HUAWEI

5G Spectrum

Public Policy Position

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Executive Summary

5G: not just faster, but a new paradigm

5G is the next generation of mobile and wireless broadband technology, capable of ultra-fast speeds, low latency and excellent reliability. 5G networks will deliver fixed and mobile broadband services to end users "on the go", at home or in the office. The 5G New Radio (5G NR) interface, with capability for low latency and ultra-reliable connections will address a massive number of devices with very different connectivity requirements that make up the Internet of Things (IoT), including industrial applications, advanced logistics and utility networks.

Multi-layer spectrum to meet different requirements

A multi-layer spectrum approach is required to address such a wide range of usage scenarios and requirements:

- The "Coverage and Capacity Layer" relies on spectrum in the 2 to 6 GHz range (e.g. C-band) to deliver the best compromise between capacity and coverage.
- The "Super Data Layer" relies on spectrum above 6 GHz (e.g. 24.25-29.5 and 37-43.5 GHz) to address specific use cases requiring extremely high data rates.
- The "Coverage Layer" exploits spectrum below 2 GHz (e.g. 700 MHz) providing wide-area and deep indoor coverage.

5G networks will leverage the availability of spectrum from these three layers at the same time: Administrations should focus on making available contiguous spectrum in all layers in parallel, to the greatest extent possible.

The C-band is the primary band for the introduction of 5G globally with uplink coverage assistance from frequencies below 2 GHz

The C-band (3300-4200 and 4400-5000 MHz) is emerging as the primary frequency band for the introduction of 5G by 2020, providing an optimal balance between coverage and capacity for cost efficient implementation. The availability of at least 100 MHz channel bandwidth per 5G network with the adoption of massive MIMO will boost peak, average and cell edge throughput with affordable complexity. Lower frequencies already licensed for mobile use (e.g. 700, 800, 900, 1800 and 2100 MHz) may be exploited in combination with 3300-3800 MHz (utilising the LTE/NR uplink co-existence feature of 3GPP standards) allowing operators to benefit from faster and cost-efficient deployment of C-band, thus delivering enhanced capacity without incurring network densification costs.

The high frequencies will complement the lower frequencies by addressing specific use cases (e.g. WTTx and hotspot) requiring extremely high data rates

High frequencies (above 6 GHz) will also play an important role for 5G in meeting the ITU-R IMT-2020 vision: at least 800 MHz of contiguous spectrum per 5G network should be available to meet the 5G requirement of very high capacity, especially in hotspot areas as well as for fixed broadband fibre-like connectivity ("WTTx").

The 24.25–29.5 GHz and the 37-43.5 GHz bands are the most promising for 5G deployments requiring coordinated efforts from all regions and countries to reach a global harmonisation for 5G use.

3GPP specifications work: full steam ahead

3GPP has already identified initial bands for the 5G NR as well as band combinations for LTE/NR uplink co-existence and dual connectivity. Release 15 of the 3GPP 5G NR specifications will be ready by June 2018, which will support the launch of commercial networks from 2020 in leading markets including Europe, China, Japan, South Korea and USA. Several key technological innovations are being introduced in the 3GPP Release 15 specifications and are being implemented and tested in 5G trials.

Regulatory frameworks need to support the 5G technology innovation

Regulatory frameworks for the available mobile communication bands need to be reviewed and new frameworks need to be established for 5G NR deployment in new frequency bands. These frameworks will facilitate innovation by removing any potential barriers to the introductions of key 5G innovations. For example:

- Regulatory frameworks should embrace the principle of technology and service neutrality ("generation neutral" regulations) for the smooth introduction of the latest available technologies and services in existing and new bands that will be made available for 5G,
- Regulatory masks should be revised to support the statistical nature of massive MIMO antenna systems,
- Incentives for network synchronisation in 5G networks should be considered,
- Provisions to support duplex flexibility should also be considered as the next step allowing for a more flexible use of the spectrum resource.

Global harmonisation, technology and service neutrality and exclusive national licensing

A globally harmonised spectrum framework for 5G will enable economies of scale, facilitating cross-border coordination and roaming for end users. Consistent spectrum release timelines and harmonisation measures are key enablers for the success of 5G.

Licenses offering exclusive use of nationally available bandwidth remain the main and preferred authorisation model for accessing 5G spectrum, bringing certainty for investments, predictable network performance and quality for end-user connectivity.

Regulations should support short- and long-term industry convergence

IMT networks are providing the platform to serve a growing number of vertical industries. Regulations should not add constraints to the introduction of such platforms (e.g. NB-IoT, C-V2X, IMT for trunking and PPDR, etc.). Regulators should also consider facilitating forward-looking strategies to support the convergence between TV broadcasting networks and IMT systems. The future use of UHF spectrum will be an important issue at WRC-23, with key discussions starting from WRC-19.

One of the core targets of 5G is to provide wireless connectivity to vertical industries: more so than improving performance from previous generations of mobile technologies. The success of 5G will therefore depend on positive collaboration between the telecoms industry and a broad range of potential industrial users of 5G networks, reaching beyond the telecoms sector.

1 Introduction and Context

5G networks are emerging not only as the foundation for advanced communication services, but also as the infrastructure supporting socio-economic development and driving industrial digital transformation. Spectrum and regulation play a fundamental role in making 5G a success, ensuring timely availability of the spectrum under appropriate conditions to allow the wireless market to respond to consumer and industrial demand for services. This position paper presents Huawei's insights and recommendations on 5G spectrum and regulations impacting the allocation of frequency bands.

2 Spectrum Requirements Across Multiple Layers

The ITU-R IMT-2020 (5G) Vision[1] includes three usage scenarios: Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra-Reliable and Low Latency Communications (URLLC). It also specifies the key capabilities of IMT-2020 (Figure 1), which contain great improvements in comparison with the previous generation of IMT systems.

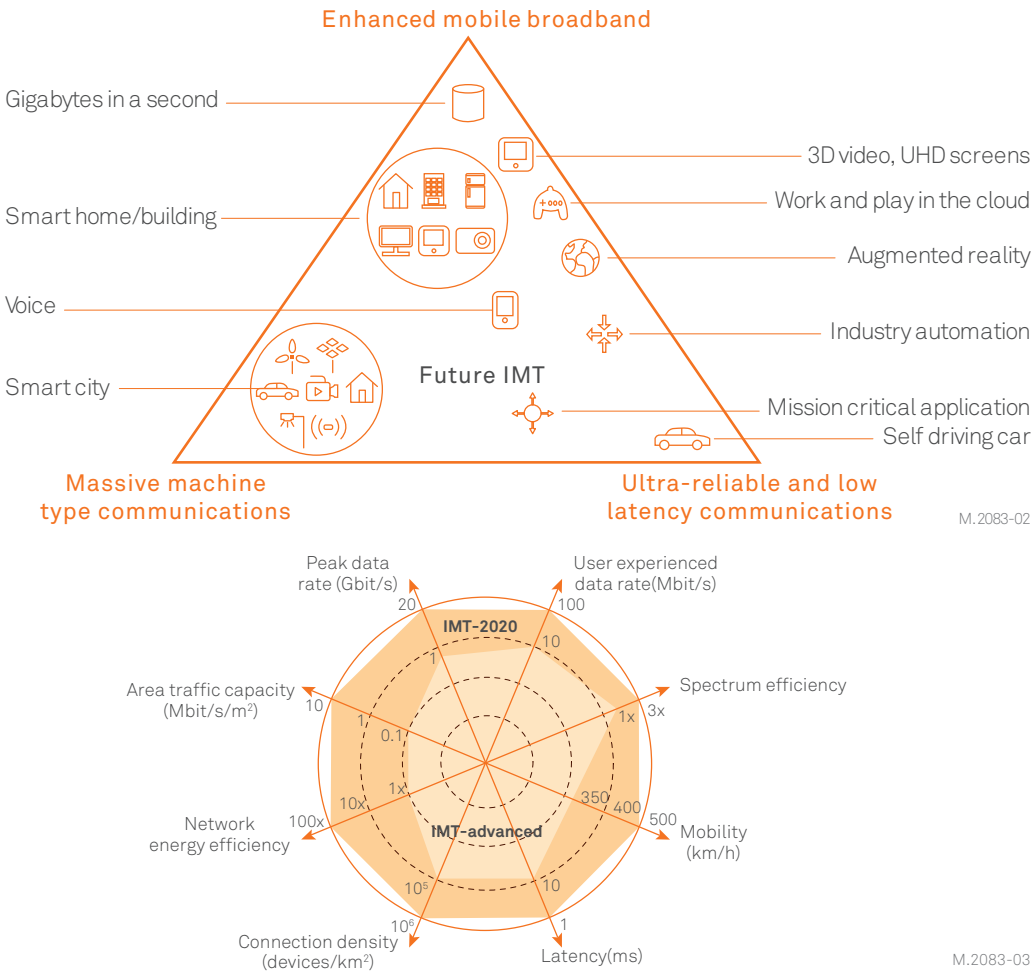

Figure 1: IMT-2020 usage scenarios and key capabilities

Source: ITU-R

1 Recommendation ITU-R M.2083, "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond"

To address diversified requirements from the envisioned 5G usage scenarios, 5G needs access to "high", "medium" and "low" frequencies (Figure 2), exploiting specific characteristics of different portions of the spectrum: frequencies between 2 and 6 GHz (e.g. 3300-3800 MHz) in combination with frequencies below 2 GHz (e.g. 700 MHz) and above 6 GHz (e.g. 24.25-29.5 and 37-43.5 GHz). A sufficient amount of harmonised spectrum in each layer should be made available by national regulators in a timely manner to enable mobile operators to deliver 5G services.

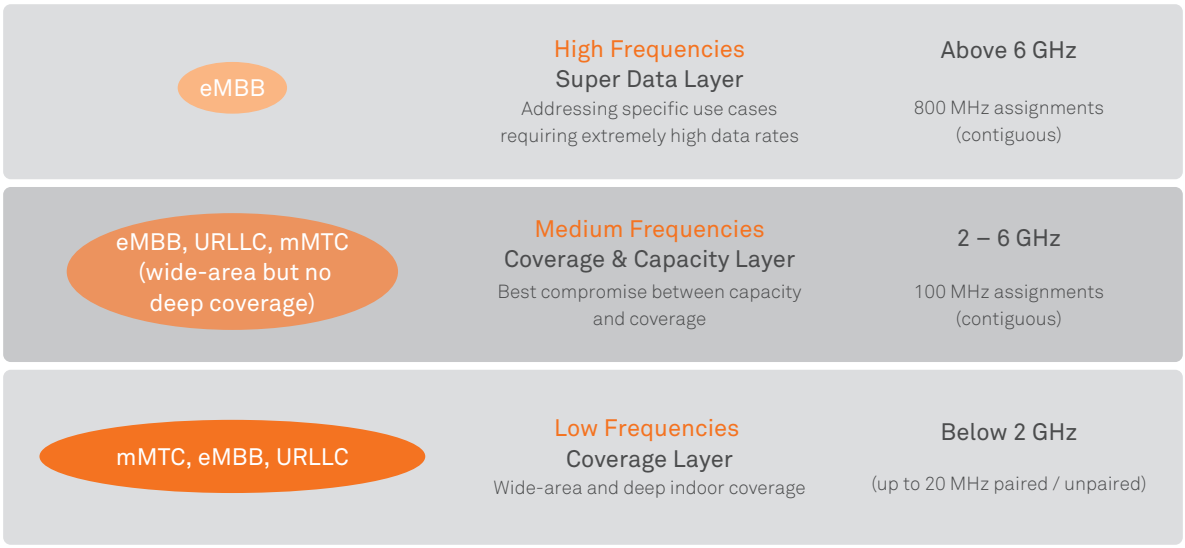

Figure 2: Multi-layer frequencies approach for 5G usage scenarios
Source: Huawei

Bands below 6 GHz are crucial to support most 5G use scenarios in a wide-area. The 3300-4200 and 4400-5000 MHz frequency ranges are suitable to deliver the best compromise between wide-area coverage and good capacity. For the early deployment of 5G, at least 100 MHz contiguous spectrum bandwidth from the C-band should be assigned to each 5G network in order to support user experienced data rate of 100 Mbps anywhere anytime and other 5G technical requirements.

Low frequencies (below 2 GHz) will continue to be essential to extend the 5G mobile broadband experience to wide areas and in deep indoor environments; mMTC and URLLC usage scenarios will also greatly benefit from the low frequencies' extended coverage. The available low frequency bands (e.g. 700, 800, 900, 1800 and 2100 MHz) may be exploited for LTE/NR uplink spectrum sharing in combination with NR on the C-band to allow operators to ensure faster and cost-effective deployment of C-band.

High frequencies (above 6 GHz) will prove indispensable for providing additional capacity and delivering the extremely high data rates required by some 5G eMBB applications. At least 800 MHz per network of contiguous spectrum bandwidth from high frequencies is recommended for the early deployment of 5G.

The assignment of contiguous wide spectrum bandwidth in each layer reduces system complexity associated with carrier aggregation, which will improve energy efficiency and reduce network cost.

3 The Need for Globally Harmonised 5G Spectrum

Spectrum harmonisation continues to be important for the mobile industry in the 5G era. Globally harmonised spectrum enables economies of scale and facilitates cross-border coordination and roaming for end users: a critical factor for the initial deployment of 5G. Regulators and the industry should take immediate action towards the following objectives:

1. Spectrum should be allocated to Mobile Service on a primary/co-primary basis globally or regionally,
2. Consistent frequency arrangements (including band plan and duplexing mode) should be adopted across all markets,
3. Consistent regulatory frameworks should be strived for – same technical conditions should govern the use of particular frequency bands (e.g. emission masks ensuring sharing and coexistence with other services in the same band or in adjacent bands),
4. Harmonised standards: the same technology standard should be adopted. ITU-R Working Party 5D is leading the development of IMT-2020 standards and the mobile industry is working on 3GPP 5G NR as the harmonised standard for 5G.

3.1 C-band (3300-4200 MHz and 4400-5000 MHz)

Spectrum availability for IMT in the 3300-4200 and 4400-5000 MHz ranges is increasing globally. The 3400-3600 MHz frequency band is allocated to Mobile Service on a co-primary basis in almost all countries throughout the world. Administrations will make available different portions of the 3300-4200 and 4400-5000 MHz ranges at different times, incrementally building large contiguous blocks.

The 3GPP 5G NR specification will support 3300-3800 MHz from the start, using a TDD access scheme. In line with the release plans from many countries, the 3300-3800 MHz band will be the primary 5G band with greatest potential for global harmonisation over time: it is recommended that at least 100 MHz of contiguous bandwidth from this band be allocated to each 5G network.

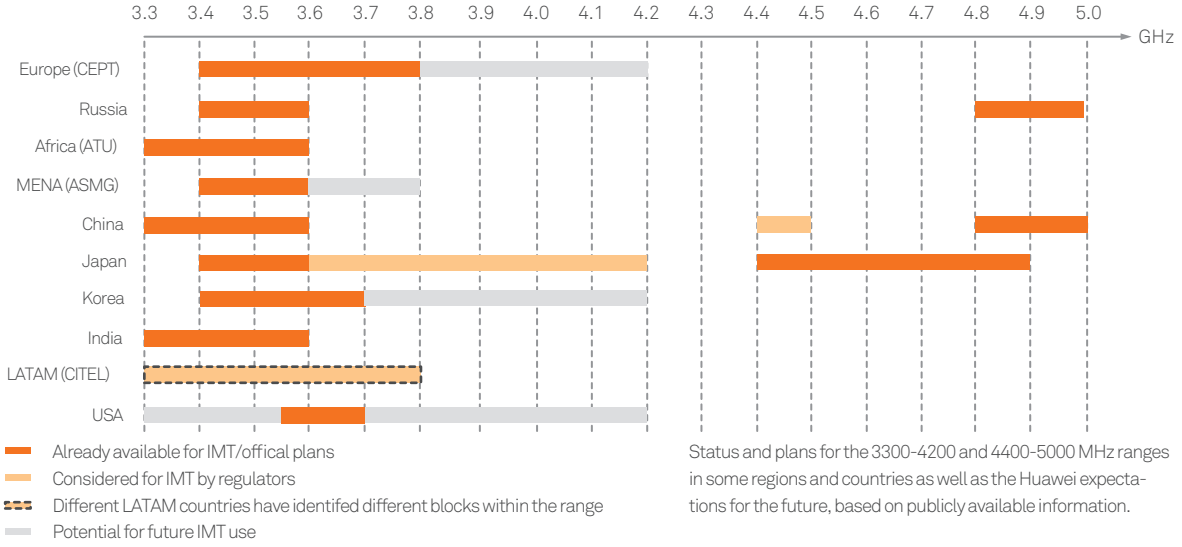

Figure 3: Global availability and planning of the 3300-4200 MHz and 4400-5000 MHz frequency ranges
Source: Huawei

In order to take advantage of the harmonized technical specification – the 3GPP 5G NR specification for 3300-3800 MHz band, regulators are recommended to adopt a frequency arrangement with an aligned lower block edge of usable spectrum and harmonized technical regulatory conditions, at least in countries of the same Region.

The 5G NR ecosystem of 3300-3800 MHz is expected to be commercially ready in 2018[2,3]. As a first step, it is highly recommended that countries allocate 3300-3800 MHz or a portion of it and make it available for 5G with consistent timelines and regulatory frameworks (i.e. frequency arrangements and emission masks). Work is ongoing in CEPT ECC PT1 towards the development of the regulatory technical conditions for the 3400-3800 MHz for 5G in Europe, and the final decisions will be published in June 2018 and will represent an important reference also for countries from other regions.

3.2 High Frequency Bands

The World Radiocommunication Conference 2015 (WRC-15) paved the way for the future development of IMT on higher frequency bands by identifying several frequencies for study within the 24.25-86 GHz range (Figure 4) for possible identification for IMT under Agenda Item 1.13 of WRC-19. The 24.25-27.5 and 37-43.5 GHz bands are prioritised within the ongoing ITU-R work in preparation for WRC-19; all regions and countries are recommended to support the identification of these two bands for IMT during WRC-19 and should aim to harmonise technical conditions for use of these frequencies in 5G.

Group 30 (GHz)	Group 40 (GHz)	Group 50 (GHz)	Group 70/80 (GHz)
24.25-27.5 31.8-33.4	37-40.5 40.5-42.5 42.5-43.5	45.5-47 47-47.2 47.2-50.2 50.4-52.6	66-71 71-76 81-86

Figure 4: Candidate frequency bands of WRC-19 Agenda Item 1.13

The frequency band of 27.5-29.5 GHz, though not included in the WRC-19 Agenda Item 1.13, is considered for 5G in the USA, South Korea and Japan.

2 GSA White Paper: "The future development of IMT in 3300-4200 MHz band", June 2017. https://gsacom.com/.
3 China IMT-2020 Promotion Group, "IMT-2020 Trial Progress", a key note speech at the PT-EXPO China, September 2017

The 24.25-29.5 and 37-43.5 GHz ranges are the most promising frequencies for the early deployment of 5G millimetre wave systems, and several leading markets are considering portions of these two ranges for early deployments (Figure 5), and the two ranges are also being specified in 3GPP Release 15 based on a TDD access scheme . It is recommended that at least 800 MHz of contiguous spectrum per network from these ranges be assigned for the early deployment of 5G. For countries that plan to release 26.5-27.5 GHz as first step, it is recommended that at least 400 MHz of contiguous spectrum per network be assigned; the remaining 24.25-26.5 GHz should be allocated as soon as practicable and specific provisions should be added to avoid fragmented assignments across the overall 24.25-27.5 GHz range.

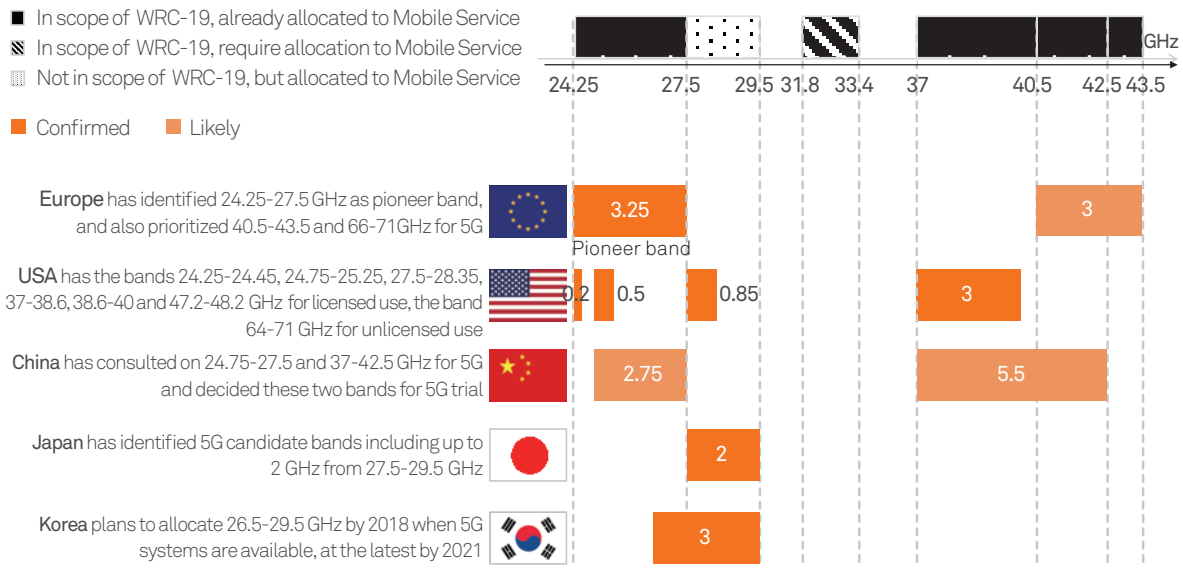

Figure 5: Frequency bands for early deployment of 5G millimetre wave systems
Source: Huawei

CEPT ECC PT1 is developing regulatory technical conditions for the 24.25-27.5 GHz band for mobile use in Europe, which may differ from the conditions agreed for 27.5-28.35 GHz in the USA. If this happens, it would be difficult to achieve spectrum harmonisation. Many other countries will decide the regulatory technical conditions for 24.25-27.5 GHz after WRC-19 confirms the criteria to protect incumbent services. These factors may delay 5G NR ecosystem development for high frequency bands. Regulators are encouraged to address these issues to allow the ecosystem over high frequency bands to be ready from 2020.

3.3 Other Frequency Bands for 5G

The L-band (1427-1518 MHz) is another 5G candidate band that has the potential to be allocated to mobile in most countries in the world. CEPT and CITEL regions have adopted the SDL (Supplemental Down Link) scheme for this band. The requirement for standalone operation in the band (both UL and DL transmissions) has emerged in some other regions. In the case of standalone 5G systems, a TDD access scheme is a potentially appropriate option, which can accommodate traffic asymmetry in the UL/DL directions with good potential for economies of scale. The same 5G NR equipment can serve both the TDD and SDL markets.

The 700 MHz band has already been harmonised for mobile in most countries. Europe plans to use this band for 5G. Over the long term, the other frequencies of UHF band (470-694/698 MHz) could also be used for mobile, while the USA has already started the process of transferring the band from broadcasting to mobile service.

4 5G Industry Progress

4.1 5G Industry Progress Around the World

As shown in Figure 6, large scale 5G trials have started globally, and commercial rollouts are being planned in leading markets.

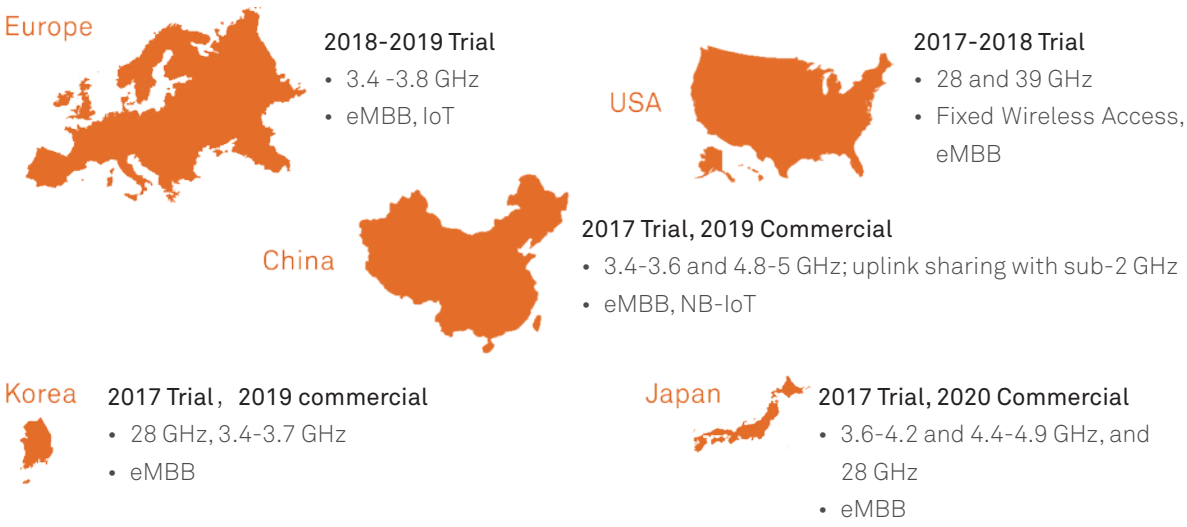

Figure 6: 5G trial and commercial spectrum plan in leading markets by 2020

Source: 2017 Q2 announcements of respective 5G promotion organizations in key countries or regions

4.2 5G Band Specification

The development of the 3GPP specifications is proceeding rapidly to support the timelines that have been defined in leading markets. The first version of 5G specifications enabling the non-standalone scenario of 5G deployment were approved in Dec. 2017, including the 5G initial bands and associated band-combinations. The full set of 5G specifications will be finalised in June 2018 addressing both non-standalone and standalone scenarios. The following table[4] shows the new bands for the introduction of 5G-NR that are being specified in 3GPP by Jan. 2018. In addition, 3GPP agreed to reuse existing LTE band numbers for NR, and some of the LTE bands are also defined as 5G-NR bands, e.g. 700MHz, L-band.

New bands for the introduction of NR

NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
n77	3300 – 4200 MHz	3300 – 4200 MHz	TDD
n78	3300 – 3800 MHz	3300 – 3800 MHz	TDD
n79	4400 – 5000 MHz	4400 – 5000 MHz	TDD
n80	1710 – 1785 MHz	N/A	SUL

4 3GPP RP-172834, "Revised WID on New Radio (NR) Access Technology"

NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
n81	880 – 915 MHz	N/A	SUL
n82	832 – 862 MHz	N/A	SUL
n83	703 – 748 MHz	N/A	SUL
n84	1920 – 1980 MHz	N/A	SUL
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz	TDD
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz	TDD
n260	37 – 40 GHz*	37 – 40 GHz	TDD

* 3GPP agreed to develop specification for the frequency band of 37-43.5 GHz. A new band number is expected to be created in the framework of release 15.

Bands combinations for LTE/NR uplink co-existence

3GPP has also agreed upon a number of LTE-NR sharing combinations[5] where the UL direction of some low frequency bands (e.g. 700, 800, 900, 1800 and 2100 MHz) is paired with the 3300-3800 MHz and 4400-5000 MHz bands.

NR band (UL)	NR band (DL & UL)
n80 (1710 – 1785 MHz)	n78 (3300 – 3800 MHz)
n81 (880 – 915 MHz)	n78 (3300 – 3800 MHz)
n82 (832 – 862 MHz)	n78 (3300 – 3800 MHz)
n83 (703 – 748 MHz)	n78 (3300 – 3800 MHz)
n84 (1920 – 1980 MHz)	n78 (3300 – 3800 MHz)
n80 (1710 – 1785 MHz)	n79 (4400 – 5000 MHz)
n81 (880 – 915 MHz)	n79 (4400 – 5000 MHz)

Band combinations for LTE/NR dual connectivity and NR carrier aggregation

3GPP has identified more than 400 band-combinations for LTE/NR (Dual Connectivity) by its meeting in January 2018. Several categories are being defined, based on the number of LTE and/or 5G-NR component carriers (CC) to be combined, including 8 combinations for non-standalone uplink sharing, 114 combinations for LTE 1 CC + NR 1 band, 164 combinations for LTE 2 CC + NR 1 band, 87 combinations for LTE 3 CC + NR 1 band, 51 combinations for LTE 4 CC + NR 1 band, 9 combination for LTE 5 CC + NR 1 band, 38 combinations for LTE 1 CC + NR 2 CC, 9 combinations for LTE 2 CC + NR 2 CC, 8 combinations for LTE 3 CC + NR 2 CC, and 1 combination for LTE 4 CC + NR 2 CC.

3GPP has also identified 37 band combinations for NR CA (Carrier Aggregation) until January 2018, including 10 combinations for intra-band contiguous CA, 20 combinations for inter-band CA with 2DL/1UL, and 7 band combinations for inter-band CA with 2DL/2UL.

5 3GPP R4-1800781, "NR band combination"

5 Regulations to Support 5G Innovation

5.1 5G Spectrum Licensing

Spectrum management and regulations have a direct impact on 5G commercialization and service provision.

Exclusive assignments nationwide

Given the large-scale investment in new nationwide networks that is required for 5G, there is still a need for operators to have exclusive[6] access to spectrum for 5G, as has been the case for 3G and 4G. This is of critical importance to avoid undermining investment certainty due to the lack of guarantee concerning spectrum quality which will inevitably translate into unpredictable quality of experience for end users.

At the same time appropriate incentives, including reasonable spectrum pricing, will play a fundamental role in maintaining the flourishing development trend in the mobile industry while promoting rapid 5G deployment.

Generation-neutral

Spectrum assignment for specific mobile technologies (e.g. 2G, 3G and 4G), and in some countries for specific services (e.g. voice, data, broadband access), can no longer keep up with the speed of market demand for new network capabilities and for new services with enhanced performance.

The principle of service and technology neutrality is a best practice that has been followed by many countries, including the most advanced markets. Such an approach has allowed operators to swiftly respond to the changes in market demands with tangible benefits for end users.

5G duplexing mode

The 5G duplexing mode will develop towards more flexibility to provide the 5G network with better adaption to service requirements from the spectrum perspective.

5.2 5G Regulation Technical Enablers

5G networks and devices will embrace many new features, exploiting the latest technical innovations. Some innovations provide an opportunity for regulators to adjust regulations for more efficient and flexible spectrum utilisation.

LTE/NR uplink spectrum sharing

An important feature of the 3GPP Release 15 standard resides in the ability for LTE and 5G NR to co-exist and share the same low frequency bands without having to fully free those bands from LTE use. In the initial stage of 5G deployment, the new bands likely to be made available for 5G are higher in frequency (e.g. C-band) and support less sub-frames for uplink than most existing 2G/3G/4G bands. Such bands will therefore have more uplink coverage limitations compared to existing bands.

6 In those cases where the incumbent services may not be cleared or migrated to other frequency bands, least restrictive provisions should be added to ensure sharing and coexistence.

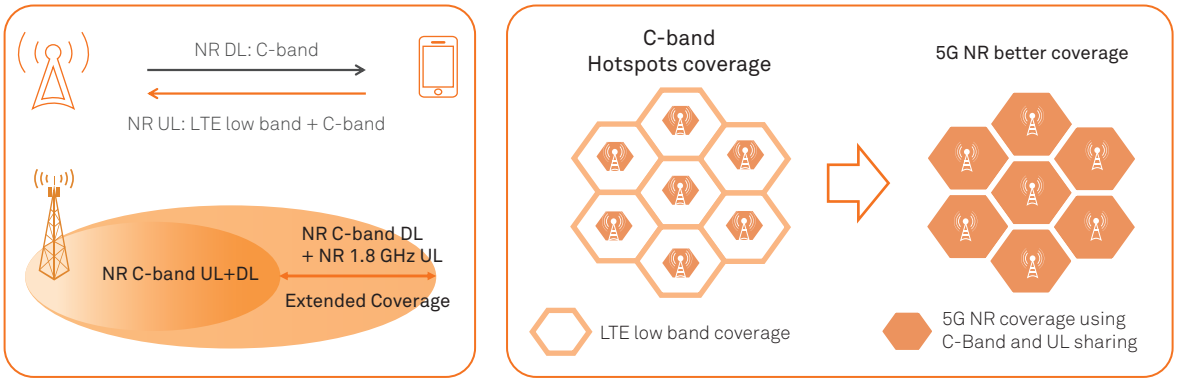

Figure 7: LTE/NR uplink spectrum sharing to extend 5G coverage at higher frequencies (e.g. C-band), accelerate deployment and reduce cost

Source: Huawei

With the uplink spectrum sharing between LTE and 5G NR, transmissions across 5G NR uplinks and downlinks can occur at higher frequency bands (e.g. C-band), while the 5G NR uplink can also exploit spectrum resources in lower frequency bands that the operator has been using for LTE (e.g. 700, 800, 900, 1800 and 2100 MHz). This scheme allows improved uplink coverage at higher frequencies leading to a considerably faster and more cost efficient 5G NR deployment with more efficient and flexible use of all spectrum assets.

Massive MIMO

Massive MIMO is a key 5G feature which uses the beamforming technique to focus signals on each user, thereby increasing data rates, and reducing interference. It adopts large-scale antenna arrays that can control the width and tilt, both vertical and horizontal, for 3D beamforming. With the application of massive MIMO, regulatory masks should be revised to support the statistical nature of massive MIMO antenna systems, and spectrum regulation management should be enhanced taking into account time, spatial and direction domains.

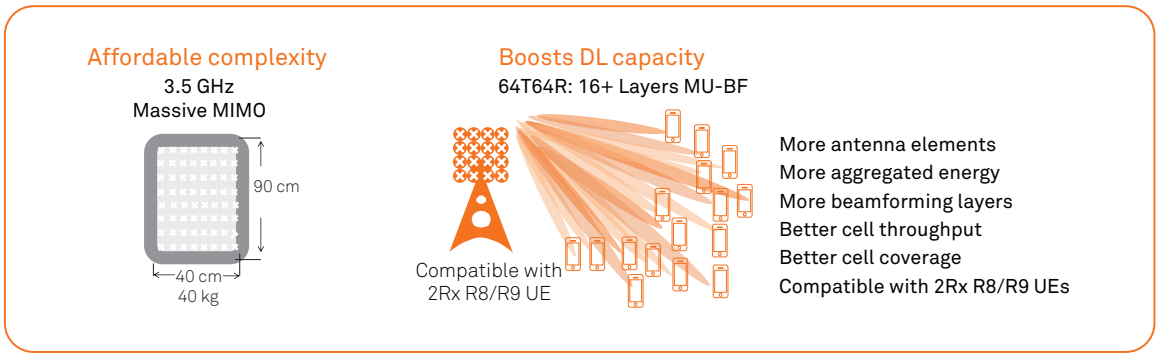

Figure 8: Massive MIMO affordable complexity

Source: Huawei

Network synchronization (inter-operator)

Network synchronisation has been successfully implemented in 4G TDD networks ensuring efficient use of spectrum resources by avoiding guard bands between operators' assignments. Inter-operator synchronisation and alignment of uplink/downlink transmissions (slot and frame synchronization) is also necessary for efficient deployment of 5G-NR networks in unpaired assignments.

Therefore, regulation should facilitate the potential for networks' synchronization in 5G to make the best use of the valuable spectrum resources.

Duplex flexibility

Duplex flexibility is another important feature in 3GPP 5G standardisation providing flexible and dynamic use of paired and unpaired frequencies. The duplex flexibility will allow smooth adaptation to the service requirements by allowing the DL spectrum resource to be used for UL transmission and vice versa. The general concept of this fully flexible radio interface design will be introduced in 3GPP Release 15 specifications. The related band definition is likely to be part of Release 16 specifications.

Given the expected regulatory implications, the analysis at regulatory side should start in the near future in order to prepare regulatory frameworks when the duplex flexibility feature becomes available.

6 Long-term Trends – Industry Convergence

Cellular infrastructure support for multiple vertical industries

A key element of the 5G era is that mobile networks will evolve to support the varying communications requirements of a diverse range of vertical end-users. Various industry-specific forecasts have been published illustrating how 5G will impact different vertical users. 5G cellular infrastructure will achieve a network performance tailored to the needs of individual vertical applications. Mobile network performance in terms of coverage, capacity, latency and reliability, can meet requirements from a variety of vertical markets such as smart metering, smart grids, autonomous driving, wideband PPDR, trunking and smart manufacturing in the context of Industry 4.0. The well-established global IMT ecosystem also brings tremendous new opportunities for rapid development in such vertical markets.

Convergence in sub 1 GHz spectrum

With the development of advanced cellular technologies, convergence of mobile and broadcasting services is happening in the sub 1 GHz band. The 470-806 MHz range is currently mainly used for broadcasting. However, the same spectrum can be used by IMT technology to meet the requirements from TV broadcasting services as well as new multimedia services. This will bring new opportunities for both the broadcasting and mobile industries. Such concepts are being tested in China[7] , where the next generation terrestrial broadcasting network based on IMT technology is being tested for the combined delivery of broadcast TV as well as innovative bi-directional multimedia services.

7 China NGB-W and NGB-E projects

7 Recommendations

Spectrum for the early deployment of 5G

Policy makers and regulators are recommended to harmonize the spectrum allocation for 5G.

1. Sub-6GHz early frequency band for 5G deployment: at least 100 MHz contiguous spectrum per network from the 3300-3800 and 4400-5000 MHz bands.
2. High frequency bands for the early deployment of 5G: at least 800 MHz contiguous spectrum per network from the 24.25-29.5 and 37-43.5 GHz bands.
3. Use of low frequencies (e.g. 700, 800, 900, 1800 and 2100 MHz) in combination with C-band (LTE/NR uplink spectrum sharing) should be permitted.

Policy and regulation for 5G

1. Nationwide exclusive licensing is the preferred authorisation model for 5G.
2. New spectrum assignments should be technology and service neutral.

Future work

1. Development of the L-band and 470-694/698 MHz spectrum in the UHF band at regional level should be undertaken
2. Trends of industry convergence should be considered when defining long term spectrum planning
3. The WRC-19 key target is harmonisation of spectrum allocation for IMT above 24.25 GHz

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