GTI White Paper

Global TD-LTE Initiative

FUTURE SPECTRUM INITIATIVE

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Executive summary

This white paper introduces the 5G work plan in ITU and 3GPP, and also summarizes the 5G spectrum release progress of some regions/countries. The potential candidate frequency bands, including both lower and above 6GHz bands, are both introduced. In order to save the money for operators, GTI suggest that some infrastructures like base station hardware, which supports promising future technologies such as 3D-MIMO is recommended to reused for future 5G's fast deployment by quick and easy software upgrade. Finally, to form and propose our GTI position on the future spectrum planning or band allocation for IMT-2020 (5G), some recommendations and suggestions are proposed as follows:

- Coordination of low frequency band and high frequency band shall be considered for both network planning and solution design. Frequency below 6GHz for coverage and capacity, that above 6GHz for 5G capacity and self-backhaul
- C band frequency range due to the already started ecosystem development and availability of contiguous bandwidth is the future golden frequency band
- As for mmWave, 24.25-27.5GHz and 37-43.5GHz are highly recommended to be harmonized around the world. Considering 28GHz band has also interested operators from Korea and USA, one tuner range from 24.25GHz to 29.5GHz is suggested in future device design. Furthermore the 32 GHz band could also be a good candidate, because this band is currently lightly used in several key markets
- To enable frequency flexibility, the network infrastructures are expected to be reused by software upgrade from LTE to 5G. In order to get high spectrum efficiency during the hardware reuse, the existing candidate E-UTRA bands is suggested to allocate with bandwidth ≧ 40/80 MHz. From this point of view, the existing frequency bands can also be reused for 5G. For example, Band 41 stands out as having the most spectrum below 6 GHz in the United States
- In order to promote the high efficiency usage on spectrum, continuing to look at any unused TDD spectrum that can be used for TD-LTE is encouraged, such as using the 1.79GHz-1.80GHz TDD band in Singapore

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1. Introduction

The spectrum is a scarce non-renewable resource, as well as the core resource for promoting the development of IMT. It is universally acknowledged by the global mobile communication research community that future mobile telecommunication system has the huge demand for globally available supply of spectrum, which attributes it to the extensive growth in mobile data traffic in future mobile communication services. In order to meet ever-increasing demand of the mobile data traffic, on the one hand, it is necessary to find ways of handling future technologies and system architecture evolution; on the other hand, freeing up additional spectrum will also be required to support capacity increases by the next generation system. Nevertheless, increasing the spectrum resource is constantly regarded as a straightforward and effective approach to respond to extensive traffic increase.

TDD based systems have some advantages in future compared to FDD. TDD utilizes unpaired spectrum compared to FDD meaning that TDD can be deployed any single available spectrum band. Another advantage is that TDD allows for adjustment of the downlink and uplink resource and therefore can efficiently respond to traffic asymmetry E.g. For small cell deployments where inter operator co-ordination may be relaxed will allow for dynamic adjustment of uplink and downlink. TDD uses uplink and downlink channel reciprocity, which will help to improve connectivity, especially under the extremely complicated network environment. Moreover, the massive MIMO antenna array technology and ultra dense network deployment can be better supported with TDD. According to the data from 3GPP[1], considering the varies deployment scenarios, it is generally considered that massive MIMO can improve the performance by additional 80% for cell average throughput and 150% for cell edge throughput. In addition, larger bandwidth's for future technologies are likely to be only available with higher frequency bands and for frequency bands with large bandwidths, TDD would be more efficient duplexing mode. Therefore for new high band spectrum that is identified for mobile use, it can be expected TDD will be the main duplexing method. The aggregation of TDD and FDD technology and spectrum provides a route to convergence of these technologies.

The objective of this white paper is to provide a comprehensive introduction about the future spectrum. In order to achieve the IMT traffic requirements in the future, spectrum is considered as the key point. Chapters 2-4 describe the 5G time plan in ITU and 3GPP. And the comprehensive introductions of global progress in 5G spectrum and 5G trails are provided in chapter 5. Furthermore, GTI proposals and recommendations for future spectrum are presented in Chapter 7.

2. WRC-15 enables more spectrum for future IMT

ITU-R conducted the study on overall capabilities for the future development of IMT-2020 and beyond as documented in Recommendation ITU-R M.2083. Based on the outcome, future IMT systems are expected to provide far more improved capabilities in traffic demand accommodation and gigabit per second user data rate with the proliferation of smart devices and a wide range of emerging services and applications. As in [1], the estimated total spectrum requirements for IMT are 1 340 MHz and 1 960 MHz for lower user density settings and higher user density settings, respectively.

For support IMT-2020 technology requirements and related spectrum requirement, the World Radiocommunication Conference 2015 (WRC-15) approved IMT identification in the following bands.

1) UHF band

   In Region2/3, the whole bands or partial were identifed as IMT bands.
   - 470-608MHz: identified in 5 countries in region 2
   - 614-698MHz: identified in 7 countries in region 2
   - 470-698MHz: identified in 4 countries in region 3
   - 610-698MHz: identified in 4 countries in region 3

   New WRC-23 AI was approved for Region1.
2) C-band

3400-3600MHz was identified globally. It is the global harmonized IMT band.
3300-3400MHz was identified in 33 countries in Africa in region 1, 7 countries in LA in region 2, 6 countries in region3.
3600-3700MHz was identified in 4 countries in Latin America .
4800-4900MHz was identified in 1 countries in Region 2, 3 countries in Region 3.

3) L-band(1427-1518MHz)

1427-1452MHz and 1492-1518MHz: identified globally.

1452-1492MHz: identified in region 2 and region 3, in 53 countries in region 1.

Some operators think that existing IMT bands can also be reused for IMT-2020, and there are several 3GPP LTE bands that are good candidates for 5G, such as B41, which stands out as having the most spectrum below 6 GHz in the United States. The FCC allows for a single Band 41 operator to aggregate up to 194 MHz of spectrum in a given geographic area. The FCC does not mandate a technology to be used in this band so there are no regulatory barriers to deploying 5g NR in this band. 5G operation in the legacy land mobile bands will have to be under the same regulation as for existing IMT and would need to co-exist with existing IMT deployments. 3GPP also needs to provide a clear migration path from existing 3GPP technologies to 5G NR.

In addition to the spectrum below 6GHz, the World Radiocommunication Conference 2015 (WRC-15) also approved WRC-19 agenda item 1.13:

Agenda item 1.13: to consider identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 238 [COM6/20] (WRC 15)

In Resolution 238 [COM6/20] (WRC-15), ITU-R is resolved to conduct the appropriate studies on the spectrum needs for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz, and to conduct the appropriate sharing and compatibility studies , taking into account the protection of services to which the band is allocated on a primary basis, for the frequency bands:

- 24.25-27.5 GHz , 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and

- 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

3. ITU clarifies the work plan for future IMT

ITU-R Working Party 5D (WP5D) has developed a detailed work plan, timeline and process for the future development of IMT as shown in the figure. The studies on technology aspect and spectrum aspect, in support of the next generation of mobile broadband communications systems beyond IMT-Advanced, were initiated after WRC-15 at the 23rd WP5D meeting.

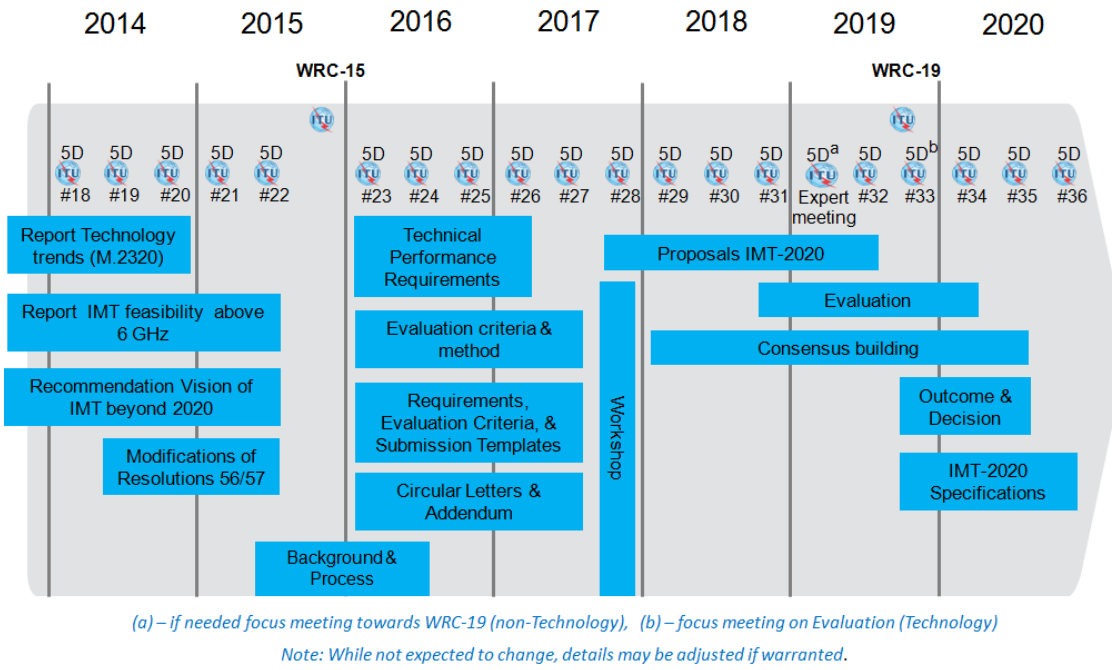

Figure 3-1. Timeline & process for IMT-2020 in ITU-R

ITU-R completed the study on IMT-2020 vision at the 22nd WP5D meeting with the deliverable of ITU-R Recommendation M.2083 to define the framework and overall capabilities of the future development of IMT for 2020 and beyond. According to the time plan of technology work track, during the timeframe from 2016 to 2017, ITU-R is further working on the detailed technical performance requirements to define what requirements IMT-2020 radio interface technology (RIT) or set of RIT (SRIT) needs to be fulfilled. Meanwhile the evaluation method and evaluation criteria need to be specified to guide how to evaluate whether the requirements are fulfilled.

In the timeframe of 2018-2019, ITU-R will start IMT-2020 RIT/SRIT proposal submission and evaluation. Independent evaluation groups will be invited to perform the evaluation in accordance with the identified evaluation method and criteria to conclude whether candidate RIT-SRIT proposals are able to meet the required requirements. IMT-2020 specification will be finalized by 2020 based on the process of submission, evaluation, consensus building and decision.

4. 3GPP Specifies the blueprint for future IMT

3GPP, as the most important Standardization body for cellular technologies, has started to develop 5G since 2015. The name of the radio access technology developed by 3GPP for 5G is NR (New Radio). NR together with evolved LTE Advanced (name of the radio access technology developed by 3GPP for 4G) will be submitted by 3GPP as a candidate 5G technologies to ITU-R.

3GPP will develop NR technical specifications in phased manner. Phase 1 is driven by the demands to have early-drop 5G deployments in some countries before 2020, and the target completion date is June 2018. Phase 2 is driven by the ITU-R IMT-2020 Submission, and the target completion date is end of 2019 to align with the ITU-R work plan described in the previous section. Similar as LTE, NR will continue to evolve onwards from 2020 after the ITU-R submission.

The overall timeline for 3GPP NR work is shown in the figure below.

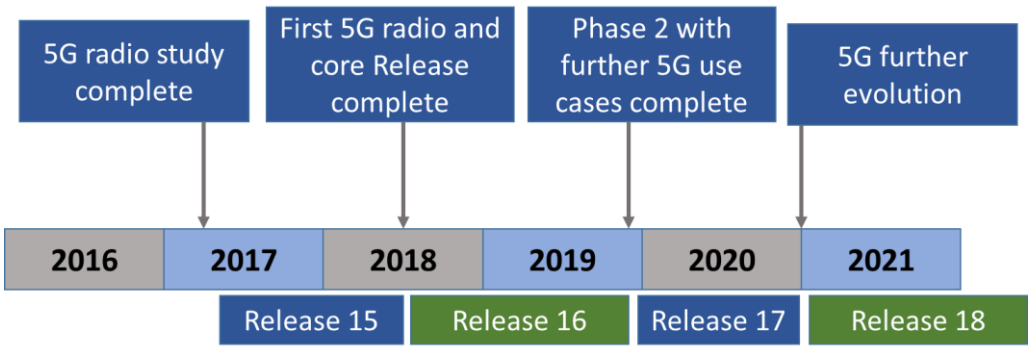

Figure 4-1. timeline for 3GPP NR work

Completed works

Scenarios and Requirements for NR. Based on the Performance Requirements defined by ITU-R for 5G as well as the inputs from the Industry, 3GPP conducted studies on the scenarios and requirements for NR, which will serve as guidelines for design of the technology. The work was completed in September 2016 and the outcomes are captured in 3GPP TR 38.913, including Usage and deployment scenarios, Key performance indicator, Requirements for architecture and migration, Supplementary-Service related requirements, Operational requirements, and Testing and Conformance Requirements.

Channel modeling for >6GHz frequency. The study covers the identification of the status/expectation of existing information on high frequencies, and the channel model(s) for frequencies above 6 GHz up to 100 GHz. This technical report documents the channel model(s). The resulted channel model(s) can be used for both link and system level evaluations under certain conditions. The work was completed in September 2016 and the outcomes are captured in 3GPP TR 38.900.

Ongoing and future works

NR Phase 1. The technical specifications for the NR Phase 1 will be developed in Release 15, and the target completion date is June 2018. The Work Item for NR technology is expected to start from March 2017, and will be based on the outcome of the ongoing Study Item for NR technology (which will be finished by March 2017).

- NR Phase 1 will include the most essential technical components for a new radio access technology with clear differentiation from 4G, while the exact content will be decided when the Work Item gets approved.
- NR Phase 1 will support both Non-Stand-alone and Stand-alone deployment scenarios, while the former is expected to be worked out earlier (at least L1/L2 design for Non-Stand-alone will be finished by December 2017).
- NR Phase 1 will support frequencies ranges both below and above 6GHz. However, the design will not be optimized for above 52.6GHz. The first batch of 5G bands will be defined based on regulatory status, interests from the operators, and feasibility for RF implementation.
- The characteristics of terrestrial IMT systems for frequency sharing / interference analysis for above 6GHz, as inquired by ITU-R WP5D, have been worked out as part of the ongoing Study Item for NR technology.

Additionally, 5G NR may develop new band structure concept. 3GPP already approved the way forward on LTE-NR coexistence and UL sharing between NR and LTE, which means some LTE UL bands should also be used for NR UL. Correspondingly, the DL/UL carrier can be flexibly placed in the DL/UL band because the new paired DL/UL band may not have the same bandwidth. Thus, NR Band structure concept on decoupling between UL band and DL band is proposed and being discussed in 3GPP, in which NR band structure is defined as multiple band packages with:

- Each band-package includes multiple frequency blocks;
- Each frequency block can be configured defined as: DL only, UL only or both DL and UL, TDD

NR Phase 2. The technical specifications for the 5G Phase 2 will be developed in Release 16, and the target completion date is end of 2019. Although the Work Item(s) for Phase 2 will start from mid-2018, there may be some Study Items for Phase 2 from March 2017, and the content of the Phase 2 will be decided based on the studies. Phase 2 specifications will be used for ITU-R submission.

NR evolution after Phase 2. It should be noted that not all usage scenarios will be covered by NR in Phase 1 and 2, e.g. if evolved LTE Advanced is able to meet the ITU-R requirements for those scenarios (e.g. mMTC). Those aspects, together with further optimizations of the technical design, will be covered in the NR evolution after Phase 2.

5. 5G Spectrum boost IMT development globally

5.1.US: FCC report and order on 5G spectrum and FNPRM

On July 14th of 2016, the FCC adopted rules to identify and open up the high frequency airwaves known as millimeter wave spectrum. Building on a tried-and-true approach to spectrum policy that enabled the explosion of 4G (LTE), the rules set in motion the United States' rapid advancement to next-generation 5G networks and technologies.
The new rules open up almost 11 GHz of spectrum for flexible use wireless broadband – 3.85 GHz of licensed spectrum and 7 GHz of unlicensed spectrum. With the adoption of these rules, the U.S. is be the first country in the world to open high-band spectrum for 5G networks and technologies, creating a runway for U.S. companies to launch the technologies that will harness 5G's fiber-fast capabilities.

A Further Notice of Proposed Rulemaking ensures that FCC will continue to dramatically increase the spectrum available for next generation services by proposing to make an additional 18 GHz of spectrum available. It proposes to apply the same licensing, service, and technical rule framework set in the Report & Order, modified to meet the characteristics of a specific band. Specifically, it proposes additional bands for consideration: 24-25 GHz (24.25-24.45/24.75-25.25 GHz), 32 GHz (31.8-33.4 GHz), 42 GHz (42-42.5 GHz), 48 GHz (47.2-50.2 GHz), 51 GHz (50.4-52.6 GHz), 70 GHz (71-76 GHz), and 80 GHz (81-86 GHz). It also seeks comment on how the Commission can provide access to additional spectrum above 95GHz.
The Further Notice of Proposed Rulemaking also develops additional rules to finalize the regulatory scheme, including detailed questions on the federal/commercial sharing regime in 37 GHz; how to structure a machine-to-machine performance requirement; how to structure a use-it-or-share-it performance requirement; various refinements and clarifications to our technical rules; and details of implementing the new spectrum aggregation limit, the appropriate holding period, and how to apply the policies to FNPRM bands.

5.2.Europe: Radio Spectrum Policy Group Strategic Roadmap

Towards 5G for Europe

In June 2016, RSPG (Radio Spectrum Policy Group), directorating general for communications networks, content and technology in European Commission has worked out a DRAFT RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G) for the Strategic Roadmap Towards 5G for Europe.

The RSPG strategic roadmap towards 5G for Europe aims to facilitate the launch of 5G on a large scale by 2020, thereby ensuring that the benefits of 5G-based services are available to all European citizens. The vision being that 5G will drive industrial and societal transformation and economic growth in Europe from 2020 and beyond.
It is expected that the first major commercial deployment will be based on lower frequencies. One of the reasons is the possibility to reach rapidly a sufficient coverage for addressing enhanced broadband communications and, above all, machine type communications market, which may require ubiquitous coverage, low latency and low complexity.
The implementation of frequency bands above 24 GHz remains needed to ensure all the performance targets of 5G, for example multi gigabit per second data rates.

The opinion of the RSPG on the strategic roadmap towards 5G for Europe
This roadmap has been developed to facilitate the launch of 5G on a large scale in Europe by 2020. The goal is that the benefits of 5G-based services are available to all European citizens in a timely manner, driving industrial and societal transformation and economic growth in Europe from 2020 and beyond.
1. The RSPG considers the 3400-3800 MHz band to be the primary band suitable for the introduction of 5G use in Europe even before 2020, noting that this band is already harmonised for mobile networks, and consists of up to 400 MHz of continuous spectrum enabling wide channel bandwidth. This band has the possibility to put Europe at the forefront of the 5G deployment.

2. The RSPG is of the opinion that 5G will need to be deployed also in bands already harmonised below 1 GHz, including particularly the 700 MHz band, in order to enable nationwide and indoor 5G coverage.

3. The RSPG considers that there will be a need to ensure that technical and regulatory conditions for all bands already harmonised for mobile networks are fit for 5G use.

4. The RSPG stresses that there are many frequency bands above 24 GHz which are of potential interest for 5G in Europe:
- To give sufficient guidance to industry, the RSPG will aim to identify at the earliest opportunity a suitable band to be made available in Europe . In order to do this RSPG members will prioritize the necessary work to assess what would be involved in enabling access to each candidate band in their country.
- In this regard the RSPG believes that global harmonisation will be essential for developing 5G.
- The RSPG will define the timeline for availability of other bands taking into account sharing and transition challenges, for example for mobile access and fixed services (including backhauling).

5. The RSPG believes that considerations of bands above 6 GHz for 5G shall be limited to the bands listed by WRC-15 in order to strengthen the global harmonisation opportunities. This work should focus on the frequency bands proposed by Europe, in particular the bands 24.5-27.5 GHz, 31.8-33.4 GHz and 40.5-43.5 GHz. The RSPG intends to identify which one of these could be harmonised in Europe for early implementation.

6. The RSPG will keep under review whether there is any requirement for European harmonisation measures in bands above 24 GHz before WRC-19.

7. The RSPG will prepare a supplementary opinion elaborating on the implementation of this opinion taking also into account the wider RSPG work programme, in particular the working groups on IoT and ITS.

5.3.Japan: MIC released radio policy to realize 5G in 2020

MIC (Ministry of Internal Affairs and Communications) in Japan recently released a report for their radio policy to realize 5G in 2020 in July 2016. This report covers several topics including 5G spectrum.

MIC established their radio policy vision towards 2020s and set up their new goals for frequency allocations to mobile communication systems:
- For below 6GHz: Promote frequency sharing with public service systems and others and to ensure a total bandwidth of 2700 MHz, ncluding bandwidth for wireless LAN, by 2020.
- For above 6GHz: Push ahead with R&D and international standardization while targeting a total bandwidth of about 23 GHz

The strategy for each frequency:
- Below 3.6GHz (IMT/3GPP Band):
  - 1.7GHz band, 2.3GHz band: Consider frequency sharing with or reallocation of public services
  - 2.6GHz band: Promote consideration of frequency sharing with the next mobile satellite communication systems
  - 3.4GHz band: Consider the use of promotion of termination acceleration measures
- 3.6GHz-4.9GHz:
  - 3.6GHz-4.2GHz: 3GPP bands and is identified for IMT in U.S. etc. However, it is necessary to share the frequencies with satellite communication systems in Japan

- 4.4GHz-4.9GHz: Promote comprehensive consideration in accordance with international harmonization, domestic/ international R&D trends, and frequency sharing with existing systems

- Above 6GHz :
  - 24.25GHz-86GHz (11bands*), *Frequency considered in WRC-19 (IMT-2020): Promote comprehensive consideration in accordance with international harmonization, domestic/international R&D trends and frequency sharing with existing systems
  - 27.5GHz-29.5GHz: Promote comprehensive consideration in accordance with U.S and Korea etc.

They think toward 5G realization by 2020, it is necessary to consider and identify candidate frequencies for 5G in order that telecom equipment manufacturers can start to develop new devices and equipment. And they need to cooperate with major countries who share their views about frequency demands for 5G and to consider and identify candidate frequencies towards 5G deployment by 2020.

5.4.Korea: K-ICT spectrum plan power 5G

Korean National Broadband Plan 1.0 in Jan, 2012 is planned to provide 600MHz of bandwidth for mobile until 2020, National Broadband Plan 2.0 in Dec, 2013 is to provide minimal additional 1000MHz of bandwidth for mobile until 2023 including 500MHz in the bands above 6GHz. And the "K-ICT Spectrum Plan" which is going to be published in Oct, 2016 will extend to all areas to meet emerging needs of industries (e.g. IoT, Drone and public safety).

Korea think IMT should be provided both lower and higher frequency bands to fulfill 3 usage scenarios in 5G Vision developed by ITU.

- Considerations of frequency below 6GHz
  - 3.4-3.6GHz (hopefully up to 3.7GHz): plan to clear
- Preparation for pre-5G trial
  - Korea will introduce pre-5G trial at PyeongChang Winder Olympic Games in Feb, 2018
  - 28GHz band will be a practical solution considering foreseen market
  - 28GHz is already allocated to MS on a co-primary basis

5.5.China: MIIT clearly declare the 5G R&D trial spectrum

The common view from IMT industry regarding 5G spectrum in China is that 5G system need to support the frequency both above and below 6GHz: frequency below 6GHz for 5G coverage and capacity, that above 6GHz for 5G capacity and backhaul. What's more, C band (3.5GHz frequency range) will be the key 5G band in China, particular for initial 5G deployment.

On January 7th, 2016, MIIT launched China 5G Technology R&D Trial to promote the development of 5G technology and standard in 3.4-3.6 GHz band. It was also planned to conduct IMT vs. FSS compatibility trial from 2016 to 2017 in this band.

At the WRC-15, China supported the identification of 3.3-3.4GHz, 4.4-4.5GHz, and 4.8-4.99GHz bands for IMT under the discussion of WRC-15 agenda item 1.1. Although China did not join the footnotes in the Radio Regulations, China is making progress in domestic coordination towards the IMT identification in 3.3-3.4GHz, 4.4-4.5GHz, and 4.8-4.99GHz frequency bands in Chinese Regulations on the Radio Frequency Allocation.

To evaluate the spectrum requirements and candidate frequency bands for IMT in high frequency band, especially in the frequency ranges listed in WRC-19 agenda item 1.13 from 24.25 to 86 GHz, operators, manufacturers, and research institutes are conducting studies under the director of MIIT within the WRC-19 preparatory mechanism in China. China administration supports the activities to promote global/regional harmonization of 5G spectrum under WRC-19 agenda item 1.13. At this stage, 26GHz and 40GHz frequency bands are taken more concentration on the compatibility studies in China.

6. Hardware reuse can easy the choice on future spectrum usage

Both NR and evolved LTE Advanced (name of the radio access technology developed by 3GPP for 4G) are both the candidate 5G technologies in ITU. Therefore, some infrastructures like base station hardware, which supports promising future technologies such as 3D-MIMO is recommended to reused for future 5G's fast deployment by quick and easy software upgrade. It will be no doubt that this smooth evolution will save a lot of money for the operators no matter what technology will be chosen in future.

Considering that it usually needs one or two years for operators to prepare 5G commercialization. And the spectrum related issues shall be considered as earlier as possible. Considering the 3GPP first version of the 5G NR specifications will be completed in 2018, and it will take at least several months or one year for the development of device supporting for 5G NR. If there is available spectrum can be used for IMT right now, which will be the best choice for this spectrum, waiting for 5G or used for LTE right now. Considering that making efficient use of the available spectrum can lead to the growth of economics, LTE is the best choice now, especially for the important TDD band like 2.6GHz, 3.5GHz and 2.3GHz, which LTE has mature industry scales on them.

What's more, contiguous wide spectrum assignments are critical to TDD performance, while fragmented assignments may not be able to support the highest data rates and offer sufficient capacity. Operation in fragmented spectrum requires more complex and costly technical solutions. It is suggested that a minimum assigned block size for each operator should be ≧40 MHz in the 2.3 GHz and 2.6 GHz bands, and ≧80 MHz in the 3.5 GHz and 3.7 GHz bands, which is also more conducive to evolution to 5G by reusing the hard wares.

7. Recommendations

In order to make future spectrum planning more clear and flexible with better global harmonization , GTI gives the following recommends.

- Coordination of low frequency band and high frequency band shall be considered for both network planning and solution design. Frequency below 6GHz for coverage and capacity, that above 6GHz for 5G capacity and self-backhaul

- C band frequency range due to the already started ecosystem development and availability of contiguous bandwidth is the future golden frequency band

- As for mmWave, 24.25-27.5GHz and 37-43.5GHz are highly recommended to be harmonized around the world. Considering 28GHz band has also interested operators from Korea and USA, one tuner range from 24.25GHz to 29.5GHz is suggested in future device design. Furthermore the 32 GHz band could also be a good candidate, because this band is currently lightly used in several key markets

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bands is suggested to allocate with bandwidth ≧ 40/80 MHz. From this point of view, the existing frequency bands can also be reused for 5G. For example, Band 41 stands out as having the most spectrum below 6 GHz in the United States

- In order to promote the high efficiency usage on spectrum, continuing to look at any unused TDD spectrum that can be used for TD-LTE is encouraged, such as using the 1.79GHz-1.80GHz TDD band in Singapore

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