailor networks for specific applications (e.g. network dimensioning, quality-of-service, latency, security, etc.). In particular, 5G technology allows enterprises to augment and replace wired

[10] https://www.telefonica.com/en/web/press-office/-/telefonica-and-seat-show-5g-connected-car-use-cases-for-safer-driving-in-a-city-environment

[11] http://5gaa.org/news/5gaa-brings-together-key-actors-to-share-advances-on-c-v2x-deployment-in-china-at-mwc-shanghai-2019/

network connections with more flexible wireless communications, as well as to build 5G capability into future equipment and processes over the longer term. 5G technology will offer performance characteristics, including time-sensitive networking, comparable to current wired connections, but without the need for physical cables requiring maintenance and limiting configuration of equipment.

Private 5G networks support deployments of wireless broadband within, for example, industrial complexes including factories, enterprises, ports, mines, petrochemical installations, agricultural environments enable the expansion or introduction of industrial IoT networks.

According to "The 5G Economy," an independent study from IHS Economics and Technology, 5G's full economic benefit should be realized around the globe around 2035, when a selection of 5 industries - manufacturing, transport, construction, utilities, and mining may produce more than USD 5 trillion worth of goods and services enabled by 5G mobile technology.[12]

The deployment of local 5G networks also provides opportunities to enable enterprises to use spectrum for private connectivity needs. Such an approach could further enhance the value of 5G spectrum.

Local private 5G networks can be accommodated:

- Within a licensed 5G wide area network by utilizing network slicing capability;
- As an independent network using the same spectrum as a licensed 5G wide area network;
- As an independent network using different licensed spectrum to a 5G wide area network; or
- As an independent network using unlicensed spectrum.

Several other countries moving forward with specific plans or considering options for local or private 5G networks include Germany, Hong Kong, Japan, the Netherlands, Sweden, Australia, Taiwan and the United Kingdom.

- **Germany's** Federal Network Agency (BNetzA) announced in March 2019 its framework for offering spectrum in the 3.7 GHz band for local 5G applications, such as industrial automation and Industry 4.0 applications, as well as agriculture and forestry. Germany will administratively assign spectrum based on land ownership or other rights of use, such as lease or rental. The services to be offered using such spectrum are for the use of the authorized party and not for the provision of public services.
- **Japan** has also taken policy decisions in support of private/localized networks utilizing dedicated spectrum. The Ministry of Internal Affairs and Communication (MIC) has announced that 28.2 – 29.1 GHz band will be used for 5G NR based local, and potentially, private networks, and policy announcements for the 28.2 – 28.3 GHz segment are expected in June-August 2019.
- **Hong Kong** has set aside 400 MHz within the 26/28 GHz band specifically for the provision of localized innovative 5G services to specific groups of users on a geographically shared basis. Applications for assignment are expected to be invited in the second quarter of 2019.
- **Australia** intends to make spectrum in the 26 GHz band available for localized 5G deployments, potentially as early as 2020, and is also currently consulting on future use of the 28 GHz band.

The industrial IoT (IIoT) is a key development enabled by 5G connectivity, including private 5G networks, bringing significant potential to transform production processes. Recently, at the Hannover Messe industrial technology trade show in Germany, Qualcomm was a key provider of connectivity solutions

[12] IHS Economics and IHS Technology, "The 5G economy: How 5G technology will contribute to the global economy," (January 2017), https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf.

powering IIoT demonstrations.[13] One such demonstration showed ultra-reliable 5G New Radio (5G NR) technology for IIoT use, using coordinated multi-point (CoMP) technology to achieve 99.9999 percent reliability. A second demonstration showcased how 5G NR can be deployed using shared and unlicensed spectrum (NR-U) to provide higher performance connectivity in terms of network capacity, user throughput, and reliability with CoMP for private and localized 5G networks. Private 5G networks are expected to account for a significant number of 5G network deployments, as discussed in Section 1.3.2.

1.4 Technology neutrality is foundational for initial 5G deployments

The full benefits of 5G are unlocked when mmWave spectrum is deployed in concert with sub-6 GHz spectrum. Given that IMDA does not propose to release sub-6 GHz spectrum for 5G until the 2021 timeframe, Qualcomm strongly encourages the IMDA to allow both non-standalone (NSA) and standalone (SA) 5G network and device architecture. NSA 5G enables licensees to begin offering 5G benefits by leveraging existing LTE infrastructure and later used a phased approach to implement SA. In fact, all 2019 5G commercial launches worldwide will employ NSA 5G.

In order to maximize the potential of 5G deployments in Singapore, IMDA should take a technology-neutral approach, allowing operators to deploy the 5G technology that is most appropriate for their spectrum resources and business plans. **To enable 5G commercial launches and services in Singapore in 2020,** Qualcomm urges the IMDA to allow operators the flexibility to deploy NSA network and device architecture. For 5G commercial launches in the 2020 timeframe, Qualcomm recommends NSA.

1.5 Future spectrum releases

Qualcomm strongly supports IMDA's consideration of additional 5G spectrum bands for release in a future wave. The paradigm shift brought about by 5G is expected to create significant demand for spectrum resources to enable a wide range of use cases. As was discussed in IMDA's first *Consultation on 5G Mobile Services and Networks*, estimated spectrum requirements for 5G are significantly higher than for previous generations of mobile technology.

As such, it will be imperative to continue to explore options for additional spectrum resources that can be put to their highest-value use by supporting 5G. This includes all of the bands identified in the Consultation Paper—700 MHz, 1.4 GHz, 2.1 GHz, 2.5 GHz, and 4.5 GHz—as well as additional mmWave bands including 39 GHz, among others. While some of these bands may not yet be available for 5G in Singapore, we encourage the IMDA to continue consideration with the aim of accelerating the timeframe for spectrum release.

1.6 Responses to consultation questions

Question 1: IMDA would like to seek the industry's views on skills requirements and the potential job demands in the future of networks and next generation of application/use-cases with 5G technology.

5G is a new kind of network: a platform for innovations that will not only enhances today's mobile broadband services, but also expand mobile networks to support a vast diversity of devices and services and connect new industries with improved performance, efficiency, and cost. 5G will redefine a broad range of industries with connected services from retail to education, transportation to entertainment, and everything in between. 5G is technology as transformative as the automobile and electricity.

[13] Qualcomm, "Bringing 5G to Industrial IoT at the Hannover Messe," (April 1, 2019), https://www.qualcomm.com/news/onq/2019/04/01/bringing-5g-industrial-iot-hannover-messe.

5G technologies will enable and accelerate the development of Industry 4.0 in Singapore and beyond, and will be a fundamental technology powering Singapore's Digital Economy. 5G's fiber-like broadband speeds and low latency connectivity will benefit the manufacturing ecosystem, enabling innovations such as wirelessly connected production processes and robotics that can be more easily reconfigured, connectivity to cloud computing resources for management of IIoT, remote monitoring and control and overall optimization of production processes. All three strategic priorities of the Digital Economy framework—digitalizing industries, integrating ecosystems, and industrializing digital—will be enabled and accelerated by 5G technologies, positioning Singapore to advance its position as a leading digital economy.

Figure 2: 5G's economic impact

The economic contribution of 5G is expected to be massive. As noted in Section 1.3.2, a 2017 IHS Economics and Technology study considered the impact of 5G on the global economy. The study forecast 5G's contribution to the global economy as enabling a total of USD 12.3 trillion of economic output by 2035, contributing to real global GDP.[14] Of that economic output figure, the contribution of the manufacturing, transport, construction, utilities, and mining sectors alone may produce more than USD 5 trillion worth of goods and services. The global 5G value chain itself will also be a major economic contributor, generating USD 3.5 trillion in output, and supporting 22 million jobs globally by 2035. Similarly, a 2018 GSMA study considering only mmWave bands estimated that 5G could add USD 565 billion to global GDP and USD 152 billion in tax revenue between 2020 and 2034.[15] It is clear that 5G is poised to have a significant impact on Singapore's productivity, economic output and job creation.

[14] IHS Economics and IHS Technology, "The 5G economy: How 5G technology will contribute to the global economy," (January 2017), https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf.

[15] GSMA, "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," (December 2018), https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

Question 2: IMDA would like to seek views on:

i) The types of innovative use-cases that could capitalize and further enhance Singapore's competitive advantages, trigger new growth potential and/or strengthen Singapore's existing strategic pillars; and

5G will enable a series of use cases that will transform not only the experience of using a mobile handset, but also transformations across all aspects of Singapore's socioeconomic fabric.

- **Improved speeds:** 5G will provide fiber-like speeds to support demand for data. Users will experience multi-gigabit download speeds, superior quality video streaming and augmented reality experiences in flagship 5G devices that are already entering the market. Improved speeds will enable faster and easier access to content, whether for entertainment or critical business communications.
- **Instant cloud access:** 5G brings extraordinary low latency. 5G is purpose-built and designed to deliver entirely new real-time experiences, bringing new capabilities to smartphones, tablets, and always-connected PCs. Low latency and super-fast broadband speeds will enable faster access to cloud services and the development of a whole new generation of cloud services offering vast processing, storage and artificial intelligence (AI) capabilities.
- **Smooth real-time multiplayer gaming:** Following from increased speeds and lower latency will be improved online or cloud gaming. This next generation of cloud gaming will improve multi-player collaboration and live-stream gameplay, improving the player experience and enabling new innovation among game creators and publishers.
- **Transformation to the Wireless Edge:** Realizing 5G's full potential requires transformation of the wireless edge, an architecture of distributed intelligence where the intelligence that deals with immediacy is moved toward the edge (closer to or on the devices) while processing-intensive functions are kept in the cloud. 5G is enabled with the help of Qualcomm's foundational inventions and mobile platforms and is engineered to provide the high-speed, low-latency link that connects them together. Use cases for 5G and edge computing include extended reality (XR), where much processing and rendering is performed in the cloud, and augmented reality.

The various 5G use cases can be described and organized in multiple fashions. One approach is to organize them by user experience scenarios, as in the figure below. This approach further specifies some of the benefits identified above, including improved speed and latency, gaming, and virtual reality and augmented reality.

Figure 3: Potential 5G user experience scenarios

As can be seen, these use cases span entertainment, person-to-person communications, content creation, and retail, and could have impacts relevant to smart city and educational goals as well.

5G and its resulting use cases will provide a dynamic platform for innovation, leveraging the benefits of eMBB, ultra-reliable low-latency communications, and mobility and opening up new opportunities for mobile operators. The capabilities and use cases powered by 5G technology will enable new synergies between the mobile sector and industry verticals that may have previously seen less utility in mobile and wireless services. The speed, latency, and massive IoT aspects of 5G could, for example, make mobile services more useful or cost effective across use cases as varied as health and medical care, immersive and interactive entertainment, retail, and the various IIoT cases described in the response to Question 1 and in Section 1.3.2.

One of the most exciting aspects of 5G is that it is impossible to fully predict all of the use cases that will be enabled by 5G technologies. As was the case with the initial introduction of smartphones, the true impact of 5G is likely to include offerings that are not being widely considered today. This innovation space provides forward-looking economies such as Singapore an important opportunity to build upon 5G capabilities to advance national interests and create products and service models that point toward the future of global developments across key sectors.

ii) Areas of government support that the industry require in order to enable innovation and development in 5G.

IMDA and the Singapore Government can enable 5G innovation and development by employing approaches that allow the 5G industry and ecosystem to blossom, enabling further innovation and development throughout Singapore's economy.

- **Spectrum release**, spectrum will be needed in low, mid, and high bands to realize 5G's full benefits and the 5G technologies and standards have been designed with this in mind;
- **Light-touch regulation**, avoiding overly prescriptive requirements and administrative obligations will permit industry to innovate and experiment, offering the appropriate mix of technologies and services for Singapore;
- **Focus on adherence to key policy principles**, such as pursuing the key IMDA policy objectives outlined in the Consultation Paper, will ensure that regulatory actions and activities undertaken are anchored by a regard for the underlying goals for the ICT sector; and

- **Government support**, potentially in the form of funding or support for research and development activities in selected strategic areas of focus, could help to ensure that 5G technologies and use cases deemed important to Singapore are developed and deployed in a timely fashion.

Qualcomm encourages IMDA to consider these approaches as it further develops its policy for enabling the deployment of 5G networks and their use as innovation platforms for a range of Singaporean sectors.

Question 3: IMDA would like to seek views and comments on the suitable technical parameters, including the reasonable amount of guard band needed to reduce potential interference between IMT and FSS use in the 3.5 GHz band.

Qualcomm studies have investigated the effect of signals from 5G NR base stations on the operating point of the LNA/LNBs of FSS earth-station receivers in the 3.5 GHz. The impact of a guard band of 100 MHz, 41 MHz and 20 MHz between the 5G NR transmission and the FSS receiver was evaluated for the three different 5G NR base station classes: wide area (macro cell), mid-range (micro cell) and indoor (pico cell).

The analytical model used in our study to calculate the minimum pathloss between the 5G NR base-stations and FSS earth stations is based on the free space pathloss model contained in Recommendation P.452, FSS protection criteria specified in Recommendations ITU-R S.1432 and Report ITU-R M.2109, and 5G NR base-station spurious emission masks specified in 3GPP TS38.104.[16]

The results of the study show that to prevent 5G NR macro cell deployments from saturating studied FSS earth stations with LNA gain of 50-60 dB a separation distance of 1.02 to 3.20 km is required regardless of the size of the guard-band because the FSS LNA operates over the entire 3400-4200 MHz frequency range. Limiting the FSS operating range and creating a 41 MHz guard-band by fitting a filter with 5-15dB attenuation enables the separation distance to be reduced to less than 1km.

For micro-cells and indoor cells the study shows that no additional filtering of the FSS operating range is required for satisfactory operation of 5G NR with FSS earth station reception.

Qualcomm is completing work on this study and will be able to share with IMDA in the coming weeks. Based on the results of this and similar studies which demonstrate the adequacy of a much reduced guardband than what IMDA has currently set aside for study, Qualcomm encourages the IMDA to release, at a minimum, an additional 50 MHz from 3600-3650 MHz from the outset. Co-existence studies of the remaining 3650-3700 MHz can continue. IMDA is requested to require the FSS earth stations to fit appropriate filtering to reduce the guard band between 5G NR and FSS earth station reception from within the 50 MHz from 3650-3700 MHz.

Question 4: IMDA would like to seek views and comments on the following:

i) Whether the industry agrees with the timelines on the expected availability of the next wave of 5G spectrum

Qualcomm commends IMDA on the release of information indicating potential spectrum availability timelines. We encourage the adoption of a formal spectrum release timeline, providing the industry with the lead time and regulatory certainty that is necessary for key business and resource allocation decisions that are central to network deployment plans.

[16] See Recommendation P.452-11 (May 2003), https://www.itu.int/rec/R-REC-P.452-11-200304-S/en; Recommendation ITU-R S.1432-1 (April 2006), https://www.itu.int/rec/R-REC-S.1432-1-200604-I/en; Report ITU-R M.2109 (2007), https://www.itu.int/pub/R-REP-M.2109-2007; and Technical Specification 38.104, https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202.

At a minimum, the spectrum availability timelines indicated in the Consultation Paper should be maintained so as to ensure 5G services and benefits can be delivered to Singapore consumers and industry in the near term. Qualcomm also encourages the IMDA to explore possibilities to accelerate the timelines, especially for the 3.5 GHz band not proposed for release until 2021. Commercial 5G services have already been launched in a number of countries around the world. As of May 2019, GSA reports that 17 operators in 10 countries have already launched commercial 5G (see Box 1).[17] In addition, in early June 2019, China issued 5G licenses to four operators, with three expected to launch service in more than 40 cities by the end of September 2019. Singapore should not fall too far behind.

Box 1: Global 5G service launches, May 2019

Operators with commercial 3GPP-compatible 5G

- AT&T (USA)
- EE (UK)
- Elisa (Finland and Estonia)
- Etisalat (UAE)
- KT (Republic of Korea)
- LG Uplus (Republic of Korea)
- Ooredoo (Qatar)
- Optus (Australia)
- SK Telecom (Republic of Korea)
- Sprint (USA)
- Sunrise (Switzerland)
- Swisscom (Switzerland)
- Telstra (Australia)
- Verizon (USA)
- Vodacom (Lesotho)
- Vodafone (Qatar)

Source: GSA

Qualcomm continues to lead 5G technology development, including through the release of the Snapdragon X50 modem for commercial 5G devices starting in early 2019. The X50 modem is featured in nearly all 5G devices that comprise the first wave to reach the market. The Snapdragon X55 modem, our second-generation 5G NR modem, will be released in late 2019, supporting all major mmWave and sub-6 GHz spectrum bands in TDD and FDD modes of operation, and is capable of both SA and NSA network deployment.[18] The Snapdragon Mobile Platform with 5G integrated into a System-on-Chip, a newly integrated 5G mobile platform, is expected to be incorporated into devices reaching the market in the first half of 2020.[19] The 5G device ecosystem is expanding rapidly and will be prepared to support Singaporean deployments at the earliest possible date.

Qualcomm encourages Singapore to maintain its long-standing technological prowess and leadership by making 5G-appropriate spectrum available at the earliest possible date.

ii) Whether current deployments in the 2.5 GHz FDD spectrum band (based on 3GPP Band 7) and in the 2.5 GHz TDD spectrum band (based on 3GPP Band 38), should be refarmed to 3GPP Band 41 for future 5G services in Singapore, and the views on the associated cost and challenges.

Both the United States and China are already moving toward deployment of 5G TDD services in the 2.5 GHz band, notably with China's recent award of 2.5 GHz band spectrum to China Mobile and Sprint's 5G deployments in the United States. Many European countries are likely to maintain LTE FDD in the 2.5

[17] GSA, "Evolution from LTE to 5G: Global Market Status," (May 2019), https://gsacom.com/download.php?id=6855.
[18] Qualcomm, "Qualcomm Unveils World's Most Advanced Commercial Multimode 5G Modem to Accelerate Global 5G Rollout," (February 19, 2019), https://www.qualcomm.com/news/releases/2019/02/19/qualcomm-unveils-worlds-most-advanced-commercial-multimode-5g-modem.
[19] Qualcomm, "Qualcomm Announces Industry's First Mobile Platform with Integrated 5G," (February 25, 2019), https://www.qualcomm.com/news/releases/2019/02/25/qualcomm-announces-industrys-first-mobile-platform-integrated-5g.

GHz in the coming years. While there is a sound expectation of a robust device ecosystem for 5G TDD in this band, we understand IMDA's proposal to not release for 5G in this initial round.

Question 5: IMDA would like to seek views, comments and suggestions on:

i) Whether Singapore should have two nationwide networks as a start given the considerations and trade-offs;

No comment.

ii) The proposed 3.5 GHz lot sizes and spectrum packages;

As discussed in the response to Question 3, for this initial release of 5G spectrum, Qualcomm recommends reducing the guard band between 5G NR and FSS earth station reception to 50 MHz at a maximum, making an additional 50 MHz from 3600-3650 MHz available for 5G services at the outset.

iii) Whether 5G equipment would be able to support 3.5 GHz bandwidths in multiples of 50 MHz;

Yes, Qualcomm's 5G products support both 50 MHz and 100 MHz carrier bandwidths in 3.5 GHz (n77 and n78).

iv) The value, if any, in assigning the remaining 50 MHz restricted 3.5 GHz spectrum in the same assignment exercise as the unrestricted lots;

There is definitely value in assigning what IMDA refers to as the remaining 50 MHz of 3.5 GHz spectrum during the same exercise as the unrestricted lots. This spectrum would provide access to additional capacity to enable new use cases and industry verticals. Further, Qualcomm encourages IMDA to award this spectrum without the potential assignment delay proposed in the Consultation Paper. By restricting the 3.5 GHz spectrum available for the provision of 5G services, IMDA may unintentionally suppress development of the very services that rely on mid-band spectrum to deliver improved connectivity and communications across Singapore.

v) The proposed mmWave lot sizes and preferred band plan option; and

No comment.

vi) The rank order preference of the 3.5 GHz spectrum package and mmWave lot combinations.

Qualcomm has no comment on the rank order preference of the spectrum package and lot combinations. However, as noted in our response to Question 5(iv), we strongly encourage IMDA to award the remaining 50 MHz spectrum in the 3.5 GHz band in this initial release.

Question 6: IMDA would like to seek views, comments and suggestions on:

i) The proposed network rollout and performance obligations to be imposed on the spectrum right holders;

Qualcomm supports the application of carrier obligations and milestones in order to ensure that new networks and services are enabled for Singapore's citizens and businesses in a timely and accelerated manner. Calibration of appropriate obligations for 5G network deployments is reasonable, but should not relax the obligations to the point that network and service deployment is slower than what is proposed in the Consultation Paper.

ii) The methodology and measurement criteria for the coverage obligation;

No comment.

iii) The network design and resilience challenges of 5G (in particular, enabling technologies, such as SDN, NFV and Cloud Computing that may fundamentally change how the network would be designed and deployed) and possible measures to address them, and whether there are other aspects that should be considered to enable trusted and resilient 5G network; and

The approach or measures that would best help to address the network design and resilience challenges of 5G is for IMDA to take a light-touch regulatory approach, only imposing regulations or obligations that are absolutely critical for the proper functioning of the 5G networks. By adopting a light-touch approach with minimal restrictions, IMDA will enable industry stakeholders to continue to innovate and introduce new approaches to addressing the challenges of 5G networks and services. In so doing, IMDA will ensure that operators and vendors can address challenges quickly and without additional administrative burdens on the industry or IMDA itself.

iv) The framework for the provision of 5G wholesale services.

No comment.

Question 7: IMDA would like to seek views, comments and suggestions on the spectrum assignment framework, including:

i) The proposed assignment approach;

No comment.

ii) The spectrum right duration of the 3.5 GHz package and mmWave lots;

Qualcomm agrees with the IMDA view that a suitable license term is necessary to provide sufficient investment certainty for mobile network operators, especially taking into account the new deployment models planned for 5G in mmWave bands. This regulatory certainty is crucial for operator considerations of level of investment required and the time available to generate an appropriate return on that investment. To this end, the longest possible spectrum right duration for spectrum in Singapore is appropriate and valuable to operators.

iii) The evaluation criteria, sub-criteria and weights to assess the proposals;

No comment.

iv) The assessment methodology, including evidence (documentary or otherwise) to evaluate the proposals; and

No comment.

v) The enforcement and/or audit mechanisms to ensure that applicants are able to deliver on their proposals.

No comment.

Question 8: IMDA would like to seek views and comments on the trade-offs (particularly on resilience, 5G capabilities) and technical feasibility of the various levels of infrastructure sharing.

Qualcomm has no comment on the technical feasibility of the various levels of infrastructure sharing. We note, however, that the use cases for IIoT, in particular, will affect the business cases for different types of 5G deployments. For example, as noted in Section 1.3.2, IIoT is likely to benefit greatly from the deployment of local, private 5G networks. Similarly, interest in infrastructure sharing may be driven by IIoT use cases, including automated vehicle transportation or fiber-like wireless connectivity to and across an industrial campus.

Question 9: IMDA would like to seek views and comments on the following:

i) The synchronisation approach for 5G TDD networks in a multi-operator environment for the 3.5 GHz and mmWave bands, specifically for the following: a. Synchronised networks: the required frame alignment, compatible frame structures and BEM specifications for AAS and non-AAS base stations; and b. Unsynchronised networks: the amount of guard band, geographical separation and BEM specifications for AAS and non-AAS base stations;

ii) The adoption of other suitable mitigation measures to mitigate interference between unsynchronised networks; and

iii) The need for IMDA to mandate a regulatory requirement for synchronisation across the 5G TDD networks or leave it to operators to co-ordinate their network deployment and parameters in order to reduce interference between networks.

For the 3.5 GHz band, when considering the scenario of 5G NR TDD coexistence, Qualcomm believes that synchronization is a valid option to prevent the need for a guard band and more efficiently utilize scarce spectrum resources. Using the permissive mask in synchronized operations would not require operator-specific RF filters thereby reducing cost and complexity.

Operators would need to agree on how to synchronize their networks (frequency, phase and time) and agree on a common TDD frame structure. The inherent risk of synchronized operations would be that the latency attainable by NR devices will be heavily dependent on the specific chosen TDD configuration. Qualcomm believes that tools such as semi-synchronization could be available by 2020 to allow more independent configuration of each network and overall better latency.

Semi-synchronization would be a special case of synchronized operation, as within the common frame configuration some subframes are left undefined and can be configured independently by each operator and dynamic re-configuration within the same network would be allowed even on a site-by-site basis (Dynamic TDD). Each operator could configure undefined subframes to minimize latency in its network e.g., by increasing the number of UL-centric subframes or special subframes. TDD configuration could be changed dynamically depending on DL/UL load ratio. The requirements would be the same as synchronized operation.

Given that the frequency planning proposed by IMDA for the 26 GHz and 28 GHz bands does not envision a guard band between network operators, synchronization would also be beneficial in these bands.

Overall, Qualcomm supports allowing operators to agree amongst themselves on synchronization parameters. This will help introduce future improvements, such as semi-synchronization, simply as an agreement between license holders, and without requiring regulatory changes. IMDA may need to provide a fallback mechanism if agreement between operators cannot be achieved.

Furthermore, the view that co-existence should be enabled without geographical separation is important, but Qualcomm also observes that there are deployment scenarios where synchronized operation might not be required, such as for indoor deployments. The case of deployment of indoor base stations unsynchronized with the surrounding macro base stations has been investigated, for example in ECC Report 296, in which CEPT considered regulatory framework options in the 3.4-3.8 GHz band.[20] Qualcomm encourages IMDA to include provisions in its regulatory framework for such special cases that do not require synchronization.

[20] CEPT, "ECC Report 296: National synchronisation regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronised, unsynchronised and semi-synchronised operation in 3400-3800 MHz," (March 8, 2019), https://www.erodocdb.dk/document/9067.

Question 10: IMDA would like to seek views and comments on the following:

i) The interest from industry players to leverage 5G spectrum or other mobile spectrum bands for fixed-wireless services that support mobile connectivity; and

Fixed wireless provides operators a means to deliver gigabit speeds to their users using the same mobile wireless network they're deploying for phones and without the need to lay out fiber to every house, dramatically accelerating the speed at which multi-gigabit Internet speeds can be enabled for their customers. Qualcomm is already developing products to leverage 5G spectrum for fixed-wireless services. At MWC19 Barcelona, Qualcomm announced its first 5G customer premise equipment (CPE) reference design for sub-6 GHz and mmWave 5G fixed wireless broadband products.[21] The reference design provides a complete 5G modem-to-antenna solution, allowing manufacturers to quickly and cost-effectively develop 5G fixed wireless broadband CPE devices that can be used by Internet Service Providers to serve customers using 5G infrastructure. This use case, in particular, makes 5G a compelling backhaul alternative to fiber or cabled solutions. The solution will enable operators to improve network performance, increase range, and expand fixed broadband coverage by leveraging 5G infrastructure.

ii) The policies (e.g., spectrum allocation, numbering) that should be considered to facilitate such use-cases.

No comment.

1.7 Conclusion

Qualcomm welcomes the opportunity to convey our views to IMDA regarding 5G mobile services and networks, and Singapore's approach to enabling them. Qualcomm strongly supports taking steps to make spectrum available in the bands identified in the Consultation Paper and is pleased to provide information that can assist IMDA in its decision-making process.

Should you have any questions or comments on this submission, please do not hesitate to contact me at +852 6348 6687 (mobile) or juliewelch@qti.qualcomm.com.

Sincerely,

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Vice President, Government Affairs, Asia Pacific
Qualcomm Inc.

cc: ST Liew, Vice President & President, Qualcomm Taiwan & Southeast Asia

[21] Qualcomm, "Qualcomm Announces 5G Reference Design for Sub-6 GHz and mmWave Fixed Wireless Broadband," (February 25, 2019), https://www.qualcomm.com/news/releases/2019/02/25/qualcomm-announces-5g-reference-design-sub-6-ghz-and-mmwave-fixed-wireless.